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Mobilising Investments in Low-Emission Energy Technologies on the Scale Needed to Reduce the Risks of Climate Change

Richard Doornbosch, Dolf Gielen and Paul Koutstaal

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Dolf Gielen is senior Energy Analyst at the IEA and coordinator of the Energy Technologies Perspectives project.

Paul Koutstaal is a program leader at the Netherlands Bureau for Economic Policy Analyses.

For further information, please contact Richard Doornbosch, Principal Advisor
Round Table on Sustainable Development, OECD Tel: +33 (0)1 45 24 14 57
E-mail: Richard.DOORNBOSCH@oecd.org

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Without changes in policies the world is on a path towards global average temperature increases of 6 degrees Celsius and perhaps more. Between now and 2050 we must halve global energy sector emissions while doubling the supply of energy and sustaining economic growth. The scale of that challenge is daunting. There are no precedents on which we can rely. But experience with the Montreal Protocol – the agreement to phase out ozone-depleting CFC's – shows on a much smaller and less complex scale that national governments will sign up to strong measures if they know technologies are available and affordable and if there is a genuinely equitable basis on which countries with very different resources can engage.

A key message of the OECD's *Environmental Outlook 2030* is that effective global action on climate change is not only possible but affordable and that equitable ways of engaging all countries are available. The IEA's *Energy Technology Perspectives 2008* adds detail and context to these conclusions by providing a detailed bottom-up study of those technologies which can be developed to meet the required emissions reductions in the energy sector. It confirms that although the costs are high (between $1 800 and $5 600 billion per annum in 2050), they could be manageable when the right policies are put in place and when set against the economic growth projected over that period.

Large gaps between what is needed and the world's current trajectory

The composite picture shows, however, a large difference between the sort of best-case outcomes that modelling exercises can produce and the trajectory the real world is on. This can be characterised as a series of gaps that need to be bridged if the least-cost outcomes of the OECD and IEA model simulations are to be achieved.

The gap between profitable opportunities to improve energy efficiency and the market's ability to capture them

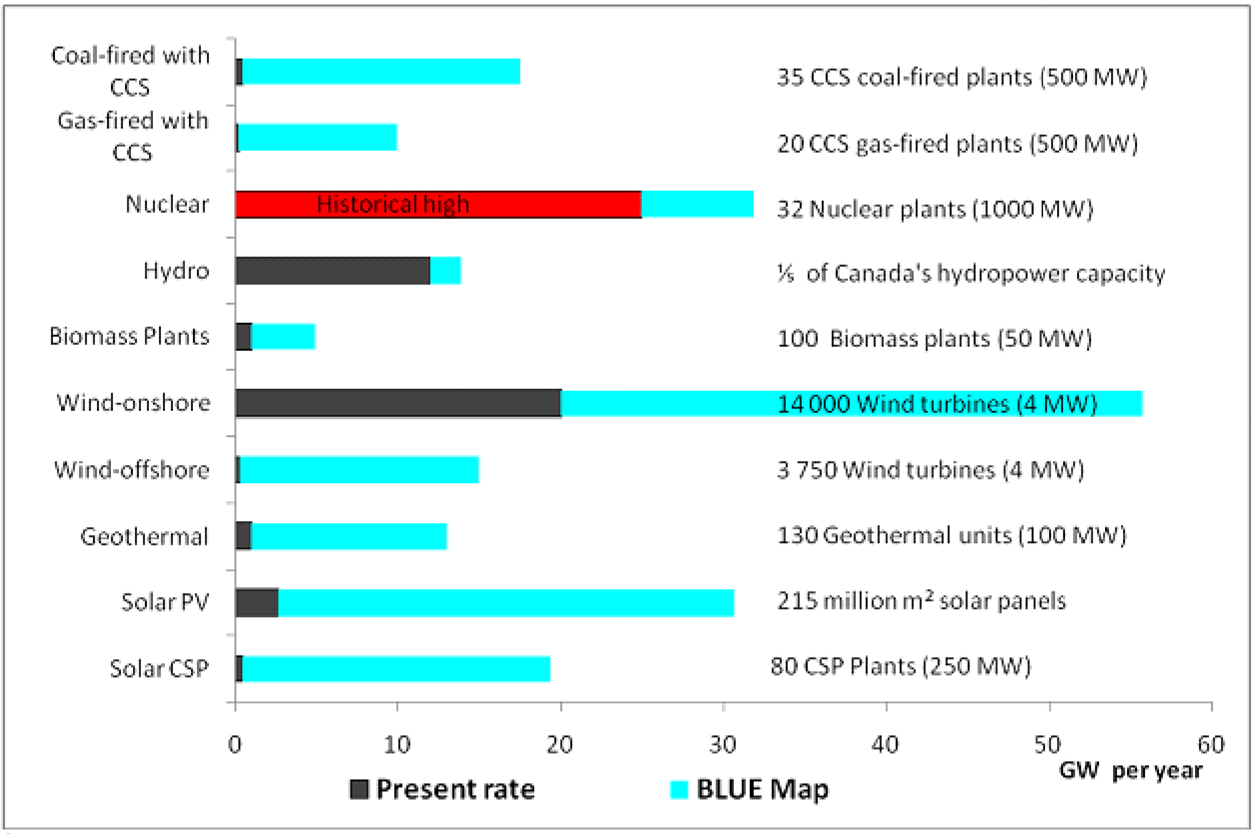
A large number of immediately available opportunities to reduce energy consumption have been identified. The so-called low hanging fruit of moving to a low carbon economy involve investments that can in principle deliver lower emissions at a profit over their lifetime. Improvements in end-use efficiency could provide around half the 48 Gt CO_2 per annum reductions that will be needed by 2050 if emissions are to be consistent with a temperature increase of around 2.4 – 2.8 degrees Celsius (see Figure 4 on page 17).

Nevertheless, businesses and consumers seem remarkably indifferent to the possibilities. The barriers to their uptake are not always well understood but include a wide range of phenomena. Sometimes it is because the gains do not seem large enough to justify the time and effort needed to extract them. In other cases, capital markets do not recognise the returns that would justify higher up-front capital costs. There is also the widely remarked-upon phenomenon whereby landlords ignore low-emission building solutions on the basis that energy costs will be met by tenants. These and other barriers at the micro level stand in the way of some very large potential emission reductions and are unlikely to be overcome simply by pricing carbon. Standards and codes can be an effective way of dealing with those non-market barriers, but because they rely on administrative actions they can be costly to impose and out of touch with dynamic change. More work is needed to find ways to keep standards and codes up to date and to reveal the price of carbon that they imply. If emission reduction is to be compatible with sustainable growth, the costs imposed by regulatory solutions need to be as transparent as carbon prices.

The gap between the state of technologies on the drawing board and their commercial viability

By 2050 the electricity sector must be virtually decarbonised. In the period between 2030 and 2050 about 30% of new capacity in the IEA scenario is projected to use fossil fuel with carbon capture and storage, 30% wind and 30% other renewables. There is a huge gap between the current state of those technologies and what they are expected to deliver. Large investments must be made in researching, developing and deploying new technologies prior to 2030 if they are to be commercialised on a large scale thereafter. The IEA estimates that sufficient deployment requires R&D investments of between $20 and $100 billion per annum and learning or early deployment investments in new technologies of $100 to $200 billion per annum on average over this period. The investments required will be much higher in the period prior to 2030 because this is the phase during which initially high deployment costs will need to be brought down. If deployment policies work well, costs should fall sufficiently for carbon markets to pay for any additional costs on a fully commercial basis after 2030. Currently these investments run at a fraction of this level ($45 billion). Without carbon markets the investments in technology required will be far higher and the overall policy mix less effective.

Figure A. Annual physical investments in low carbon power generation in BLUE (average 2005 – 2050)



Source: IEA, 2008

A large financing gap for low carbon energy technologies

Under current settings, the extent to which carbon markets will mobilise the capital needed to finance the incremental costs of low carbon technologies is projected to be around $20 billion in 2010. Whereas the incremental cost of the technologies required to make deep emission cuts will be at least on the order of $100 to $300 billion per annum by 2020, growing to as much as $1 800 to $5 600 billion per annum by 2050. The carbon market would have to grow considerably in coming years to bridge this gap (see Figure 10 on page 28). Announced trading schemes and other policies are insufficient.

The gap between the present segmented market and the possibility of a global coalition of countries exploring all least-cost opportunities to reduce emissions in an integrated market

More than 75% of the global growth in CO_2 emissions will be in developing countries, with more than 50% in China and India alone. Halving emissions in OECD countries alone will yield only around 10 Gt CO_2 emission reductions of the 48 Gt CO_2 needed. Halving emissions everywhere is probably not feasible, as developing countries are in a different – more energy intensive – development phase and will enjoy much higher economic and population growth leading emissions to rise quickly. However, even if it were assumed that emissions in OECD countries could be reduced to zero this would still only deliver up to 38% of the 48 Gt CO_2 emissions reductions needed against the business-as-usual trajectory.

Without prejudging what would constitute an equitable outcome, it is clear that the current architecture cannot deliver either a fair sharing of the burden or exploit the least-cost opportunities to reduce emissions at the global level within a timeframe that will head off huge sunk investments in emission-intensive technologies. Given the high costs of adjustment, it seems that only some sort of integrated trading system can provide a reasonable means of securing a fair sharing of the burden by guiding private investments towards developing countries. The current segmentation of markets will lead to much higher CO_2 prices and mitigation costs. It could be argued that, as inefficient as they are, these higher prices might induce additional investments in the deployment of new technologies. On the other hand, resulting uncertainty around the development of CO_2 price levels is likely to delay these investments.

Time is of the essence

Delay could prove very costly. The period between now and 2020 will be crucial for closing these gaps. Without early action, billions of dollars of conventional technology will be installed in buildings, infrastructure and power generation, thereby casting a long emissions shadow over the future. This is best illustrated by the rapid increase in the market share of coal fired power plants in recent years. Despite climate change concerns, emissions from coal use accelerated from a growth rate of 1% per year between 1990 and 2000 to 4.4% per year between 2000 and 2005. The IEA estimates that in the period through to 2030, $600 billion will be invested in replacing and expanding the capacity of coal fired power plants around the world. To virtually decarbonise electricity supply this capacity must be retired early or large scale retrofitting with CCS will be needed.

Options for international collaboration to close the gaps

The question of technology development and commercial scale deployment cannot be separated from the international architecture of an agreement on climate change. Both domestic capital formation and international capital flows will be influenced by such architecture. A sense of this can be derived from policy scenarios that provide alternative future policy settings characterised both by the level of urgency given to mitigating climate change and the level of international cooperation. Both will influence international capital flows in low carbon energy investments.

Three scenarios are elaborated in the paper to highlight the way in which these two dimensions might influence investment flows:

- A **Grand Coalition** scenario, in which there is a broad recognition of the climate change problem and countries are willing to cooperate by setting a target for emissions and providing for international trade in emission allowances.

- A **Fragmented** scenario, in which countries do acknowledge that climate change poses a problem but cannot agree on an all-encompassing international approach. Instead, there is a range of different national or regional policies with only limited collaboration.

- A **Lowest Common Denominator,** scenario in which countries align their ambitions to those with the lowest ambitions because no country wants to be found ahead of other countries for competitiveness reasons.

Figure B. Carbon investment flows between regions (in $ billions), 2020

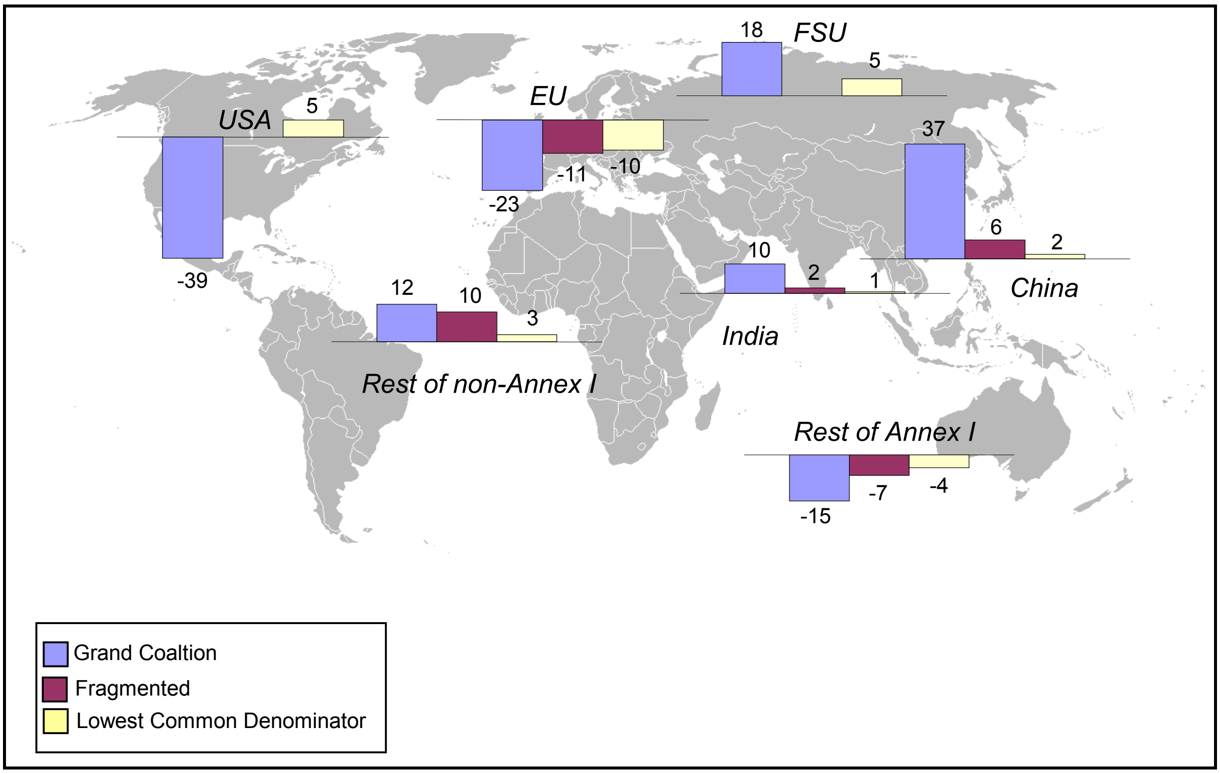


Figure B shows what happens under these policy scenarios to international investment flows made available through carbon markets. In the Grand Coalition scenario, the fast-developing countries benefit optimally from the large availability of relatively inexpensive mitigation options in their countries as they participate fully in emission trading. By contrast, Annex 1 countries (except the countries of the former Soviet Union) are the major importers of emission allowances as emission reduction targets are based on emissions per capita. The total value in 2020 of the allowances bought by these Annex 1 countries is about $75–80 billion for an importation of 3.6 Gt of CO_2 allowances. In the Fragmented and Lowest Common Denominator scenarios these investment flows are likely to be lower, because demand for emission reductions will be subsequently lower and because international financing of emission reductions rely almost complete on CDM.

Collective action allows for emission reductions in developing countries without harming economic growth

A striking point is that countries such as China and India could benefit from taking part in an international agreement by limiting their rates of emission growth in a way that would generate saleable carbon credits. In developing countries, private investment is unlikely to extend to low carbon emission technologies unless there is an incentive to do so. But if emission reductions in developed countries are sufficiently stringent (and the demand for carbon credits high enough) the demand for low-emission investment opportunities could be significant.

What would be needed to channel that demand in the direction of developing countries would be some sort of (voluntary) limitation in the rate of emission growth to generate a supply of carbon credits. If this were to happen, private investment would become the principle vehicle for financing low emission technologies in developing countries. The analyses suggest that emission limitations in developing countries could actually have a positive effect on their GDP given the scale of likely capital flows. Designing mechanisms that could generate such an outcome would go a long way towards satisfying the need for a burden sharing consistent with the universally agreed formula of 'common but differentiated responsibilities'. Without such a mechanism, compensation and support for mitigation will rely on government transfers which have no hope of bridging the gap.

CDM: More than expected, less than needed

The Clean Development Mechanism (CDM) has provided valuable experience in mobilising capital for investments in low emission technologies in developing countries. However, the CDM is unlikely to be a complete answer. There are both fundamental and practical problems limiting the medium and long term potential of CDM to deliver carbon finance for sustainable development and emission reductions.

The CDM will lead to more carbon leakage at the individual firm level, where it has a subsidy effect by reducing production costs. The result is that with CDM the price of carbon is not internalised in consumer prices (see paragraph 112 for further explanation). A more practical reason limiting the long-term potential of CDM is the transaction costs associated with establishing and verifying additionality. One way of coping with this is by bundling projects or bringing projects under an umbrella CDM programme of activities. The possibilities of scaling up CDM in this way might be larger than has been imagined but risk being limited through methodologies becoming too complex to manage.

Sectoral approaches might be a feasible way to ramp up investments in low emission technologies in developing countries

To achieve mitigation efforts in developing countries on the required scale and the financial flows needed to support them, it will probably be necessary to move in the short to medium term to a financial mechanism closer to emission trading schemes. One mechanism that has been suggested is a sectoral CDM. Under this approach, carbon credits would be granted to those companies that exceeded a baseline performance or intensity target. The perceived political advantage over an allowance system is that there is no downside. If emission reductions are not achieved, there is no compliance regime forcing participants to buy allowances in the market.

To work, a sector-wide baseline would need to be negotiated internationally to secure the environmental integrity of the scheme and a commitment from buying countries that credits will be eligible and demand sustained for a long period of time. However, the fundamental shortcomings of an offsetting scheme – implicitly subsidising energy use – will remain. Whether this is a price worth paying in the medium term to ensure a broader international coalition would depend on the final design and detail of the system.

A further step would be to establish cap-and-trade systems for distinct economic sectors in return for making the allowances tradable in other emission trading schemes. The additionality problem is again tackled at the outset when establishing the relative or absolute cap for the installations under the trading scheme. Burden sharing would be confronted by determining the cap in relation to the caps in linked trading systems (permit allocation). While developed countries would necessarily be pursuing absolute cuts in emissions, developing countries might pursue measurably lower rates of emission growth in the sectors in question.

Since many of the cheaper abatement options are likely to be in fast-developing economies, the benefit to developing countries would be likely to come in the form of a strongly increased inflow of carbon finance through the sale of allowances at a higher price to developed countries' trading schemes. Another advantage could be that the discount at which emission reduction under the CDM is currently sold would be avoided, increasing the profitability of cutting emissions for developing countries.

Carbon markets will not be enough

While only private capital is likely to provide the huge investment that will ultimately be needed, carbon markets are not a panacea, particularly in the early stages. While technologies are still being developed and the learning process of early deployment is under way, governments have an important role to play. Cost effective policies that encourage innovation and deployment in all countries are currently insufficient.

1. Introduction

1. The global economy is set to grow fourfold between now and 2050 and developing countries such as China and India could grow nearly tenfold. This growth rate will have huge benefits for the well being and living standards of billions of people. The implied pressure on natural resources and the environment poses an enormous challenge for the energy sector. The IEA's upcoming *Energy Technology Perspectives 2008* estimates that, without changes in policy, oil demand will increase by 70% by 2050, and CO_2 emissions by 130%. According to the Intergovernmental Panel on Climate Change (IPCC) this could put the world on a path towards global average temperatures rising by 6 degrees Celsius and perhaps more.

2. If, instead, the world aims to stabilise GHG concentrations at 490–535 ppm CO_2-eq. with a view to limiting the increase in global mean temperature to 2.4–2.8 degrees Celsius, GHG emissions would need to be reduced to a level between 30 and 60 percent below 2000 levels by 2050[1]. The IPCC states that for low to medium stabilisation levels (450–550 ppm CO_2-eq.) developed countries as a group would need to reduce their emissions by 10–40% below 1990 levels by 2020[2].

3. Stabilising GHG emissions at a level that avoids dangerous anthropogenic interference with the climate system will necessitate a comprehensive change in the way energy is supplied and used. If no action is taken, the current emissions track would see energy-related emission increase to around 62 Gt CO_2 in 2050[3]. Reducing those emissions to half the current level by 2050, for example, implies cutting energy-related emissions to just 14 Gt CO_2 per year. Halving today's level of emissions while doubling the supply of energy is a daunting challenge. Although this paper focuses on the energy sector, emissions from non-energy sectors and non CO_2 GHG need to be reduced in a similar vein. Energy-related CO_2 emissions comprise only around 55% of total GHG (IPCC, 2007). But this percentage is likely to rise substantially in the future.

4. An energy technology revolution is needed if deep emission reductions are to be secured in the energy sector. Higher levels of energy efficiency, deployment of renewables, nuclear power, carbon capture and storage and decarbonisation of the transport sector are all needed on a massive scale. This will depend critically on the way governments incentivise technological change and influence market conditions both in developed and developing countries. A step change is needed in government policies to remove barriers to investment and create a high level of certainty around the future demand for low carbon technologies on which industry can rely. More than 75% of the global growth in CO_2 emissions will be in developing countries and more than 55% in China and India alone. Effective climate action therefore also means an unprecedented level of cooperation amongst all major economies.

5. Deep emission cuts imply ambitious policy targets in OECD and non-OECD countries. However even halving of emissions in OECD countries will yield only 6.5 Gt CO_2 emission reduction. Halving emissions everywhere is politically difficult, as developing countries will enjoy much higher economic and population growth and under business as usual emissions are bound to rise quickly. It will also raise equity questions as historic emissions and per capita emissions are much lower in developing countries. Looked at on the basis of per capita emissions, for example, the average American currently emits 20 tonnes per year, while the average European or Japanese emits between 11 and 13 tonnes, the average Chinese emits just 5 tonnes and the average Indian 2 tonnes. This means policies are set to fail if non-OECD countries do not participate in a meaningful way. The question is therefore how to ensure as efficient and equitable an adjustment path as is possible. Least cost opportunities in all energy sectors and in all regions should be exploited to avoid compromising economic growth. Directing financial flows from North to South will be crucial to achieve an efficient and equitable outcome.

6. This paper explores strategies for mobilising the investments needed to develop and commercialise low emission energy technologies. Section 2 will present the result of the IEA's *Energy*

Technology Perspectives 2008 which outlines the least-cost options for reducing emissions in both developed and developing countries. Section 3 will show the difference in investments and cost of holding global energy emissions in 2050 to 2005 levels and reducing them by a further 50%. Section 4 will describe the current state of the carbon market and the carbon finance available to pay for the incremental costs of using low emission technologies. The available carbon finance will be compared with the cost estimates in Section 3 to show the financing gap for low emission technologies. Section 5 describes options for a post-2012 architecture and their implications for mobilising investments in clean energy investments.

2. What are the most promising energy technologies to support the transition to a low carbon economy?

7. The transition to a low emission energy system requires an investment regime that directs capital to the most promising opportunities to reduce emissions. A global and uniform carbon price has long been acknowledged to be an important tool to achieve this. But even if the barriers to generating such a global price were to be surmounted there would still be a role for governments in helping to research and develop the portfolio of technologies needed to deliver low emission energy services at acceptable costs. Therefore governments should execute an innovation strategy aimed at pushing a broad portfolio of technologies closer to commercialisation. Though picking winners in a fine-grained sense should be avoided, governments must make choices when setting global research and development priorities and formulating deployment policies. These choices encompass the scale of government research budgets, the distribution of these budgets and the geographic spread of demonstration projects. Their critical mass also needs to bear some relationship to the likelihood of technologies to deliver emission reductions on the scale required and within timeframes that can make a difference.

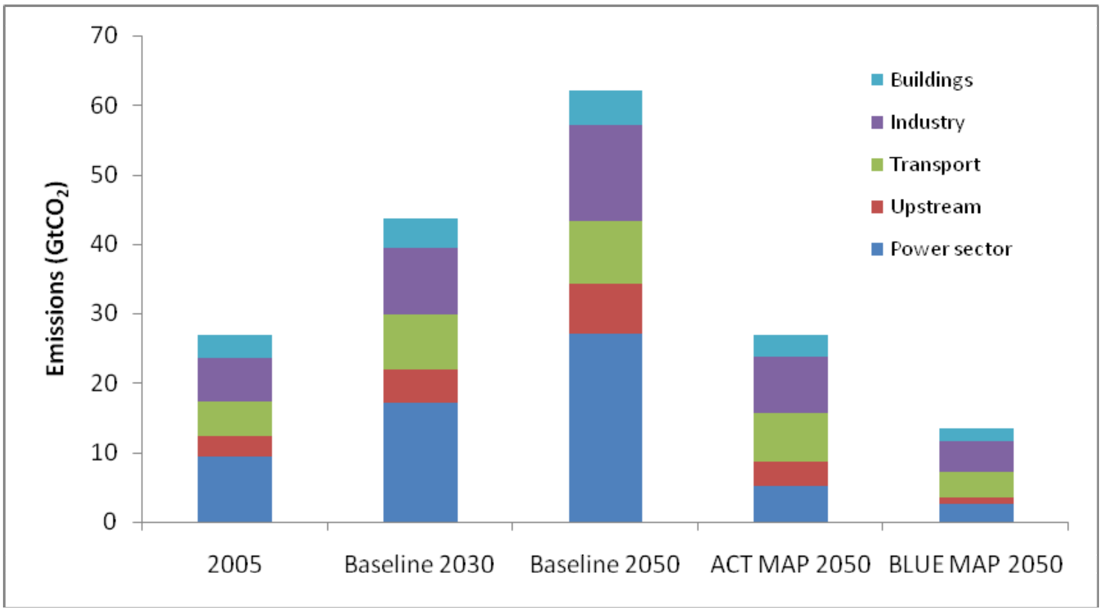
8. This section highlights the most promising energy technologies that would support the transition to a low carbon economy and their regional distribution by combining and comparing the technical and economic potentials of the different options known today. The analysis in the IEA's *Energy Technologies Perspective 2008* does just that by comparing two climate change mitigation scenarios (and several sub-scenarios) with a business-as-usual scenario.

9. The first mitigation scenario is called the Accelerated Technologies scenario (ACT) in which energy-related emissions return to about today's level by 2050. Emissions are reduced by 35 Gt compared with the Baseline scenario and this scenario is consistent with an increase in temperature of about 2.8 – 3.2 degrees Celsius (eventual stabilisation level)[4].

10. The second scenario is called BLUE and reduces global energy related emissions to half their current level in 2050, which would be consistent with an expected increase in temperature of 2.4 – 2.8 degrees Celsius and require a reduction of 48 Gt in 2050 compared to the baseline. In the ACT scenario these deep emission cuts require that all technologies with a cost of up to \$50 per tonne of CO_2 saved are to be deployed, whereas in BLUE all technologies with a cost of up to \$200/t CO_2 would be needed.

11. Figure 1 gives an overview of the global energy-related CO_2 emissions in the baseline and the two ambitious climate change mitigation scenarios. As can be seen, the ACT scenario implies deep emission cuts in power generation and energy efficiency, whereas achieving the 50% reduction of emissions in BLUE requires deep emission cuts across all sectors. Action in both power generation and energy efficiency is urgent and necessary, whichever final target is being pursued.

Figure 1. Global energy-related CO_2 emissions in Baseline, ACT and BLUE scenarios



Source: IEA, 2008

2.1 Decarbonising electricity generation

12. Electricity production is today responsible for 32% of total global fossil fuel use and 41% of energy-related CO_2 emissions (Figure 1). Without new policies, emissions from power generation are expected to continue to grow rapidly and account for 44% of total CO_2 emissions in the Baseline scenario. This high share is the net result of a significant growth in production and a massive switch to coal, driven by its lower relative price in many regions. Coal accounts for 52% of power generation in the Baseline scenario. This is to a large extent caused by the rapid increase in power generation in China and India and the relative abundance of coal reserves. Coal is expected to regain its dominant position.

13. The Baseline outlook has deteriorated in recent years despite climate policy efforts. From 1990 to 2000, the average annual increase in emissions was 1.1% per year. Between 2000 and 2005, however, growth accelerated to 2.9% per year despite the increased focus on climate change. High economic growth, notably in coal-based economies, and higher oil and gas prices (which have lead to an increase in coal-fired power generation) are the main reasons for the increase. Emissions from coal use increased by 1% per year between 1990 and 2000, but they rose by 4.4% per year between 2000 and 2005.

14. Decarbonising the electricity sector is at the same time the single biggest contributor to deep emission cuts. A combination of electricity end-use efficiency and supply side measures will be needed. Emissions on the supply side are reduced by 15 – 18 Gt CO_2 in the ACT and BLUE scenarios respectively. Introducing economic CO_2 incentives as assumed in these scenarios will immediately improve the relative attractiveness of gas over coal and increase efforts to improve generation efficiency. Across all fossil fuels the technical fuel savings potential is between 1.75 to 2.50 Gt CO_2 per year. The largest savings are from improving the efficiency of coal-fired plants, which alone provide savings of 1.40 to 1.98 Gt CO_2.

15. The total share of renewables in power generation is set to more than double: from 18% to 35% in ACT, and up to 48% in the BLUE scenario. Most of the growth is for the emerging renewable technologies – wind, solar, biomass, and, to a lesser extent, geothermal. However, the use of mature hydropower technology also doubles from today's level, bringing it very close to what is seen to be its ultimate technical potential.

16. Variable renewables play an important role in these scenarios. In terms of power production, hydro, wind and solar reach equal importance in the BLUE scenario in 2050. Until 2020 biomass and wind constitute the bulk of new renewables capacity, with solar beginning to make significant contributions after 2020. Hydro shows continuous growth over the whole period, but the rate of growth levels off after 2030 as the availability of suitable sites becomes constrained.

17. Most electricity generated by coal fired power plants in ACT and BLUE and half of the gas fired power generation in BLUE comes from plants equipped with carbon capture and storage (CCS). Retrofitting of coal plants with CCS plays a significant role in ACT, but new purpose-built plants with CCS dominate in the BLUE scenario. The strong growth of CCS in BLUE compared to ACT can be attributed to gas and biomass with CCS.

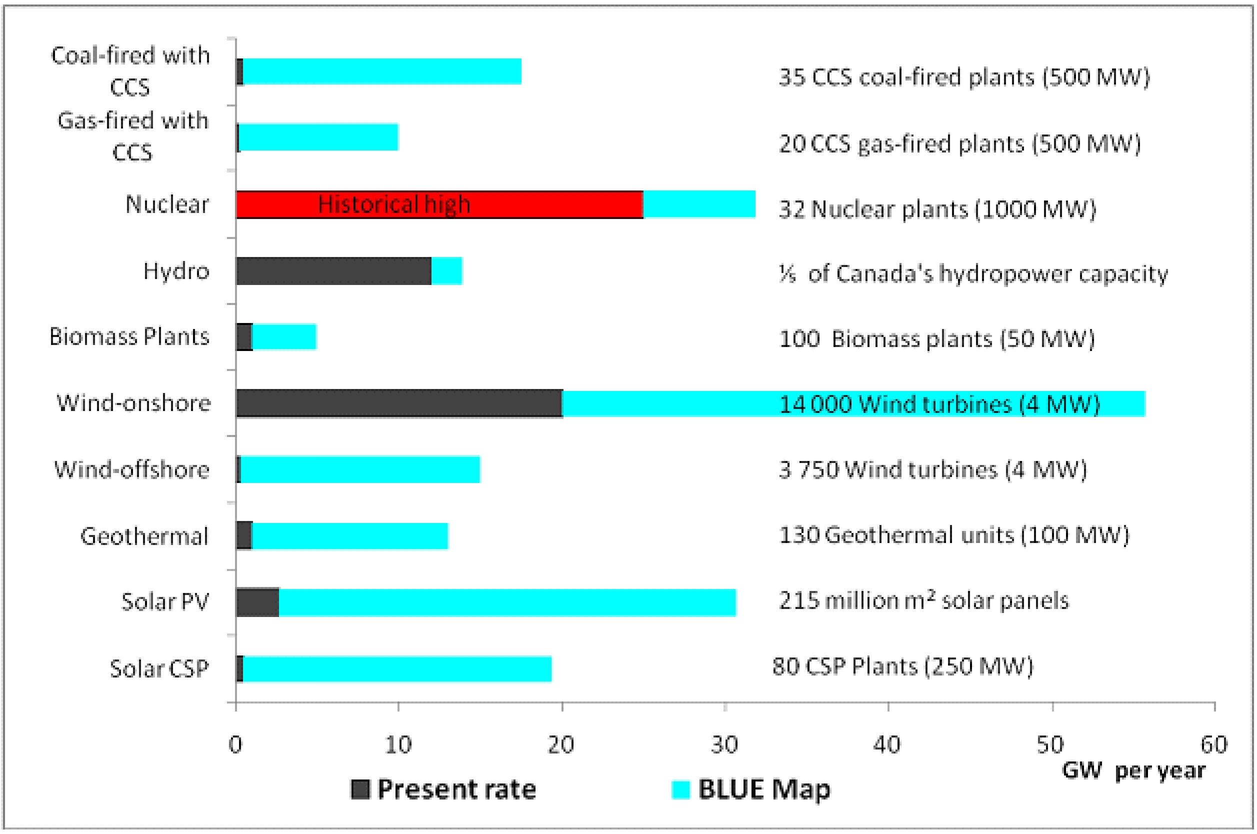
18. Nuclear power generation already plays an important role in the Baseline. Nuclear capacity in the Baseline scenario increases from 368 GW to 570 GW in 2050, and output increases by 61%. As most of the existing capacity will need to be replaced in the next 45 years, the Baseline implies an average of more than ten new reactors per year. Without this capacity replacement, more CO_2-emitting coal-fired capacity would be built and reference emissions would be even higher. The nuclear share rises further in ACT and BLUE. However, the use of nuclear is constrained at 1250 GW, based on past experience of limits to the number of reactors that can actually be built in one year (about 25 GW). A sub-scenario (not shown here) where the share of nuclear can increase to 2000 GW shows that its further expansion would be cost-effective, largely at the expense of fossil-fueled plants with CCS. This would raise the contribution of nuclear to global emission reduction considerably, but the acceptance and feasibility of such expansion remains to be seen. Moreover, the 2000 GW case does not yield substantial further emission reductions.

2.2 Technological change crucial for massive deployment of low carbon power generation

19. The physical investments in technologies that are still under development or even in the demonstration phase and that are needed to reach the deep emission cuts in the BLUE scenario are enormous. Figure 2 details the challenge for low carbon power generation over the period 2005-2050 in BLUE. A few examples can illustrate the scale of the challenge. The 32 nuclear power plants that should be opened on average every year through 2050 could be compared with the 2 nuclear power plants opened and 8 plants retired in 2006. The historical height is much higher though, with 25 nuclear power plants that opened in a single year. An average 58 power plants would need to start operating every year with Carbon Capture and Storage (CCS) of CO_2 emissions while at present there is no commercial scale CCS plant operating at all. The deployment of CCS is crucial as coal will remain the most accessible fuel for some of the largest emerging and OECD countries. 2007 saw 20 GW of new wind generation commissioned – a level of growth that is regarded as booming. But to reach its goal, the BLUE scenario need to assume the addition of 70 GW per year for 46 years.

20. To achieve these kinds of growth rates it is crucial that further technological progress is achieved through further research and in particular through the learning process that can be expected with increased deployment. Investments in low carbon generation are increasing over time and in the 2030-2050 period about 30% of the new capacity is fossil fuel with CCS, 30% wind and 30% other renewables. Once capital-intensive power plants are built they will be used. To prevent locking in old technology, the timing of investment in new technologies is critical. This can be illustrated by considering China, which alone added around 70 GW, or one hundred and forty 500 MW coal-fired power plants, to its generating capacity in 2007. The present high growth rate in developing countries and the high replacement rate of existing capacity in OECD countries over the next 15 years underlines the urgency of speeding up the technological development of low carbon emissions as assumed in the IEA's scenarios. Every year that low carbon alternatives can be brought earlier to the market will avoid costly write-offs of expensive capital stock.

Figure 2. Annual physical investments in low carbon power generation in BLUE (average 2005 – 2050)



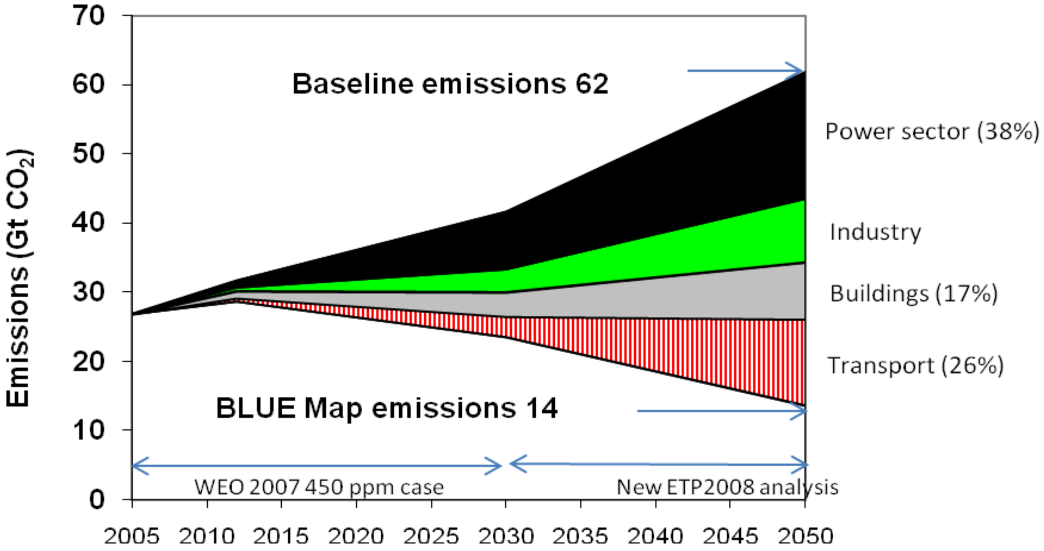
Source: IEA, 2008

2.3 Large potential for energy efficiency

21. Lower energy demand from improved demand side energy efficiency is the second largest contributor to emission savings in the IEA's scenarios. When supply side efficiency improvements from power generation are added, it becomes even the largest and certainly the least expensive. In ACT, power demand is reduced by 21% because of end-use efficiency measures in the building and industry sectors and measures that reduce transmission and distribution losses. This results in 6 Gt CO_2 emission reduction. In BLUE, electricity demand is reduced less because of increased electricity use for heatpumps and plug-in vehicles, but is still 15% below baseline electricity demand.

22. In Figure 3 the CO_2 reductions from electricity savings have been allocated to the end-use sectors for the BLUE scenario. It shows the importance of action in the end-use sectors.

Figure 3. Reduction of energy-related CO_2 emissions from the Baseline scenario in the BLUE scenario by sector, 2005-2050



Source: IEA, 2008

23. In the Baseline scenario, direct and indirect CO_2 emissions from the building sector increase by 129% between 2005 and 2050. This high growth rate is reduced strongly in ACT and BLUE to 35% (7.0 Gt) and 43% (8.6 Gt) respectively below the Baseline level[5]. The single most important reason for the lower emissions is energy savings with demand being around one-third lower in ACT and 40% in BLUE compared to the Baseline. Significant reductions in fossil fuel and electricity use occur in both scenarios as a result of increased energy efficiency. Electricity savings dominate total savings in the buildings sector (lighting, appliances, stand-by losses). Energy efficiency improvements in space and water heating are responsible for much of the remainder.

24. In industry, efficiency gains account for 64% of the total 5.9 Gt CO_2 reduction in ACT. However, emissions are still 66% higher than in 2005. In BLUE emissions are reduced by roughly 12 Gt CO_2, 22% below the 2005 level.

25. In addition to incorporating energy efficiency gains from existing technologies, a large number of novel technology options for mitigating CO_2 emissions from industry have been considered in the ACT and BLUE scenarios. Approximately 37% of the emission savings, or 4.4 Gt CO_2, in the industry sector can be attributed to carbon capture and storage. Industrial cogeneration of heat and power doubles in Baseline and quadruples in ACT and BLUE[6].

2.4 Forecasting technology change in transport very difficult

26. Deep emission reductions in the transportation sector appear to be the most challenging. Transport suffers from a much more acute case of technological lock-in than electricity generation. While there are many power generation alternatives already in the field, the internal combustion engine remains overwhelmingly dominant for transportation. In ACT and BLUE, a 15% reduction in car, truck, and air travel is projected in 2050 through switching to public transportation and other low carbon modes compared with a tripling in the reference case. Far deeper reductions are needed, however, and strong

policies to moderate travel growth may be required if new propulsion systems and fuel switching in transport are not forthcoming. The necessary technology breakthroughs to enable electric vehicles and hydrogen fuel cell vehicles cannot be reliably forecast at this stage. Plug-in electric hybrid vehicles are a likely interim option.

27. In the Baseline Scenario CO_2 emissions from transportation (well-to-wheels) grow by 149% to 18.4 Gt in 2050. Well-to-wheels emissions increase faster than tailpipe emissions due to the significant introduction of coal-based synfuels in the Baseline Scenario. These fuels are already economic at current oil prices. Their production would triple well-to-wheels emissions. Tailpipe emissions alone are about 14 Gt by 2050 in the Baseline Scenario.

28. Growth in CO_2 emissions, like growth in energy demand, varies by region. Developing countries show much steeper increases than do developed countries. In the Baseline Scenario, CO_2 emissions from transport in non-OECD countries increase by more than 300%, while OECD countries see an increase of about 50%. This is mainly due to differing rates of growth in transport activity, but also to the faster deployment of clean and efficient transport technologies in OECD countries.

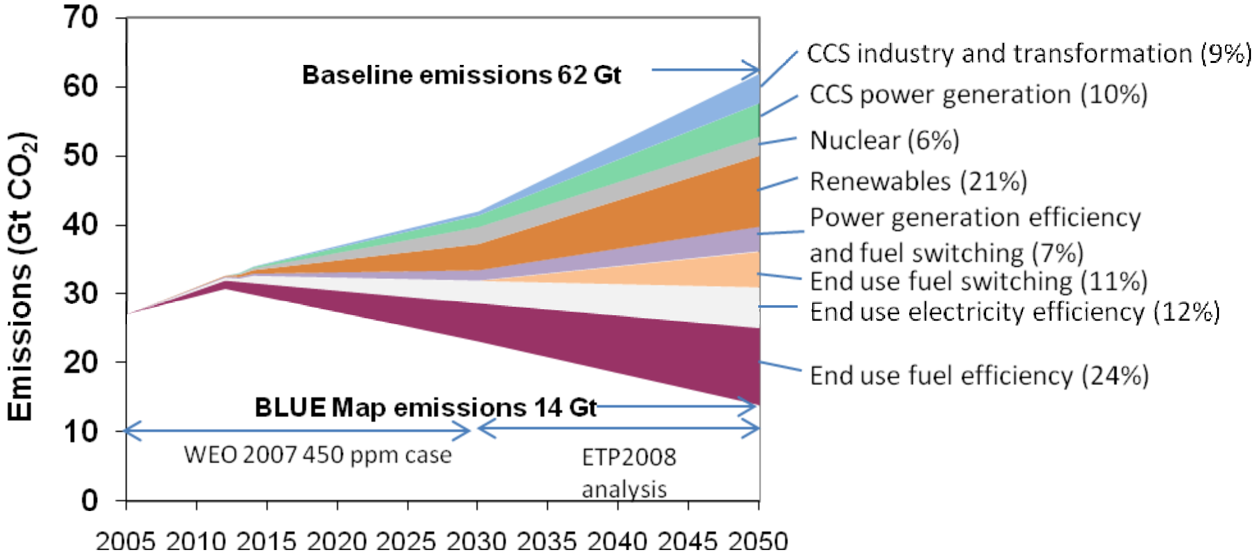
29. In the ACT scenario, well-to-wheels CO_2 emissions are 44% (8.1 Gt CO_2) lower than the Baseline level. Slightly more than two-thirds of this reduction is due to improved fuel efficiency, while the rest is the result of the increased use of biofuels. The improved fuel economy of Light Duty Vehicles (LDVs) provides most of the CO_2 emission reductions. The average fuel intensity of the LDV stock in 2050 is more than 50% lower than in 2005. This reflects a combination of better efficiency from the remaining conventional vehicles, a very large share of hybrid vehicles and some reduction in the average size of vehicles on the market, particularly in those regions where vehicles are now very large.

30. In BLUE a combination of maximum efficiency and a much stronger penetration of biofuels, hydrogen and electricity is assumed leading to an additional 4.4 Gt CO_2 reduction against the ACT case. The fuel savings in BLUE account for 52% of the CO_2 reductions in 2050. The most significant improvements beyond those included in the ACT scenario come from the introduction of plug-in hybrids and pure electric vehicles, and/or hydrogen fuel cell vehicles. Electric vehicles and fuel cell vehicles each reach a 30%-plus market share.

31. In both the ACT and BLUE scenarios the use of synfuels from coal and gas is reduced significantly, which has important CO_2 benefits. Biofuels increase to 17% of total transportation fuel demand in ACT, with equal shares of ethanol and biodiesel. Second generation biofuels dominate, with sugar cane as the principal first generation biofuel feedstock. Use of biofuels is 700 Mtoe, or 26% of total transportation fuel demand in BLUE[7].

32. Figure 4 summarises the analysis by presenting the reduction in CO_2 emissions by technology area in the BLUE scenario in 2050.

Figure 4. Reduction in CO_2 emissions by technology area in BLUE, 2050



Source: IEA, 2008

3. What are the additional costs of low emission energy technologies?

33. In the previous section the contribution to emission reductions that might be expected from new technologies was outlined against two target outcomes: emissions at 2005 levels in 2050 and 50% lower still. The investment levels needed to realise the enormous scaling up of energy supply to a more than doubling of demand will by itself pose considerable difficulties, especially in developing countries. To move towards a low carbon energy supply at the same time will be even more challenging, as low emission technologies often come at a premium. This section will review the investment and cost consequences of the two scenarios.

3.1 Energy investments in 2005 – 2050

34. The cost of the ACT and BLUE scenarios can be divided into a number of categories[8]:

- the cost of Research, Development and Demonstration (short and medium term);
- the cost of deployment and learning investments (short and medium term);
- the increased cost of investments in low- CO_2 technologies in their commercial stage (medium and long term).

35. All three terms have been quantified in the ETP 2008. The study concludes that additional RD&D investments are very important but also very difficult to assess. They should be increased with $10 - 100 billion a year. The learning investments through deploying new technologies that are not yet commercial amount to roughly $100 - 200 billion a year. The remainder – and by far the largest part – is the investment in fully-commercialised technologies. These last are the subject of the analysis that follows.

3.2 Incremental investments in 2005-2050

36. Investments in the baseline are dominated by the demand side, totaling $4 500 billion a year or 90% of total investments. More than 90% of these relate to the transport sector. Supply-side investments of $500 billion per year are dominated by the electricity sector, with half of this being allocated to power plants.

37. According to the IEA, placing the energy sector on a lower emission path means that the increased or incremental investments in commercial technologies for the period 2010 to 2050 amount to an annual average of $400 billion for ACT and $1 000 billion for BLUE[9]. Large as these numbers are, they amount to 0.4–1.1% of total GDP for the 2005-2050 period.

38. In both scenarios, consumers invest heavily in more energy efficient devices – especially cars (light duty vehicles) – with the latter making up more than half of incremental investments. Investments in energy efficiency are quite distinct from those on the supply side. They are often economic in their own right, based on total life cycle cost due to the resulting fuel savings, but must be made by millions or even billions of companies and consumers, increasing transaction costs and making replication more complicated. Whereas the additional investments on the supply side in low carbon power generation often come at a premium and are executed by large (state owned) companies and utilities that are very price sensitive.

39. Policies to mobilise investments and encourage innovation on the demand side therefore also require a very different approach. More emphasis should be placed on addressing non-market barriers by optimising codes and regulations (e.g. building codes), providing information (e.g. certificates) and capacity building support for innovative energy efficiency projects (e.g. by international development banks). End-use efficiency measures deserve special attention because a significant potential exist on the short and medium term.

40. For electricity generation the incremental investments can be divided into higher investments needed for fossil fuel-fired power plants with CCS, wind, solar and other renewable power generation and reduced investments flowing from lower electricity consumption as a result of improved energy efficiency. In terms of transmission investment, lower demand is offset by the need to connect and strengthen the grid to account for the intermittent nature of most renewables.

41. Almost half of additional investments in the ACT and Blue scenarios are in OECD countries and the remainder in developing countries, although a substantial share of the investment would accrue in developing countries in later decades.

3.3 Abatement costs

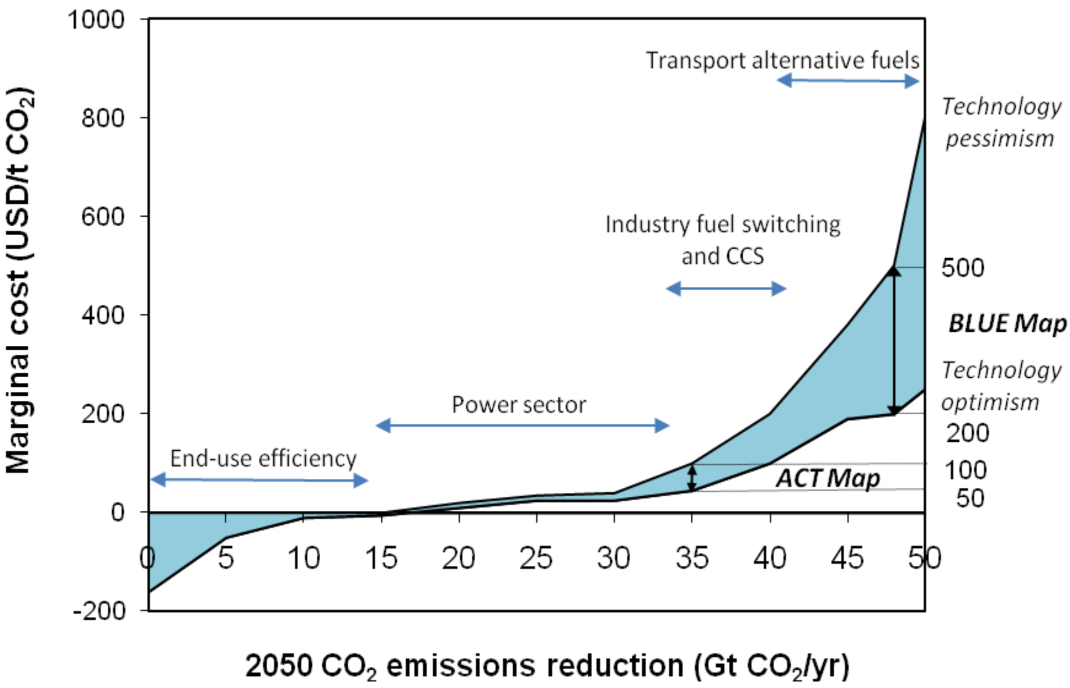
42. The incremental investments as calculated above are both commercial investments that are profitable in their own right and non-commercial investment costs that must be overcome in the absence of a price on carbon. The aggregate investment numbers hide large differences in the financial viability of the underlying project investments. To see which investments would be profitable in the absence of a price on carbon and which would not it is necessary to look at the marginal cost curve for emission reductions.

43. Figure 5 shows this curve which is used to compare costs between different technological options in 2050. The x-axis shows the emission reduction compared to the Baseline scenario. The y-axis shows the costs of the most expensive option that is applied to meet a certain emission reduction target. The marginal cost rises as deeper emission reductions are aimed for and more expensive solutions required. As can be seen in Figure 5, the deep emission cuts of 35 Gt in ACT requires a global carbon price of $50 per tonne CO_2,while the 48 Gt reductions in BLUE requires a price of $200 per tonne CO_2. The approximate position

along the curve of categories of options is indicated. While ACT can be achieved with end-use efficiency and changes in power generation, BLUE will also require more costly measures in other end-use sectors, in particular the transport sector.

44. A cost band (vertical arrows) is indicated to reflect the difference between technology optimism and pessimism. It does not reflect the uncertainty that if certain key technologies such as CCS and nuclear fail to be deployed on a massive scale, behavioural change and reduced economic activity would be the only way to meet the target. It should be kept in mind that this figure is a schematic, greatly simplified, representation. The curve consists of hundreds of options. While energy efficiency is generally cheap, expensive efficiency options also exist.

Figure 5. Marginal emission reduction cost for the global energy system in 2050



Note: Marginal abatement cost curves are not suited for planning of deep emission cuts, but they can provide a useful snapshot of the changes in a certain year. For example, many options are not additive. Technology learning also changes the shape of the curve.

Source: IEA, 2008

45. This schematic representation conveys some important messages. First, costs are relatively flat up to the stabilisation target of ACT but rise quickly as the additional emission reductions technologies in BLUE are added. Second, while cost uncertainty is important in the early stages of emission reduction, it narrows around the ACT target but then increases again significantly for BLUE. While \$200 per tonne is the lower end estimate for the cost in BLUE, if technological progress is slower than expected, costs might rise as high as \$500 per tonne of CO_2. Therefore, at the margin the BLUE scenario requires technologies at least four times as costly as the most expensive technology needed for ACT. It also should be stressed that this curve assumes global action in which all least-cost opportunities to reduce are utilised. If developing countries do not implement all options up to a cost level of \$200 per tonne, both the optimistic and the pessimistic end of the range would move upwards sharply.

46. The total cost of reducing emissions is substantial in both cases. The cost per tonne of CO_2 may even be higher than the marginal cost for a specific period in the deployment phase of new technologies. The total area under the curve in Figure 5 is a measure of the total annual incremental cost in 2050. These costs range from $1 800 to $5 600 billion in 2050. The average incremental costs of reducing CO_2 emissions by 50% against current levels are in the range of $38 to $117 per tonne of CO_2 saved in 2050.

47. Although the IEA analysis does not specify the total incremental cost in 2020, it does estimate that research, development and early deployment expenditure will need to be between $120 and $300 billion per year on average over the 2010-2050 period. These costs are higher in the period prior to 2030 because this is the phase during which initially high technology costs will need to be brought down. If deployment policies work well, costs should fall sufficiently for carbon markets to pay for any additional costs on a fully commercial basis after 2030. To remain on a trajectory limiting temperature increases to under 3 degrees Celsius at the end of the century, by 2020 global energy emissions should be reduced by roughly 7 Gt lower than they would be on a business-as-usual path. The incremental cost would be $140 to $280 billion in 2020 if this 7 Gt were to be reduced at an average cost of $20 to $40 per tonne of CO_2 saved[10].

48. Another way to estimate the additional cost is by using a general equilibrium model, as in the recently published *OECD Environmental Outlook*. In a scenario that reduces global emissions in 2050 by 45% over 2005 levels, world GDP would be reduced by about 2.5% over the total period relative to the baseline. This would be equivalent to slowing annual world GDP growth rates by about one-tenth of one percent (0.1%) over the 2005 to 2050 timeframe, leading the OECD to conclude that climate change mitigation is affordable[11]. In the OECD study it is assumed that all countries implement a $25 tax on CO_2 and other GHG emissions from 2008 onwards, making it possible to exploit least cost options to reduce emissions across all gasses and sectors and in all countries.

49. IPCC estimates suggest that mitigation of climate change would be less than 1% of GDP if GHG concentrations were to be stabilised around 550 ppm CO_2-eq. For stabilisation between 445 and 535 ppm CO_2-eq, costs are less than 3% of GDP[12]. However, these costs are calculated in the absence of any burden sharing agreements. As a result, the costs would be distributed unequally. The OECD concludes that costs to OECD countries would be lowest (about 1% in GDP loss in 2050), while the GDP losses in Brazil, Russia, India and China would be roughly five times this level, and those in the rest of the world about four times as high as in the OECD. The oil and gas exporting Middle East region and Russia would suffer a 10.5% reduction in GDP over the period to 2050. It is likely that the negotiation of a more equitable burden-sharing arrangement would reduce particular inequities, but although efficient and equitable solutions are possible it will in practice probably be at a greater cost to overall GDP than the minimal losses calculated above. This trade-off will be at the heart of any future negotiation.

4. How much capital is being mobilised for clean energy investments at present?

50. The investment in low emission energy technologies depends on a multitude of factors: a country's general business climate, its legal and regulatory regime in the energy sector, financial and technology specific rules and regulations. As commercial investments are driven by risk and return, the level and direction of investments is determined by both long-term financial viability and the degree of regulatory certainty. Therefore, in addition to an enabling environment for investments a clear and predictable long-term price on CO_2 emissions would be an important driver guiding investments into low emission technologies and overcoming their premium cost.

51. Technological development, however, begins by researching and developing new technologies that could provide energy services with lower emissions. These investments are only indirectly guided by a price on carbon. The prospect of a large, stable future market for low emission technologies will help guide

research and development budgets towards finding those technologies. But that market will be too far in the future to directly influence the commercial viability of research and development expenditures.

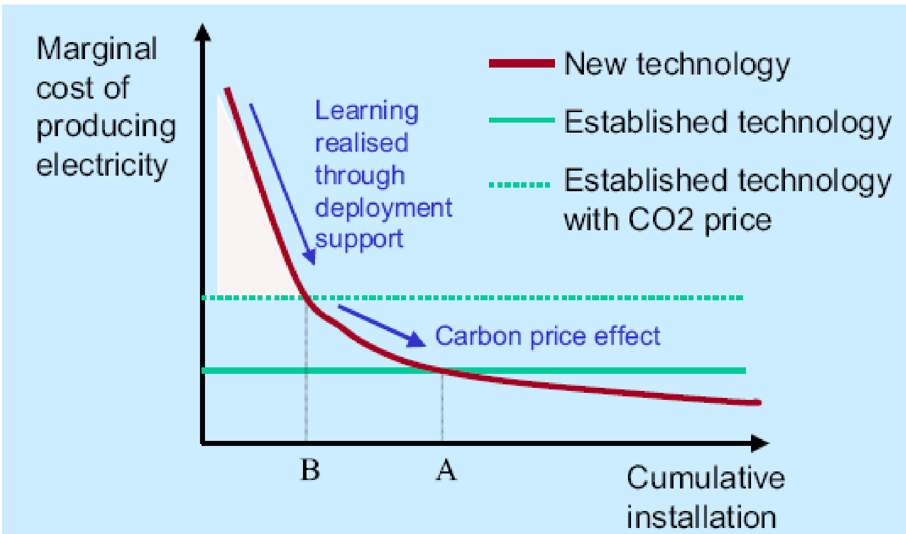
52. Section 4 therefore begins by describing current efforts to accelerate innovation and bring low emission energy technologies closer to commercialisation. We then assess demand in the carbon market and the role of both private and government carbon funds and financial instruments before examining the role standards and regulations can play in influencing the overall investment environment. Finally, this section compares the annual investments needed to move towards a low carbon energy sector with the carbon financing available in different regions and given current policies.

4.1 Research and development in low emission energy technologies

53. The private sector is likely to under-invest in researching and developing new technologies because companies are unable to appropriate the full benefits of their investments as a result of knowledge spill-overs. In addition, the long time periods and uncertainties are often such that they will be hard to finance in even the most efficient capital markets. Examples include capturing and storing carbon from coal-fired power plants or the development of a new generation of nuclear power plants. A huge effort will be needed, as many technologies distinguished above are not yet available and many others require further refinement and cost reduction. Innovation will help to lower these costs.

54. Innovation and technological development is a dynamic process. It begins with the discovery phase. Larger scale investments are then needed to demonstrate new technologies. Subsequently, with commercialisation, cost reductions flow from the scaling up of applications. The high up-front costs and likelihood that competitors will step in as a new technology is commercially successful make innovation a risky business. This is particularly so with electricity production. Electricity is the same whether it comes from wind or coal. It is much more difficult to recoup investment costs through high initial prices as is possible with consumer products such as mobile phones and PCs. Figure 6 shows how a price on carbon complemented with support for early deployment could bring a technology to commercialisation. The support in early deployment should be for a limited period only and an appropriate exit strategy should be agreed in advance to ensure that deployment subsidies will not result in permanent support to an uncompetitive industry.

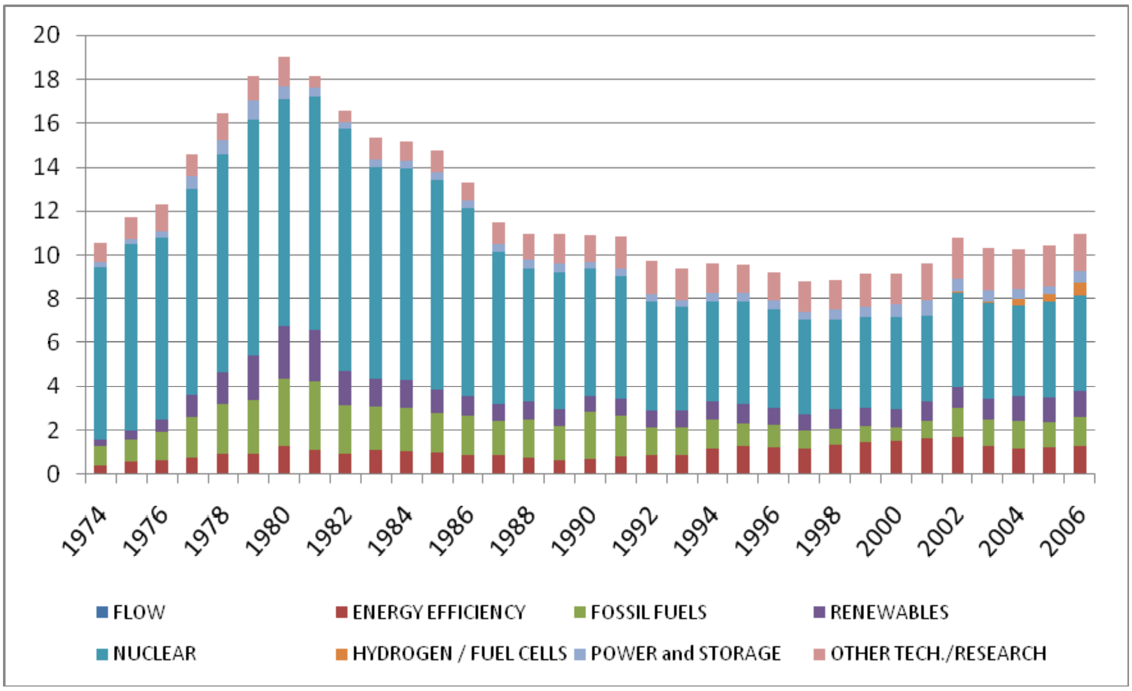
Figure 6. Interaction between carbon pricing and deployment support



Source: Stern (2006)

55. Unfortunately, government energy R&D budgets have been declining since the beginning of the 1980s, though Figure 7 shows that this trend may have been arrested. However, budgets are still low compared to other sectors in both absolute and relative terms. Total government R&D expenditure in IEA countries for low carbon energy technologies was around $9.5 billion in 2006.

Figure 7. Government R&D expenditure in IEA countries 1974-2006 (in billion 2006 USD)



Source: IEA database R&D expenditure

56. Deployment support can be provided through a range of instruments from project subsidies to sophisticated feed-in tariffs to attract private sector investments. These instruments are commonly used in OECD countries and to a lesser extent in developing countries. The Stern Review estimates deployment support in 2004 of $10 billion for renewables and $16 billion for nuclear.

57. Corporate investments in low carbon research, development and deployment are picking up, increasing from $8.37 billion in 2006 to $10.5 billion in 2007[13]. This is approximately the same level as governments were spending in 2006. The venture capital market has been moving swiftly into the market for low emission energy technologies, attracted by a global market potentially worth hundreds of billions per year. Reliable estimates of the venture capital for start-up companies are difficult to obtain. According to New Energy Finance, the total activity in the venture capital and private equity market was $8.6 billion in 2006, with $3.6 billion invested in existing companies and a further $1.4 billion changing hands through buy-outs and spin-offs. A relatively modest $42 million was invested in renewable energy companies in the form of seed capital or angel finance[14]. In total, government and corporate R&D expenditure for low emission energy technologies amounts to roughly $20 billion at present.

4.2 Carbon markets

The Kyoto Protocol

58. As soon as new technologies have been proven to work on a commercial scale and their cost is within reach of higher emission alternatives, governments can help accelerate their uptake by placing a price on carbon. Ideally, any tax or cap-and-trade system should affect all countries, sectors and GHGs in order to have the market exploit all least-cost opportunities to reduce emissions[15].

59. The Kyoto Protocol is the first combined effort of countries to limit or reduce GHG emissions by adopting binding emission reduction targets. Under the Protocol, 37 countries have agreed to reduce their emissions (on a differentiated basis) between 2008–2012 over their 1990 levels. Each country has received emission allowances or Assigned Amount Units (AAUs) equal to the total amount they are allowed to emit. The Kyoto protocol allows countries to trade those emission allowances between one another to lower the economic costs of abatement, as some countries will be able to curtail emissions more cheaply than others.

60. The international 'Kyoto' carbon market will, of course, only mobilise capital for investments in emission reductions projects when the emission allowances handed out to countries are lower than they would emit on a business-as-usual basis. There will only be a price on carbon if the overall market is 'short' on emission rights. If not, projects that reduce emissions against a positive cost will never provide an interesting financial return because it will be cheaper to buy the surplus of emissions in countries that are 'long'.

61. Table 1 compares the baseline emissions of the countries that have ratified the Kyoto Protocol in 2010 (the middle of the commitment period 2008–2012) as projected in the *OECD Environmental Outlook* with their annualised Assigned Amounts Unit (AAUs).

Table 1: Surplus / shortfall foreseen under the Kyoto protocol in 2010

In Gt CO_2 e	**Annual initial assigned amount (2008 – 2012) under Kyoto protocol**	**Baseline GHG emissions in 2010**	**Annual surplus / shortfall**
EU-25 + Iceland, Norway and Switzerland	5.5	6.0	- 0.4
Japan	1.2	1.4	- 0.2
Canada	0.6	0.8	- 0.2
Ukraine	0.9	0.3	0.6
Russia	3.3	2.3	1.1
New Zealand and Australia	0.6	0.9	- 0.2
Total	**12.2**	**11.6**	**0.5**
Total excl. Russia and Ukraine	**7.9**	**9.0**	**- 1.1**

Source: *OECD Environmental Outlook 2008* and (UNFCCC assessments of the) Initial Reports of the parties to the Kyoto Protocol (http://unfccc.int/national_reports/initial_reports_under_the_kyoto_protocol/items/3765.php). To account for the expected RMU's Table 2 of the Compilation and synthesis report is used (document FCCC/SBI/2007/INF.7). For Ukraine and Russia the baseline emissions in 2010 are adjusted from the *Environmental Outlook 2030* data by assuming both countries emissions for 2010 are proportional in their group compared with 2005.

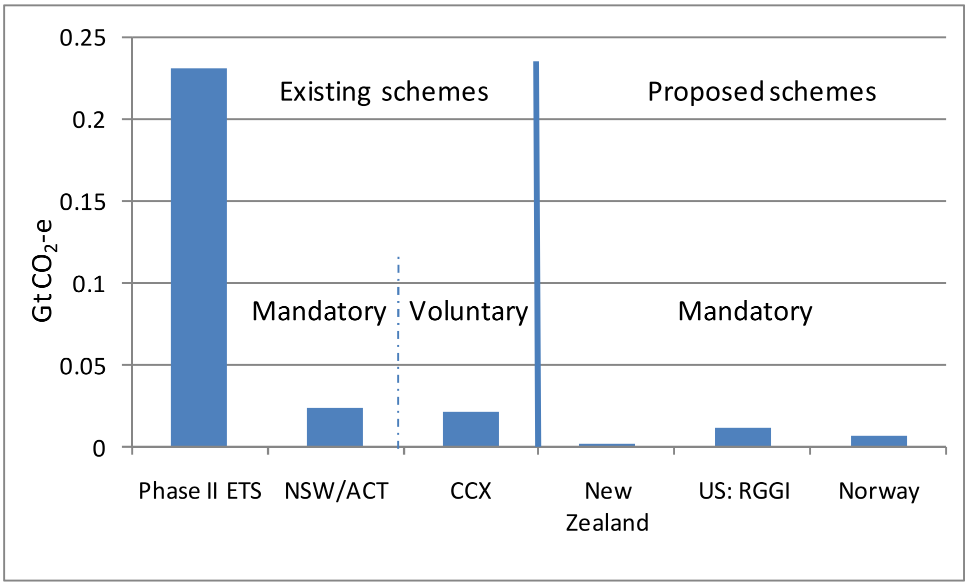
62. It becomes immediately clear from the table that overall, emission targets of all countries that have ratified the Kyoto Protocol are above their expected baseline emissions. This is because baseline emissions in Ukraine and Russia are likely to be smaller than their assigned amount under the Protocol, due to the restructuring of the energy intensive Soviet economy and the economic depression in these countries in the 1990s. If other countries were willing to buy the surplus allowances from these two countries in order to meet their obligations, no capital would be directed to 'real' abatement reduction projects.

63. Most countries have however indicated that they are not (yet) planning to buy allowances from Russia or Ukraine to meet their commitments. Without the emission allowances for these two countries the 'market' would be 1.1 Gt CO_2-eq short as can been seen in Table 1. The demand for GHG reduction projects under the Protocol is therefore expected to be somewhere between 0 and 1.1 Gt CO_2-eq[16].

Emission trading schemes

64. In response or in addition to the international 'Kyoto' carbon market between countries, some governments have created domestic carbon markets by capping emissions by sectors or installations and allowing the trading of emission reductions (credits) or emission rights (allowances). The emission trading systems established and under consideration are regional, national and international systems for segmented parts of the economy. The European Union Emission Trading Scheme is the largest such system, but Japan, Australia, New Zealand, Switzerland and the US also have emission trading systems either in place or under consideration. Excepting the trading systems in the US, all are seen as a contribution to achieve compliance with the Kyoto commitments.

Figure 8. Expected shortfall of different trading schemes in 2010 (see Annex 1 and 2 for further details).



Source: Adapted from Ellis and Tirpak (2006).

Note: The Japanese Voluntary and Swiss ETS are not shown because the expected shortfall is less than 0.001 Gt per year in 2010.

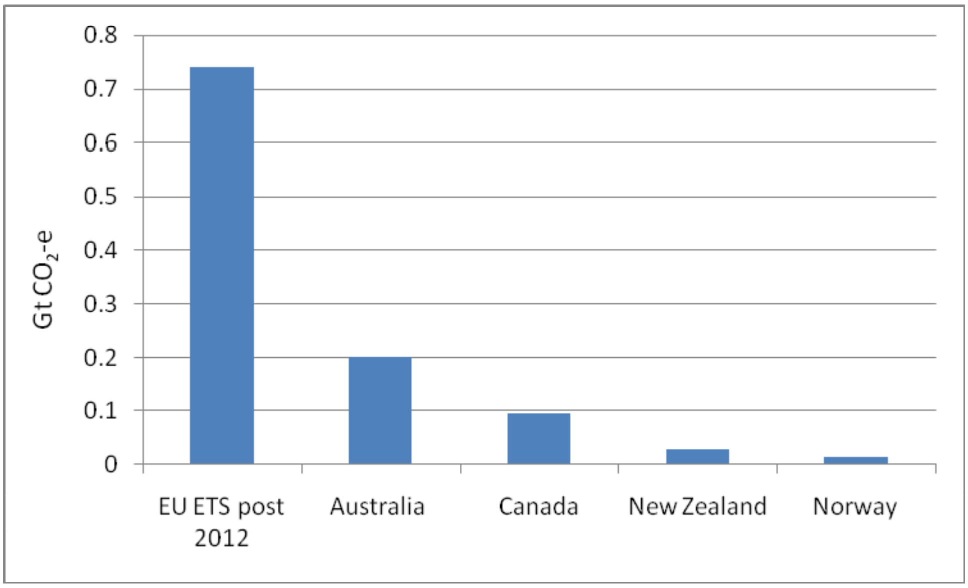
65. Figure 8 gives an idea of the demand for emission reduction in 2010 in several established and proposed emission trading schemes. The total demand for emission reductions (shortfall in the market) would amount to almost 0.3 Gt CO_2-eq with the European Union Emission Trading Scheme responsible for

80% of the demand. The European Union Emission Trading Scheme does not allow the commitment gap to be filled by imported AAUs. Only EU allowances allocated under EU ETS, Certified Emission Reductions (CERs) from Clean Development Mechanism projects and Emission Reduction Units (ERUs) from Joint Implementation projects can be used for compliance (see below). The CERs and ERUs only add up to roughly 10%[17]. It remains to be seen how many other emission trading schemes will follow Europe in prohibiting the import of foreign AAUs. This will determine whether the surplus in Russia and Ukraine can reduce the pressure to achieve emission reductions in these markets. The proposed scheme in New Zealand for example does allow for the import of AAU's.

66. Some countries have already proposed extensions of their trading schemes beyond 2012 and new national schemes have been announced in Australia, New Zealand and Canada. The European Union has committed to reduce GHG emissions by 20% against 1990 levels in 2020 and will continue the European Union Emission Trading Scheme after 2012. These countries are planning to have schemes in place after 2012 regardless of the outcome of an international agreement on emission reductions. The expected demand for emission reductions is therefore likely to be larger in 2020.

67. Figure 9 provides a preliminary overview of the expected shortfall by comparing baseline emissions in 2020 with the stated reduction targets for the sectors covered by the trading scheme. The demand for emission reduction or the expected shortfall for these trading schemes would be roughly 1 Gt CO_2-eq in 2020 – still far short of the 7 Gt reduction in energy-related emissions that would be needed by 2020 to limit long term temperature increase to 2.4–2.8 degrees Celsius as envisaged by the BLUE scenario.

Figure 9. Expected shortfall for announced emission trading schemes in 2020



Clean development mechanism and joint implementation

68. Emission trading is based on the exchange of credits and allowances created and allocated under cap-and-trade regimes. Besides trading of emission rights, emission reductions can also be transacted on a project-by-project basis. In this scenario the buyer purchases emission credits from a project that can verifiably demonstrate GHG emission reductions compared with what would have been generated otherwise (World Bank, 2007). The most notable examples of flexible mechanisms under the Kyoto Protocol are the Clean Development Mechanism, generating credits called certified emission reductions

(CERs) and Joint Implementation, generating emission reduction units (ERUs). These instruments allow the credits from emission reduction projects in one country to be used by another to meet its Kyoto commitment.

69. Credits generated in the project market are, once verified and certified by the UNFCCC, acceptable in the Kyoto market to offset national commitments under the Kyoto Protocol. CERs and ERUs are added to countries' Initial Assigned Amount to create additional emission allowances. The demand for CDM and JI projects is therefore an alternative to more expensive emission reductions in developed countries.

70. The United Nations Environment Program maintains and publishes a database for projects with project design documents that have been submitted for validation by the UNFCCC (the UNEP/RISOE project pipeline) [18]. On 1 February 2008 projects totaling 2.9 Gt CO_2-eq were in the pipeline[19]. If all these projects are transacted, realised and delivered in 2012, the total annual volume over the first commitment period will be roughly 0.6 Gt CO_2-eq per year. The pipeline for Joint Implementation projects is much smaller with a total annual volume of 0.0078 Gt CO_2-eq per year.

71. The CDM and JI mechanisms do not create an additional demand for carbon reduction units, they simply transfer where emission reduction activities take place. Only when CDM credits are purchased in the voluntary market to offset emissions will they be additional to the compliance market. For this reason it is not appropriate to add the demand in the project based markets to the demand in the emission trading market to calculate the total demand in the carbon market. As most systems have adopted limits to the use of CDM/JI, the demand for CDM projects will be limited by those thresholds. Notwithstanding that, the total annual CERs are already providing 54% of the calculated expected shortfall of 1.1 Gt CO_2-eq in 2010 in the 'Kyoto' market (excluding Russia and Ukraine). The anticipation of further reduction commitments post-2012 could already be underpinning demand in the CDM market.

The voluntary market

72. Since the late 1990s a growing number of companies and individuals are choosing voluntarily to reduce and offset their GHG emissions. Sometimes this is done for specific activities such as airplane flights or large-scale events, but more and more companies and organisations aim to become 'completely' carbon neutral. This is acheived to a large extent by offsetting their emissions via projects that generate Voluntary Emissions Reduction (VER) credits to distinguish them from the Certified Emission Reductions under the Kyoto protocol.

73. The voluntary market is estimated by the World Bank (2007) to be around 0.013 Gt CO_2-eq in 2006 and expected to have grown further in 2007. Though relatively small, it is a vibrant and creative market providing new abatement ideas for the more mature Kyoto market, as there is more room for project experiments, fewer rules and less bureaucracy. The counterside of this flexibility is that the markets are plagued by questions over the additionality of the offsets and even fraud (selling offsets twice, permanence of offsets, etc.). In response to the latter concerns, quality labels are being developed and introduced that should provide some guarantee with respect to their environmental integrity. Provided real additional emission reductions occur, the voluntary market is an additional source of projects in countries that have no Kyoto commitments.

Linking carbon markets

74. Currently there are limited linkages between different emission trading schemes and markets. The links that are in place are mostly unilateral (expect for the markets that are integrated in the EU ETS) by allowing a certain percentage of offsets for compliance. The offsets are mostly CDM and JI emission

reduction certificates. The benefit of further linking of carbon markets is evident, as it would further facilitate the economic efficiency of the system by providing opportunities to achieve emission reductions at the lowest costs. However, without clear rules or a single market regulator, strong two-way linking might very well damage the environmental integrity of the system[20].

75. The experience with the first phase of the EU ETS has shown the importance of setting the appropriate allocated amount to avoid over allocation and the collapse of prices. Full linking of emission trading schemes between different regions and markets will reinforce the need for international coordination and clear allocation rules. As the EU experience has shown, competitiveness concerns can provide powerful incentives to shield domestic markets through the issue of relatively abundant allowances. The consequence will be prices falling to levels that do not provide sufficient incentives to drive investments in low carbon projects and power sources, thereby compromising the environmental outcome sought. However, not only the level of allowances but also the specific allocation rules (auctioning, new entrants, etc.) will determine the incentives for emission reductions[21]. Linking will therefore require transparent negotiations and terms of agreement in advance of trading periods.

76. As shown in Annexes 1 and 2, the characteristics of the different trading schemes currently in place or under consideration have different sizes, design features and sectoral coverage, which will make it more difficult to guarantee the overall integrity of the linked markets.

4.3 The enabling environment

77. Investments in low emission technologies are not only driven by the carbon market and government investments in research, development and deployment. An enabling environment for private investment depends on a broad range of conditions. The World Bank emphasises that it will be a real challenge to close the investment gap for the electricity sector in many developing countries because the regulatory environment is not conducive to investment and sustained profitable operation[22].

78. Even when business in a country can be done relatively easily there are several situations in which price instruments will not be enough to induce investments in low emission technologies. An often-used example is the split incentive in building insulation, where landlords are responsible for investments in insulation but tenants pay the energy bill[23]. In these situations there is a case for complementing price instruments with other approaches such as building codes. However, standards should be used with some caution. The implicit carbon price must be made transparent in order to value their cost effectiveness. It is also important to avoid standards and codes falling behind the technical leading edge when governments lack the means to update them.[24]

79. Foreign direct investment and trade in low emission technologies will be hampered by the investment regime in countries limiting foreign ownership, failing to protect intellectual property rights and levying high tariffs on imported goods and services related to those technologies. Most of the barriers will be generic, however, and addressing them will not necessarily – although important for encouraging trade and foreign investments – discriminate investments in favor of low emission technologies[25]. However, targeted initiatives such as the recent proposals to eliminate tariffs on specific climate-friendly technologies could make a positive difference when implemented. Furthermore, the regulatory environment can strongly influence technology development. For example, a key legal issue with carbon capture and storage is how to deal with leaking from storage sites and distribute liabilities between the private sector and governments.

80. Another barrier to investment in low emission technologies is the existence in many countries of subsidies to fossil fuels which effectively place a negative price on carbon. Fuel tax rebates, energy price regulations and producer subsidies are still very large. Although reliable estimates are lacking the partial

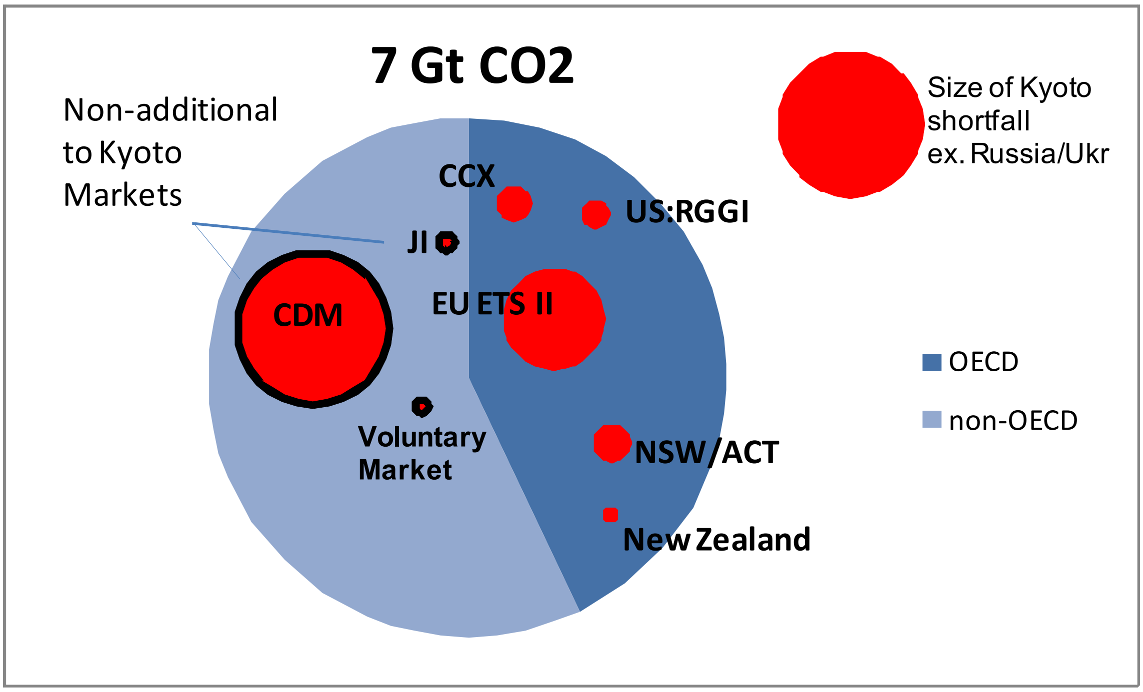
research available suggests energy subsidies to fossil fuels might be as high as $180–200 billion per year in developing countries (estimates for OECD countries are not available)[26]. Reforming these subsidy schemes is made difficult by the fact that they are used to protect low income families from immediate rises in energy prices. But the perverse incentives for energy efficiency and emissions make it important to find other ways of delivering these social objectives.

4.4 Carbon markets and low emission energy investments

81. Efficient carbon markets should mobilise investments in projects that reduce GHG emissions at the lowest possible cost. The capital mobilised for clean energy investments is therefore likely to be determined by the relative cost of using low emission energy technologies as opposed to reducing GHG in other sectors and the total demand for emission reductions projects. Figure 10 shows the required emission reduction in 2020 – to remain on a trajectory limiting temperature increases to under 3 degrees Celsius at the end of the century – against the estimates of the size of the carbon market in 2010 (both in Gt CO_2). As Figure 10 demonstrates, the demand for emission reductions from post-Kyoto commitments needs to grow tenfold if a 7 Gt reduction is to be achieved against the baseline. The use of market instruments in relation to the Kyoto commitments is very large.

82. Existing emissions trading schemes (ETSs) are expected to cap annual emissions in 2010 at around 0.3 Gt CO_2 below business-as-usual emissions. The CDM/JI market is expected to be around 0.6 Gt in 2010, though part of this will be used to meet the shortfall in ETSs. It is largely a political decision how much of the expected shortfall will be supplied by CDM/JI credits. In the EU ETS II, for example, the import of credits earned from CDM projects is capped between 10 and 20% of total allowances[27].

Figure 10. The financing gap to be closed between 2010 - 2020



Source: Graphic adapted from presentation by Jane Ellis.

The required emission reduction of 7 Gt CO_2 is calculated as a 20% reduction against the business as usual path in 2020. The graph shows the size of the carbon market as measured by the emission reductions in ETSs and CDM in 2010 and compares this with the needed emission reductions in 2020.

Announced trading schemes and commitments post-2012 are therefore not included. The shortfall in the ETSs (0.3 Gt CO_2) will be partly met by CDM/JI credits (0.6 Gt CO_2) and therefore the two should not be summed. The distribution of OECD and non-OECD reflects the location of least-cost emission reduction opportunities and does not imply any judgement on who should pay for the emission reductions.

83. At this point, the carbon market is too small to meet the increased costs that scaling up of low emission technologies will require. These costs are lower to start with but rise steeply towards 2050 as cheap abatement opportunities diminish. Around $100-$300 per annum would be needed in 2020 but by 2050 that figure may have increased to as much as $1 800 to $5 600 billion per annum, as described in Section 3.

84. At a carbon price of $25 per tonne, the ETSs shortfall of 0.3 Gt CO_2 together with the current CDM pipeline of 0.6 Gt CO_2 would stimulate $20 billion to cover the incremental cost of low emission technologies in 2010. The annual financing gap for low emission technologies that needs to be closed between 2010 and 2020 would still be around $80-280 billion in 2020.

85. The real financing gap will be larger, as not all carbon finance will be directed to the energy sector. Experience to date suggests that approximately half of total CDM emission reductions are likely to be coming from energy-related technologies up to 2012[28]. This is broadly in line with energy-related CO_2 emissions being around 55% of total GHG emissions. It is to be expected though that the share of energy-related projects in CDM will gradually increase over the years as cheaper, non-energy sector abatement options diminish.

86. Another means of estimating the financing gap is to analyse current and required investment levels in low emission technologies. Data on a project by project basis, presented by UNEP and New Energy Finance[29], shows total investment in low emission energy technologies at around $71 billion in 2006, forecasted to grow to $85 billion in 2007. According to their report, investments were still very much driven by policy, including the broad array of tariff and fiscal support regimes in many developed and developing countries. Not all of these investments will be incremental though, as some investments in low emission energy technologies will replace carbon-intensive technologies. However, even if all of these investments were incremental they would need to be scaled up substantially in the coming decades. Incremental investments of $1 000 billion per year would be required on average in the 2005-2050 period to halve emissions (see Section 3.2).

5. How could sufficient investments be mobilised to fill the financing gap?

87. The preceding sections have presented the additional costs of low emission energy technologies and the amount of finance currently available to pay for them. It is evident that the level of investments will have to increase very significantly to close this financing gap. The volume of investments available worldwide will to a large extent be determined by the international policy context in the years after 2012. Whereas an international agreement on climate change combined with emission trading on a global level can be expected to generate large amounts of capital, less complete international agreements will probably not be able to release the necessary funds.

88. The uncertainty about the post-Kyoto climate framework makes it difficult to develop a view on the investments that will be available after 2012 for low emission energy technologies. Indeed, the uncertainty will in itself have a negative effect on the available investments. This reality is already reflected in the case of CDM projects, which generate emission reductions in the years beyond 2012. Prices for these credits are considerably lower than those paid-for credits generated up to 2012.

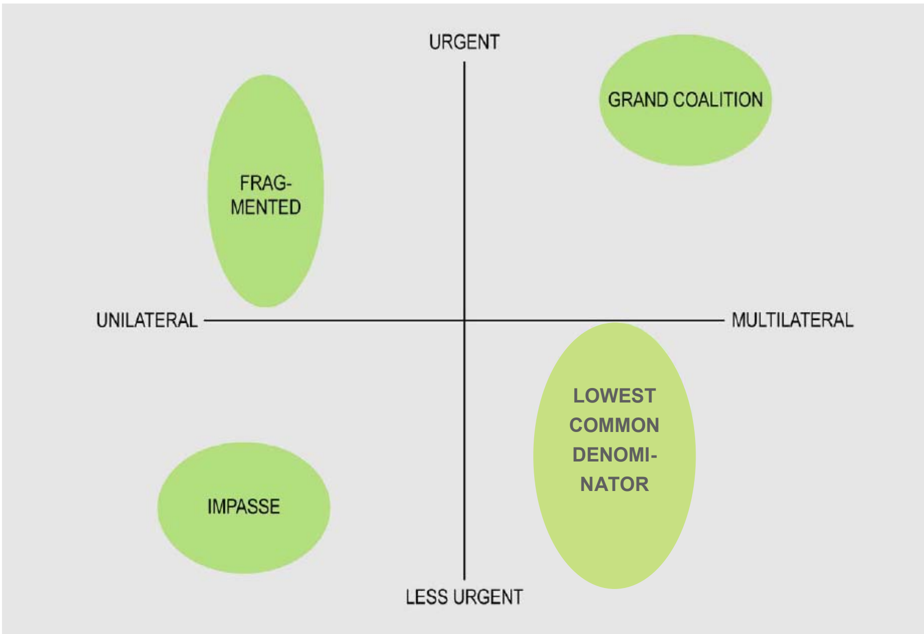
89. One way of dealing with this uncertainty is to postulate alternative international policy scenarios which would in turn stimulate a range of alternative investment climates beyond 2012. We present four

policy scenarios which focus on the period from 2012–2020 to see how actions in the medium term play out and influence the investment climate for low emission energy investments and the implications for emission reductions and economic growth in both developed and developing countries.

5.1 Policy scenarios

90. The four policy scenarios presented here have been developed by the CPB Netherlands' Bureau for Economic Policy Analysis and the Netherlands Environmental Assessment Agency (Boeters et. al. 2007). Scenarios are, at their level of aggregation, feasible, internally-consistent representations of the future. They are not predictions, but simply provide alternative future developments that – from today's point of view – have similar chances of materialising. As the emphasis lies on exploring the consequences of globally divergent climate policy settings for the availability of investment, the scenarios are distinguished along two dimensions: the extent of urgency expressed by the policy measures, and the willingness to resolve the climate problem through international collaboration either unilaterally or multilaterally. In principle, the four scenarios are defined by these two distinguishing dimensions. Figure 11 indicates these dimensions and the positions of the scenarios.

Figure 11. Policy scenarios



Source: Boeters et.al. 2007

91. In the Grand Coalition scenario there is a broad recognition of the seriousness of the climate change problem. Therefore, countries are willing to cooperate in reducing GHG emissions in order to keep the world on track for limiting climate change-induced temperature rise to below 3 degrees Celsius. By contrast, in the Impasse scenario, even though the seriousness of the problem might be recognised by some countries, there are many factors which make it difficult for them to address the problem together. Consequently, it is not possible to create a sufficiently large coalition to effectively reduce GHG emissions. In this scenario the EU is the only region which is prepared to limit its emissions significantly. However, recognising that on its own it will have limited effect on worldwide emissions, the ambitions of the EU are limited.

92. The scenarios Fragmented and Lowest Common Denominator take intermediate positions. In the former, countries do acknowledge that climate change poses a problem, but they differ with respect to the priority that should be given. Consequently, countries implement a range of different national or regional policies with varying (implicit) emission targets. By contrast, in the Lowest Common Denominator scenario, the main concern of countries is to align their climate policies to those of other countries. They do not want to be found to be ahead of other countries, fearing the possible negative economic consequences of being in the lead. The result is that international agreements are set at the level of the least ambitious country (the lowest common denominator).

Scenario facts and outcomes

93. The scenarios are run with WorldScan, a general equilibrium model for the world economy. WorldScan has been used extensively for the analysis of international climate change policies (Boeters et.al. 2007). The scenarios are evaluated against a baseline, business-as-usual scenario without climate change policy. The baseline used in the scenario study is a so-called middle-course scenario, which is based on the IPCC scenarios.[30]

94. Table 2 below provides the main assumptions and outcomes of the different scenarios in 2020 compared to the baseline. The first part of the table shows the emission reduction targets for the various countries and regions in Gt. Emission reduction targets for those countries that take on a binding emission objective in Grand Coalition and Lowest Common Denominator are based on emissions per capita. Therefore, countries with a relatively high emission-per-capita level have a relatively heavy reduction target, reflecting the greater financial responsibility of OECD countries. In Fragmented, targets are based on assumptions about country-specific policies such as, for example, energy efficiency and biofuels in the USA and emission reduction targets for the EU and Japan.

95. The second part of the table shows actual emission reductions achieved in 2020. It shows in which regions and countries emission reductions are actually taking place, not who is paying for them – that is, after emission trading and CDM transactions[31] (post-trade) have shared the burden of emission reduction according to the assumed reductions targets in the different scenarios and as presented in the first part of Table 2. In Grand Coalition there is emission trading between all the major emitting regions and countries. Consequently, the EU, US and the rest of the OECD will buy allowances from the former Soviet Union countries and the fast-developing countries such as China, India and Brazil. This is reflected in the third part of the table on national income, which shows an increase compared with the baseline for those countries which sell emission allowances. In Lowest Common Denominator there is also emission trading, but only between Annex I countries. Large, fast-growing countries participate through CDM. In Fragmented, the EU and Japan use CDM in countries in Latin America, China and India to lower the costs of emission reduction (up to 20% of the total reductions). The other OECD countries do not use CDM, which reflects the emphasis put on local policy priorities such as security of supply or local air pollution.

96. Global emission reductions are highest in Grand Coalition, keeping the world on course to limit temperature increases to below 3 degrees Celsius. In the other scenarios, emission reductions are lower and consequently concentrations of GHG rise further. Costs in Fragmented are as high as in Grand Coalition even though emission reduction is considerable less, because of the lack of international cooperation. Impasse shows the effects of climate policy in only one region, the EU. The effect on global emissions of the EU's 24% emission cut over the baseline in 2020 (equalling a 5% emission reduction compared to 1990 emissions or 1.14 Gt in absolute reductions) is almost negligible, while costs for the EU are even higher than in Grand Coalition.

97. A striking point is that countries such as China and India could gain in terms of National Income if they took part in a Grand Coalition-style international agreement because of the positive effect of the

inflows of capital into these countries. Other regions and countries will not be prepared to go as far in limiting greenhouse gas emissions if there is no global coalition and therefore the effectiveness of worldwide emission reduction is significantly reduced in the other scenarios. Moreover, the willingness to buy emission reductions through CDM in countries which do not take part in an agreement will probably be limited, as exemplified by the recent proposals of the European Commission that limit the use of CDM for compliance by Member States to 3% of non-ETS 2005 emissions if no international agreement can be reached[32].

Table 2: Assumption and outcomes policy scenarios

	Grand Coalition		*Fragmented*		*Largest Common Denominator*		*Impasse*	
Emission Reduction Targets 2020 [Gt] and (%) reductions compared to 2020 baseline								
EU-25	1,80	(-38)	1,52	(-32)	1,23	(-26)	1,14	(-24)
USA	3,23	(-47)	0,82	(-12)	0,82	(-12)	0,21	(-3)
Former Soviet Union	-0,20	(7)	0,20	(-7)	0,20	(-7)	0,09	(-3)
Rest of OECD	1,16	(-39)	0,75	(-25)	0,72	(-24)	0,09	(-3)
China	0,51	(-10)	0,25	(-5)				
India	0,10	(-5)	0,10	(-5)				
World[1]	7,12		3,85		3,08		1,52	
Post-trade Emission Reductions 2020 (Gt) and (%) reductions compared to 2020 baseline								
EU-25	0,71	(-15)	1,28	(-27)	0,62	(-13)	1,14	(-24)
USA	1,37	(-20)	0,82	(-12)	1,17	(-17)	0,21	(-3)
Former Soviet Union	0,63	(-22)	0,20	(-7)	0,55	(-19)	0,09	(-3)
Rest of OECD	0,54	(-18)	0,60	(-20)	0,45	(-15)	0,09	(-3)
China	2,29	(-45)	0,41	(-8)	0,10	(-2)		
India	0,57	(-30)	0,13	(-7)	0,04	(-2)		
World[1]	7,12	(-21)	3,85	(-11)	3,08		1,52	(-4)
National Income (% change compared to baseline)								
EU-25		-0.4		-0.6		-0.3		-0.5
USA		-0.3		-0.0		-0.0		0.0
Former Soviet Union		0.8		-0.7		-0.2		-0.4
Rest of OECD		-0.4		-0.4		-0.2		0
China		0.4		0.0		0.0		0
India		0.1		0.0		0.0		0
World[1]		-0.2		-0.2		-0.1		-0.1
(Implicit) emission price (2001 $ / tCO_2)								
EU-25		21		45		16		37
USA		21		12		16		2
Former Soviet Union		21		6		16		2
Rest of OECD		21		30		16		3
China		21		2				
India		21		4				
World		21						

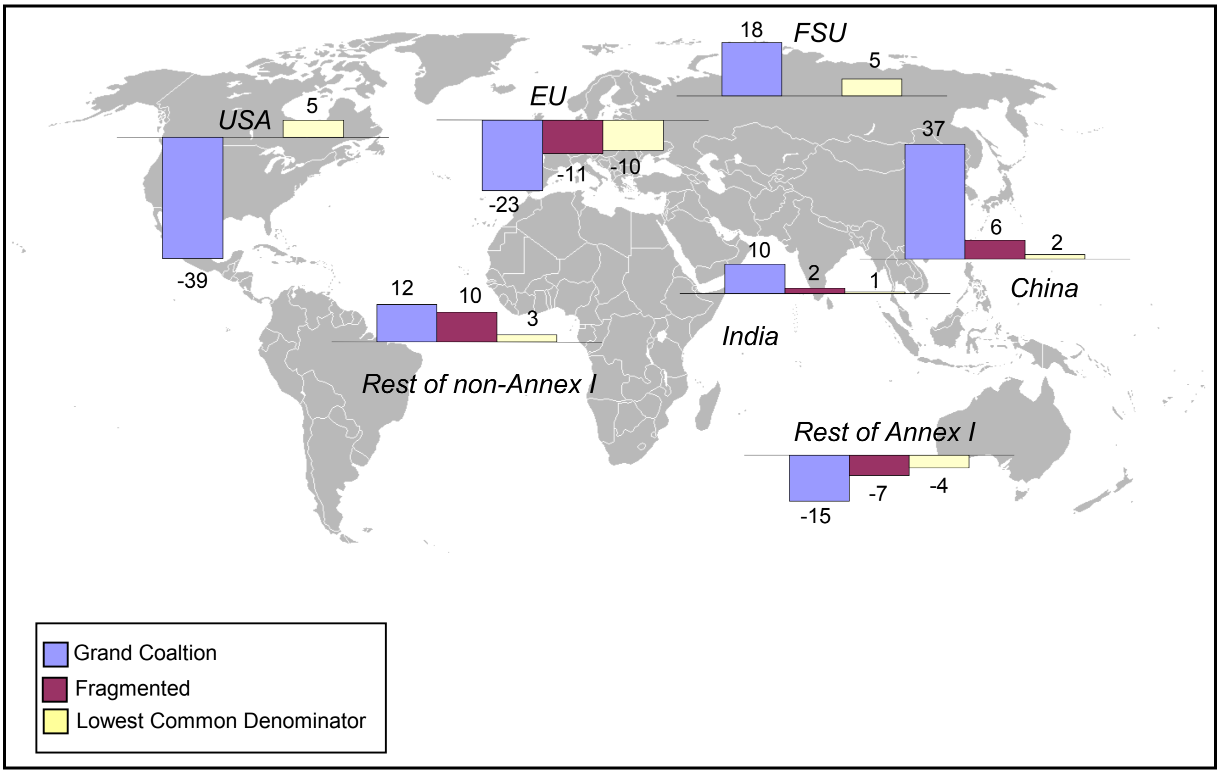
[1] includes the rest of the world

Investments

98. Given these scenarios, what are the consequences for international investment flows? Figure 12 (see also Table 3 below) shows the trade flows resulting from emission trading and CDM in the different scenarios. These trade flows represent the international component of the investments which are made

available through carbon markets for investments in CO_2 reduction. They are in addition to domestic funding that will be mobilised.

Figure 12. Carbon investment flows between regions (in $ billions), 2020



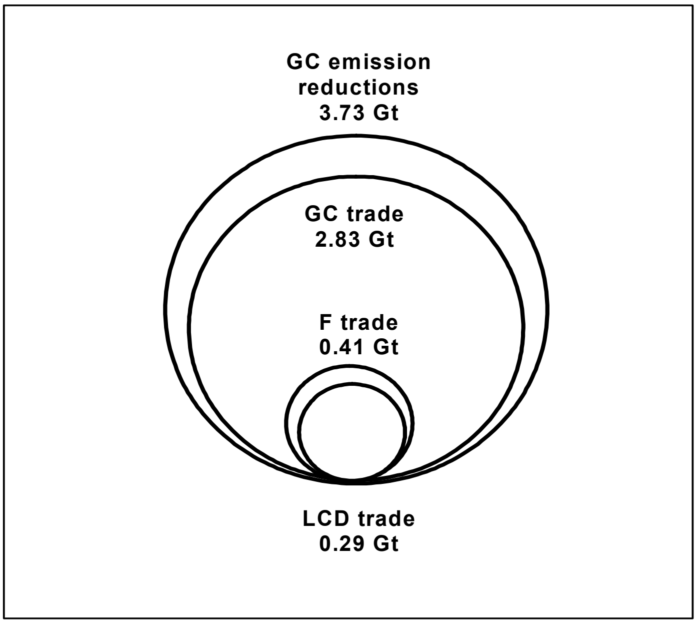
99. In Grand Coalition it is assumed that there is emission trading between all major emitters, including China, India, Latin America, Middle East and North Africa. Given the large availability of relatively inexpensive mitigation options in the fast-developing countries which take part, there will not be a large role for CDM as developing countries will be able to sell their allowances directly on the international market. Annex I countries (except the countries of the former Soviet Union) are the major importers of emission allowances, as is to be expected given the reduction targets which are based on emissions per capita. The total value in 2020 of the allowances bought by these Annex I countries is about $70–80 billion for an importation of 3.6 Gt of CO_2 allowances. The United States is the largest single buyer, spending almost $40 billion. The largest single recipient is China, which receives almost $40 billion for the emission reductions it sells abroad. This is reflected in the positive effects on its National Income. The same holds for other exporting countries and regions such as India, although to a lesser extent.

100. In Fragmented, there is no international trading system. Although there is some trade between the EU and Japan (not shown in the table), the main channel for international investment flows is CDM. The trading schemes in the EU and Japan create a demand for CDM-credits which is met by developing countries. The volume is considerably smaller than the trade volumes in Grand Coalition. Demand is 0.4 Gt in 2020, for a total value of $18 billion (assuming that the EU carbon price sets the international price for CDM-credits). For CDM a maximum has been set, limiting the use of CDM credits to about 20% of total required reductions. This reflects uncertainty regarding future availability of CDM emission reduction credits, transaction costs and limited willingness of the EU and Japan to acquire emission reductions in non-participating countries.

101. The Lowest Common Denominator scenario includes both emission trading between Annex I countries and CDM with non-Annex I regions. Trade between the Annex I countries covers about 0.7 Gt; CDM provides on the order of 0.3 Gt in 2020. The value of trade within Annex I is $10 billion per annum, while CDM generates $4 billion in 2020. As in Fragmented, access to CDM credits has been capped at 10% of the emission reductions needed compared with the baseline for the countries which buy allowances.

102. The relevance of emission trading and CDM in non-Annex I countries is shown in Figure 13. *GC emission reductions* gives the total emission reductions realised in Grand Coalition. *GC trade* presents the part of these reductions purchased by Annex I countries. *F trade* and *LCD trade* are emission reductions exported in Fragmented and Lowest Common Denominator. This equals the total emission reductions in non-Annex I countries, as these countries have no target in these scenarios and will therefore not realise emission reductions unless financed from outside.

Figure 13. Foreign investment gap non-Annex I in Gt



103. The share of total reductions (GC emission reductions) financed from abroad in 2020 in the most ambitious scenario (GC trade) is large: 76%. This reflects the burden sharing in the Grand Coalition scenario, in which emission reduction targets are based on emissions per capita. The exported emission reduction in Grand Coalition can be considered as the benchmark for foreign investment, against which the trade in reductions in the other scenarios can be measured. The far smaller trade flows in Fragmented and Lowest Common Denominator illustrate how large the investment gap in developing countries will be without an optimal international framework for emission reduction.

Table 3: Carbon investment flows in 2020

Grand Coalition	*Trade*		*share of CDM*	
	Volume	Value	Volume	Value
	[Gton CO_2]	[$ bln]	[Gton CO_2]	[$ bln]
EU-25	-1.07	-22.63		
Former Soviet Union	0.82	17.28		
USA	-1.83	-38.70		
Rest of OECD	-0.7	-14.86		
China	1.76	37.20		
India	0.45	9.59		
Others	0.57	12.14		

Fragmented	*Trade*		*share of CDM*	
	Volume	Value	Volume	Value
	[Gton CO_2]	[$ bln]	[Gton CO_2]	[$ bln]
EU-25			-0.3	-13.27
Former Soviet Union				
USA				
Rest of OECD			-0.1	-4.59
China			0.14	6.11
India			0.04	1.92
Others			0.22	9.81

Lowest Common Denominator	Trade		share of CDM	
	Volume	Value	Volume	Value
	[Gton CO_2]	[$ bln]	[Gton CO_2]	[$ bln]
EU-25	-0.62	-9.76	-0.12	-1.89
Former Soviet Union	0.34	5.44	0	0.00
USA	0.34	5.46	-0.08	-1.34
Rest of OECD	-0.27	-4.26	-0.06	-1.02
China			0.09	1.45
India			0.03	0.46
Others			0.15	2.33

5.2 Foreign investment gap

104. The scenario analysis highlights the consequences of specific international policy settings for the availability of investment funds in low emission energy technologies generated through carbon markets. There is an order of magnitude difference between, on the one hand, the funds generated in the Grand Coalition scenario and the funds available in the other scenarios. The cost effectiveness of an international coordinated climate policy is clear. Only a Grand Coalition type of policy framework will generate the required funds for the implementation of low emission energy technologies that would limit temperature increases on acceptable levels. Moreover, those countries that export emission reduction credits will benefit most in terms of national income under an agreement comparable to Grand Coaliton. This conclusion is consistent with the analysis in the *OECD Environmental Outlook 2008* that also shows that permit allocation could be used to share the burden in an equitable way under an emission trading system[33].

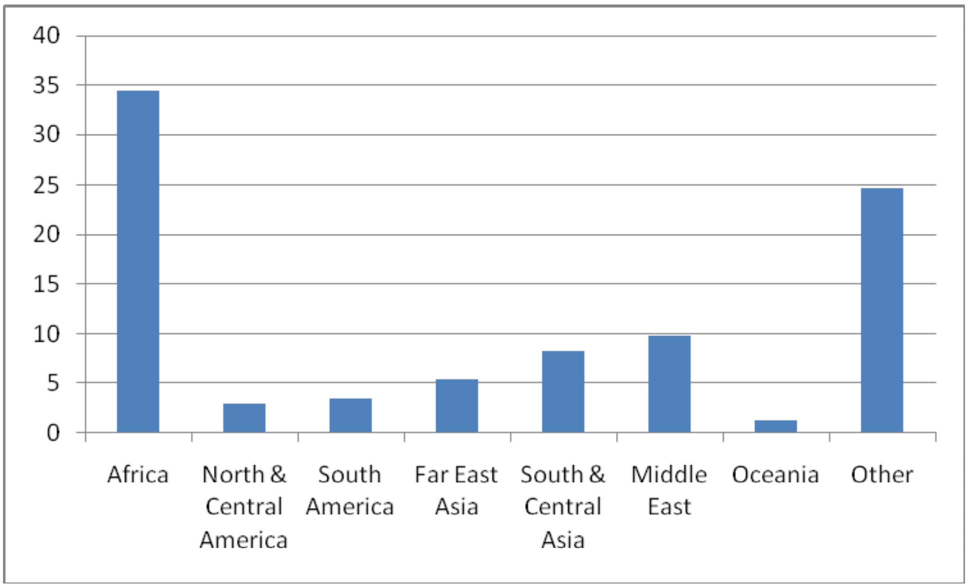
105. In reality, however, it has proven extremely difficult to achieve consensus on how to design an international framework conducive to investments in low emission technologies. The detail of any

international framework could have substantial consequences on economic growth and wealth distribution and therefore countries are extremely cautious about taking steps towards agreeing one. The question is whether the investment gap in developing countries could be met by any other instruments through to 2020 assuming that developed countries would commit to the required emission reductions and pay for the reductions that could be achieved in developing countries at lower costs.

Official Development Assistance

106. Under the UNFCCC, developed countries have agreed to assist developing countries in their mitigation actions. In a cost-efficient scenario the annual incremental investments in low emission technologies would be $100 to $300 billion in 2020, of which more than half should take place in developing countries. If it is implied that the resources to meet the developing country fraction should come from development assistance (ODA) budgets then these would need to increase on the order of $65 billion per year or by more than 50%. There is no precedent for this sort of increase. Even if there were, there are many more urgent claims on ODA budgets than climate change. Furthermore, within climate change related expenditures substantial funds will be required for the costs of adaptation. Considering that in 2050 the incremental costs of low emission technologies will grow to around $900 billion in developing countries, it is clear that development assistance funds cannot supply the complete answer.

Figure 14. Official Development Assistance in 2006 (in $ billion)



Source: OECD International Development Assistance (ISD) online www.oecd.org/dac/stats/idsonline.

The role of multilateral development banks

107. However, ODA plays an important catalysing role in scaling up investments in low emission technologies in developing countries via the multilateral development banks. They work with developing country governments to foster a business environment conducive to private investments by providing technical assistance and policy advice on energy pricing, subsidies and policies to promote energy efficiency. In addition, multilateral development banks cover risks that are still perceived to be excessive by the private sector and leverage investments by sharing these risks with the private sector.

108. The multilateral development banks were early movers in the carbon market, purchasing up-front emission reduction units from projects in developing countries. This has increased the commercial viability of projects that lower emissions by taking away some of the regulatory risk on the price (as a consequence of declining demand in the compliance market) and lowering the capital cost of the project (by reducing transaction costs and providing upfront payment). In addition, the Stern Review noted that commercialising emerging technologies requires risk capital that is often unavailable in developing countries and carbon finance alone might not be sufficient to fund the incremental costs to make a project viable. The Review saw a role for international financial institutions to help in project development and building a pipeline of low carbon projects by using public funds to cover part of the regulatory, country and project risk.

109. The recently established Carbon Partnership Facility run by the World Bank is a case in point. In this facility the World Bank aims to overcome the drawbacks of a project-by-project approach and use carbon finance in sectoral and programmatic initiatives (see next section)[34]. The Facility is to address barriers that prohibit countries from building an enabling environment for large-scale mitigation efforts. The approach can be characterised by three elements: 1) a preparation fund, to finance development and policy preparation; 2) a carbon fund that would purchase carbon credits; and 3) a partnership of buyers and sellers. The Facility could be seen as a way to mobilise the voluntary carbon market and experiment with ways to capitalise the purchased emission reductions in the compliance market. In this way it is testing ideas and methodologies that could possibly be used in the compliance market as it evolves and to ensure market continuity post 2012. But although the multilateral banks play an indispensable role in project identification, technical assistance and catalysing investments, more efficient and effective financial intermediation is not a source of capital in itself that could pay for the additional costs. This needs to come from governments and companies buying emission reduction units.

The Clean Development Mechanism

110. The Clean Development Mechanism (CDM) is the main channel for supporting investments in low emission technologies in developing countries and as such has been successful in helping OECD countries move towards compliance with their Kyoto targets. The current pipeline could provide ideally up to 0.6 Gt CO reductions in 2010; however it is unlikely that stand-alone CDM projects could be scaled up to a 3 to 4 Gt CO_2 market in 2020 and certainly not to the 20 Gt plus market that is needed in 2050. A fundamental limitation of CDM is that it does not reduce net global greenhouse gas emissions, it only compensates (offsets) emissions in countries with binding targets. This means that for every tonne of emissions reduced in a host country, an investor is allowed to emit one tonne more at home.

111. Another problem associated with CDM is carbon leakage, because it creates a subsidy effect at the individual firm level by reducing production costs. This works as follows. Companies make a profit on emission reductions if they can reduce their emissions at lower costs than the price they receive for selling them. This is true both for companies that sell CDM credits and those that sell emission allowances under a cap-and-trade system. However, there is an important difference. In an emission trading scheme the profit does not affect a company's production costs because it must take into account the opportunity costs of its allowances. These opportunity costs equal the value of the allowances if a company closes and sells its allowances in the market. In the EU ETS, power-generating companies received emission allowances for free but did include the market price of allowances in the prices they charged their customers. This gave the companies a windfall profit but did not reduce the effectiveness of the scheme because the costs of emissions were included in product prices. With CDM there are no opportunity costs because a company will have no allowances to sell if it shuts down. Indeed, if the costs of emission reductions are lower than the price of allowances on the market, production costs will fall. In this way, CDM has the same effect as a product subsidy[35]. The result is that with CDM the price of CO_2 is not internalised in the host country and moreover creates a competitive advantage for firms in these countries.

112. There are also more practical reasons why CDM in its current form cannot be scaled up to the required level. The most important is the substantial transaction costs that must be incurred to ensure emission reductions are actually achieved and additional to business-as-usual. If a CDM project does not reduce emission compared to what would happen anyway the net effect is not only zero contribution to overall GHG reduction but net emission will actually increase. This has made it more difficult to establish methodologies and get approval for projects to receive CERs, increasing their transaction costs.

113. Another practical problem of the approval process is that new technologies need international agreement under the UNFCCC to become eligible under the CDM and acceptance by the host country. This creates an additional hurdle for innovative technologies to get access to financing from the carbon market. For example no decision on the eligibility of carbon capture and storage has been taken yet. Reaching international agreements on these technologies is complicated by the skewed distribution of geological formations suitable for CO_2 storage that might generate large volumes of credits in only a limited number of developing countries making it more difficult for others to access carbon finance.

114. In summary, CDM has been successful in leveraging private and public capital towards low carbon projects in developing countries. It has also proven to be a useful way of establishing trust between developed and developing countries as it has become clear that CDM projects can make a contribution to sustainable development objectives in host countries. At the same time, the project-by-project nature, the need to discuss and agree methodological issues at the international level and the long term limitations of offsetting programs – e.g. carbon leakage - limit the role CDM can play in scaling up investments to the level required. Given the limits of both ODA and the role of multilateral development banks, it is clear that stronger international coordination is required. This will be discussed in the next section.

6. Options for international coordination

115. Section 6 considers mechanisms and options to further international cooperation in the period up to 2020 in order to develop and deploy low emission technologies in an efficient and equitable manner. The investment in such technologies is likely to fall well short of the level required in the absence of significant and sustained collective international action. This will hamper both innovation in low carbon emission technologies and their rate of deployment – a critical factor in reducing the cost of new technologies. For this reason it is important to consider ways in which emission reductions in developing countries can be accelerated so as to help fill the investment gap and keep the world on track towards the deep emission cuts needed by the middle of the 21st century.

116. Given this, the period 2012–2020 is vital. Although climate change scenarios need to have very long-term outlooks it is important not to lose sight of what needs to be done on the short and medium term. Minimising the global cost of mitigating and adjusting in a gradual manner requires early action, as the turnover rates of energy intensive capital stocks are very slow. Without early action, billions of dollars of conventional technology will be installed, thereby casting a long emission shadow over the future. Early action is needed to reduce the regulatory uncertainty that will otherwise significantly limit the extent to which global capital markets can mobilise the resources needed to deploy low emission technologies.

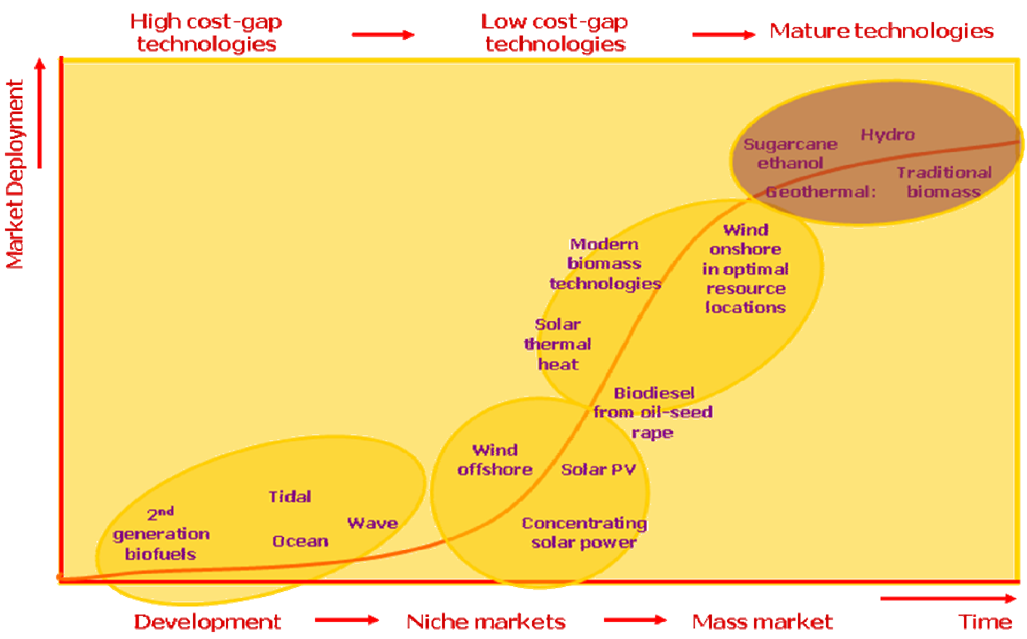
6.1 Accelerating the innovation of low carbon emission technologies

117. Accelerating innovation requires well-designed policies and investments at both the supply (technology push) and demand (technology pull) sides. As innovation follows an unpredictable path, neither governments nor corporations can afford to pursue a single strategy. The risks and uncertainties imply keeping parallel lines of enquiry open. Markets tend to focus on the least-cost technologies in the short term that might not be the best alternative in the long run. Furthermore, low emission technologies will have to be implemented across the globe. The high costs and global common good character of

innovation in low emission technologies argue in favour of international collaboration in developing a broad portfolio of technologies. Several networks exist at present such as the Asia Pacific Partnership, the Carbon Sequestration Leadership Forum and the International Partnership for a Hydrogen Economy. The IEA has the most comprehensive network in which thousands of technology experts from around the world coordinate their technology programmes.

118. However, not enough importance and urgency is given to all technologies in the portfolio at present. For example, by 2020 at least 20 major power plants fitted with CCS technology need to be operating[36]. These plants would cost between $0.5 and $2 billion each, half of which would be additional cost for CCS, whereas current spending is only $0.2 billion. This gap of more than $10 billion needs to be closed if the development of this technology is to be taken seriously. The same holds for developing the use of renewables in electricity generation. As can be seen in Figure 15, many promising technologies are still in the early phases of the innovation process and will need large investment in early deployment to bring down their costs.

Figure 15. The innovation chain for renewable electricity generation technologies



Source: IEA, 2008

119. At the moment, research, development and deployment on energy is still largely concentrated in (a few) OECD countries (US and Japan in particular). This needs to broaden to include developing countries to achieve a more even regional distribution of activity. Some support to developing countries is given, for example via the Global Environmental Facility, but the level is relatively low. The proposed funding of climate change activities under the Global Environmental Facility for the period 2006-2010 is, for example, around $0.2 billion per year including some adaptation funding. Most of this is used to address barriers to the uptake of low emission technologies and improving the enabling environment, not for direct support for research and development.

120. The Stern Review commissioned a modelling exercise that estimated that the level of support via early deployment instruments should increase globally to between $70 and $ 175 billion per year. This is broadly consistent with the ACT and BLUE scenarios, which assume learning investments between $100

and $200 billion per year to achieve the emission cuts in these scenarios. A substantial part of these investments need to come from governments.

121. In response to the need to step up efforts the IEA identifies 17 technologies for energy efficiency, power generation and transport that are crucial in delivering the deep emission cuts required and actions that need to be taken[37]. For each technology cluster these actions are laid out in roadmaps. The IEA seeks further development of these roadmaps under international guidance, drawing together the energy technology programmes of all major economies and in close consultation with industry. This framework could provide impetus for the transfer of technology between countries.

122. This process of strengthened international cooperation needs to be supported and driven by well funded research institutions. Energy research and development expenditure needs to increase. Setting exact targets will be difficult, as the quality of investments is as important as the quantity, but several independent studies have suggested that public sector R&D needs to increase to between two and ten times its current level[38]. As the output of low emission technologies that are still under development will have to grow more than tenfold, it seems appropriate to support this by investing in a new generation of scientists and engineers who will be essential in achieving the penetration of new technologies. This means reversing the trend of declining absolute government energy R&D levels and the declining share of energy R&D in government budgets.

123. Though comparing R&D levels among sectors is difficult, it may be noted that if energy R&D were to double to $20 billion a year it would still represent around one quarter of public spending on defence R&D and 60% of public health care R&D budgets. The costs of this additional expenditure would typically be on an order of magnitude lower than those of full-scale demonstration and deployment programmes. Given that it is important to avoid budget volatility, which makes it hard for laboratories to develop their human capital, a well-directed and sustained effort in energy R&D seems likely to represent good value for money.

Technology transfer

124. The need for technology transfer has been repeatedly acknowledged as discussions on climate change have progressed. For many developing countries the term implies a transfer of technical know-how, access to intellectual property and financial resources from developed country governments. For many developed countries, technology transfer is a process that may occur as the result of development assistance, but is equally the result of technical expertise accompanying private investment flows. The frequency with which the term is used – and inserted into internationally negotiated texts – suggests that greater specificity would be useful. Otherwise, the term is in danger of being used to embrace quite different and sometimes contradictory expectations.

125. For the reasons outlined earlier, there is a valuable role for governments to play assisting with the deployment of leading-edge technologies that are not yet commercially viable in the marketplace. This is as true in developed countries as it is in developing countries. It is also a legitimate activity for development assistance agencies to pursue. Beyond that, technology is likely to be most effectively transferred through direct investment in the energy generation sector. It is clear from the sheer scale of the investment in low emission technologies that will be required between now and 2050 that this investment will not come from governments but from the private sector. In developed countries, the level of emission reductions (and any resulting carbon price) will determine the extent to which those low emission technologies are routinely used.

126. Clearly distinguishing between technology transfer as the explicit object of government expenditures on R&D and deployment subsidies and the transfer of technology as a consequence of

investment flows will be important if measureable progress is to be made. Account needs also to be taken of large changes in the scale and direction of investment flows in recent years. A decade ago, foreign direct investment as a motor for technology transfer was driven by companies domiciled in developed economies. Investments in developing economies gave access to technology but not ownership. Today, significant foreign acquisitions by companies like Tata and Mittal are seeing ownership of advanced technologies pass to companies domiciled in developing countries.

6.2 Harnessing carbon markets

127. In the absence of effective international coordination, commercial investments in emission reductions will be far from optimal, as shown in Section 5. Existing mechanisms such as CDM or ODA alone will not be enough to exploit all low-cost opportunities to reduce emissions in developing countries and close the investment gap. Therefore, other options to include developing countries should be considered, such as broadening the CDM or (sectoral) emission trading schemes. These options are discussed below.

Broadening the Clean Development Mechanism

128. There is a range of options being discussed to broaden the CDM and increase its effectiveness. The first (and furthest advanced) is programmatic CDM. A programmatic approach aggregates smaller projects within a programme of activities that is registered as a single CDM project. This could be the implementation of an energy efficiency lighting program to replace incandescent bulbs with compact fluorescent lights bulbs in a city, for example. The relatively high transaction costs of CDM projects and the small and dispersed nature of these activities would make it impossible to register each household separately as a CDM project. The overall potential for GHG savings under programmatic CDM could be large, as it could be particularly useful for energy efficiency uses and policies. Programme activities can be implemented in several locations, in more than one sector and even involve more than one project type. Another example would be a programme that implements fuel-switching in industrial facilities that use furnaces, boilers and roasters[39].

129. If the institutional barriers to programmatic CDM could be overcome it could greatly enhance its potential by lowering transaction costs and increasing the number of eligible projects. However, lowering transaction costs will not do away with some of the other barriers limiting CDM addressed above and will have no effect on large scale, capital intensive projects such as the construction of wind farms or coal-fired power plants with CCS.

130. A second option is to create regional, sectoral, sub-sectoral, or cross-sectoral project activities that are the result of targeted governmental policies eligible for CDM[40]. The resulting emission reductions should be measured and be rewarded with CERs if accepted and validated as additional under the Kyoto Protocol. This is often called policy CDM. Examples are a renewable energy standard or a new building code requiring more energy-efficient construction methods.

131. A third option is sectoral CDM which refers to voluntary private sector initiatives establishing a sectoral baseline and granting carbon credits to those companies that exceed the baseline performance or intensity target (discussed in more detail below)[41]. For the moment discussions in the UNFCCC seem to exclude both policy and sectoral CDM types from eligibility under the CDM.

132. The UNFCCC gives some room for manoeuvre, however, as policies or standards might be eligible for CDM if it can be demonstrated that they are not presently systematically enforced or, if they are enforced, remain open to significant improvement. There is a fine line between safeguarding environmental integrity and introducing perverse incentives into the system. On the one hand it is very

important to guarantee the additionality of CDM projects and avoid carbon leakage and free riding, because every CER issued leads to an additional tonne of CO_2 emitted by the compliance buyer. On the other hand, if the rules for additionality become too strict, developing countries will have a perverse incentive to refrain from undertaking any climate mitigation policies and measures on their own, as this could render projects non-additional and therefore ineligible for the CDM.

133. The potential for this perverse incentive has been partially removed by the decision to take into account only those policies and standards that were implemented before the adoption of the Kyoto Protocol in December 1997. Policies implemented since that date are not taken into account when the baseline for a CDM project is established. For example, when a developing country has implemented a standard in 2004 that requires 10% of all electricity to come from renewable, this will not be taken into account to establish a baseline for a CDM project to construct a wind farm. The baseline will refer to a hypothetical situation as if there was no renewable standard for electricity generation in the country and all emission reductions compared to the default (least expensive) technology will be regarded as additional and will generate credits.

134. However, the decision will not do away with all free rider and additionality issues. As long as there are no sectoral or country level baselines established there will always be discussion on how to correctly establish the hypothetical project baseline. This will limit the transparency and predictability of the validation and registration process and create regulatory uncertainty for project developers.

Emission trading schemes and non-binding targets

135. To achieve the mitigation efforts and financial flows needed to support them in developing countries on the scale required it is probably necessary to move in the short to medium term to a financial mechanism closer to emission trading schemes. As shown in Section 5, emission trading with appropriate burden sharing could bring win-win opportunities to developing countries in terms of reduced emissions and related co-benefits (including enhanced energy security) while supporting economic growth.

136. To make this acceptable under the rubric of common but differentiated responsibilities, any medium term scheme is likely to rely on action in developing countries that is voluntary and non-binding. There are many ways to interpret this, but a key distinction could be made between a crediting system that rewards emission reductions below the baseline and an allowance system that caps relative or absolute emission levels. The first option could be seen as a broadening of the CDM. The second would give emission trading schemes a more prominent role in developing countries. In theory both could be applied on a country, regional or sectoral level, but in practice trading schemes have been implemented for discrete economic sectors (with New Zealand being the only exception until now).

137. A sectoral CDM that grants carbon credits to those companies that exceeded the baseline performance or intensity target is close to current efforts to broaden CDM, for example by making a programme of activities eligible as a single CDM projects. The perceived advantage over an allowance system could be that there is no downside (if emission reductions are not achieved there is no compliance regime forcing individual participants to buy allowances in the market). There is only an upside in that if emissions are reduced below the baseline they can be sold at a profit. This is, of course, only partly true. Costs must be incurred up-front to deploy the technologies that limit emission growth – an insufficient price for emission reductions certificates will result in a loss. To limit these investment risks it has been suggested to offer companies active in such a scheme a minimum price for their emission reduction units[42]. The up-front purchase of credits by (multilateral) banks on behalf of compliance buyers will also help share those risks.

138. For a sectoral crediting system to successfully complement CDM a wide range of issues need to be addressed. These include, among others[43]:

- International negotiation of a sector-wide baseline in order to make resulting credits acceptable for compliance countries. This would require investments in establishing credible GHG inventories and the institutional capacity to evaluate, monitor and verify proposals from emitting facilities under the scheme;
- The sector should ideally be excluded from eligibility under the CDM as the co-existence might raise concerns as to the additionality of both;
- A commitment from buying countries that credits will be eligible and demand sustained for a long period of time.

139. The second option would be to encourage developing countries to establish cap-and-trade system for distinct economic sectors in return for making these allowances tradable in other emission trading schemes. The advantage would be that developing countries would not have to rely on a complicated approval process under the UNFCCC to receive their credits. The additionality problem is tackled at the outset when establishing the relative or absolute cap for the installations under the trading scheme. This would be no different than what has already been faced in existing trading schemes. However, it would be very important to secure some sort of quantifiable and measureable limitation on the growth of emissions that would be comprehensive enough to avoid massive carbon leakage to other regions and sectors. But the limitations need not be absolute – a reduction in the rate of growth in emissions would be sufficient. Determining that limitation would be a voluntary step by a sovereign government and would lie outside any of the non-compliance mechanisms envisaged by the UNFCCC architecture.

140. However, there would be a need for an independent authority to agree on the procedures establishing the baseline and the level and allocation of allowances. The fact is that all of these issues have to be confronted in respect of single CDM projects. The benefit to developing countries would come in the form of a strongly increased inflow of carbon finance by selling allowances for a higher price to developed country governments with post-2012 commitments and companies with commitments under an emission trading scheme. The discount at which CERs are currently sold on the carbon market (because of the investment and regulatory risk) would be avoided, increasing the profitability of cutting emissions for developing countries.

141. Complementing the flexible instruments under the Kyoto protocol by sectoral trading systems in developing countries is perhaps the most feasible way to sufficiently ramp up commercial investment in low emission technologies in developing countries. It could build trust in developing countries, that lowering the trajectory of their emission growth does not have to come at the cost of economic growth while developed countries could feel more secure that their efforts to reduce emissions would not be undone by the rapid growth of emissions in emerging and developing economies.

ENDNOTES

1. According to the IPCC (2007).

2. IPCC (2007): Summary for Policymakers.

3. IEA baseline scenario in *Energy Technologies Perspective* (ETP).

4. (IPCC, 2007): while assuming non-CO_2 GHG to decline slightly more than energy CO_2.

5. Using the 2005 electricity sector emissions factor.

6. In the IEA energy accounting system the cogeneration benefits are allocated to the power sector, where they show up as higher efficiencies of power plants (mainly in gas-fired power generation).

7. Without the efficiency gains assumed in BLUE this would amount to a 15% market share likely to lead to a high use of the total biomass that can be sustainably produced and used worldwide. For a discussion see also Doornbosch and Steenblik (2007).

8. In the ETP analysis a very simple approach is applied. The impact of reduced oil and gas cost and the GDP costs are not taken into account. While reduced oil and gas costs constitute a benefit to oil and gas importers, it represents reduced economic activity of oil and gas exporting countries. It also makes a significant difference if these credits are valued at import price level or at production cost level. Given these complexities, they are left outside of the discussion. GDP will be affected, as the optimal resource allocation will change if the external effects of CO_2 are internalised. Reductions of GDP can only be assessed using general equilibrium models. However, the use of such models for the purpose of such drastic changes in the world economy as described by the BLUE Map scenario is complicated. The Lucas critique to the econometric approach applies: past relations cannot be used to forecast future developments with accuracy, as the level of required change is unprecedented.

9. There are two ways to calculate the required incremental investment in low emission energy technologies: using specific bottom up models or top down macro-economic models. A combination of both is also possible. Bottom up models consider the probable cost of a set of technological and output changes that are likely to achieve the desired reductions against the default option of staying largely with fossil fuel technologies. The least-cost technology options selected in the model are based on assumptions about resource availability and the decline over time of the costs of the technologies. Macro-economic models try to model the changing behaviour of firms and households driven by changing costs and prices and the consequences for resource allocation. The technological changes and innovations needed to achieve emissions reductions are not explicitly modelled but are assumed based on past experience. *The Energy Technology Perspectives* results used in this section are derived from a bottom up model with explicit input on technological and costs development. The result of any policy cost analysis for climate change depends on factors such as the discount rate that is applied, the expression in market exchange rates or based on purchasing power parity, the time horizon and the consideration of benefits for long-term technology innovation. For simplicity reasons the costs have not been discounted in the IEA analysis.

10. The average cost of $20 is taken from the Worldscan model exercise in Section 5.

11. In the *OECD Environmental Outlook* emissions growth is lower in the baseline, which will keep costs lower than in the IEA scenario as less Gt CO_2 need to be reduced.

12. (IPCC, 2008), p 79-80.

[13] R&D figures are based on industry estimates gathered by New Energy Finance's Insight Note 14 January 2008: www.newenergyfinance.com.

[14] UNEP, New Energy Finance (2007), published under the Sustainable Energy Finance Initiative: www.sefi.unep.org.

[15] In theory both taxes and a cap-and-trade system could achieve a global carbon price across countries, sectors and gasses. Given the uncertainties on the optimal level of the tax or cap, in practice both systems will almost certainly not be the same, with a tax giving more certainty on the price or the cost of CO_2 emissions and a cap giving more on the environmental outcome or level of emissions. Another practical difference is that cap-and-trade systems arguably give more possibilities for burden sharing, since direct money transfers between countries can be combined with a differentiation in commitments.

[16] What are the chances that the surplus emissions allowances of Russia and Ukraine will be used to meet the commitments of the other Kyoto countries? Most countries that have ratified the Kyoto protocol have indicated their intention not to purchase emissions allowances from Russia and Ukraine, as these are not related to 'real' emission reductions. Additionally, up to now neither country has been eligible to sell its rights as they have not yet met the institutional and accounting requirements for a country to engage in trading of allowances as set out in the Protocol. However, as long as countries have not absolutely ruled out the option of buying allowances from Russia and Ukraine there will be a risk that the market might be flooded by so-called 'hot air' credits, thereby depressing carbon prices. As the end of the commitment period nears and the costs of mitigation starts posing budgetary constraints on governments it will be politically tempting to turn to the allowance market in Russia and Ukraine to avoid a failure to meet commitments. For example, the expected shortfall of 0.2 Gt CO_2-eq at current policies in Canada at a price of $20 per tonne would amount to a cost of $4 billion per year in 2010 (roughly 0.5% of expected government revenues in 2010). Also, the inclusion of Eastern-European countries means that the European Union has inherited some 'hot air' from those countries, making it more acceptable for other countries to buy allowances from Russia and Ukraine in their turn.

[17] See last column in Table 1 of Reinaud and Philibert (2007) for an overview.

[18] http://cd4cdm.org.

[19] A project is transacted when the emission reductions are bought from the project developer (primary CDM market). This can be done before the CERs are issued. The buyer will then have the risk of the project not receiving any or a reduced amount of CERs and therefore they will normally be bought at a certain discount. The pipeline includes projects that were already transacted, as shown in Figure 10.

[20] Ellis and Tirpak, 2006

[21] Carbon Trust (2007) based on analyses of Climate Strategies: www.climate-strategies.org.

[22] World Bank (2006).

[23] OECD (2008b), The report lists the following non-market barriers: 1) when emissions are difficult to monitor (e.g. fugitive emissions from pipelines); 2) in enterprises facing soft budget constraints (some state owned companies); 3) when information about emissions and abatement options is costly or incomplete (e.g. energy consumption by electrical appliances of households); 4) when markets fail because incentives will be split (e.g. building insulation to be installed by landlords while tenants pay the energy bill).

[24] OECD, 2008b.

[25] OECD, 2007.

[26] IEA, 2006.

[27] See Table 1 in Reinaud and Philibert (2007).

[28] UNEP/Risoe database accessed on 3 March 2008.

[29] A program under the UNEP umbrella. The analysis is based on a comprehensive database of investors and transactions in low emissions energy and run by New Energy Finance.

[30] The baseline is comparable to the reference scenario of the *World Energy Outlook 2004*. Worldwide economic growth is around 2% per year and the global population will expand to 9-10 billion in the middle of the 21st century. Energy consumption will increase, showing a doubling of current consumption levels in 2050. In the period 2001-2020, energy consumption will increase with 1.4% per year in the Annex I countries and with 3.3% in Non-Annex I.

[31] Assuming a project-based mechanism like CDM will be negotiated post-2012.

[32] The use of CDM reductions in the ETS is also limited in the post-2012 proposals of the European Commission.

[33] OECD, 2008a.

[34] Website World Bank, The Carbon Partnership Facility leaflet.

[35] Gielen et al, 2002 and Bollen et al, 2005.

[36] IEA, 2008.

[37] The 17 technologies distinguished by the IEA are:

Power Sector:
CO2 capture and Storage (CCS) – Fossil-Fuel Power Generation
Nuclear power plants
Onshore and offshore wind energy
Biomass integrated gasification combined cycle (BIGCC) & co-combustion
Photovoltaic systems (PV)
Concentrating solar power (CSP)
Coal integrated gasification combined cycle (IGCC) systems
Coal ultra supercritical steam cycles (USCSC)

Building Sector:
Energy-efficiency in buildings and appliances
Heat pumps
Solar space and water heating

Transport Sector:
Energy efficiency in transport
Second-generation biofuels
Electric and Plug-in vehicles
Hydrogen fuel cell vehicles

Industry Sector:
CO2 capture and storage (CCS) – industry, H2 & fuel transformation
Industrial motor systems

[38] The Stern Review (2006) recommends a doubling of the public investments in energy R&D, whereas other advocate much larger increases, e.g. 3 to 10 times (Nemet & Kammen, 2007).

[39] Hinostroze, 2007.

40 Cosbey et al, 2005 as cited in Hinostroze, 2007.

41 Idem.

42 Müller, 2007. The idea of offering companies a minimum price in Müller's paper was meant to apply for government-funded unilateral CDM activities. However, a similar instrument could also be used by multilateral banks to leverage private sector investments in the anticipation of a full post-2012 framework.

43 Adapted from Baron and Ellis, 2006.

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Annex 1: Key characteristics of different emissions trading schemes (currently operating)

	Eligible gases	Sources	Mandatory (M) or (V) Voluntary?	Participants	Target: indexed or fixed	Time scale	Non-compliance penalty?	Use of offsets?	Banking	Unit
EU ETS (Phase I)	CO_2	Combustion plants, oil refineries, coke ovens, I&S, cement, glass, lime, brick, ceramics, pulp and paper	M	Emitters	F	2005-2007	Y: EUR 40 (+ shortfall to be made up in following year)	Y: CDM (excluding forestry)	(Allowed in some countries)	1 metric ton CO_2-eq
EU ETS (Phase II)	CO_2 + opt-in (e.g. N_2O)	As above, + possible "opt-in" for some gases/sectors (e.g. industrial N_2O in the Netherlands)	M	Emitters	F	2008-2012	Y: EUR 100 (+ shortfall to be made up)	Y: CDM (excluding forestry) , JI	Y	1 metric ton CO_2-eq
NSW/ ACT scheme	6 GHG	Production and use of electricity	M	Electricity retailers, large elec. users	I	Initially 2003-12 (yearly), extended to 2020	Y: AUS$11.5/t shortfall if over-emission not made up in subsequent year	Y: some project types	Y[1]	1 metric ton CO_2-eq
UK ETS (direct participants)*	6 GHG	Various industrial sectors and energy use.	V	Emitters and users	F	2002-2006	Y: GBP30 + make up credit in next year + non-payment of subsidy	N	Y	1 metric ton CO_2-eq

[1] In the NSW/ACT scheme, an offset remains in force unless cancelled by the system administrator. "Borrowing" of up to 10% of the subsequent year's target is also allowed. See Part 8A of the Electricity Supply Act 1995 (http://www.legislation.nsw.gov.au/view/inforce/act+94+1995+FIRST+0+N)

Japan JVETS	CO_2	Industry: food, breweries, pulp, chemicals	V	Emitters[2]	F	FY2006 FY2007	Y: return of subsidy, “naming and shaming”	Y: CDM	Y	1 metric ton CO_2-eq
Chicago Climate Exchange	6 GHG	Electricity generation, manufacturing industry	V	Emitters (and offset providers)	F	2003-6, 2007-10	No defined penalty[3].	Y: CDM, certain countries/sectors	Y	100 metric tons CO_2-eq

* Provisions for direct participants in the UK ETS are different from those that have Climate Change Agreements. These latter are not included here.

Sources: Ellis and Tirpak (2006).

2 32 installations were covered by JVETS in its first year, and 38 in its second year.

3 There are no defined penalties for entities with emissions targets under the CCX. However, there are make-good and penalty provisions for some “offset providers”.

Annex 2: Key characteristics of different emissions trading schemes (under consideration)

	Eligible gases	Sources	Mandatory (M) or (V) Voluntary?	Participants	Target: indexed or fixed	Time scale	Non-compliance penalty?	Use of offsets?	Banking	Unit
Regional Greenhouse Gas Initiative (RGGI)	CO_2	Electricity only, possible extension to other sources	M	Emitters	F at the same level to 2014, decreasing 2.5% p.a. from 2015-18	2009-2018	Y extent increases with the 12m rolling average spot price of carbon: if <$7/t then max. 3.3%; if >$10/t then maximum 10% (adjusted annually for consumer price index)	N	Y	1 short ton CO_2-eq
California	CO_2	Entities that provide electric power to consumers, potentially also natural gas sector	M	Emitters and retailers	F (not determine d yet)	Not yet defined	Y – but not yet defined	Not yet defined (but a state-wide GHG limit will become operational on 1.1.2012)	Not yet defined	1 ton (not defined) CO2-eq
Switzerland	CO_2	Cement, Iron and Steel, aluminium, pulp and paper, glass, ceramics, other industry	V (but legally binding once a participant)	Emitters	F	2008-2012	Y: CO_2 tax since exemption + interest	Y: CDM, JI	Y	1 metric ton CO_2-eq
New Zealand	All GHG	All major sectors	M	Emitters and retailers	F	2008- forestry; 2009 - Liquid fossil fuels; 2010 – stationary	Y (NZD 30/t plus a 1:1 make-good requirement)	Y: CDM, JI	Y	1 metric ton CO_2-eq

						energy and industry; 2013 agriculture, waste and all other sectors				
Australia (federal)	All GHG	All major sectors excluding land use sectors and agriculture	M	Emitters and retailers	F	2011 – 2030 (with ten year commitment periods)	Y (not yet defined)	Y: domestic, CDM, JI	Y price gap not yet defined	1 metric ton CO_2-eq
Canada	All GHG	Electricity by combustion, oil and gas, forest products, smelting, refining, iron and steel, cement, lime, chemical products	M	Emitters	I	Start in 2010	Y (not yet defined)	Y: CDM, domestic offsets, compliance possible via a technology fund at CAN 15/t and increasing to CAN 20/t then increase linked to GDP growth; limited to 70% of obligation in 2010 falling to 10% in 2017)	?	1 metric ton CO_2-eq

Sources: Dennis and Tirpak (2006) and Reinaud and Philibert