



**Financing technology
to support
low-carbon and climate-resilient
growth**

World Bank



Table of Contents

<i>Executive Summary</i>	1
<i>The climate change crisis</i>	4
<i>The need for all countries to respond</i>	5
<i>The investment challenge</i>	6
<i>The need to deploy proven technologies on a large scale: an issue of strategy, policy and incentives.</i>	8
<i>But climate change is a threat of such magnitude that breakthrough technologies will also be needed...</i>	14
<i>Conclusion: a way forward?</i>	<i>Errore. Il segnalibro non è definito.</i>

Executive Summary

The world is currently facing two global man-made crises – the financial downturn and climate change. Both must be addressed urgently to avoid continued widespread negative consequences. However, if the growth in greenhouse gas emissions is left unchecked, the scale of climate change impacts will dwarf the economic downturn, and mistakes in managing these risks may be irreversible. Solutions must be found simultaneously for both crises, as we currently have a critical window of opportunity for an integrated response.

Scientific evidence points towards an urgent need to ensure global average temperatures do not rise beyond 2°C, which means emission concentrations must stabilize around 450 ppm. This is particularly important for maintaining development prospects as countries face higher costs due to climate change. The need to simultaneously re-configure development paths while addressing other social and poverty issues will be challenging, especially in poor countries that are the most vulnerable to the impact of global warming and least able to respond.

Developed countries must rework their energy- and carbon-intensive economic model, and in the near term must provide assistance and incentives to enable developing countries to move toward lower-carbon development and climate-proofed economies. Middle-income countries must invest in economic growth and development without locking in high emissions trajectories. Low-income developing countries must increase resilience to climate change impacts while investing in growing their economies and eradicating poverty.

At the global level, this requires a coherent framework which signals a long-term future of decarbonization, enables further development and consolidation of carbon markets to ensure a credible carbon price, and delivers enabling financial support and investment. There is an opportunity now that must not be missed to adopt climate-smarter growth paths, promote energy security and maximize local co-benefits, and drive the transition to low-carbon and climate-resilient economies using clean technology.

The investment challenge

Globally, this implies large investment needs with significant incremental costs for both mitigation and adaptation: in developing countries alone estimates indicate an additional \$220 billion per annum is needed for mitigation and \$30 billion per annum for adaptation to 2020. Global mitigation costs for achieving 450 ppm are estimated at 1 – 3 percent of global GDP by 2050.

The United States, the European Union and China account for nearly 60 percent of the world's total emissions currently and will each install 800-1,000 GW of new power capacity by 2030. Mitigation by these countries or regions will be essential to stabilize the climate. Decarbonizing these massive investments provides an opportunity to shift the global economy decisively onto a low-carbon path.

Many countries are already adopting clean energy policies and setting clean energy targets, which must be analyzed and replicated. At the global scale, the international community must agree to a set of ambitious GHG-reduction targets as part of the UNFCCC negotiations to provide greater certainty to the private sector to shift their investment decisions towards low-

carbon options and to ensure that carbon is appropriately priced. The global agreement must also provide sufficient financial incentives for developing countries with significant GHG emissions to participate in taking accelerated action to reduce emissions. It should be recognized that several of these countries are already doing so as integral elements of their national sustainable development strategies.

Two-pronged strategy for technology deployment

Technology will be critical to addressing this unprecedented investment challenge at reasonable cost. A two-pronged strategy is needed: wide-scale deployment of existing technologies; and development and diffusion of breakthrough technologies in a big way. Both are necessary, but they will require different approaches and levels of public effort to deliver them.

Wide-scale deployment of existing technologies

In shifting investment patterns towards lower-carbon options, the deployment of available low-carbon technologies must be accelerated. More critical than finance is the establishment of suitable enabling environments, including the removal of non-financial barriers to action, the alignment of incentives for climate-friendly investments and the development and implementation of supportive policies and regulations.

Country-specific low-carbon strategies are helpful to determine how best to deploy an appropriate suite of technologies facilitated through supportive policies and regulations. To support implementation of these strategies, financial instruments exist that must be used smartly – often in combination with one another – and financial incentives in the form of market instruments can be improved to operate at scale.

Ironically, the current financial crisis may turn out to be a golden opportunity to move toward low-carbon growth. Countries' efforts to reinvigorate their economies through a variety of fiscal stimulus packages offer an unprecedented opportunity to shift off higher carbon business-as-usual growth paths. A 'green' fiscal stimulus of approximately \$400 billion in the next year, directed towards clean power generation, energy efficiency and fuel switching, would be consistent with long-term climate ambitions, simultaneously providing an effective boost to the economy, and building the foundations for strong and sustainable future growth. *Urgent attention is needed to ensure that implementing the stimulus packages does not aggravate the mitigation challenge by locking in high-carbon infrastructure* but rather used to provide additional incentives to developing countries to green their recovery programs.

Development and deployment of new technologies

The rapid deployment of existing low-carbon technologies in countries around the globe will likely not suffice. There must be a commensurate program of innovation and technological breakthrough, akin to what might have been necessary to, say, send a man to the moon. But this time, it will require a radical institutional shift internationally in the way technology research and development is to take place.

First, the need for urgent action requires an unprecedented level of *international collaboration*, involving a large cross-section of developed and developing countries with the scientific capabilities to meaningfully contribute to technology development. Second, collaboration will

need to extend to how public and private sectors work together. There is a need to widely use the business model in which governments agree to share expenses in long-term RD&D, through the establishment of *public-private partnerships*. Third, some innovative thinking will be required to *manage the financial risks* of dissemination (the so-called “valley of death”). A careful allocation of public monies to those steps where risks are particularly prohibitive could go a long way in complementing what private sources of capital, responding to long-term market signals, could provide.

Conclusion

The greatest challenge in the next 10-15 years of transition is to establish an international and domestic policy environment conducive to accelerating both the dissemination of existing technologies and the development of new ones on a large scale. A successful set of actions requires at least the following synergistic elements from the public sector perspective:

- *Realizing the critical role of public policy:* The public sector will be essential for getting clean technologies deployed at scale through its role in providing first and foremost an effective enabling environment to promote a fertile ground for receiving low-carbon technologies.
- *Realizing the critical role of collaboration and partnerships* for the development of new technologies, be it at the international or domestic level, across public and private sector institutions from industry, research and academia.
- *Creating a coherent framework for the use of a range of financing instruments:* Existing financing instruments need to be deployed at scale and packaged in a complementary way to maximize synergies, and should be embedded in development strategies to deliver the ‘biggest bang for the buck’.
- *Identifying and prioritizing critically needed additional finance:* Deploying existing technologies and finances at scale will be inadequate. Additional financing will be essential; governments can embed low-carbon solutions into the financial stimulus packages currently on the table. To facilitate the transition to a global mature carbon market, international (developed countries) support to developing countries will be crucial. Most importantly, countries must deliver on their commitments, to build confidence and lend credibility to the process – vital for driving private investment.

Financing technology to support low-carbon and climate-resilient growth

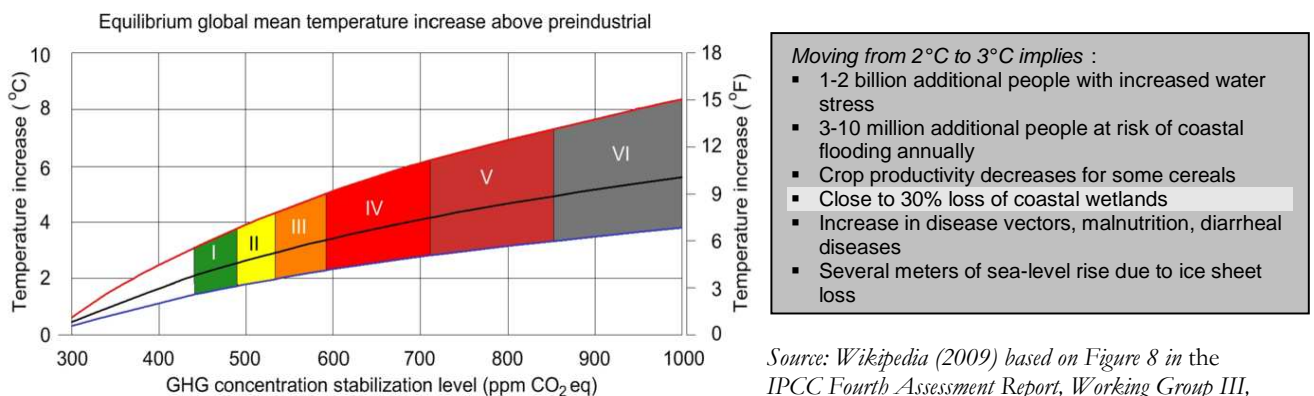
The climate change crisis

The world is currently facing two global man-made crises – the financial downturn and climate change. Both crises will have widespread implications, financial and otherwise, if left unaddressed. The outcomes of tackling the financial crisis will be more immediately visible, but the scale of climate change impacts that we are likely to see if emissions growth is left unchecked will dwarf by orders of magnitude the economic downturn currently being experienced. The real difference between these two crises is that mistakes in managing the risks of the global climate crisis will be irreversible. Solutions for each of the two crises must therefore necessarily be found simultaneously, and there is a critical window of opportunity for an integrated response which cannot be missed.

The scientific evidence on the pace of global warming and its likely impacts is advancing constantly and new analyses points clearly towards an urgent need to ensure global average temperatures do not rise beyond 2°C. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC FAR, 2007) concluded that climate change scenarios as well as recent observations (e.g., accelerated glacier retreat and permafrost melt, and changes in the intensity of heat waves and hurricanes) strongly suggest that the emerging risks to societies will likely be beyond their existing collective experience and coping capacity.

Current concentrations of greenhouse gases in the atmosphere have reached 385 parts per million (ppm) CO₂eⁱ and each year of delay in taking significant mitigation action adds 3 - 5 ppm to the stock. For the world to avoid the worst impacts associated with climate change, emission concentrations must stabilize around 450 ppm (Figure 1). The science has made it clear that the risks of severe climate impacts greatly increase by shifting from a 450 to 550 ppm stabilization scenario. This represents a fast diminishing window of opportunity to stabilize emission concentrations at a safe level. This is particularly important for maintaining development prospects as countries face higher costs due to climate change. Periodic reality checks will be essential to ensure that adaptive measures are adequately provided for, should concentrations reach higher levels and consequently impacts are more severe. The need to simultaneously re-configure development paths while addressing other critical social and poverty issues will be challenging, especially in poor countries that are the most vulnerable to climate impacts and least able to respond.

Figure 1: Projected temperature increases at different GHG concentration levels

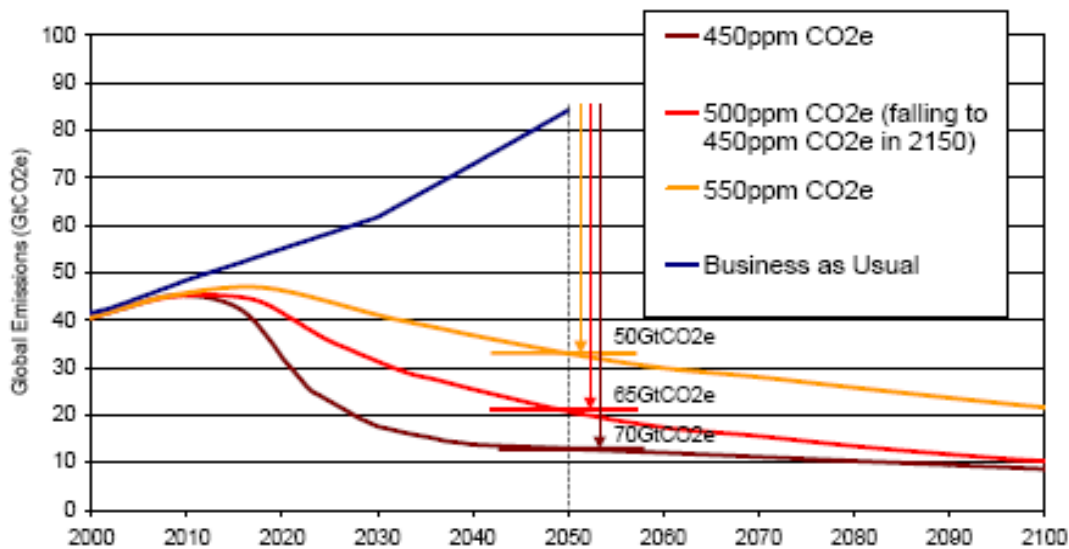


The weight of evidence has intensified the need for coordinated global action on mitigation and adaptation, to control drastically and respond to the rise of emission concentrations beyond 450 ppm. In short, many experts are advising that we need to “aim at 450 ppm and plan for 550 ppm”. The IPCC has called for developed countries to take the lead by taking on stringent targets of 25-40% reductions below 1990 levels by 2020, followed by reductions of 80-90% by 2050. They also call on developing countries as a whole to grow their emissions 15-30% below business-as-usual trends by 2020. Developing countries are projected to account for more than 90 percent of the incremental increases in global energy consumption and CO₂ emissions over the next 20 years, so developed countries alone will not be able to keep the world at or below 2°C, even if they were to reduce their emissions to zero. This clearly implies that for the world to keep emissions at a safe level, all countries, including developing countries, need to take action now. That does not however imply that the action must be equal in all countries or that it necessarily be self-financed – particularly in the case of developing countries.

The need for all countries to respond

The scale of efforts required to stabilize at 450 ppm necessitates peaking global emissions in the next 10-15 years followed by a rapid decline of 70 GtCO₂e to 2050 (Figure 2). This volume of emission reductions, to be achieved in such a short time frame, will require that all countries undertake radical redesign of their development paths in the direction of low-carbon alternatives. Developed countries will need to rework the energy-/carbon-intensive patterns within which their societies and economies have evolved and thrived. Likewise, the future growth patterns and development strategies of developing countries will need to be directed towards low-carbon and climate-resilient alternatives. This implies a global shift in investment patterns to prevent long-term high carbon lock-in.

Figure 2: Trajectories for stabilizing emissions concentrations



Source: Stern Review (2006)

All countries have critical roles to play in ensuring the movement to global low-carbon development. Developed countries must take the lead by committing to and carrying out deep emissions cuts and establishing a low-carbon growth path in their own economies. Infrastructure capital stocks have a long lifetime and, if well-planned and maintained, should

have effective lives of decades (e.g., power plants), even a century (e.g., urban infrastructure), before turn over. The current economic climate and the position on the infrastructure investment cycle offer a great opportunity to achieve this transition in many developed countries. As countries look to replace old infrastructure assets and expand their overall stock – particularly of energy infrastructure – in the near term, this presents a clear opportunity to de-carbonize their economies.

Developing countries will install half or more of the long-lived energy capital stocks between now and 2020. This presents opportunities to build efficient and low-carbon technologies into new infrastructure. Missing this opportunity in both developed and developing countries, essentially delaying action on climate change, will substantially increase both mitigation and adaptation costs. Failure to act now will likely lock in significant volumes of high-carbon infrastructure – even more costly to replace/retire early. Slower emission reductions now will increase the long-run costs of stabilization as a greater volume and faster pace of mitigation will be required in later years. Moreover, as we move towards higher concentrations, there will be associated environmental damage en-route and adaptation costs in the most vulnerable countries will increase.

For middle-income emerging economies, the challenge is to invest in continued economic growth and development without locking in high emissions trajectories. In many of these countries, it is similarly important to increase resilience to and minimize the impacts of climate change since large populations of poor communities that are highly vulnerable to climate change reside in those countries.

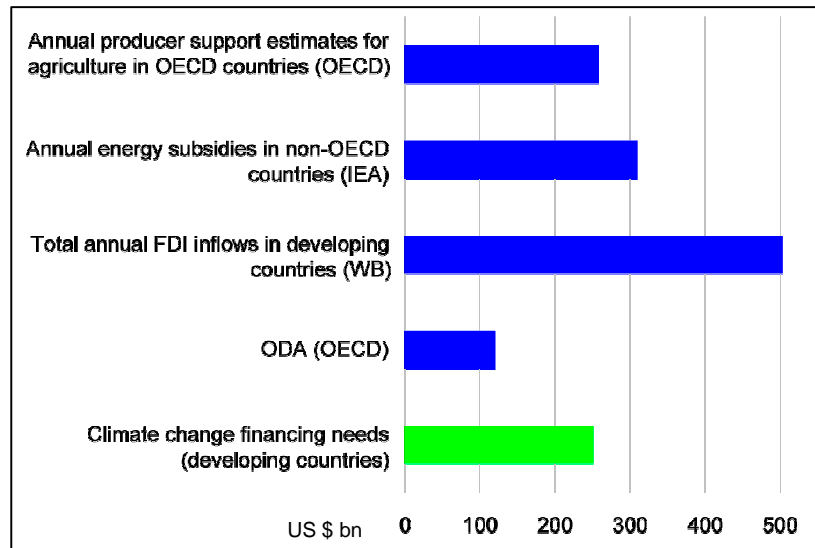
In low-income countries, particularly those faced with the current impacts of increased climate variability, the imperative is to find rapid solutions for increasing resilience to and minimizing negative climate change impacts while investing in growing their economies and eradicating poverty. In such countries, there is an opportunity to leap-frog technologies to achieve greater sustainability, promote energy security and maximize local co-benefits, and drive the transition to low-carbon and climate-resilient economies using clean technologies.

At the global level, this requires the provision of a framework which signals a long-term future of de-carbonization, including ensuring a credible carbon price and financial support and investment to facilitate this approach. In the near term, developed countries must provide sufficient assistance and incentives so that developing countries are able to move toward adopting lower-carbon development solutions and climate proofing their economies.

The investment challenge

Globally, acting now translates into large investment needs carrying significant incremental costs for both mitigation and adaptation. It is estimated that an additional \$250 billion per annum needs to be invested in developing countries alone to meet the incremental costs of mitigation (\$220 billion p.a.) and adaptation (\$30 billion p.a.) to 2020ⁱⁱ. This amount does not reflect the total value of investments in the necessary infrastructure – only the cost of making it climate-friendly. Global mitigation costs for achieving 450 ppm are estimated to fall in the range of 1 – 3 percent of global GDP by 2050ⁱⁱⁱ. This is manageable at a global level, and there would be substantial payback from reduced demand and lower fuel costs to justify the upfront investments. When considered in comparison to the amounts spent on energy or agriculture subsidies globally, this becomes a more manageable sum.

Figure 3: Comparing climate financing needs in developing countries with other global public expenditures



Source: World Bank (2009)

The United States, the European Union and China account for nearly 60 percent of the world's total emissions currently. While India currently contributes only 4 percent of global emissions, its share is projected to increase to 12 percent by 2050 under a business-as-usual scenario. Thus, the contributions of these countries or regions to emission reductions will be essential to stabilize the climate. The next 20 years will see an unprecedented increase in energy investment as developed countries replace power plants built in the 1960s and 70s, and rapidly industrializing economies accelerate their construction of modern energy systems. The US, Europe and China will each build around 800-1,000 GW of new power stations by 2030. These massive investments provide an opportunity to shift the global economy decisively onto a low-carbon path.

Many countries – both developed and developing – are already taking mitigation action by adopting clean energy policies and setting clean energy targets in their national climate and energy action plans and strategies. For example, China has adopted a target of reducing the energy intensity of production by 20 percent between 2005 and 2010. This is expected to yield 1.5 billion tCO₂ of emission reductions – a sizeable global co-benefit resulting from a domestic program initiated due to local concerns of energy security and environmental quality. These climate action plans offer a significant opportunity to rapidly address the mitigation challenge if adequate financing can be provided to accelerate efforts.

Likewise, Mexico, Turkey, and Egypt are early movers in accessing the Clean Technology Fund (CTF). Egypt's CTF Investment Plan envisages a \$1.8 billion program for: (i) scaling up wind power from less than 1,000 MW to 2,500 MW, supporting the national goal of generating 12% (7,500 MW) of electricity from wind by 2020, and (ii) investments in bus rapid transit (BRT) corridors and light rail as part of the Greater Cairo Urban Transport Master Plan. A scaled-up program could lead to 12 million tCO₂ of emission reductions annually, representing over 10% of emissions from the electricity sector.

Mexico's CTF Investment Plan projects investments of \$6.2 billion for: (i) BRT corridors with low-carbon bus technologies as part of a national BRT program that aims to have a ridership share of 30% and to reduce the transport sector's carbon footprint by 20% by 2030, and (ii) a large-scale program to replace inefficient lighting and appliances, representing 15-30% of the Mexican market share is expected to deliver emission reductions of 4 million tCO₂ per year.

In Turkey, the CTF Investment Plan could save about 1.5 million tCO₂ per year, with investments of \$2.1 billion. The focus is on: (i) promoting private sector development through credit lines to local development banks, doubling lending for renewable energy and energy efficiency, and (ii) implementing "intelligent" grid management and control systems to support large-scale integration of wind power into the grid, as part of the government's goal of scaling up wind capacity to 20,000 MW by 2020 or about 20% of the country's electricity generation capacity. Turkey has also established strong legal and regulatory frameworks for renewable energy and energy efficiency. Turkey's National Communication on Climate Change estimates 11% emission savings by more than doubling its renewable electricity generation, introduction of nuclear power, and modal shifts in transport from road to rail.

For any chance of success in mobilizing the financial resources to undertake similar investments at the scale and pace required, the global community must provide greater certainty and incentives to business world-wide of the long-term need to shift their investment decisions towards low-carbon options. Carbon markets need to continue deepening, providing such incentive and ensuring that carbon is appropriately priced. The structure and implementation of the global agreement that achieves these goals should provide sufficient financial incentives for major developing emitters to participate in taking accelerated action to reduce emissions.

In order to deliver the transformation required in the time frame necessary and prepare countries to adapt to climate change, technology will be critical to addressing the investment challenges at reasonable cost. A two-pronged strategy is needed: (i) wide-scale deployment of existing technologies, particularly as regards renewable energy and energy efficiency; and (ii) development and diffusion of new technologies in a big way (e.g., carbon capture and storage and concentrated solar power). Both are necessary, but they will require different approaches and levels of public effort to deliver them.

The need to deploy proven technologies on a large scale: an issue of strategy, policy and incentives.

The first challenge in the next 10-15 years is to create the necessary momentum to start bending greenhouse gas emission trajectories. This must be undertaken in all countries, whether under binding or non-binding commitments. In a first phase, such a transformation can be achieved through a combination of a shift in investment patterns towards lower-carbon options, widespread deployment of available low-carbon technologies and appropriate financing mechanisms to support such a shift. It involves addressing the challenges of *enabling environments*, targeting non-financial barriers to climate action, aligning incentives for climate-friendly investments, supporting and accelerating research and development and diffusion (RD&D) of climate-friendly technologies, institutional capacity-building, and the development of supportive policies and regulations. The examples mentioned above demonstrate the possibilities.

Most major studies on climate mitigation reach similar conclusions in this regard: a suite of technologies is required, the necessary principal technologies required have been largely identified, and the rough scale of deployment to mitigate climate change has been analyzed. For most countries, including developed countries, the first step resides in formulating an explicit *strategy* to pursue a low-carbon path and facilitate its implementation through the adoption of consistent policies and regulations. Such a strategy will benefit from an assessment of the main sources of greenhouse gas emissions, the identification of sectoral opportunities and the determination of priorities for action to achieve the biggest impact, engaging the developing countries in international efforts to set and achieve meaningful emission reduction targets, formulation of appropriate policies and regulations to facilitate their implementation, and removal of barriers preventing their adoption (e.g., subsidies).

The end-result of such strategic exercise is a systematic approach towards low-carbon technology deployment. The question is how to rapidly take these technologies, in particular technologies for modernization of existing generation capacity, from niche applications to widespread deployment so that they can displace existing high-carbon energy technology systems. New models of regulation, business, and investment in infrastructure are likely needed to better align with the prevailing market economy. While the hardware is relatively easy to put in place, the software – the lack of an enabling environment – is in many countries the main stumbling block.

Indeed, numerous market failures and other barriers deter commercialization of new technologies in addition to those preventing deployment at a global level. While these obstacles are observed in a wide range of countries, in both the developed and developing world, they are felt most acutely in many of the latter. They include:

- *Priority of Poverty Alleviation.* Many developing countries are hard pressed to achieve and maintain growth rates required for poverty alleviation. The additional financial and technical burden of growing along a low carbon pathway is seen by them as an obstacle to their resolving more immediate national problems.
- *Biases towards conventional systems.* There is a natural bias towards existing technologies and systems, since people understand them, delivery channels are developed and financing modalities and risks have been documented. There is a tendency across all sectors to stick to what is familiar rather than take risks to try something new.
- *Subsidies for conventional energy products.* Many developing countries have subsidies supporting conventional, more polluting energy products. This makes it significantly more difficult to enter the market with a new low-carbon technology and compete against a subsidized price.
- *Regulatory capacity.* Many low-carbon technologies require reviews and adaptation of regulatory regimes to fit into existing systems (e.g., establishing feed-in tariffs, setting up smart grids to handle wind intermittency) (Box 1). Developing countries tend to have less experience in this area and fewer regulations to accommodate new low-carbon technologies. In addition, capacity for enforcing existing environmental regulation may lack OECD norms.
- *Technical capacity.* The base of technical capacity among individuals and firms in many developing countries requires strengthening to initiate and sustain technology shifts.
- *Support networks.* New low-carbon technologies require operations and maintenance (O&M) networks to service them. These networks will only be developed with adoption

of the technologies- but targeted technical assistance to develop such networks will be essential in many developing countries.

- *Access to financing.* Small entrepreneurs are an engine for technical creativity in any field, including low-carbon technologies. However, they rely on venture capital for support, which is much more predominant in developed countries than in developing countries. Even larger, more established companies face this challenge with newer technologies with which financiers lack experience.
- *Market entry.* Despite advances by many developing country markets, most major low-carbon technology companies come from developed countries. They are less familiar with developing markets, perceive potential political instability, and therefore can be reluctant to enter. In addition, many technology providers are concerned about protecting the intellectual property rights (IPRs) of their low-carbon technologies.
- *Consumer base.* Developed countries have consumer bases which have demonstrated willingness to pay price premiums for “green” products. This is less common in developing countries. Consequently private companies are more inclined to develop and market low-carbon technologies in the richer countries.

Box 1: Feed-in tariffs to scale up deployment of renewable energy technologies

Innovative "feed-in tariff" programs have successfully provided output-based incentives to increase the adoption of renewable energy technologies in domestic markets. Local power companies are obliged to buy renewable energy from independent producers, at a fixed price above the average cost of production. These incremental costs of renewable energy over fossil fuels can be passed on to consumers, but this can also be capped. This transparent, competitive, and stable pricing approach has attracted investors to renewable energy by offering a guaranteed return. This approach has seen growing support as everyone has the opportunity to profit, either by investing themselves or by tapping into the upsurge of economic activity the incentive creates.

Germany has had striking success with feed-in tariffs over the last two decades, supplying 15% of its energy needs through renewable sources and helping create the country's vibrant green energy sector. The German approach involves guaranteed fixed payments for 20 years designed to deliver a profit of 7 to 9 percent. The rates charged vary by energy source and are tied to the cost of production. The rates paid for new contracts decline annually, providing an incentive to invest sooner and lock in the higher rates for the duration of the tariff. This also forces the green energy sector to innovate. If they want to stay in business and hold on to their margins, manufacturers have no choice but to continually seek out new efficiencies. Studies have shown that feed-in tariffs deliver more renewable energy than other market incentives and at a lower cost.

This approach has also been successful in green job creation. Some 300,000 people work in Germany's renewable energy sector today. By 2020 green technology is expected to pass the auto and electrical engineering industries to become the nation's top employer, with more than 700,000 workers. One of the forces driving this growth is exports. Germany's success has encouraged more than 40 countries from Nicaragua to Israel to subsequently follow suit.

One essential component of low-carbon technology transfer and deployment that is often given insufficient attention is the local regulatory environment. It is an important part of the work of international development institutions, through policy dialogue, capacity building, and financial support, to help individual countries address those barriers which are directly under their control. Plans are under consideration for establishing a Technology Policy Support Program to provide developing countries with the assistance they request in implementing policies that encourage rather than discourage new low-carbon and clean energy technologies.

Similar support in terms of capacity building, financing, policy development and information will also be needed to promote adaptation. Climate-proofing future investment is an additional challenge to be addressed. This is less a question of technology, and much more an issue of knowledge (knowing what the impact of climate change is likely to be in a particular country, region, etc), understanding the economics of adaptation and developing suitable adaptation measures, adjusting operational practices and reconsidering spatial development, and changing behaviors. As of late, greater attention has been given to this critical aspect of development as the international community becomes better aware of the likely impacts of climate change (Box 2).

Box 2: Economics of adaptation

Rough cost estimates for developing countries to adapt to climate change start at about \$4 billion per year in the medium term (2015 to 2030), and surpass \$100 billion per year at the higher end. While these estimates provide a rough indication of the cost of adapting to climate change, they are neither particularly accurate nor fully comprehensive. Most of these estimates were derived using rules of thumb largely focused on the cost of climate-proofing future infrastructure investments. They underestimate the diversity of the likely adaptation responses and ignore changes in behavior, innovation, adjustments to operational practices, or relocations of economic activity. They also ignore the need for adaptation to non-market impacts, such as those on natural ecosystems. More importantly, they provide developing countries and international partners with little guidance on how to adapt; when to adapt (sequencing and timing); where to adapt; or the robustness of such decisions given the inherent uncertainties about the magnitude of likely impacts at the local level.

The World Bank is currently leading a technical study in partnership with the Governments of the UK, Netherlands and Switzerland to examine the Economics of Adaptation to Climate Change. The full set of results from this study will be available during the months leading up to the COP-15 of the UNFCCC. The study comprises both global level analysis and country case studies which inform each other in a number of ways providing a consistent and coherent set of adaptation results.

The global estimates of the cost of adaptation will be based on a detailed analysis of the key economic sectors against a counterfactual development scenario under a no-climate change world. A common set of assumptions is being used across the various sectors providing much needed coherence and consistency in the cost estimates. The sectoral analysis enables identification and measurement of the scale and types of specific adaptation technologies and programs necessary to reach explicit goals. While the transfer and diffusion of specific technologies is part of this study, its treatment of new and emerging technologies is more limited.

In the agriculture sector, for instance, the study examines the efficacy of investments in irrigation, agricultural research in seeds, and the construction of rural roads on the basis of detailed simulations of 32 major commodities in 281 food production units defined by country and watershed. The public cost of adaptation is estimated as the incremental public investments needed to maintain production levels under climate change so that malnourishment levels are maintained at levels under a no-climate change world.

A set of 7 country case studies is also used to significantly strengthen the global analysis. They examine the specific circumstances and decisions that developing country governments and partners face in formulating and implementing a climate change adaptation strategy. They assess the costs and benefits of specific adaptation measures in a national context; identify the sequencing and timing of these measures as well as the robustness of such decisions to uncertainties around the likely climate change impacts at the local level. They also explore the use of a wider range of adaptation measures including for instance policy and institutional changes such as weather-based risk insurance, differentiated taxes or insurance based on risk, or land use zoning regulations.

As governments and international development institutions consider how to prioritize spending their limited resources, it is important to look at sectors and programs as a whole to see which will be the worst affected by climate change and also which can deliver the most returns in terms of co-benefits. One sector particularly affected by climate change is agriculture, which remains the source of livelihoods for billions of people in developing countries. It is an area where there is the greatest potential for deriving both mitigating and

adaptation benefits, but it will require the further development of emerging technologies (Box 3).

Box 3: Technological interventions to harness agricultural mitigation and adaptation potential

Agriculture contributes about 13.5% of global greenhouse gas (GHG) emissions, primarily nitrous oxide from fertilizers and methane from flooded rice and ruminant livestock. Land cover change (deforestation and other clearing) contributes an additional 17% of GHG globally. The IPCC (2007) estimated that 74% of total agricultural emissions originate in developing countries and the technological mitigation potential of agriculture is around 5.5 Gt CO_{2e} per year to 2030. This must be viewed in concert with the fact that 75% of the world's poor live in rural areas in developing countries, and most depend on agriculture for their livelihoods.

Intensifying agriculture and improving productivity per unit of land is an important strategy to improve adaptive capacity against climate change and minimize forest clearance for new agricultural land. Analysis indicates that 89% of the mitigation potential identified can be achieved through soil carbon sequestration through improved land and water management, rehabilitation of degraded lands, use of conservation and no-till agriculture, and agro-forestry; and the remainder can be gained through improved rice cultivation, livestock feed and forage systems (9%), and improved cropping and nitrogen fertilizer use (2%). This requires a new paradigm for agricultural intensification focusing on: scaling up landscape management decision support tools, creating new breeds/varieties of rice ruminant livestock systems, scaling up testing and application of emerging technologies such as BioChar and remote sensing for aboveground biomass and soil types, and developing a new generation of "stealth fertilizers".

The manufacture and wide-scale deployment of BioChar could go a long way towards sustainable agriculture. BioChar is a granular carbon produced from plant biomass and organic residues which can be added to soil to improve land quality and lock up carbon for +1000 years. Its long-term sequestration potential is much larger than from conventional agricultural soil carbon practices. Approximately \$500 million is needed over the next 5 years to test and scale it up. The Clean Development Mechanism does not include carbon credits for agricultural carbon sequestration, but sequestration through BioChar is easily accountable and verifiable through its chemical signature, which could make it suitable for future CDM-type projects if the rules are modified.

Similarly, stealth fertilizers with ultra low emissions and high use efficiency need to be developed to enhance agricultural productivity and reduce deforestation. Given the high global warming potential of nitrous oxide, its emissions from inefficient use of fertilizers need to be addressed. Further research is needed to create "smart" fertilizer products that will release nutrients only when needed and in appropriate amounts. It is estimated that \$200 million per year over the next 5 years will be needed to mature the currently available research knowledge, develop and test the manufacture, distribution, and field testing of new generation, low emissions fertilizers. The original fertilizer development program in the US generated a return of \$57 billion from an initial investment of \$41 million, yielding a benefit/cost ratio of more than 20:1. Given such returns, it should be possible for public sector funding and incentives to leverage significant private sector and venture capital.

While the rapid deployment of existing technologies necessary to start transforming the world economy may seem a daunting task, there are already mechanisms in place that are clearly making a difference:

- *Impact of the Kyoto Protocol:* Despite all its imperfections and limitations, the market created by the implementation of the Kyoto Protocol has had a significant impact: (i) it has produced a price for carbon; (ii) there is increasing evidence of greater technology development and transfer in developed and developing countries having ratified the Kyoto Protocol. While innovation in climate change technologies and innovation in all technologies were growing at the same pace until the mid-nineties, the former has now increased much faster^{iv}; (iii) the flexible mechanisms of the Protocol^v have enabled developing countries and countries with economies in transition to "taste" new technologies and invest in mitigation. There is strong evidence that the mechanisms

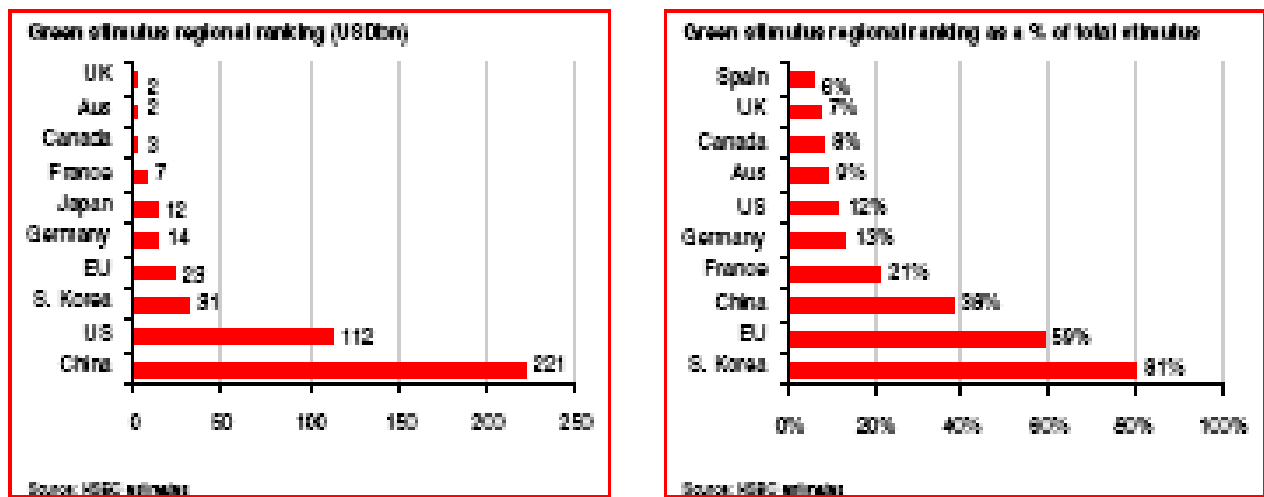
have fostered a great deal of private sector entrepreneurship, contributed to jumpstart mitigation efforts, particularly in the private sector, and promoted the idea that it is possible to depart from the business-as-usual scenario. Behavioral changes are visible at the micro level.

- *Need to scale up:* Market mechanisms are critical to bring about the needed transformation. But they need to evolve to serve on a much broader scale. A global agreement must allow for project-level carbon offsets to progressively evolve towards programmatic approaches and sectoral crediting. The proposed development of scaled-up methodological approaches would help move away from a project-by-project approach and consider the application of the flexible mechanisms to strategic development programs, taking a sectoral approach when suitable or a spatial approach when desirable (e.g., urban development). While the private sector responds more easily to market signals, it is critical that public sector entities – that often play an important role in the supply of infrastructure services, particularly in developing countries – integrate a carbon constraint at the core of their development planning and take advantage of the financial incentives provided by market mechanisms. This, in some countries, will require a not so insignificant change in policies and mindsets.
- *Providing a suitable financing package to enable the absorption of the incremental costs of low-carbon options:* This is where the enhanced market mechanisms mentioned above used in combination with existing financial instruments can provide a financing package to collectively provide underlying finance for the base investments and the incremental cost of low-carbon options. Development financial institutions such as the World Bank and regional development banks can support countries' climate change mitigation efforts, including the adoption of low-carbon technologies, through the combination of conventional lending, concessional funding, carbon finance, and guarantees, which in turn can leverage traditional commercial lending. The recently established Clean Technology Fund and various post-2012 carbon finance initiatives of multi-lateral financial institutions (e.g., the World Bank's Carbon Partnership Facility) are examples of instruments specifically geared towards encouraging developing countries to implement climate change mitigation investment programs. Through those initiatives, technical, policy and financial know-how combine to facilitate the strategic deployment of low-carbon technologies within an enabling environment where hardware and software can go hand-in-hand.

Ironically, the current financial and economic crisis may turn out to be a golden opportunity to move toward low-carbon growth. Countries' efforts to reinvigorate their economies through a variety of economic stimulus packages offer an unprecedented opportunity to shift off business-as-usual growth paths in terms of carbon intensity. The IMF has suggested that a fiscal stimulus of 2% of GDP is necessary to lift the G20 countries out of recession, and almost \$3 trillion in support has been pledged globally to date. A worldwide 'green' fiscal stimulus of approximately \$400 billion in the next year^{vi}, directed towards clean power generation, energy efficiency and fuel switching, would be consistent with the long-term policy goal of stabilizing emissions. While the whole point of such spending is to provide *temporary* fiscal stimulus to weakened economies and thus does not represent a long-term solution, these efforts can simultaneously provide an effective boost to the economy, stimulate labor demand, and build the foundations for sound, sustainable and strong growth in the future.

Many countries have already introduced ‘green’ spending directed primarily towards low-carbon vehicles and energy efficiency improvements in buildings as part of their stimulus packages. China and the USA have pledged the most in absolute terms, while green spending accounts for 81% of South Korea’s stimulus package (Figure 4). Implementing the stimulus packages should allow countries to put in place the right policy frameworks to shift to low-carbon growth. However, in order not to aggravate the mitigation challenge and not to miss this opportunity, it is critical to provide additional incentives to developing countries to green their recovery programs. At the very least, any fiscal measures adopted that are not explicitly ‘green’ should not make achieving climate change goals more difficult by subsidizing greenhouse gas emissions or locking in high-carbon infrastructure for decades to come. Developed countries should consider an advanced provision of incentives to developing countries for green recovery ahead of the post-2012 climate finance package. Given the large size of the bail-outs being introduced, this would be a very modest additional expense, which will have a very good return.

Figure 4: ‘Green’ stimulus spending already pledged by countries



Source: HSBC (2009) *A Climate for Recovery – the color of stimulus goes green*

In summary, known technologies are already available to facilitate the urgent transformation required by the global community to respond to the challenge of climate change. Much depends on the political will and readiness of individual countries to take action and put in place the enabling environment, policies and regulations as well as building the technical and human capacity necessary for the rapid deployment of these technologies. In short, countries have to create a market pull. To support these efforts, financial instruments exist that must be used smartly – often in combination with one another – and financial incentives in the form of market instruments can be improved to come to scale.

But climate change is a threat of such magnitude that breakthrough technologies will also be needed...

The rapid deployment of existing low-carbon technologies in countries around the globe will likely not suffice. To undertake the level of effort required to reduce emissions of greenhouse gases and keep global warming to 2°C – a global challenge of unprecedented magnitude – will require a commensurate program of innovation and technological breakthrough, akin to what might have been necessary to, say, send a man to the moon.

What is needed is a strong and sustained technology push now. But unlike the efforts that went into sending a man to the moon, it will require a radical institutional shift internationally in the way technology research and development is to take place:

- First, it is unlikely to remain the business of isolated countries. Investment in research, development, demonstration, and deployment (RDD&D) is currently insufficient for the task at hand, and the financial crisis is reducing private spending on climate-smart technology. The need for urgent action requires an unprecedented level of *international collaboration*, involving a large cross-section of developed and developing countries with the scientific capabilities to meaningfully contribute to technology development. Facilitation by developed countries of a stronger South-South cooperation would also be highly desirable, all the more as regional centers of excellence creating South-South partnerships have shown great potential in fostering innovation. Identifying, evaluating and integrating foreign technologies involve learning costs, as do their modification and improvement. This requires capacity building to improve the knowledge infrastructure of universities, research institutes and firms. Such capacity building needs to be differentiated among developing countries as no one size fits all. Some of them have capable research and commercialization infrastructures on which to build while others require assistance at more fundamental levels.

Innovation and diffusion of new low-carbon and adaptation technologies will require concerted action along the innovation chain. Innovation will also be needed to drive radical market transformations, to rapidly adapt technology to developing country conditions and drive effort on 'orphan' research areas, such as drought-resistant crops, soil conservation techniques or sustainable fertilizers (Box 2). This will require incentives for innovation in new areas and in a wider set of countries than at present. Multilateral action is required to give incentives for additional national actions, drive international collaboration and help correct critical market and policy failures. Successful examples of such collaboration may serve as useful models for the future, such as the experience garnered under the Montreal Protocol (Box 4).

Box 4: International cooperation on technology transfer: the case of the Montreal Protocol

The 1987 Montreal Protocol on substances that deplete the ozone layer, amended in 1990 and 1992, obliges both developed and developing countries to phase out the use of chlorofluorocarbons (CFCs). While developing countries' CFC phase-out obligations would only take effect from 2009 onwards, their consumption of CFCs in the early 1990s increased rapidly with increased use of CFCs for cleaning electronic parts and equipment, including CFC-113 in solvent-cleaning applications. Since these products were intended for international markets in developed countries, where there was a shift in consumer preference for CFC-free products, it was imperative for developing countries to phase out CFCs at the same pace as their competitors in developed countries to keep their market share.

In response, the Industry Cooperative for Ozone Layer Protection (ICOLP) and Japan Industry Cooperative for Ozone Layer Protection (JICOLP) were formed in North America and Japan. Technical cooperation projects allowed experts from ICOLP and JICOLP companies to travel to Mexico, India, China, Thailand, Turkey and Vietnam, to carry out technical assessment and provide advice to private companies. These government-collaborative projects were part of the World Bank's Montreal Protocol program. This initial technical collaboration led to tangible technology transfer at the factory level, nation wide in these countries. By mid-1990s, most CFC consumption in the solvent sector in developing countries was eliminated. This initial cooperation was subsequently expanded to the refrigeration sector.

International cooperation will also need to be rigorously prioritized, focusing on portfolios of technologies critical to achieving aggressive mitigation scenarios and areas requiring large-scale investments with a high public-good component or high benefits to developing countries. Such international collaboration, with enhanced prospects for wider dissemination and market penetration, should enable participants to lower the cost of development of new technologies and individual providers of technology to overcome the temptation of creating “technology monopolies”.

- Second, collaboration will need to extend to how public and private sectors work together. There is a need to widely use the business model in which governments agree to share expenses in long-term RD&D, through the establishment of *public-private partnerships*. Reflecting the need for a combination of technology push and market pull, such partnerships will be required at all steps along the innovation chain, not least to move as quickly as possible from demonstration to deployment and commercialization. The public sector will play a critical role on the innovation pathway (R&D, demonstration, deployment, diffusion, and commercial maturity), by setting the rules of the game (policies supporting innovation and R&D, regulations for the use of new technologies, etc), and sharing the cost of R&D (Box 5). As developed countries expand and improve the use of cap-and-trade systems and resort increasingly to auctions for the distribution of emission allowances, part of the revenues from these auctions may be pooled together to be invested in R&D for breakthrough technologies to boost private sources of funding, and use the remainder to support the deployment of pre-commercial technologies, especially when these have not yet reached the commercial stage.

Critical to both creating the technology push and instigating a market pull will be the long-term predictability of a price for carbon, resulting from a long-term global agreement on emission reductions and an assurance that market mechanisms will reward the development of these technologies (e.g., case of CCS) (Box 5).

Box 5: Developing and deploying new technology: Advanced oxyfuel combustion technology

In the mid-1990s, the owner of a US aluminum manufacturing company developed a new method for advanced oxygen fuel combustion technology and burner systems, a technology proven over the last 10 years through use in industrial furnaces to consistently reduce fuel consumption by about 70% and lower fuel bills and CO₂ emissions. The technology can be retrofitted and has significant commercial potential in addition to substantial net CO₂ emission reductions.

The company sought to deploy their patented technology internationally in order to capitalize on the growth in incentives for CO₂ avoidance in the EU and other Kyoto signatory countries. Having identified potential opportunities for the technology in India and China, they presented their technology at various international fora to generate interest. The Asia Pacific Partnership on Clean Development and Climate was instrumental in bringing the company into direct contact with industry representatives from India and China. It has taken four years, but deployment is now fast moving forward in India.

Their deployment approach is to license the technology to buyers, using third party engineering companies with exclusive local rights for installation and maintenance, recognizing the need for a local presence to be able to get a foothold in the market. This entails getting a reliable partner with contacts and influence, that can be trained to be an effective sales and implementing agent in the country.

A prominent hurdle in deploying the technology has been the need to convince companies that they should change their current way of working. Implementing a project successfully in-country is key to building demand as potential investors are more easily convinced of the merits having seen the technology operate in a familiar environment instead of overseas. To significantly tap into the huge potential of energy efficiency in industrial processing in sectors such as steel, aluminum and cement, concrete funding is necessary to start implementing the technology. Sectoral approaches such as those proposed under the World Bank's Carbon Partnership Facility working in tandem with other sources such as the donor-funded Clean Technology Fund are seen as strong potential options for motivating potential investors.

Encouraged by favorable results from the implementation of the technology in industrial furnaces, the company engaged in a public-private partnership with the US Department of Energy and the National Energy Technology Laboratory to apply the patented oxy-fuel technology to fossil fuel-fired boilers, which allows for cost effective CO₂ capture. In addition to public funding (\$3 million over 3 years), the partnership has involved joint staff and equipment and provided significant reputational benefits and credibility through joint publication of results. This has helped the NETL to develop and test an integrated pollutant removal system based on the oxy-fuel technology that can capture 95% of the CO₂ and remove other pollutants while increasing boiler efficiency. This still needs to be tested at a real-scale power plant and will require substantial additional public funding. Given the scale of the associated costs this is not manageable as a private investment. Getting the financial support necessary for piloting this at scale would be much easier if CCS were covered by the CDM. For CCS and other first-of-a-kind technologies to emerge as viable options they need public private partnerships that combine financing with practical application.

- Third, some innovative thinking will be required to *manage the financial risks* of dissemination (the so-called “valley of death”). Worth exploring would be whether multilateral financial institutions may be able to extend the use of their guarantee mechanisms to mitigate the risks associated with the transfer and adaptation of technologies to developing countries (e.g., IPR risk, operational risks) (Box 6). In sum, a careful allocation of public monies to those steps where risks are particularly prohibitive could go a long way in complementing what private sources of capital, responding to long-term market signals, could provide. Multilateral development institutions may also have a role to play in providing financial support to pre-commercial technologies, such as is being done for the dissemination to developing countries of the technology for concentrating solar power (CSP). Grant financing from the Global Environment Facility has been instrumental in rejuvenating interest in this technology and its uptake – supporting its path to maturity as a core part of the mitigation solution.

Box 6: Using guarantees to support breakthrough and existing clean energy technologies

Investment in developing countries typically involves the government or developer purchasing equipment from a major international supplier. Although this provides the purchasing nation with a power plant, it does not provide a technological capability. A more sustained development of the technology base in the developing country requires transfer of intellectual property so that there is an underlying growth in the sector capability. However, studies find that technology transfer is occurring only to a limited extent and below the global social optimum. Additional intervention using guarantees may be required to encourage technology transfer of breakthrough technologies where individual developers would find it too costly or too risky.

The focus would need to be on risks that investors cannot easily manage and are, to some extent, influenced or are under the control of governments. The non-carbon credit price risks can be classified as either project-specific, related to the host government, or related to the wider CDM process. For risks associated with the performance of host governments, such as policy decisions, government approvals, or the regulatory framework (e.g. priority of power plant dispatch), there may be an opportunity for greater use of World Bank guarantee products to ensure that the host government acts in a manner that minimizes risks for the investor.

For example, Brazil pioneered the use of biomass as an automobile energy source. It intervened heavily through a combination of subsidies, agreements with foreign automobile manufacturers, and structuring of the sugar cane production system. The World Bank could offer partial risk guarantees for such national programs that support technology transfer – by guaranteeing the performance of government commitments to support the technology including its broader local application throughout the economy and further local innovation.

Conclusion: a way forward?

In sum, there is no silver bullet. Given the enormity of the problem and the need to act big and fast, a two-pronged approach to technology deployment must be deployed. Whereas large-scale adoption of *existing* technologies is feasible provided individual countries adopt appropriate strategies, policies and regulations, the development and application of *breakthrough* technologies will require that countries collaborate at the international level on all aspects of technology development and deployment and establish robust public-private partnerships to mobilize all the financial, technical and human resources needed for this unprecedented effort.

The greatest challenge in the next 10-15 years of transition is to establish an international and domestic policy environment conducive to accelerating both the dissemination of existing technologies and the development of new ones. The transition will place increased demands on governments to drive the shift in investment patterns while promoting the development of comprehensive markets. This will involve addressing the challenges of enabling environments, targeting non-financial barriers to climate action, aligning incentives for climate-friendly investments, supporting and accelerating R&D and the diffusion of climate-friendly technologies, institutional capacity building, and the development of supportive policies and regulations.

A successful set of actions to develop and deploy both existing and new climate-friendly technologies, to arrive at a world in which we have achieved livable low-carbon growth and development across the globe, requires at least the following synergistic elements from the public sector perspective:

- *Realizing the critical role of public policy:* Technology is indispensable to addressing the climate challenge at reasonable cost; but it poses a significant public policy challenge in terms of delivering and deploying new technologies and engineering a massive shift of global investment in a short time frame. The public sector will be essential for getting clean technologies deployed at scale through its role in providing first and foremost an effective enabling environment to promote a fertile ground for receiving low-carbon technologies. As in most policy areas, there will be trade-offs involved in pursuing low-carbon technologies and infrastructure, however it is the responsibility of governments to ensure these are managed such that any obstacles to the full implementation of domestic climate objectives are eliminated.
- *Realizing the critical role of collaboration and partnerships* for the development of new technologies, be it at the international or domestic level, across public and private sector institutions from industry, research and academia. The challenge is of such magnitude and requires such a long-term and sustained efforts that it can only be met by pooling resources, be they human, technical, or financial, to maximize results and manage risks more effectively.
- *Relying on and creating a coherent framework for the use of a range of financing instruments:* The wide variety of existing financing instruments needs to be deployed at scale and packaged in a complementary way to maximize the synergies between them through simultaneous or sequential programming. They need to be embedded -- individually or in combination -- in development strategies, making best use of existing instruments and testing and developing new ones, including guarantees, to support green market transformation.

Maximizing synergies and better packaging is essential for using scarce public resources in the most useful way – to deliver the ‘biggest bang for the buck’.

- *Identifying and prioritizing critically needed additional finance:* Deploying existing technologies and financing at scale is important but will be inadequate to fully achieve the 2°C goal. Additional financing will be essential so governments will need to use the current small but vital window of opportunity to embed low-carbon solutions into the financial stimulus packages currently on the table. Developed countries should consider an advanced provision of incentives to developing countries for green recovery ahead of the post-2012 climate finance package. While it is expected that the majority of funding for mitigation will be generated and channeled by the private sector through carbon markets, we are still a long way off from having a global mature carbon market and a uniform carbon price. In the interim, international (developed countries) support to developing countries will be crucial to facilitate the transition. Most importantly, to build confidence and lend credibility to the process vital for driving private investment, countries must deliver on their commitments. ‘All talk and no action’ in the run up to Copenhagen and beyond will make it increasingly difficult to achieve stabilization of emissions at a safe level resulting in unprecedented impacts.

i Nicholas Stern (2008): Key elements of a global deal on climate change.
ii Mean estimate based on various sources.
iii Barker et al (2007) The Costs of Avoiding Dangerous Climate Change: Estimates Derived from a Meta-Analysis of the Literature
iv Invention and transfer of climate change mitigation technologies on a global scale: A study drawing on patent data.
http://www.cerna.ensmp.fr/index.php?option=com_content&task=view&id=192&Itemid=288
v The Clean Development Mechanism (CDM) and Joint Implementation (JI).
vi Bowen, Fankhauser, Stern and Zenghelis (2009): An outline of the case for a ‘green’ stimulus