MITIGATION TECHNOLOGY CHALLENGES: CONSIDERATIONS FOR NATIONAL POLICY MAKERS TO ADDRESS CLIMATE CHANGE

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Capacity development for policy makers: addressing climate change in key sectors
The UNDP "Capacity development for policy makers" project seeks to strengthen the national capacity of developing countries to develop policy options for addressing climate change across different sectors and economic activities, which could serve as inputs to negotiating positions under the United Nations Framework Convention on Climate Change (UNFCCC). The project will run in parallel with the "Bali Action Plan" process – the UNFCCC negotiations on long-term cooperative action on climate change set to conclude in December 2009 in Copenhagen at the fifteenth Conference of the Parties.

This paper is one of a series produced for the project that provides in-depth information on the four thematic building blocks of the Bali Action Plan – mitigation, adaptation, technology and finance – as well as on land-use, land-use change and forestry. The project materials also include executive summaries for policymakers, background briefing documents and workshop presentations. These materials will be used for national awareness-raising workshops in the participating countries.

Disclaimer

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CONTENTS

Boxes

Figures

Tables

Acronyms

Annex I	Annex to the Convention listing industrialized and transitioning countries
Annex II	Annex to the Convention, listing mostly OECD countries, with additional commitments to assist developing countries with funding and technology transfer
AR4	Fourth Assessment Report (of the IPCC, see below)
AWG-LCA	Ad Hoc Working Group on Long-term Cooperative Action under the Convention
CER	Certified emission reduction
CCS	Carbon capture and storage
CDM	Clean Development Mechanism
CH_4	Methane
CHP	Combined heat and power
CO_2	Carbon dioxide
COP	Conference of the Parties (to the UNFCCC)
CSLF	Carbon Sequestration Leadership Forum
DEWI	German Wind Energy Institute
GHG	Greenhouse gas
GDP	Gross domestic product
EGTT	Expert Group on Technology Transfer (of the UNFCCC)
EU	European Union
H_2	Hydrogen
HFC	Hydrofluorocarbons
I&F	Investment and finance
iCER	Insured certified emission reduction
IEA	International Energy Agency
IGCC	Integrated gasification combined cycle
IPCC	Intergovernmental Panel on Climate Change
IPRs	Intellectual property rights
JI	Joint Implementation
Km	Kilometer
LDCs	Least developed countries
LULUCF	Land use, land-use change, and forestry
NEF	New Energy Finance
NAI Parties	Non-Annex I Parties not included in Annex I to the Convention (mostly developing countries)
NGCC	Natural gas-fired combined cycle
PCC	Pulverized coal combustion
PV	Photovoltaic
R&D	Research and development
RDD&D	Research, development, demonstration, and deployment
SBSTA	Subsidiary Body for Scientific and Technological Advice
SRES	Special Report on Emission Scenarios (of the IPCC)
SRES A1	High economic growth scenario
SRES A2	Scenario of self-reliance and preservation of local identities
SRES B1	As in the A1 storyline, but with rapid change in economic structures toward a service and information economy.
SRES B2	High population growth-intermediate economic growth scenario
tCER	Temporary certified emission reduction
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Connection for Climate Change
WBCSD	World Business Council for Sustainable Development
WGIII	IPCC Working Group III, assesses options for mitigating climate change through limiting or preventing GHG emissions and enhancing activities that remove them from the atmosphere
WMO	World Meteorological Organization

Units and Measures

CO_2-eq	CO_2 equivalent
$GtCO_2$-eq	Gigatons CO_2 equivalent
$GtCO_2$-eq/yr	Gigatons CO_2 equivalent per year
GJ	Gigajoules: 10^9 joules, a billion joules
Gt	Gigatons: 10^9 tons, 1 billion tons
GW	Gigawatts: 10^9 watts, 1 billion watts
kW	Kilowatts (power measurement)
kWh	Killowatt hour
kWth	Kilowatt thermal
Mt	Megatons: 10^6 tons, 1 million tons
Mt/yr	Megatons per year
MW	Megawatt: 10^6 Watt, 1 million watts
MWe	Megawatt electric
tC	tons of carbon
tCO_2	tons of CO_2
t/h	tons per hour

FOREWORD

The purpose of this paper is to review the role that existing technologies and those under development can play in meeting the climate change challenge. Additional purposes are to help the reader to consider which technologies could help meet the development needs of his/her country while limiting greenhouse gases (GHGs) and to identify specific suggestions under an international climate change agreement that could help introduce new technologies in developing countries.

The paper is an input to a series of workshops that UNDP will organize in developing countries with the aim of improving their capacity to respond to climate change. It borrows extensively from the International Energy Agency (IEA) report titled *Energy Technology Perspectives: 2008* and from a United Nations Environment Programme (UNEP) report titled *Global Trends in sustainable Energy Investment 2008*. The paper summarizes the scope of the technology challenge needed to address climate change; the mitigation options and likely global costs; the trends in financing sustainable energy investments; and the status and issues relating to a selective set of technologies likely to be of particular interest to developing countries.[1] An extensive treatment of all technologies has not been possible, therefore the reader may wish to review the IEA *Energy Technology Perspectives 2008* report for a broader treatment of technologies. Questions are included at different parts of the document to help the reader reflect on the circumstances in his/her country. A final section provides insights about technology issues and options under consideration in the United Nations Framework Convention on Climate Change (UNFCCC) process to negotiate a new climate change agreement.

Climate change confronts us with a major technological challenge if we are to reduce GHG emissions to levels that will prevent dangerous anthropogenic interference with the climate system. The good news from the Intergovernmental Panel on Climate Change (IPCC) is that many mitigation scenarios for the medium term (i.e., until 2030) suggest there is considerable economic potential for reducing GHG emissions at costs ranging from negative to about $100 per ton of carbon dioxide (CO_2). However, if we are to stabilize GHG emissions – for example, at current levels by 2030 as a first step – additional mobilization of investment and finance (I&F) flows in the order of $200 billion (mostly aimed at the energy supply and transportation sectors) would be needed. These additional I&F flows are large relative to the funds currently available, but low as compared to global Gross Domestic Product and investment. Recent evidence indicates that due to policies in some countries, investment in clean energy technologies is growing and that new financial products and markets are being developed worldwide.

There are many existing and emerging technologies, such as, advanced fossil fuel power generation, biomass and bioenergy, wind power, buildings and appliances, and electricity transmission and distribution technologies, that can help achieve a low carbon future and other environmental goals. Each of these is at a different stage of the research, development, demonstration and deployment (RDD&D) cycle, however they are not being developed and diffused at the rate required because of a number of technological, financial, commercial and regulatory barriers. Given the urgency of the climate change problem, policy makers in developing countries need to consider how they will contribute to reducing the rate of growth of GHG emissions in their countries, their unique circumstances and special technology needs, and how to encourage innovation and the diffusion of the technologies using both public and private finances. Policy makers also need to consider how the international community could help their countries through a "full package" approach, consisting of equipment, software, enhanced human capacities, regulatory and institutional support, and financial mechanisms designed for each element of the approach.

[1] In the context of the current climate negotiations, there is substantial interest in developing adaptation technologies. The paper does not explore this topic because of the limited literature on the matter.

1. INTRODUCTION

The international debate on how to enhance and upscale the development and transfer of climate-friendly technology for mitigation and adaptation is gaining momentum in the framework of negotiations for a post-2012 climate agreement. This is reflected in the central role that issues relating to technology (notably to RDD&D as well as transfer) have had in past deliberations of the UNFCCC Long Term Dialogue and are having in current sessions of the Ad Hoc Working Group on Long-Term Cooperative Action (AWG-LCA). To a large extent, the relevance of these issues stems from the huge technology challenge posed by emissions stabilization at current levels, as well as from the fact that capacity building, technology transfer and finance are key to facilitate developing countries' implementation of substantial action on mitigation and adaptation. (Information on the terminology used in this paper can be obtained from the glossary in Annex 3).

Climate change confronts us with a major technology challenge. For example, it is estimated that stabilizing CO_2 equivalent concentrations in the range of 535-590 ppm would lead to a temperature increase of approximately 2.8-3.2^0 Celcius over pre-industrial levels. Achieving this level requires emissions to peak in the 2010-30 period (IPCC 2007a). Global CO_2 emissions (mainly from energy use) in 2050 would have to be in the range of -30 to +5% of 2000 levels. However, a temperature increase of 3^0 Celcius would have significant global impacts according to the IPCC (IPCCb). Consequently, serious consideration is being given to limiting concentrations to approximately 450 ppm equivalent. This would imply the need to reduce global emissions between 50-85% by 2050. To achieve such a scenario, the world would have to undergo a significant transformation in its production and use of energy.

It is important to note that, for some technology-related issues, the ongoing international debate reflects a growing international consensus; others remain highly controversial. Reaching an international agreement on the concerted actions needed to upscale technology development and transfer and the means to deploy them widely will likely require further dialogue, as well as in-depth analysis of the circumstances of each country. (*For an overview regarding Conference of the Parties (COP) decisions relevant to technology, please refer to Annex 2*).

A growing consensus is being reached on a number of important issues:

- Several key technologies needed to achieve low-cost mitigation (in particular for developing countries and in the energy sector);
- The main (information and incentive) barriers that hinder the development and deployment of low-cost mitigation technologies in both industrialized and developing countries;
- The need to stimulate international technology cooperation in order to accelerate RDD&D and transfer of efficient climate-friendly technologies;
- The existence of a substantial financing gap that needs to be filled in order to reach the necessary upscaling of technology development and transfer. This calls for new and improved instruments to this aim.

However, there are important issues that remain controversial, for example:

- **How quickly we can change to a low carbon energy world.** This has serious implications for the urgency and scale of international technology cooperation, and concerns for example, whether we should focus on the dissemination of existing technologies or on research and development (R&D) for new technologies that are too costly at present.
- **The policy approach necessary to accelerate technology development and deployment.** Some analysts argue that climate policies alone (e.g., a price signal from carbon markets and project mechanisms such as Clean Development Mechanism (CDM) and Joint Implementation (JI)) provide enough incentives for technology development and diffusion, while others argue in favor of additional technology policy instruments (e.g., efficiency standards or goals, subsidies, and information diffusion instruments). However, in general, it is believed that a package of policies will be necessary to encourage innovation and large-scale mitigation efforts.
- **Investments for sustainable technologies.** Investments have increased in some countries, but as noted in UNFCCC 2007, there is a significant gap between current investments in developing countries and the level of funding that will be needed to reduce the rate of growth in GHG emissions. A significant shift in investments to sustainable technologies is needed, but how this can be achieved in an efficient way remains a subject of some analysis and political debate.
- **The role of intellectual property rights (IPRs) for**

the development and deployment of climate-friendly technologies. Some developing countries argue that they increase the cost of access to technology and therefore act as a barrier to the adoption of climate friendly technologies and call for new, specific international mechanisms to purchase IPRs for key technologies and licencing policies. By contrast, most industrialized countries' representatives stress the need to grant IPRs and long lived patents to innovators in order to provide enough incentives for the development and commercialization of new technologies.

- **The form that international RDD&D co-operation should take.** There is some debate over this issue, notably, whether the object and financing for such cooperation should be decided in the framework of the UNFCCC or not.
- **The role and ultimate scope of carbon markets and the CDM for technology transfer.** Some suggest that CDM has hardly involved new technologies or North-South transfer of innovative solutions, while others note that many CDM projects have been initially developed solely by developing countries. Furthermore, most CDM projects have been implemented in a few fast-growing, middle-income developing countries (India, China and Brazil). By contrast, countries that could benefit the most from CDM related technology transfer and sustainable development effects – notably least developed countries (LDCs) – have hardly any participation in the CDM. While it is recognized that CDM has helped to mobilize investments in clean technology that in the mechanism's absence would not have been implemented (at least not to the same extent), the ability of CDM to fill the technology financing gap remains an open question.

2. MITIGATION OPTIONS AND COSTS

GHG emissions have been on a high growth path for the past few decades and will continue on that path unless climate change mitigation policies are considerably upgraded. Emissions have grown by 70% between 1970 and 2004, and in a business as usual scenario – i.e., if no further mitigation policies are implemented – an increase in a range of 25-90% (in absolute terms, 9.7-36.7 Gigatons CO_2 equivalent ($GtCO_2$-eq)) is projected for 2000-2030.

Most projected GHG emissions growth will continue to result from energy use and most additional emissions will originate in developing countries. More specifically, CO_2 emissions from energy use are expected to grow 40-110% over 2000-2030, with two-thirds of that increase coming from non-Annex I (NAI) countries. This reflects the importance of technological change in these countries for GHG emission stabilization.

It is necessary to substantially increase investment in clean energy technology development and deployment from current levels. In spite of climate policies, both government support and private expenditure on cleaner energy R&D are estimated to be low as compared to the levels achieved after the oil shocks of the 1970s and 1980s. Current government funding for energy R&D is estimated to be half of its 1980 level (in real terms).

It is also important to introduce regulatory and economic instruments that provide long-term incentives for technology development, demonstration, and deployment.[2] Policies introducing a carbon price, accompanied by measures to reduce barriers to technology adoption could substantially increase the incentives for (interest of) mitigation. For example, a carbon price of $20 per ton of CO_2, accompanied by measures to overcome barriers to technology adoption, would make it worthwhile to reduce GHG emissions by 9-18 $GtCO_2$-eq per year (that is a 14-34% reduction as compared to a high growth business as usual scenario). If the carbon price reaches $100 per ton of CO_2, mitigation would increase but not in the same proportion: it may reach 23-46% reduction in emissions relative to the same baseline scenario.

In general, it is believed that a mix of existing and new technologies and practices will be necessary to achieve the relevant mitigation levels predicted in the IPCC stabilization scenarios (*see Annex 1 for more detailed information on available technologies and those under development in different sectors as well as for results on the relative importance of specific mitigation technologies*). Even if the relative role of existing and new options remains controversial, a recent survey of mitigation measures for 2030 found that more than two-thirds of the measures with mitigation potential are available today (Vattenfall, 2008).

While there is considerable economic potential for reducing GHG emissions, the costs of different mitigation options (technologies) vary considerably. At one extreme, available mitigation options may imply net benefits of €150/ton CO_2. At the other end, they may entail costs approaching €80/ton CO_2 (*see Figure 1*). This means that emissions growth could be checked, but a careful cost assessment should be made in order to avoid high economic impacts (costs) of mitigation.

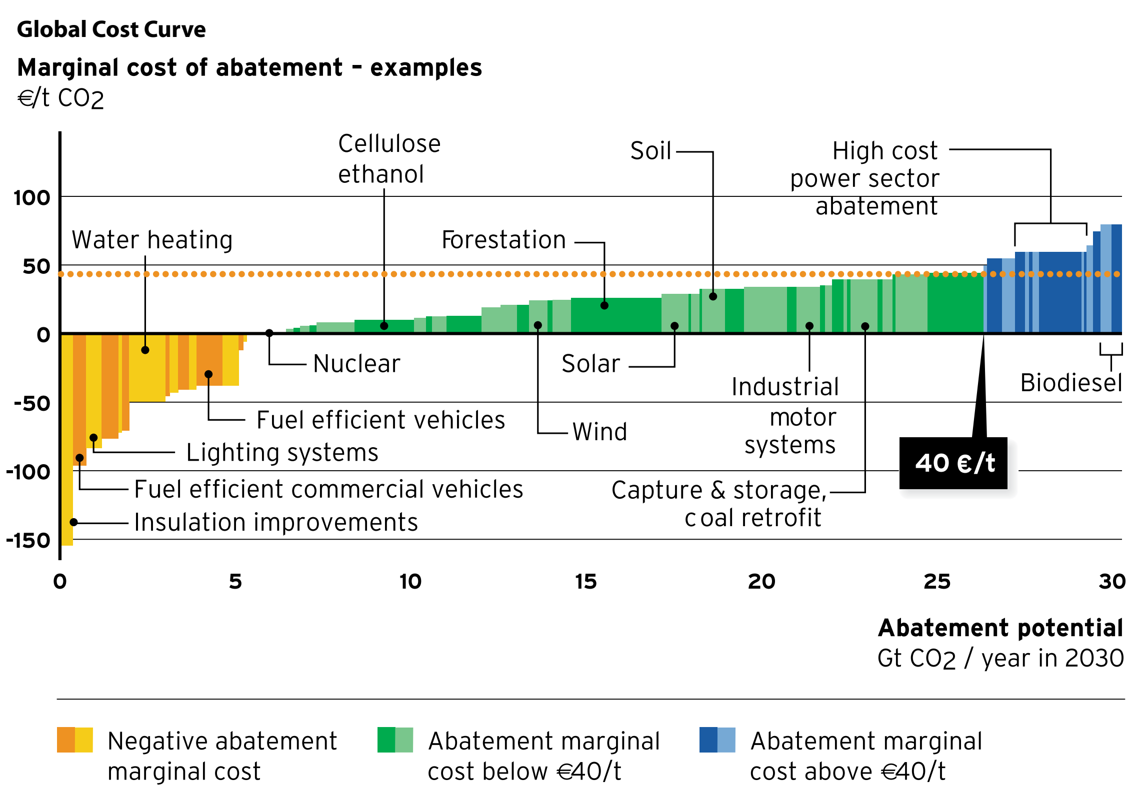
There is also a large potential for no-cost mitigation. Many mitigation opportunities, mostly related to improving energy efficiency in buildings, imply negative costs (i.e., net benefits) if implemented, but require specific action and policies to deal with implementation barriers (e.g., minimum regulatory requirements for insulation and equipment efficiency). According to IPCC Fourth Assessment Report (AR4), these no-cost measures add up to a mitigation potential of 6 $GtCo_2$-eq/yr. Similarly, Vattenfall's survey estimated that nearly one-quarter of the total mitigation potential identified for 2030 would entail net benefits (*see Figure 1 for examples of no-cost technologies*).

In general, energy efficiency measures play a key role for mitigation according to most studies. In particular, IEA and IPCC estimates put energy efficiency at the top of all mitigation options according to their large potential (*see Annex I*). The Stern Review further stresses that energy efficiency provides the best option for the medium term (i.e., up to 2025) but for the longer term (up to 2050), renewable energy options show a larger potential.

[2] B.Metz et al 2007 (op.cit.), chapters 3 & 13.

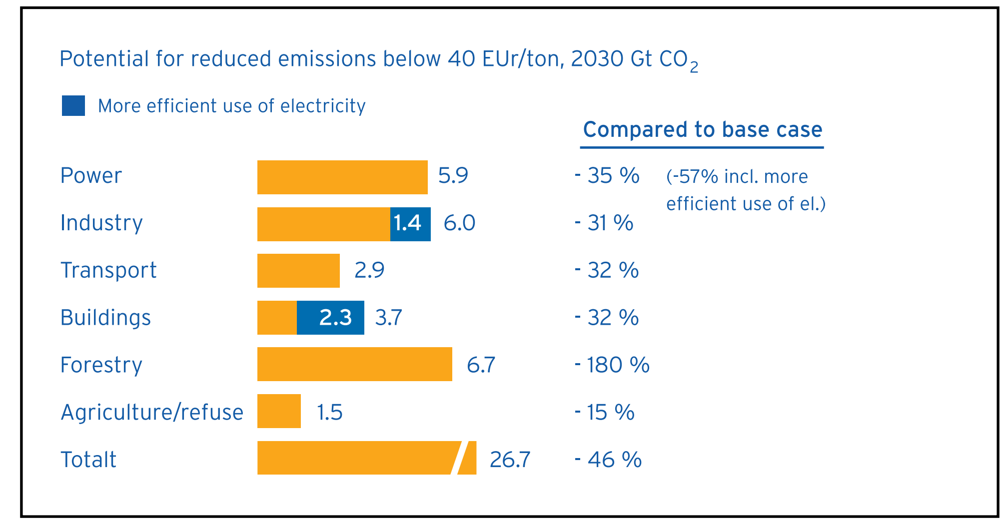
Likewise, Vattenfall (2008) shows that measures to improve the efficiency of electricity use in three sectors (power, industry, and buildings) result in the largest mitigation potential identified by 2030 (7.4 Gt CO_2, or 28% of total mitigation potential). At the sector level, avoided deforestation shows the highest potential (6.7 Gt or 25% of total mitigation potential) (*see Figure 2*).

Figure 1: Global mitigation cost curve



Source: Vattenfall (2008)

Figure 2: Potential emission reductions per sector, by 2030



Source: Vattenfall (2008)

As to the regional distribution of the world's aggregate mitigation potential, it is clear that some fast-growing developing countries already play an important role. When considering the mitigation potential at costs below €40/ton CO_2 (estimated at 26.7 $GtCO_2$), Vattenfall (2008) estimated that the US and Canada may contribute with 4.4 Gt (16.4%), China with 4.6 Gt (17.2%), European countries of OECD with 2.5 Gt (9.3%), Eastern Europe (including Russia) with 1.6 Gt (5.9%), other industrialized countries with a further 2.5 Gt (9.3%), and the rest of the world with 11.1Gt (41%).

More generally, the magnitude of necessary mitigation efforts and costs will depend on a number of features of future international climate agreements that should be carefully evaluated. More precisely, costs will be higher, the greater the ambitiousness of the stabilization goal, the lower the number of parties that will share the mitigation effort and the more limited the scope for flexibility (such as mitigation options allowed and flexibility mechanisms available, e.g., emissions trading).

For lower stabilization levels, the preferred technology options are low carbon energy sources (renewables, nuclear, etc.) and technologies that are not yet available at a commercial stage (such as carbon capture and storage (CCS)). If gases other than CO_2 and land use, land-use change and forestry (LULUCF) options are included, then greater flexibility for mitigation is achieved (and lower costs result).

Macroeconomic costs consistent with emissions stabilization between 445 and 710 ppm CO_2-eq are estimated as ranging from a 3% decrease in global GDP and a small increase compared with the business-as-usual scenario (IPCC, 2007a). However, regional costs may differ considerably from the global average. GDP loss may be substantially reduced if revenues from a tax or a permit auction is spent in low carbon technologies promotional programs or to reduce other distortionary taxes. Similarly, if induced technological change (i.e., accelerated innovation due to climate policies) is verified, then costs could be much lower than the previous estimate. Modelling studies consistent with stabilization at 550 ppm by 2100 indicate that equilibrium carbon prices would lie in a range of \$20-\$80 per ton of CO_2 by 2030 and \$30-\$155 per ton of CO_2 by 2050. If price incentives lead to technological change, then equilibrium carbon prices would be reduced to ranges of \$5-\$65 per ton of CO_2 by 2030 and \$15-\$130 per ton of CO_2 by 2050.

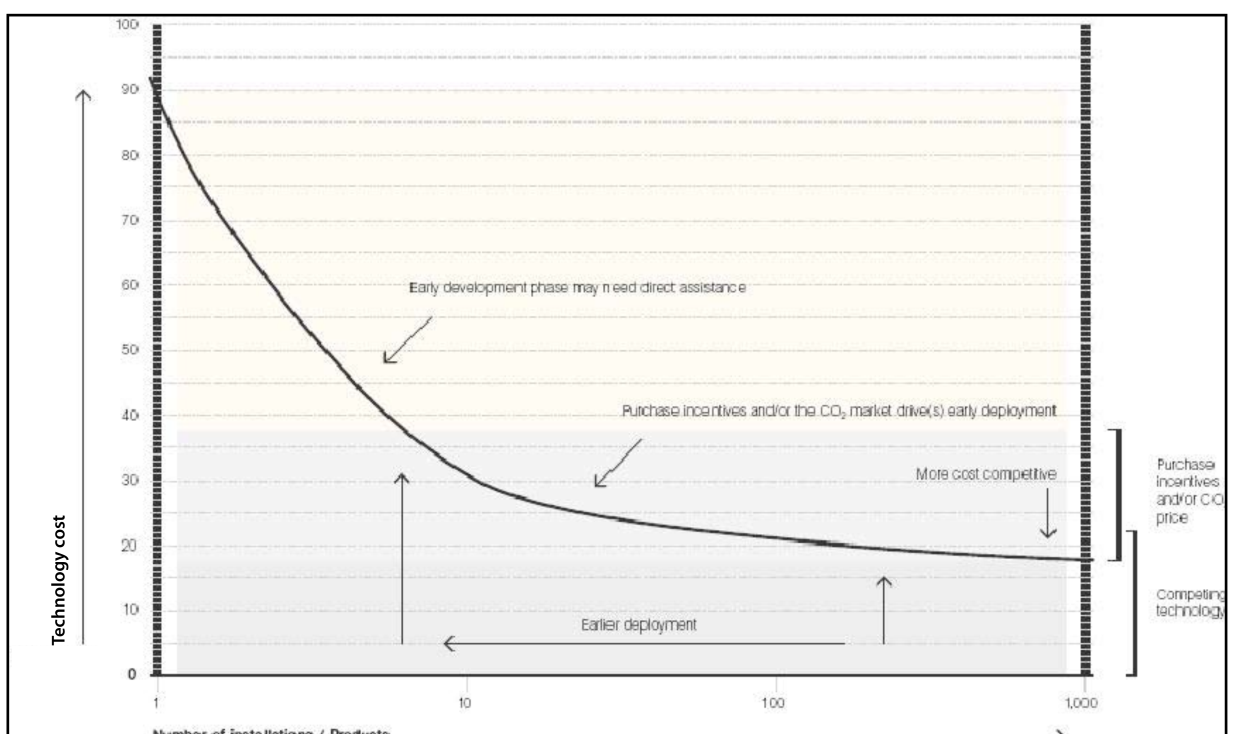
Irrespective of the precise costs involved, it is clear that one barrier to the implementation of cleaner technologies is the availability of finance to cover upfront costs. For example, renewable energy and energy efficiency solutions often face low operation costs (or even operation benefits, as reflected in a lower energy bill) but higher capital costs as compared to conventional energy or existing sources. In this regard, there is room for optimism, as shown by recent trends in clean energy (renewable energy and energy efficiency) financing (reviewed in the next section).

It is important to consider that technology finance and policy needs will vary at different stages of the technology development process (i.e., research, development, demonstration, commercial development, and deployment), as illustrated by *Figure 3* (WBCSD, 2007b and UNFCCC, 2007; chapter 9). For instance, in early stages of development, investment and financial flows are high, since technology has high costs as compared to competing technologies and substantial R&D efforts (investment) are necessary. However, private funding is in general unlikely to be available due to high perceived risks. At this stage, direct assistance (R&D subsidies) as well as public sector finance for demonstration may become crucial.

By contrast, when technologies reach the commercial stage, for early deployment to occur, purchase incentives and other policy driven signals (such as carbon markets) become highly relevant. At this stage, some forms of private sector finance may step in (e.g., venture capital).

For a wider deployment of available technologies, even if finance mechanisms may abound (e.g., bank project finance), purchase incentives should be reinforced to overcome adoption barriers whenever these technologies have higher cost than less climate friendly alternatives (e.g., with policy-driven carbon prices). As the adoption rate increases (*moving to the right of the horizontal axis in Figure 3*), technology costs will decrease, technologies will become common practice, and the barrier imposed by lack of access to finance will disappear. Before that happens, local funding sources may be scarce if these technologies are perceived to pose high technology or project specific risks (e.g., if they are new in a given national context). Policy and finance needs at the demonstration stage should not be underrated since many technologies with high R&D investments sometimes find it difficult to overcome barriers in this phase. As an example, it is important to consider that promising technologies, such as CCS and coal gasification, still need to successfully get through the demonstration stage.

Figure 3: Technology cost in relation to the number of installations/products



Source: UNFCCC (2007, chapter 9)

3. TRENDS IN CLEAN TECHNOLOGY FINANCING

It is increasingly recognized that the challenges to fill the finance gaps to upscale cleaner technology development and deployment are considerable but not insurmountable. First, because some investment and funding reallocation is desirable, e.g., in the energy sector, away from conventional carbon-intensive technologies to cleaner ones. Second, because the additional funding needs may easily become available. In order to stabilize GHG emissions at current levels by 2030, additional mobilization of I&F flows in the order of $200 billion (mostly aimed at the energy supply and transportation sectors) would be needed (UNFCCC 2007). These additional flows will be large relative to the funds currently available, but low as compared to global GDP and investment. As a matter of fact, it will only represent 0.3-0.5% of global GDP and 1.1-1.7% of global investment in 2030. Furthermore, as shown below, funds and mechanisms available for finance clean energy technologies have grown considerably in recent years.

Current trends show that investment in clean energy technologies is growing fast and that new financial products and markets are being developed worldwide, (i.e., I&F mechanisms to this aim are broadening in scope and increasing in magnitude). Investment in sustainable energy[3] has been estimated at $148.4 billion in 2007 (growing 60% as compared to previous year) (UNEP/NEF 2008). Furthermore, current projections indicate that annual investment between now and 2030 will reach $450 billion by 2012 and $600 billion by 2020. Both traditional financing (financial system mechanisms for large scale projects, public subsidies) and new mechanisms (e.g., microfinance, public and private green funds, etc.) along with policies such as new regulations and guidelines are behind the observed growth in renewable energy generation capacities.

Total I&F in sustainable energy was mostly made up of asset finance (generation capacity projects) that reached $84.5 billion in 2007. The rest was explained by public markets ($23 billion), R&D funding (private and public) reaching $17 billion, venture capital/private equity (amounting to $9.8 billion), and small scale projects that reached $19 billion.

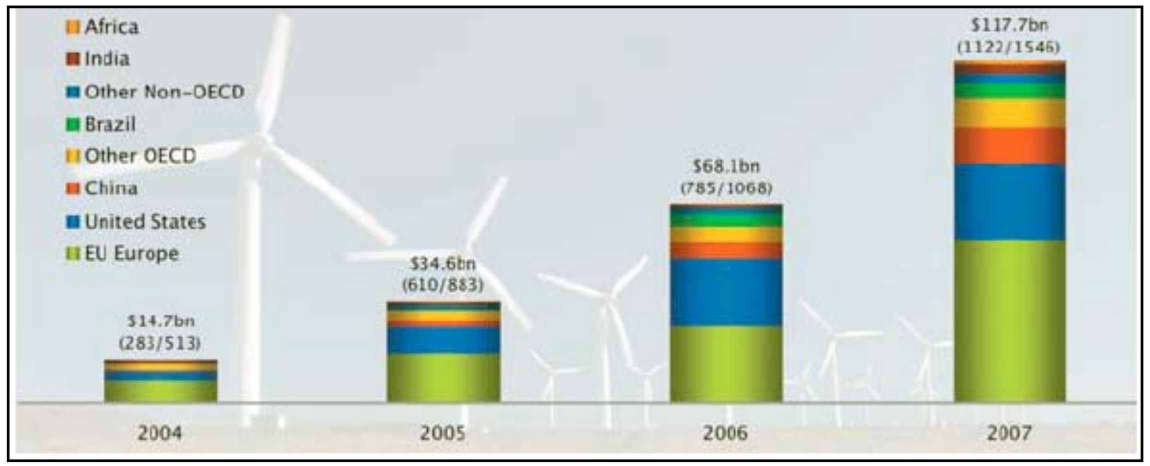
In order to guarantee that the necessary scale of (climate friendly) technological change is achieved, government budgets for R&D need to double and private incentives should be reinforced. Since the private sector is responsible for most climate-related I&F efforts (86%), private incentives for investment should be modified along with an upscale in public support for R&D in order to considerably upscale clean technologies development and deployment.

Investment in R&D and for new technologies to reach commercial stage is also growing, helped by funding from venture capital and private equity as well as public (stock and share) markets (UNEP/New Energy Finance (NEF), 2008). Furthermore, clean energy technology companies from developing countries (notably from India and China) have managed to raise funds from international capital markets via private equity (convertible bonds) and by raising venture capital and foreign direct investment.

As to regional distribution, the European Union (EU) is the world leader in sustainable energy investment (receiving $55.8 billion), followed by the US (with $26.5 billion). Developing countries currently receive roughly one quarter of global I&F related to climate change mitigation (UNFCCC, 2007) and sustainable energy investment (UNEP/NEF, 2008). However, developing countries should capture an increasing share of global investment to this aim, for various reasons. First, in these countries, mitigation investment is expected to be highly cost-efficient (due to the availability of low-cost mitigation options). It is estimated that developing countries will account for 46% of needed investment even if – by 2030 – they could produce 68% of global emissions reduction. Second, they will retain a growing share of energy-related investment and capacity. The question is whether developing countries will be able to finance the needed investment in order to cover their energy demands with clean energy sources.

[3] This includes investment in renewable energy production, externally financed energy efficiency projects, R&D, and related equipment production capacity.

Figure 4: New investment in clean energy by region, 2007



Source: UNEP/NEF, 2008

As mentioned above, prospects are good since the availability of clean energy funding is rapidly growing and given that developing countries (at least the large, fast-growing ones such as China, India and Brazil) are gaining a higher share of clean energy-related I&F. Current investment in sustainable energy is mainly aimed at new generation capacities ($84.5 billion in 2007). In the high-growth context of renewable energy, developing countries managed to double their overall share of global sustainable energy investment, which reached 22% in 2007 (17% concentrated in three countries: China, India, and Brazil). This is mostly explained by the fact that China received $10.8 billion of asset finance, Brazil accounted for $6 billion and India for $2.5 billion. Together, these three countries received 20% of global asset finance (aimed at energy generation or biofuel production projects). Since they are also becoming important players as renewable energy technology suppliers (in particular, Brazil for ethanol production, India for wind turbines, and China for solar panels), they are also capturing an increasing share of global public markets and private equity investment.

It is important to stress the contribution of new mechanisms to fund distributed generation capacities in developing countries (mostly home solar photovoltaics (PV), solar water heating and biomass cogeneration) that are being offered by microfinance (through specialty banks such as Grameen) and public programs receiving international finance from multilateral or bilateral development banks (e.g., rural electrification devised at national level or renewable energy programs at municipality level). These technologies and programs help improve access of the poor and remote rural areas to (off-grid) energy services, most notably in countries (like China, Brazil, and India) where rapid growth is leading to increasing pressure to raise living standards and mounting energy demand. In some cases, host countries have also raised part of the necessary funding via carbon markets (in particular through the CDM). As discussed below, the CDM does not cover full costs. However, the funding raised through this channel may prove enough to overcome other investment (roll out) barriers. Even if the CDM does not cover full costs, the funding raised through this channel may prove enough to overcome other investment (roll out) barriers. In addition, many countries are expecting the CDM to further enlarge the funding opportunities available to these programs via new options for "programs of activities" and new sectors.

As to the technologies mostly favored by I&F trends, it is worth noting that, in recent years, the most favored technologies were wind energy, solar, and biofuels. The former accounted for $50 billion investment, i.e., 43% of new investment, in 2007. Some 60% of new investment in wind capacity was installed in the US, Spain, and China. Together, wind, solar and biofuels explain 85% of total new capacity investment in 2007. For its part, venture capital and private equity were mostly directed at solar technologies in 2007, with energy efficiency being the second most important technology receiving this type of funding, and biofuels ranking third. It is also worth noting that the only sector that nearly stagnated in 2007 was biofuels, to a large extent due to concerns related with food availability and high feedstock prices (that, for example, led to a freeze in the implementation of new biofuel minimum content policies in some countries, such as Mexico and China and slower growth in others, such as the US).

In spite of the good prospects, many challenges remain:

- First, it is worth noting that sustainable energy investment is still small in magnitude. It represents only 9% of global energy infrastructure investment and 1% of global fixed asset investment.
- Second, in spite of expanding policies to foster renewable energies, most energy policies still favor conventional (fossil fuel based) energy: the annual amount of global energy subsidies aimed at fossil fuels was $180-$200 billion, while subsidies directed at renewable energies totalled $16 billion.
- Third, energy related R&D only received 4% of total government-funded R&D (UNEP/NEF, 2008). Similarly, it is worth noting that private and public funding for renewables R&D (amounting to $16.9 billion in 2007 and involving a 30% growth in the past two years) has been growing, but at a much slower pace than venture capital directed at renewables (which grew 106% over the past two years).
- Fourth, with regard to the components of sustainable energy investment, a remaining challenge is to increase energy efficiency-related investment. Even if it is difficult to measure (since most investments in energy efficiency are self financed by companies and households), it is worth noting that (externally financed) energy efficiency investment only contributes to 3.7% of total investment in sustainable energy. This could be partly explained by the difficulties these type of projects face to reach traditional commercial funding (i.e., low scale, high transaction costs, difficult to specify, etc.). As a matter of fact, energy efficiency is financed via other channels (such as venture capital, private equity, and public markets). Externally funded energy efficiency investment nearly doubled in Europe and the US suggesting that new mechanisms are becoming available. Further growth in energy efficiency funding depends on the enlargement and extension of newly designed programs that help bundle small energy efficiency projects (either at geographical level, e.g., municipalities, or sectoral level, e.g., appliance efficiency).
- Finally, many developing countries are not participating in the growth in financing for renewables and energy efficiency for various reasons, such as low investment levels in energy capacity, scarce CDM project development, and lack of specific policies to foster the application of clean energy sources. This may well be due to the lack of skills to promote such a public policy or due to other perceived priorities.

All the same, it is important to keep in mind that the renewables sector is playing an increasingly important role for energy provision and is set to become ever more relevant. Even if renewable sources (excluding large hydro) still only account for roughly 5% of global production and generation capacity, over the past two years they accounted for over 20% of new capacity and production.

Carbon markets (including the CDM and carbon funds) can play an important role for developing countries' uptake of renewable energy technologies. However, it should be kept in mind that CDM projects do not fund full costs and are highly concentrated, both geographically and among project types. According to UNEP/Risoe figures,[4] China and India concentrate more than two-thirds of credits (certified emission reductions (CERs)) expected by 2012, and four countries (China, India, Brazil, and Mexico) account for two-thirds of total CDM projects. China is the leader with 45% of CERs expected by 2012, India ranks second with 17%, Brazil follows with 10% and Mexico with 4% of total 2012 CERs. In terms of projects, India leads with 33% of projects, followed by China (17%), Brazil (13%), and Mexico (11%). This differing ranking has to do with the relative scale and global warming potential of different GHGs involved in projects of different countries. China, for example, generates a large share of its credits from

[4] Taken from the CDM/JI pipeline as of April 2008. Available from www.cd4cdm.org.

HFC projects (large scale and with the highest global warming potential of all GHGs).

As to the importance of energy efficiency and renewable energy projects, they are quite salient in China, Brazil, and India. India is the leader in these types of projects, having developed 79 energy efficiency projects and 197 renewable energy projects (111 biomass, 49 wind, 36 hydro, and one solar). China has 115 renewable energy projects (56 wind energy, 51 hydro, and 8 biomass). For its part, Brazil has developed two energy efficiency projects and 64 renewable energy projects (37 biomass, 23 hydro and 4 wind), while Mexico has developed 37 renewable energy projects (5 wind, 3 hydro and 29 biogas).

It is estimated that the CDM will generate funding in the order of $25 billion annually until 2012 (UNFCCC, 2007). Private and public carbon funds raised nearly $13 billion by the end of 2007 (UNEP/NEF, 2008). Furthermore, even in the uncertain context we face before a post-2012 deal is reached, some large development banks and brokers are promoting (buying) post-2012 credits, thus giving continuity to carbon market transactions. However, most analysts believe the carbon market contribution should increase at least fourfold in order to reach the necessary scale of clean technology adoption in developing countries.

The recent developments reviewed above can be seen to bring new opportunities as well as new challenges for developing countries in order to upscale investment in clean energy technologies (and other mitigation options). Regarding the opportunities, it is increasingly important for these countries to identify them by assessing the different finance options available and their relative merits as well as their applicability to their national needs and circumstances.

There are considerable differences in technology needs and national capacities to identify and address them in different developing countries. While large, fast-growing countries seem to be profiting from current trends, smaller and lower income developing countries as well as LDCs are still to see the benefits of larger I&F markets for sustainable energy. As to the challenges, it is increasingly important that clean energy technologies and other mitigation options gain a more important role in long-term planning priorities and public/private investment strategies. International organizations and donors should help by providing technical assistance and capacity building to enlarge the ability at the local level to deal with these challenges in smaller developing countries, especially in LDCs, and to find the adequate mix of finance options to implement the right technology solutions for their energy needs.

Questions:

- Does your country provide grants or other financing to support for research, development, or deployment of technologies?
- How is the construction of energy or other infrastructure projects financed in your country: development assistance, government or private loans, equity markets, private capital, or other financial instruments?
- Are there venture capital funds operating in your country or have venture capital funds provided financing to new companies in your country?
- What are the major obstacles to investments in your country, e.g., the creation of venture capital funds or new equity offerings in your country? What might the international community do to help improve the investment climate in your country?

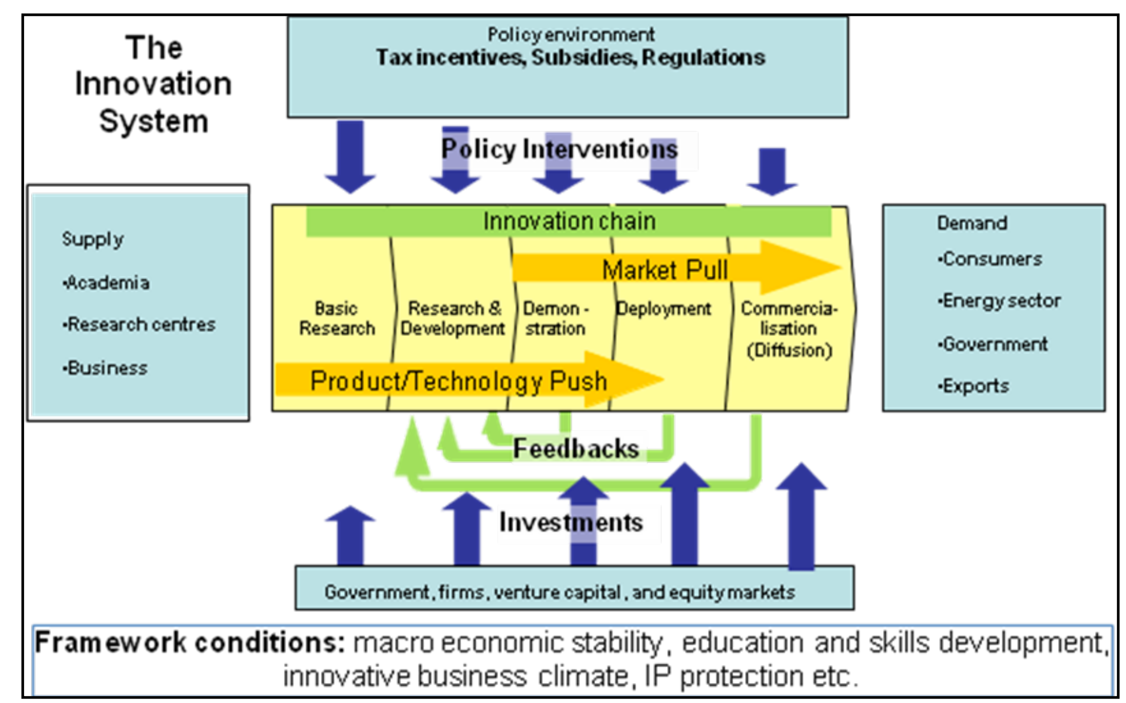
4. KEY TECHNOLOGIES – CONSIDERATION OF ISSUES RELATING TO THEIR DEVELOPMENT AND DEPLOYMENT IN DEVELOPING COUNTRIES

The International Energy Agency (IEA, 2008) lists over 300 new key energy technologies that may play a role in reaching a low carbon world, but it admits that even this list is not exhaustive. This section will focus on just a few technologies that may be of particular interest to developing countries, while recognizing that each country has unique circumstances and technology interests which may not coincide with those addressed in this section. We omit many that are either expensive (nuclear), not sufficiently mature (ocean energy) or diverse (industrial processes), but first a word about the research, development, and demonstration, and deployment cycle (RDD&D). This section does not focus on national policies to promote RD&D or the deployment of technologies, as this subject is treated in another paper in this series, *National policies and their linkages to negotiations over a future international climate change agreement* by Dennis Tirpak.

4.1 The research, development, and demonstration, and deployment cycle

The generally recognized phases of the innovation and deployment cycle for new technologies, while often depicted as a linear process, is in reality quite complex, with many feedback loops between the market and technology users and the R&D community (*see Figure 5*). In 2007, nearly $17 billion was spent on R&D on clean energy and energy efficiency, with the corporate sector, which generally supports more applied research, accounting for $9.8 billion and governments, which usually support more basic research, accounting for about $7.1 billion. Europe and the Middle East saw the most corporate R&D activity, followed by the Americas and Asia. Patterns of government spending are the reverse, with Asian governments (notably Japan, China, and India) investing heavily in R&D.

Figure 5: The research, development, demonstration, deployment, and commercialization cycle



Source: IEA 2008

There are numerous mechanisms for collaborating and sharing technology R&D information, although some corporate R&D is proprietary (*see Box 1*).[5] The IEA's implementing agreements are the largest of these with the participation of more that 60 non-IEA member countries.[6] The aim is to share best practice, build capacity, and facilitate technology transfer.

However, there are limits to these efforts – i.e., not all developing countries can participate, some agreements are more active than others as progress is driven by the resources countries are willing to put into a particular agreement, and the participation of companies may be limited. Moreover, some efforts may not address topics of a high priority to developing countries and they cannot hope to capture the customer feedback loops noted above.

Given the large number of technologies and participants in the RD&D cycle, the international community, particularly the UNFCCC process, faces significant challenges if it wishes to accelerate R&D and the transfer of information among countries. If such improvements are to be made, they will have to be based on the experience of countries and their corporations. That being a goal, some key questions for the reader are:

Questions:

- Does your country provide any support for RD&D? Which R&D areas are of special interest to your country?
- Are the topics covered by the existing international mechanisms relevant to your country? What is missing?
- Are the existing international cooperative mechanisms transparent and open to your country?
- Has your government ever sought to participate in such a mechanism? If so, what was the result?
- What specifically is needed to enhance the participation of developing countries? Are there high priority R&D topics, of special interest to your country, that should be included in a future international agreement and perhaps subjected to oversight by the Convention process?

Box 1. Examples of coordinated international R&D and technology promotion activities

- **International Partnership for a Hydrogen Economy:** Announced in April 2003, the partnership consists of 15 countries and the EU, working together to advance the global transition to the hydrogen economy, with the goal of making fuel cell vehicles commercially available by 2020. The Partnership will work to advance the RD&D of hydrogen and fuel cell technologies and to develop common codes and standards for hydrogen use. See: www.iphe.net.
- **Carbon Sequestration Leadership Forum (CSLF):** This international partnership was initiated in 2003 and has the aim of advancing technologies for pollution-free and GHG-free coal-fired power plants that can also produce hydrogen for transportation and electricity generation. See: www.cslforum.org.
- **Generation IV International Forum:** This is a multilateral partnership fostering international cooperation in R&D for the next generation of safer, more affordable, and more proliferation-resistant nuclear energy systems. This new generation of nuclear power plants could produce electricity and hydrogen with substantially less waste and without emitting any air pollutants or GHG emissions. See: http://nuclear.energy.gov/genIV/neGenIV1.html.
- **Renewable Energy and Energy Efficiency Partnership:** Formed at the World Summit on Sustainable Development in Johannesburg, South Africa, in August 2002, the partnership seeks to accelerate and expand the global market for renewable energy and energy-efficiency technologies. See: http://www.reeep.org.
- **International Energy Agency Implementing Agreements:** A collaborative effort to share the development of, and information on, more than 40 key energy technologies among participating countries. See: http://www.iea.org/textbase/techno/index.asp.
- **Asia-Pacific Partnership on Clean Development and Climate:** Inaugurated in January 2006, the aim of this partnership between Australia, China, India, Japan, Republic of Korea, and the US is to focus on technology development related to climate change, energy security and air pollution. Eight public/private task forces are to consider (1) fossil energy, (2) renewable energy and distributed generation, (3) power generation and transmission, (4) steel, (5) aluminium, (6) cement, (7) coal mining, and (8) buildings and appliances. See: http://www.asiapacificpartnership.org.

[5] Gupta, S., D. A. Tirpak, N. Burger, J. Gupta, N. Höhne, A. I. Boncheva, G. M. Kanoan, C. Kolstad, J. A. Kruger, A. Michaelowa, S. Murase, J. Pershing, T. Saijo, A. Sari, 2007: Policies, Instruments and Co-operative Arrangements. In Climate change 2007: Mitigation. Contribution of Working Group III to the AR4 of the IPCC, B. Metz, O. R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[6] For a list of existing IEA Implementing Agreements see http://www.iea.org/Textbase/techno/index.asp.

4.2 Deployment

The deployment stage of the technology cycle is one during which the technology has been demonstrated to be successful, but is not yet economically competitive except in niche markets. It may possibly need government support to overcome cost and non-cost barriers. Such support may range from providing financial incentives to introducing or reforming regulations to overcome barriers. Moving a technology forward at this stage often requires technical and economic feasibility studies, environmental assessments, preliminary approvals by local and national governments, technology assessments, and other analyses.

The prospect that a given technology will be produced and sold on the market may stimulate private industry to undertake applied research and improvements in the manufacturing process. Subsequent market feedback may suggest further avenues for improving technology and influence the ultimate adoption rate. This process, often called the learning rate, varies by technology and country. To date, none of the efforts adequately engages the private sector, which has the potential to bring far greater resources to bear on the challenges, combined with different and complementary skills.

Table 1: Types of interventions required to address specific local barriers to technology innovation and diffusion

ACTIVITY	GAP/NEED ADDRESSED	BENEFITS
Applied research and development Grant funding, open and/or directed at prioritized technologies	Inadequate support for relevant applied research for technologies where private funding is minimal due to classic innovation barriers	New ideas from local scientific knowledge base applied and developed to point of potential commercial relevance
Technology accelerators Designing and funding projects to evaluate technology performance, e.g,, field trials	Uncertainty and skepticism about in-situ costs and performance, and lack of end user awareness	Reduction in technology risks and/or costs by independent collection and dissemination of performance data and lessons learnt
Business incubator services Strategic and business development advice to start-ups	Lack of seed funding and business skills within research / technology start-ups – the 'cultural gap' between research and private sectors	Investment and partnering opportunities created by building a robust business case, strengthening management capacity and engaging the market
Enterprise creation Creation of new low carbon businesses by bringing together key skills and resources	Market structures, inertia and lack of carbon value impede development of low carbon start-ups or new corporate products and services	Creation of new high growth businesses to both meet and stimulate market demand Development of local commercial and technical capabilities
Early stage funding for low carbon ventures Co-investments, loans, or risk guarantees to help viable businesses attract private sector funding	Lack of financing (typically first or second round) for early stage, low carbon businesses due to classic innovation barriers combined with perceived low carbon market/policy risks	Enhanced access to capital for emerging businesses that demonstrate commercial potential Increased private sector investment in the sector through demonstrating potential investor returns
Deployment of existing energy efficiency technologies Advice and resources (e.g,, interest-free loans) to support organizations to reduce emissions	Lack of awareness, information and market structures limit uptake of cost-competitive energy efficiency or low carbon technologies	Improved use of energy resources through enabling organizations to implement energy efficient measures and save costs Catalyzing of further investment from organizations receiving support
Skills/capacity building Designing and running training programs	Lack of capacity to install, maintain, finance and further develop emerging low carbon technologies	Growth in business capacity and employee capabilities to enable more rapid uptake of existing and new low carbon technologies
National policy and market insights Analysis and recommendations to inform national policy and businesses	Lack of independent, objective analysis that can draw directly on practical experience to inform the local government and the market	Enhancing the policy and market landscape to support the development of the low carbon economy

Source: Low Carbon Technology Innovation and Diffusion Centres, The Carbon Trust, www.carbontrust.co.uk

The main barriers to technology deployment include: information (persuasive information about a new product), financing (to reduce the costs relative to other technologies and absolute costs), capacity to introduce or use technology, transaction costs, excessive or inadequate regulations, including investment policies, and uncompetitive markets. Efforts to overcome these barriers need to be tailored to individual technologies through the unique initiatives of the country wishing to deploy a technology and by the country providing the technology.[7]

However, developing countries, even after taking steps to address national barriers, often encounter obstacles to the deployment of technologies. One of the elements that make technology deployment mores difficult in developing countries is the relation between the new technology and the countries' resource endowment and scale. In most cases, technologies reflect the original combination of resources (particularly capital, labor, technological capabilities, and, also scale of production) in a given country, which may not fit well with the particular technology that is to be deployed (see Table 1). The challenge facing the international community and national governments is to determine how these barriers can be overcome.

Questions:

- Given the respective roles of industry and governments, should the international community enhance the RD&D learning cycle? If so, how?
- Which barriers in your country are amenable to an international effort to reduce them?
- What mechanisms would be the most appropriate means of addressing each barrier to each technology in your country?
- Could a new international mechanism be a means to help your country overcome barriers? If so, what might its role be?

4.3 Fossil Fuel Power Generation

Overall, 40% of the world's electricity production comes from coal, 20% from natural gas, and the remainder mainly from nuclear and hydro. This percentage varies by country, with South Africa and Poland using coal for nearly 90% of their electricity, China, 80%, and the US, 50%. Russia uses natural gas for nearly 50% of its production.

The efficiency of coal-fired power plants averaged about 35% from 1992-2005 globally, but the best operating plants can achieve 47%. The efficiency of most plants is therefore well below the potential offered by state-of-the-art technologies. Improved efficiencies can be achieved by retrofitting existing plants or installing new generation technology.

Pulverized coal combustion (PCC) accounts for nearly all of the world's capacity, but many smaller, old PCC plants have an efficiency below 30%. Improving efficiency has therefore been a major goal of many utilities; for example, by installing PCC sub-critical technology which can reach efficiencies of 35-36%. New supercritical plants, which have become common in Europe and Japan, can achieve efficiencies in the range of 42-45% (*see Table 2*). There is also considerable scope for improving the efficiencies of gas fired plants, primarily by replacing old gas-fired steam cycle technology with more efficient combined-cycle plants. The costs vary with the age of the plant; the younger the plant, the more economical it is to retrofit. For example, because most coal plants in China are under 15 years old, it is planning to repower many facilities with supercritical plants.

There are newer technologies that are even more efficient, e.g, ultra-supercritical plants have been deployed in a few countries. Reducing the cost of this technology remains a challenge, but advances in metallurgy and control problems are expected in the next few years. New high alloy steels are likely to minimize corrosion problems and new control equipment will allow these types of plants to be more flexible.

Combined Heat and Power (CHP) is the simultaneous utilization of heat and power from a single source. CHP plants range in size from 1 to 500MW and can achieve efficiencies of 75-80% using either coal or natural gas. Most countries have a significant potential to expand the use of CHP, but they must address challenges such as finding suitable facilities to use the heat in chemical, food/wood processing, and refining industries; the resolution of interconnection issues; and providing a suitable regulatory framework which provides for exit fees and back-up fees.

[7] See the case studies in the paper by Tirpak titled, *National Policies and Their Linkages to Negotiations over a Future International Climate Change Agreement*, that is part of this series.

Table 2: Performance summary for different fossil-fuel-fired plants

PLANT TYPE		PULVERIZED COAL COMBUSTION (PCC)	PCC	PCC	PCC	NATURAL GAS FIRED COMBINED CYCLE (NGCC)	INTEGRATED GASIFICATION COMBINED CYCLE (IGCC)
Fuel		Hard coal	Hard coal	Hard coal	Hard coal	Natural gas	Hard coal
Steam cycle		Sub critical	Typical super-critical	Ultra-super-critical (best available)	Ultra-super-critical (AD700)	Triple pressure reheat	Triple pressure reheat
Steam conditions		180 bar 540 °C 540 °C	250 bar 560 °C 560 °C	300 bar 600 °C 620 °C	350 bar 700 °C 700 °C	124 bar 566 °C 566 °C	124 bar 563 °C 563 °C
Gross output	MW	500	500	500	500	500	500
Auxiliary power	MW	42	42	44	43	11	67
Net output	MW	458	458	456	457	489	433
Gross efficiency	%	43.9	45.9	47.6	49.9	59.3	50.9
Net efficiency	%	40.2	42.0	43.4	45.6	58.1	44.1
CO_2 emitted	t/h	381	364	352	335	170	321
Specific CO_2 emitted	t/MWh net	0.83	0.80	0.77	0.73	0.35	0.74

Note: MW = Megawatt, t/h = tons per hour
Source: IEA 2008

There are, of course, other emerging technologies that have the potential to make important contributions to the production of electricity in the future such as fuel cells. While several thousand systems are produced each year, more R&D is need before these systems are ready for wide deployment.

CCS – a set of systems to capture CO_2 from large stationary sources – is also extremely relevant to the fossil fuel power sector. While used in the oil and gas industry to enhance oil recovery, the challenge is to demonstrate the feasibility to deploy this add-on technology at a reasonable economic cost. Several pre- and post-combustion processes are being considered to capture CO_2 and, subsequently, transport and inject it into deep geological formations. The most cost-effective capturing technologies are likely to add $25-$50 per ton of CO_2 avoided and result in a loss of generated electricity. Transportation costs may add an additional $10-$15 per ton of CO_2. Future cost projections depend on which technologies are used, how they are applied, how fast costs fall as the result of RD&D, market uptake, and fuel costs. On a smaller scale, there are a number of efforts underway to demonstrate other technologies for capturing CO_2 such as the use of algae. Such technologies are unlikely to play a significant role in the power sector, but could find niche markets at other industrial facilities. They may also prove to be more adaptable to the needs of developing countries.

A number of initiatives relating to CCS have been announced by Algeria, Australia, Canada, EU, Norway, and the US, and interest has been expressed by China and South Africa. However, a number of legal, regulatory, environmental, financial, and technical barriers need to be overcome before large-scale deployment of CCS is made possible. The CSLF noted in Box 1, with the participation of 21 countries and the EU Commission, is the largest forum for international coordination of CCS activities. The CSLF aims to make these technologies broadly available and to address the wider barriers to deploying the technology.

Questions:

- What mixture of coal, oil, gas, hydro, nuclear, and other sources are used to produce electricity in your country? What is the average age and efficiency of these facilities?
- What plans do your utilities have for increasing

electricity in your country? What would be necessary to retrofit or replace the coal and gas fired power plants? What international assistance (technical, legal/regulatory, or financial) is needed by your country?
- Is your country interested in participating in an R&D consortium that addresses fossil-fuel power generation technologies?
- Can you envision a time in the next 10-15 years when your country would be interested in implementing a CCS project? Is your country interested in participating in cooperative R&D efforts such as the CSFL to stay abreast of developments in this field?

4.4 Biomass and Bioenergy

Biomass – i.e,, organic material grown and collected for energy use – is a source of renewable fuel that can be converted to provide heat, electricity, and transport fuels. Total biomass consumption is estimated to be around 10% of global primary energy consumption, with approximately two-thirds consumed in developing countries as traditional fuels for cooking and heating. Some countries, such as Nepal, are dependent on traditional biomass to meet 90% of their total energy demand. With more people living in urban areas and because of the greater uptake of efficient stoves, such as small scale biogas converters and biomass-based liquid fuels such as ethanol gels, the overall efficiency of small scale biomass is expected to improve in the coming decades.

At a larger scale, biomass is consumed to provide heat and power and transport fuels. The scope for biomass to make a large contribution to global energy demand is dependent on its sustainable production, improved efficiencies in the supply chain, and new thermo-chemical and bio-chemical conversion processes.

Biomass can be used in a number of ways:
- Biomass can be co-fired with coal in traditional coal-fired boilers to produce electricity thereby making a contribution to CO_2 emission reductions. Co-firing has been successfully demonstrated in more than 150 installations worldwide. For regions with access to both coal and biomass, this may be an attractive option as it lowers investment costs for new boilers, enables higher efficiencies than in a dedicated biomass facility, reduces the risk of biomass supplies, and requires smaller storage areas.
- Biomass can also be gasified at high temperatures using restricted oxygen to produce methane and other synthetic gases. The gas can be used in engines, gas turbines, and co-firing boilers. Small scale gasified solid biomass demonstration plants are widespread, but investment and operating costs still have to be reduced to gain a large market share.
- Biomass can also be used in CHP plants to produce both heat and electricity. While it is normally more costly to build a CHP plants than to have separate power and heating plants, such plants are cheaper to operate as less fuel is required and the lifetime of such facilities is longer.
- Biomass can also be converted to produce ethanol and biodiesel fuel. The use of sugar cane and grains has received a significant boost in the past few years as a number of developed countries have set targets for the use of ethanol and biodiesel as substitutes/supplements for/to conventional gasoline. However, there are many hurdles to be overcome and it remains unclear what contribution liquid biofuels will make to the global energy picture. Considerable research is underway to reduce the costs of biofuels using second generation technology that will use a wider variety of cellulosic materials and may some day be of importance to developing countries. Success in the development of second generation biofuel technologies will depend on many factors including: the level of public and private financial support, policies that encourage their production and use, demonstration and pre-commercial testing, better understanding of the potential resources, and analyses of the social, environmental, and other costs.

Table 3: Typical plant size, efficiency and capital cost for a range of bioenergy conversion plant technologies

CONVERSION TYPE	TYPICAL CAPACITY	NET EFFICIENCY	INVESTMENT COSTS
Anaerobic digestion	< 10 MW_e	10-15% electrical 60-70% heat	
Landfill gas	<200 kW_e to 2 MW_e	10-15% electrical	
Combustion for heat	5-50 kW_{th} residential 1-5 MWth industrial	10-20% open fires 40-50% stoves 70-90% furnaces	EUR~100/kW_{th} stoves EUR 300-800/kW_{th} furnaces
Combustion for power	10-100 MW_e	20-40%	EUR 1 600–2 500/kW_e
Combustion for CHP	0.1-1 MW_e 1-50 MW_e	60-90% overall 80-100% overall	EUR 2 700-3 500/kW_e EUR 2 500-3 000/kW_e
Co-firing with coal	5-100 MW_e existing >100 MW_e new plant	30-40%	EUR 100-1 000/kW_e + power station costs
Gasification for heat	50-500 kW_{th}	80-90%	EUR 700-800/kW_{th}
BIGCC for power	5-10 MW_e demos 30-200 MW_e future	40-50% plus	EUR 3 500-5 000/kW_e EUR 1 000-2 000/kW_e future
Gasification for CHP using gas engines	0.1-1 MW_e	60-80% overall	EUR 1 000-3 000/kW_e
Pyrolysis for bio-oil	10 t/hr demo 100 t/hr future	60-70% ~ 85% with char	EUR 700/kW_{th} for 10 MW_{th} near commercial

Source: Based on IEA Bioenergy, 2007

Table 3 provides information on plant size, efficiency, and investment costs of different bioenergy conversion technologies. There are different outlooks for biofuels concerning future land availability, the rate of improvement in crop yields, environmental requirements, and estimates of available crop and forest residues. Compared to coal and gas, biomass is also more difficult to store, handle, and combust efficiently. Production costs vary with the size of the area to be harvested, types of crop and soils, nearness to roads, and storage requirements. Large scale plants can achieve economies of scale, but this can be offset by transportation costs needed to ensure the required volumes of material. In some countries, non-food types of crops (grasses) are being cultivated and harvested to provide an energy source. A large commercial processing plant of 400K t/yr would require a grass feedstock to be bought in from a radius of 100km to ensure 24-hour operation, seven days a week. There is however no reason why big biomass plants could not develop appropriate supply chains. Around 400 Gigawatt (GW) of modern biomass heat-production equipment, consuming 300 Megatons per year (Mt/yr) of biomass, is in operation worldwide.

Questions:
- Are commercial biomass facilities operating in your country? If so, what do they produce and on what scale?
- Has your country done an assessment of the potential for biomass to fill part of its energy demand? What type of biomass facilities would be of greatest interest to your country given its capacity and technological capabilities?
- What type of barriers currently exists to expanding the use of biomass? What form of international assistance would be needed to expand the use of biomass in your country? Would your country be interested in joining an international biomass R&D consortium?

4.5 Wind Power

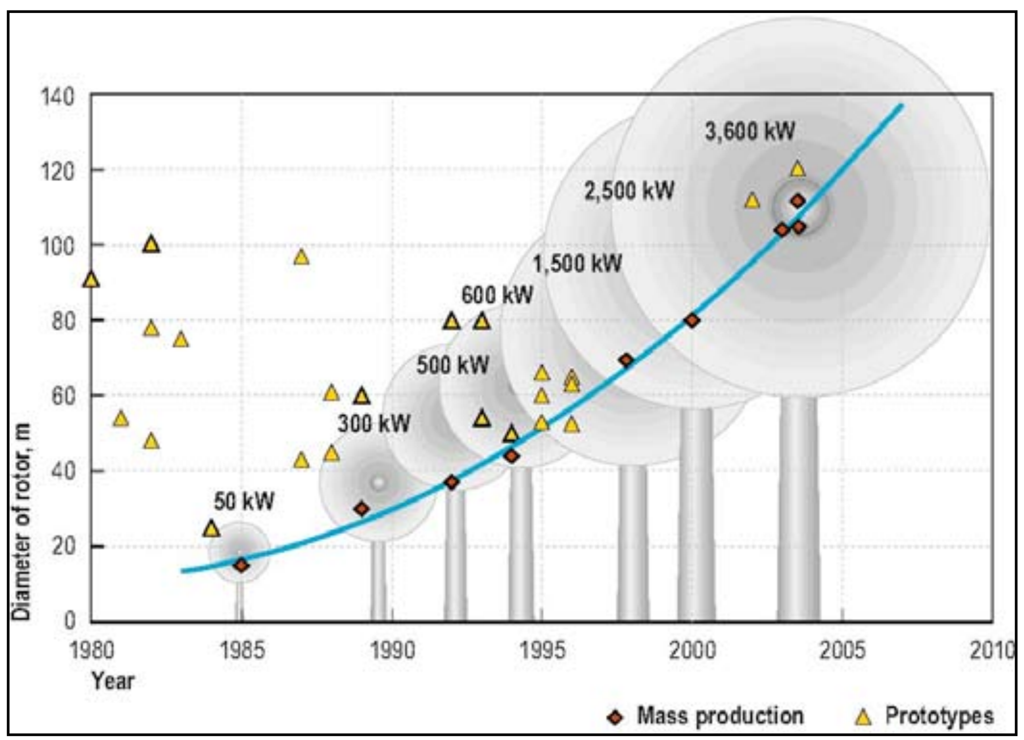
Wind power has grown rapidly since the 90s. Global installed capacity reached 94GW in 2007, with more than 40 countries having wind farms. In 2007, global capacity increased by 40% or nearly 20 GW, with China, Spain, and the US the leading the way. A total of $39 billion went into building new wind farms while $11.3 billion was raised in public markets.[8] Some of the biggest manufactures are located in India and China. Much of this momentum, particularly in the US, was provided by "renewable performance standards", i.e., state requirements for utilities to purchase a minimum amount of renewable energy.[9]

The outlook is for continued double digit growth. Costs have decreased by a factor of four since the 1980s as a result of scaling up of turbine sizes, increased manufacturing capacity, and other technological advances. Wind turbines need no fuel, incur almost no CO_2 emissions, and can be installed relatively quickly. However, turbine prices have risen since 2005 as a result of commodity prices.

Power from wind turbines is mainly a function of the wind regime at the site, turbine height and turbine efficiency. Turbines have nearly doubled in size every five years, although this growth is not expected to continue. The largest wind turbines today are 5-6 MW units with a rotator diameter of up to 126 meters. In a search for good sites, many countries are now looking for offshore locations which can produce up to 50% more power than land-based sites. However, offshore wind farms face several challenges, particularly harsh conditions, competition with other marine users, environmental impacts, grid connections and higher costs driven by the need for secure foundations (*see Figure 6*).

The cost of electricity produced at sites with low average wind speeds ranges from \$0.089 to 13.5/kWh to \$0.065 to 9.4/kWh at high wind sites. The costs are expected to continuously drop to \$0.05-6/kWh over the next five to seven years. The investment cost structure for onshore wind farms is shown in *Table 4*.

Figure 6: Development of wind turbine size, 1980-2005



Source: German Wind Energy Institute (DEWI), 2006 in IEA 2008 [10]

[8] This total was buoyed by an IPO of Iberenova for \$7.2 billion which accounted for 60% of the total raised on the public market.

[9] See the case studies on experience with wind in India, Senegal and Argentina in the paper by Tirpak titled, *National Policies and Their Linkages to Negotiations over a Future International Climate Change Agreement* that is part of this series.

[10] DEWI, Deutsches Windenergie-Institut GmbH (2006), DEWI website: www.dewi.de.

Table 4: Cost structure for a typical medium-size onshore wind installation

	SHARE OF TOTAL COST %	TYPICAL SHARE OF OTHER COSTS %
Turbine (ex works)	74-82	-
Foundation	1-6	20-25
Electric installation	1-9	10-15
Grid connection	2-9	35-45
Consultancy	1-3	5-10
Land	1-3	5-10
Financial costs	1-5	5-10
Road construction	1-5	5-10

Source: IEA 2008

There are a large number of R&D initiatives that are aiming to improve wind power technologies. Examples include efforts to:

- Increase the size of turbines to 8-10MW and make them lighter, more reliable and fatigue resistant;
- Reduce or eliminate the need for gear boxes;
- Develop smart rotors;
- Improve grid interconnections and operating control systems;
- Continue cost reductions; and
- Minimize environmental impacts.

Questions:

- Does your country currently have a wind farm? If so, what has been the experience?
- Has your country conducted a survey of the wind potential and feasibility studies of potential wind farms? What are the main obstacles to the introduction of wind power and how could the international community help to overcome those problems?
- Suppose the international community offered to subsidize the capital costs associated with the installation of a wind farm in your country by up to 10%. Would this be sufficient to spur the introduction of wind power?

4.6 Buildings and Appliances

Residential, commercial, and public buildings encompass a wide array of technologies in the building envelope, including: insulation, space heating and cooling systems, water heating systems, lighting, appliances, and consumer products. Unlike consumer products, buildings can last for decades, even centuries. Buildings are, however, often refurbished – heating and cooling systems are often changed after 15-20 years, while household appliances are often changed over 5-15 year time periods. Choosing the best available technology at the time of renovation therefore is important to long-term energy demand.

The IPCC (2007) has noted that there is, and will be, considerable opportunities to reduce emissions from the building sector at relatively low costs using existing technologies. Many of these technologies are economical based on life-cycle costs, but non-economic barriers slow their penetration in many countries. However, in many developing countries there is a boom in urban construction and, as incomes rise, a corresponding demand for energy-consuming appliances.

There are many examples of energy-saving measures. Well-designed, passive solar homes can minimize or eliminate the need for air conditioning. Evaporative coolers work well in hot, dry climates and cost about half as much to install as central air conditioners. The thermal performance of windows has improved greatly through use of multiple glazing layers, low-emissivity coatings and low conductivity frames. Solar thermal hot water systems, such as those used in China, can reduce the demand for energy in many countries at very reasonable costs. It has also been estimated that technical potential exists for a 30-60% improvement in the energy efficiency of appliances.

Table 5: Country average variations in direct use in power plants and transmission and distribution losses as a percentage of gross electricity production, 2005

COUNTRY	DIRECT USE IN PLANT (%)	TRANSMISSION & DISTRIBUTION LOSSES (%)	PUMPED STORAGE (%)	TOTAL (%)
India	6.9	25.0	0.0	31.9
Mexico	5.0	16.2	0.0	21.1
Brazil	3.4	16.6	0.0	20.0
Russia	6.9	11.8	-0.6	18.1
China	8.0	6.7	0.0	14.7
EU-27	5.3	6.7	0.4	12.5
US	4.8	6.2	0.2	11.2
Canada	3.2	7.3	0.0	10.5
Japan	3.7	4.6	0.3	8.7
World	5.3	8.8	0.2	14.3

Note: Transmission & distribution losses include commercial and technical losses. Commercial losses refer to un-metered use.
Source: IEA 2008

Countries have typically relied on appliance standards, labeling programs, and building codes to curtail the growth in the demand for electricity in the building and appliance sector. These efforts have had mixed results, particularly in countries that are rapidly developing and have poor enforcement capabilities. That said, the building and appliance sector represents a special challenge – one that is less dependent on the availability of technologies than on the introduction of well-designed and implemented government policies.

Questions:
- Are there technologies that your country has not had access to in the building and appliance sector?
- What obstacles has your country encountered in stimulating the introduction of new technologies?
- Do you view the deployment of technologies in this sector as largely a domestic matter or can the international community help in some way? If so how?

4.7 Electricity Transmission and Distribution

Much of the electricity that is produced is never used. Transmission and distribution losses account to 8.8% of the electricity produced worldwide. The losses are significantly higher in developing countries (5-25%), in part caused by illegal connections (*see Table 5*).

Most grid managers aim to transport electricity over the shortest possible distance. In many large countries the grid consists of a series of grids, often with different characteristics so that it may not be possible to optimize the demand for electricity in one part of the country with supply from another part. To cope with variable demand, utilities in developed countries typically use gas turbine peaking power plants which have lower capital cost to provide a flexible supply. However, developing countries often have short falls in electricity production that are met simply by curtailing electricity to different regions at certain times of the day. In some countries, such as India, a significant portion of the population does not have any access to electricity; therefore expanding the grid is a high priority. Additional losses, up to 3%, can be incurred in systems due to the need to transform the power to lower voltages.

Investment costs for transmission and distribution systems are of the same magnitude as production plant investments. Transmission and distribution costs for low-voltage users can account for 5-10% of the delivered electricity price. In most countries, these costs are averaged among all customers to the benefit of those in remote areas.

There are several technological options available or under development to improve efficiencies of the grid:
- Utilities can increase the use of high voltage lines. Losses in high-voltage, AC lines amount to 15% per 1,000km at 380kW and 8% per 1,000km at 750kW.
- It has become possible to transmit DC power at higher voltages and over longer distances with low transmission losses – typically 3% per 1,000km. Such systems require less land, are easier to control and can now be easily integrated with AC grids.
- New transformers are available that, if used to replace those that are 30 years' old, could reduce transformer losses by 90%.
- Storage options are also expanding beyond the traditional use of hydro-pump-storage systems. Research is underway to improve the use of super capacitors, batteries, and underground compressed air energy storage systems.

Questions:
- Assuming that there is a need to expand the availability of electricity for the poor and the reliability of electricity supplies for industry in your country, what barriers relating to transmission and distribution need to be overcome to meet these needs?
- How could the international community help to over come these barriers? What would be the best means for the utility operators in your country to gain information, know-how and technology needed to improve their transmission and distribution systems?

4.8 Transport

Transport accounts for nearly half of the oil used worldwide and nearly 25% of energy-related CO_2 emissions. Since 1990, transport emissions of CO_2 worldwide have increased by 36%. According to IEA 2008, energy use for transport is likely to increase by more than 50% by 2030, with a significant part of this growth occurring in developing countries. The fastest growth is likely to come from air travel, road freight, and light duty vehicles. Two main factors influence the growth in emissions: the volume of travel and the changes in efficiency of the mode of travel, which have only partially offset the growth of the former in recent years.

Improving the fuel economy of light-duty vehicles is one of the most important and cost effective measures to save energy. With strong policies, available technologies have the potential to reduce the energy use per kilometer of new vehicles by up to 30% over the next 15 years. There are numerous options to improve efficiencies and reducing emissions such as: increasing the use of biofuels particularly from sugar cane; improvements in drive trains, aerodynamics, tires and auxiliary equipment; hybridization; and light weight materials. Other technologies such as fuel cells and on-board storage of electricity (batteries and ultra-capacitors, H_2 storage) are not yet mature and may take some time before they are ready for widespread deployment.

In addition, modal shifts can have a large impact on energy use, but the dynamics of city growth are complex and what works in one city may not work in others. However, several elements appear to be important: strong urban planning, investments in public transport and non-motorized infrastructure, and policies to discourage car use (e.g., congestion charges and road pricing).

Given the nature of this paper, we cannot hope to cover all the emerging technologies or the modes of transport (truck, marine and air) in depth. However, this is a critical sector for most developing countries that are rapidly expanding transportation and facing congestion problems. We add a few questions below for consideration by the reader with the hope that they provoke more thorough and thought-provoking consideration.

Questions:
- Does your country have a record keeping system for data on motorized vehicles?
- Does your country have a transportation plan and does it encourage cities to develop integrated urban/transport development plans? Are there efficiency standards or other policy measures in place that promote the use of efficient vehicles?
- If your country has used subsidies to offset the price of gasoline, has your country adjusted these subsidies in light of the recent price of gasoline?
- How can the international community help to encourage a more efficient transport system in your country?

5. SOME ISSUES RELATING TO AN INTERNATIONAL AGREEMENT

The previous sections have provided insights into the RDD&D cycle, including the roles of industry and government, the trends in financing sustainable technologies, including some financial mechanisms, and the status of a few key technologies. In the political forum of the UNFCCC, Parties are currently struggling to find means to enhance innovation and expand the deployment, transfer to and commercialization of new technologies, particularly in developing countries. Various proposals have been put forth by Parties in submissions for the second session of the AWG-LCA and at workshops of the Expert Group on Technology Transfer (EGTT) in 2008. Examples of these proposals are listed in *Box 2*, however the list is by no means exhaustive.

The reader may wish to consider these proposals in the light of the current experience of his/her country in developing and deploying technology. Without going into the merits of each proposal, it may be useful to consider criteria that might guide the consideration of the list in Box 2 and/or any additional ideas. However, keep in mind that it is generally recognized that a "full package" approach, i.e., not only equipment, but also software, human capacities, financial resources and assistance in developing an appropriate regulatory and institutional framework, is often needed. Such an approach would also have to address different technological stages: retrofitting existing equipment; wider deployment of existing climate friendly technologies and the development, and demonstration of new technologies. Each of these stages have unique barriers that may require a different financial solutions. Finally, the international community will need to determine how to monitor, report, and verify any agreement to enhance RDD&D of technology. A comprehensive discussion of options under consideration is beyond the scope of this paper, but the reader may wish to review FCCC/SBSTA/2008/INF.2 for additional information.[11]

Following the framework of the RDD&D cycle (rather that the structure in Box 2), the following questions relating to evaluation criteria are posed for consideration:

A. Expanding technology research, development, and demonstration and promoting innovation

- Will the proposal encourage or discourage institutions from undertaking R&D?
- Are the technologies to be investigated of importance to your country?
- Is the proposal applicable to all technologies or just a few?
- What would be required of your government if it wished to avail itself of the new proposal?
- How might your government or industry benefit from the proposal?
- Can and, if so, how should the proposal be financed, evaluated and implemented?
- Would the "proposal" help the industry in your country?

B. Deploying, Commercialising, and Transferring Technology

- Is the problem to be addressed a real problem in your country?
- Does the problem warrant an international mechanism (and its associated bureaucracy) or would it be more appropriately addressed on a case by case basis?
- Can the "proposal" be implemented to the benefit of all or only a few countries?
- Will the "proposal" inhibit or encourage the participation of industries in the developed and developing country?
- Will the "proposal" result in additional investments for technology and capacity building in your country?
- Can the "proposal" be evaluated?

C. Financing Technology

- Does the financial "proposal" address a significant need and what are the chances of success if it is implemented?
- Are the financial needs of each part of the RDD&D cycle addressed by the proposal and is the proposed solution appropriate for each part of the cycle?
- Does the financial "proposal" address each element of the "full package approach" and is the proposed solution appropriate for each element?
- Can the financial proposal be evaluated and monitored?

[11] FCCC/SBSTA/2008/INF.2 - Proposed terms of reference for a reporting on performance indicators and for a report on future financing options for enhancing technology transfer (SBSTA: Subsidiary Body for Scientific and Technological Advice).

Box 2. Proposals from Parties to the UNFCCC

i) Institutional arrangements for a new enhanced mechanism for RDD&D and transfer of technologies in a future international agreement:
The creation of a new body is proposed with mandate to adopt initiatives for enhanced action on, e.g,:
- Compulsory licensing;
- Patent purchase;
- Financing within UNFCCC framework for technology transfer;
- Incentive provisions for technology transfer;
- Funding for technology cooperation activities;
- Further identification of national and regional technology needs;
- Development of indicators, monitoring, verification and reporting of technology transfer activities and their impacts.

ii) New policy initiatives (co-ordinated at international level):
- Specific technology or sector-based approaches. In this regard, it is necessary to identify parties with an interest in particular technologies or sector initiatives for technology cooperation (RDD&D) or relating to project based mechanisms;
- Technology and efficiency standards;
- Identification of breakthrough technologies to be focused by multilateral technology cooperation;
- Creation of excellence centers to promote technology development and deployment, disseminate information, and participate in international technology cooperation;
- Information diffusion mechanisms (national and international).

iii) New financial mechanisms:
- Multilateral Fund (public funding) aiming at the purchase of licenses to support diffusion of existing technologies, provide financial incentives for technology transfer, support technology cooperation and promote capacity building activities;
- Venture capital initiative (private funding).

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ANNEXES

Annex 1. Main mitigation technologies per economic sector

As shown below, available studies point at a number of sectors (power, buildings, and industry) and related technologies (energy efficiency, CCS, and renewables) as the main contributors to GHG mitigation in the medium and long term.

SECTOR	EXISTING TECHNOLOGIES	NEW TECHNOLOGIES (AVAILABLE BY 2030)
Power (energy supply)	Improved supply and distribution efficiency Fuel switching (coal to gas) Nuclear power Renewable heat and power CHP CCS (early applications)	CCS for gas, biomass and coal fired electricity generation Advanced nuclear power Advanced renewables (tidal, concentrating solar, etc.)
Transport	Fuel efficient vehicles Hybrid vehicles Biofuels Modal shifts from road transport to rail Land use and transport planning	Second generation biofuels Advanced electric and hybrid vehicles
Buildings	Efficient lighting Efficient appliances/heating/cooling Improved cook stoves and insulation Passive and active solar design	Integrated design including technologies such as intelligent meters Solar PV integrated in buildings
Industry	Efficient end use electrical equipment Heat and power recovery Material recycling Control of non CO_2 emissions Process-specific technologies	Advanced energy efficiency CCS for cement, ammonia and iron Inert electrodes for aluminium production
Forestry	Afforestation – reforestation Forest management Reduced deforestation Harvested wood product management Use of forestry products for bioenergy	Tree species improvement to increase biomass and carbon sequestration Improved remote sensing technologies for analysis of sequestration potential and mapping land use change
Waste management	Landfill methane recovery; waste incineration with energy recovery; composting of organic waste; controlled waste water treatment; recycling and waste minimization	Biocovers and biofilters to optimize methane oxidation
Agriculture	Improved crop and grazing land management to increase soil carbon storage; restoration of cultivated peat soils and degraded lands; improved rice cultivation techniques and manure management to reduce CH_4 emissions; improved nitrogen fertilizer application techniques to reduce N_2O emissions; dedicated energy crops to replace fossil fuel use; energy efficiency	Improvements of crop yields

Source: Summarized from IPCC (2007a), chapter 13

Figure a: Stern Review estimates of mitigation potential for different technologies

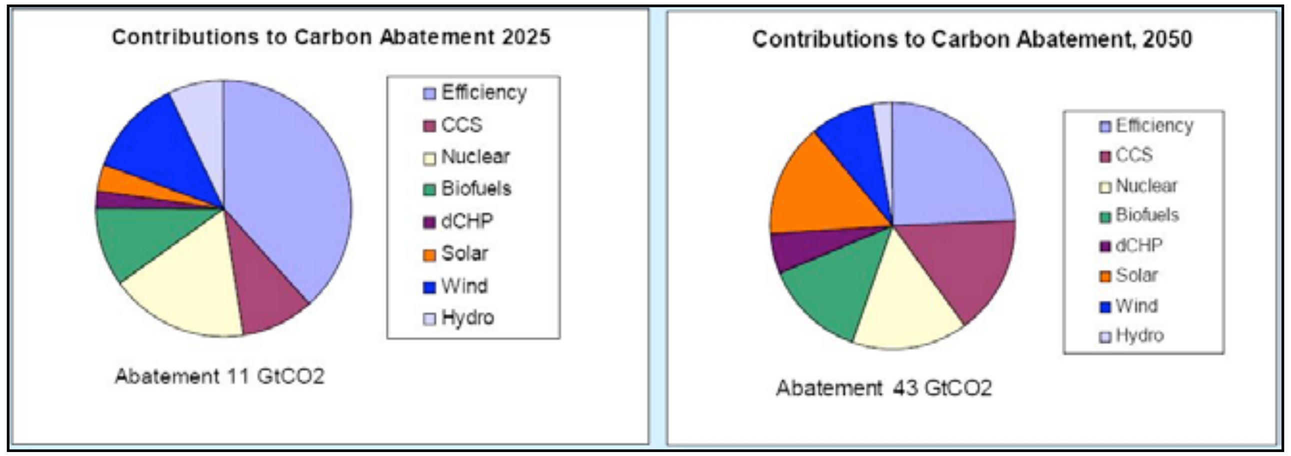
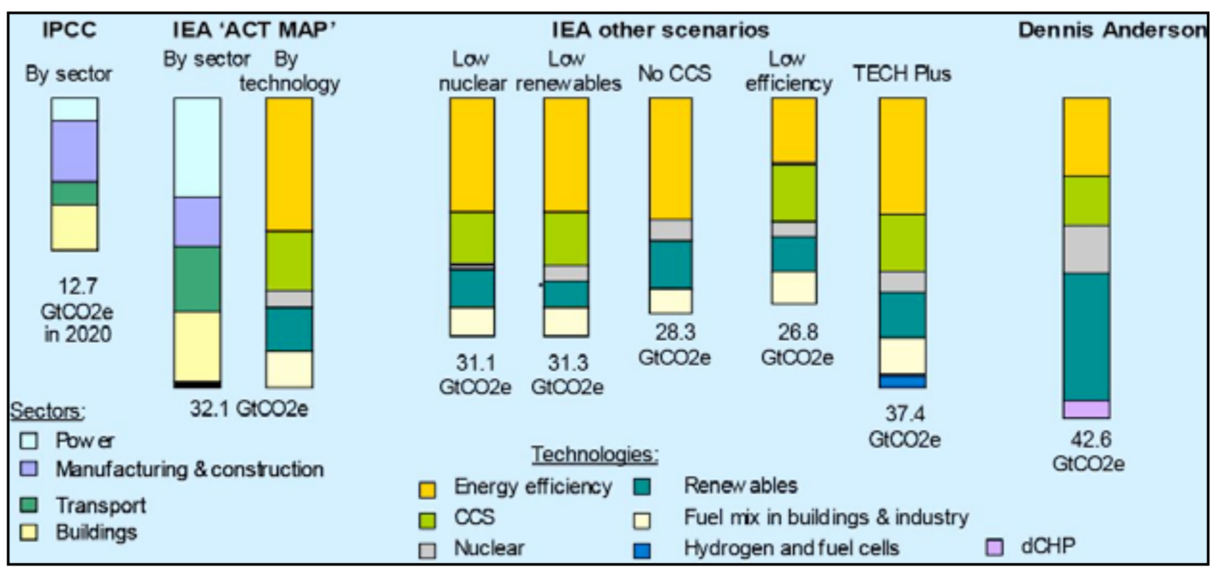


Figure b: Stern Review (Dennis Anderson) mitigation estimates vis-a-vis IEA and IPCC: sources of fossil fuel related emission savings in 2050



Source of figures a and b: Stern Review[12], chapter 9

[12] N.Stern (editor) (2006): The Stern Review Report: The Economics of Climate Change, London, HM Treasury.

The bars in *Figure b* show the composition of emissions reductions achieved in different models. The IPCC work relates to emissions savings in 2020, while the others relate to emissions savings in 2050. Separately, the IPCC have also estimated plausible emissions savings from non-energy sectors.

The IPCC reviewed studies on the extent to which emissions could be cut in the power, manufacturing and construction, transport, and buildings sectors. They find that for a cost of less than \$25/tCO_2-eq, emissions could be cut by 10.8-14.7 GtCO_2-eq in 2020. The savings presented in *Figure b* are around the mid-point of this range.

The IEA Energy Technology Perspectives report sets out a range of scenarios for reducing energy-related CO_2 emissions by 2050, based on a marginal abatement cost of \$25/tCO_2 in 2050 and investment in R&D of new technologies. The 'ACT MAP' scenario is the central scenario; the others make different assumptions on, for instance, the success of CCS technology and the ability to improve energy efficiency. Total emission savings range from 27 to 37 GtCO_2/yr. In all scenarios, the IEA finds that the CO_2 intensity of power generation is half current levels by 2050. However there is much less progress in the transport sector in all scenarios apart from TECH PLUS, because further abatement from transport is too expensive. To achieve further emission cuts beyond 2050, transport would have to be decarbonised.

Annex 2. COP decisions related to technology transfer

ISSUE	DECISIONS	PROVISIONS
COP 13 (Bali, 2007)	Decision 1/CP.13	Bali Action Plan
	Decision 2/CP.13	Reducing emissions from deforestation in developing countries: approaches to stimulate action
	Decision 3/CP.13	Development and transfer of technologies under the Subsidiary Body for Scientific and Technological Advice
	Decision 4/CP.13	Development and transfer of technologies under the Subsidiary Body for Implementation
	Decision 6/CP.13	Fourth review of the financial mechanism
	Decision 9/CP.13	Amended New Delhi work program on Article 6 of the Convention
	Decision 13/CP.13	Program budget for the biennium 2008–2009
COP 12 (Nairobi 2006)	Decision 3/CP.12	Additional guidance to the Global Environment Facility
	Decision 4/CP.12	Capacity-building under the Convention
	Decision 5/CP.12	Development and transfer of technologies
COP 11 (Montreal, 2005)	Decision 1/CP.11	Dialogue on long-term cooperative action to address climate change by enhancing implementation of the Convention
	Decision 2/CP.11	Five-year program of work of the Subsidiary Body for Scientific and Technological Advice on impacts, vulnerability and adaptation to climate change
	Decision 5/CP.11	Additional guidance to an operating entity of the financial mechanism
	Decision 6/CP.11	Development and transfer of technologies
	Decision 12/CP.11	Program budget for the biennium 2006-2007
COP 10 (Buenos Aires, 2004)	Decision 1/CP.10	Buenos Aires program of work on adaptation and response measures
	Decision 6/CP.10	Development and transfer of technologies
	Decision 12/CP.10	Guidance relating to the CDM
	Draft decision -/CMP.1	Simplified modalities and procedures for small-scale afforestation and reforestation project activities under the CDM in the first commitment period of the Kyoto Protocol and measures to facilitate their implementation
COP 9 (Milan, 2003)	Decision 3/CP.9	Report of the Global Environment Facility to the Conference of the Parties
	Decision 4/CP.9	Additional guidance to an operating entity of the financial mechanism
	Decision 5/CP.9	Further guidance to an entity entrusted with the operation of the financial mechanism of the Convention, for the operation of the Special Climate Change Fund
	Decision 16/CP.9	Program budget for the biennium 2004-2005
	Decision 19/CP.9	Modalities and procedures for afforestation and reforestation project activities under the CDM in the first commitment period of the Kyoto Protocol

ISSUE	DECISIONS	PROVISIONS
COP 8 (New Delhi, 2002)	Decision 1/CP.8	Delhi Ministerial Declaration on Climate Change and Sustainable Development
	Decision 3/CP.8	Consultative Group of Experts on National Communications from Parties not included in Annex I to the Convention
	Decision 6/CP.8	Additional guidance to an operating entity of the financial mechanism
	Decision 7/CP.8	Initial guidance to an entity entrusted with the operation of the financial mechanism of the Convention, for the operation of the Special Climate Change Fund
	Decision 10/CP.8	Development and transfer of technologies
	Decision 11/CP.8	New Delhi work program on Article 6 of the Convention
	Decision 12/CP.8	Relationship between efforts to protect the stratospheric ozone layer and efforts to safeguard the global climate system: issues relating to hydrofluorocarbons and perfluorocarbons
	Decision 13/CP.8	Cooperation with other conventions
COP 7 (Marrakech, 2001)	Decision 2/CP.7	Capacity building in developing countries (non-Annex I Parties)
	Decision 3/CP.7	Capacity building in countries with economies in transition
	Decision 4/CP.7	Development and transfer of technologies (Decisions 4/CP.4 and 9/CP.5)
	Decision 5/CP.7	Implementation of Article 4, paragraphs 8 and 9, of the Convention (Decision 3/CP.3 and Article 2, paragraph 3, and Article 3, paragraph 14, of the Kyoto Protocol)
	Draft Decision -/CMP.1	Matters relating to Article 3, paragraph 14, of the Kyoto Protocol
	Decision 14/CP.7	Impact of single projects on emissions in the commitment period
COP 6 (The Hague, 2000)	Decision 1/CP.6	Implementation of the Buenos Aires Plan of Action
COP 5 (Bonn, 1999)	Decision 9/CP.5	Development and transfer of technologies: status of the consultative process
	Decision 10/CP.5	Capacity-building in developing countries (non-Annex I Parties)
	Decision 12/CP.5	Implementation of Article 4, paragraphs 8 and 9, of the Convention and matters relating to Article 3, paragraph 14, of the Kyoto Protocol
	Decision 17/CP.5	Relationship between efforts to protect the stratospheric ozone layer and efforts to safeguard the global climate system
COP 4 (Buenos Aires, 1998)	Decision 1/CP.4	The Buenos Aires Plan of Action
	Decision 2/CP.4	Additional guidance to the operating entity of the financial mechanism
	Decision 3/CP.4	Review of the financial mechanism
	Decision 4/CP.4	Development and transfer of technologies
	Decision 5/CP.4	Implementation of Article 4.8 and 4.9 of the Convention (decision 3/CP.3 and Articles 2.3 and 3.14 of the Kyoto Protocol)
	Decision 11/CP.4	National communications from Parties included in Annex I to the Convention
	Decision 13/CP.4	Relationship between efforts to protect the stratospheric ozone layer and efforts to safeguard the global climate system: issues related to hydrofluorocarbons and perfluorocarbons
COP 3 (Kyoto, 1997)	Decision 3/CP.3	Implementation of Article 4, paragraphs 8 and 9, of the Convention
	Decision 9/CP.3	Development and transfer of technologies
	Decision 13/CP.3	Division of labor between the Subsidiary Body for Implementation and the Subsidiary Body for Scientific and Technological Advice
	Decision 15/CP.3	Program budget for the biennium 1998-1999
	Kyoto Protocol to the UNFCCC	Articles 2, 3, 10, 11

ISSUE	DECISIONS	PROVISIONS
COP 2 (Geneva, 1996)	Decision 7/CP.2	Development and transfer of technologies
	Decision 9/CP.2	Communications from Parties included in Annex I to the Convention: guidelines, schedule and process for consideration
	Decision 10/CP.2	Communications from Parties not included in Annex I to the Convention: guidelines, facilitation and process for consideration
	Decision 12/CP.2	Memorandum of Understanding between the Conference of the Parties and the Council of the Global Environment Facility
	Resolution 1/CP.2	Expression of gratitude to the Government of Switzerland
	Other action taken by the conference of the parties	The Geneva Ministerial Declaration
COP 1 (Berlin, 1995)	Decision 1/CP.1	The Berlin Mandate: Review of the adequacy of Article 4, paragraph 2 (a) and (b), of the Convention, including proposals related to a protocol and decisions on follow-up
	Decision 2/CP.1	Review of first communications from the Parties included in Annex I to the Convention
	Decision 6/CP.1	The subsidiary bodies established by the Convention
	Decision 11/CP.1	Initial guidance on policies, program priorities and eligibility criteria to the operating entity or entities of the financial mechanism
	Decision 13/CP.1	Transfer of technology

Annex 3. Glossary

TERM	DEFINITION
Adaptation	Adjustment in natural or human systems to a new or changing environment. Adaptation to climate change refers to adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation.
Ad Hoc Working Group on Long-term Cooperative Action under the Convention (AWG-LCA)	At its thirteenth session, the COP, by its decision 1/CP.13, launched a comprehensive process to enable the full, effective and sustained implementation of the Convention through long-term cooperative action, now, up to and beyond 2012, in order to reach an agreed outcome and adopt a decision at its fifteenth session. It decided that the process shall be conducted under a subsidiary body under the Convention, the AWG-LCA, that shall complete its work in 2009 and present the outcome of its work to the COP for adoption at its fifteenth session.
Afforestation	Is the direct human-induced conversion of land that has not been forested for a period of at least 50 years to forested land through planting, seeding and/or the human-induced promotion of natural seed sources.
Baseline	The baseline (or reference) is any datum against which change is measured. It might be a "current baseline," in which case it represents observable, present-day conditions. It might also be a "future baseline," which is a projected future set of conditions excluding the driving factor of interest. Alternative interpretations of the reference conditions can give rise to multiple baselines.
Biomass fuels or biofuels	A fuel produced from dry organic matter or combustible oils produced by plants. These fuels are considered renewable as long as the vegetation producing them is maintained or replanted, such as firewood, alcohol fermented from sugar, and combustible oils extracted from soy beans. Their use in place of fossil fuels cuts GHG emissions because the plants that are the fuel sources capture carbon dioxide from the atmosphere.
Capacity building	Increasing skilled personnel and technical and institutional abilities.
Carbon Capture and Storage (CCS)	CO_2 is already being captured in the oil and gas and chemical industries. Several plants capture CO_2 from power station flue gases for use in the food industry. However, only a fraction of the CO_2 in the flue gas stream is captured.
Certified Emission Reductions (CERs)	A Kyoto Protocol unit equal to 1 metric tonne of CO_2 equivalent. CERs are issued for emission reductions from CDM project activities. Two special CERs – temporary certified emission reduction (tCERs) and long-term certified emission reductions (lCERs) – are issued for emission removals from afforestation and reforestation CDM projects.
Clean Development Machanism (CDM)	Defined in Article 12 of the Kyoto Protocol, the CDM is intended to meet two objectives: (1) to assist parties not included in Annex I in achieving sustainable development and in contributing to the ultimate objective of the convention; and (2) to assist parties included in Annex I in achieving compliance with their quantified emission limitation and reduction commitments. Certified Emission Reduction Units from CDM projects undertaken in non-Annex I countries that limit or reduce GHG emissions, when certified by operational entities designated by Conference of the Parties/ Meeting of the Parties, can be accrued to the investor (government or industry) from parties in Annex B. A share of the proceeds from certified project activities is used to cover administrative expenses as well as to assist developing country parties that are particularly vulnerable to the adverse effects of climate change to meet the costs of adaptation.
Climate	Climate in a narrow sense is usually defined as the 'average weather', or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. These quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system. The classic period of time is 30 years, as defined by the World Meteorological Organization (WMO).

TERM	DEFINITION
Climate change	Climate change refers to a change in the state of the climate that can be identified (e.g,, using statistical tests) by changes in the mean and/ or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that UNFCCC, in its Article 1, defines "climate change" as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods". The UNFCCC thus makes a distinction between "climate change" attributable to human activities altering the atmospheric composition, and "climate variability" attributable to natural causes.
Combined Heat and Power (CHP)	CHP is the simultaneous generation of usable heat and power (usually electricity) in a single process. Through the use of an absorption cooling cycle, trigeneration or CHP schemes can also be developed. CHP is a highly efficient way to use both fossil and renewable fuels and can therefore make a significant contribution to sustainable energy goals, bringing environmental, economic, social and energy security benefits.
Deforestation	Conversion of forest to non-forest. For a discussion of the term forest and related terms such as afforestation, reforestation, and deforestation, see the *IPCC Special Report on Land Use, Land-Use Change, and Forestry* (IPCC, 2000).
Emissions	In the climate change context, emissions refer to the release of GHGs and/or their precursors and aerosols into the atmosphere over a specified area and period of time.
Energy efficiency	Ratio of energy output of a conversion process or of a system to its energy input.
Finance	The science that describes the management of money, banking, credit, investments, and assets.
Fossil fuels	Carbon-based fuels from fossil carbon deposits, including coal, oil, and natural gas.
Integrated gasification combined cycle (IGCC)	IGCC is a process in which a low-value fuel such as coal, petroleum coke, orimulsion, biomass or municipal waste is converted to low heating value, high-hydrogen gas in a process called gasification. The gas is then used as the primary fuel for a gas turbine. IGCC can also be viewed as the two-stage combustion of an opportunity feedstock. First, the feedstock is partially combusted in a reactor or gasifier. Then the combustion is completed in the gas turbine.
Intellectual property rights (IPRs)	IPRs, very broadly, are rights granted to creators and owners of works that are the result of human intellectual creativity. These works can be in the industrial, scientific, literary or artistic domains. They can be in the form of an invention, a manuscript, a suite of software, or a business name, as examples. In general, the objective of intellectual property law is to grant the creator of a work certain controls over the exploitation of that work, as the unfettered ability of others to copy the work or invention may deprive the creator of reward and incentive. For some IPRs, the grant of protection is also in return for the creator making the work accessible to the general public. Intellectual property law maintains a balance by (in most cases) granting the rights for a limited time. Some rights require registration, for example, patent right, whilst other rights accrue automatically upon the work's creation as in copyright.
International Energy Agency (IEA)	Paris-based energy forum established in 1974. It is linked with the Organisation for Economic Cooperation and Development to enable member countries to take joint measures to meet oil supply emergencies, to share energy information, to coordinate their energy policies, and to cooperate in the development of rational energy programs.
Intergovernmental Panel on Climate Change (IPCC)	Established in 1988 by the World Meteorological Organization and UNEP, the IPCC surveys world-wide scientific and technical literature and publishes assessment reports that are widely recognized as the most credible existing sources of information on climate change. The IPCC also works on methodologies and responds to specific requests from the Convention's subsidiary bodies. The IPCC is independent of the Convention.
Investment	Investment from the perspective of the domestic economy is the purchase of capital equipment, e.g,, machines and computers, and the construction of fixed capital, e.g,, factories, roads, housing, that serve to raise the level of output in the future. From the perspective of an individual, investment is expenditure, usually on a financial asset, designed to increase the individual's future wealth.
IPCC Fourth Assessment Report (AR4)	The main activity of the IPCC is to provide in regular intervals Assessment Reports of the state of knowledge on climate change. The latest one is "Climate Change 2007", the Fourth IPCC Assessment Report.
IPCC Working Group III (WGIII)	Assesses options for mitigating climate change through limiting or preventing GHG emissions and enhancing activities that remove them from the atmosphere.
Mitigation	An anthropogenic intervention to reduce the sources or enhance the sinks of GHGs.

TERM	DEFINITION
Natural gas fired combined cycle (NGCC)	NGCC is an advanced power generation technology, which allows improving the fuel efficiency of natural gas. Most new gas power plants in North America and Europe are of this type. A gas turbine generator generates electricity and the waste heat is used to make steam to generate additional electricity via a steam turbine
New Energy Finance (NEF)	New Energy Finance is a provider of information and research to investors in renewable energy, low-carbon technology and the carbon markets, operating across all sectors of renewable energy and low-carbon technology, including, wind, solar, biofuels, biomass, and energy efficiency, as well as the carbon markets.
Photovoltaics (PV)	This is the direct conversion of solar radiation – sunlight – into electricity by the interaction of light with the electrons in a semi-conductor device or cell.
Pulverized coal combustion (PCC)	Combustion and conversion systems can generally be categorized into either of the following two categories: 1) current commercial technologies or 2) emerging technologies. The CCBs currently produced and used primarily result from current commercial technologies, and of these, the most common are pulverized coal combustion, cyclone firing, and stoker firing.
Reforestation	The direct human-induced conversion of non-forested land to forested land through planting, seeding and/or the human-induced promotion of natural seed sources, on land that was forested but that has been converted to non-forest land (UNFCCC).
Renewables, Renewable Energy	Energy sources that are, within a short time frame relative to the Earth's natural cycles, sustainable, and include non-carbon technologies such as solar energy, hydropower, and wind, as well as carbon-neutral technologies such as biomass.
Research, development and demonstration (RD&D)	Scientific and/or technical R&D of new production processes or products, coupled with analysis and measures that provide information to potential users regarding the application of the new product or process; demonstration tests; and feasibility of applying these products processes via pilot plants and other pre-commercial applications.
Scenario	A plausible and often simplified description of how the future may develop, based on a coherent and internally consistent set of assumptions about driving forces and key relationships. Scenarios may be derived from projections, but are often based on additional information from other sources, sometimes combined with a narrative storyline.
Sector	A part or division, as of the economy (e.g,, the manufacturing sector, the services sector) or the environment (e.g,, water resources, forestry).
Special Report on Emission Scenarios (of the IPCC) (SRES)	The storylines and associated population, GDP and emissions scenarios associated with the SRES (Nakićenović et al., 2000), and the resulting climate change and sea-level rise scenarios. Four families of socio-economic scenario (A1, A2, B1 and B2) represent different world futures in two distinct dimensions: a focus on economic versus environmental concerns, and global versus regional development patterns.
SRES A1	The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income.
SRES A2	The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.
SRES B1	The B1 storyline and scenario family describes a convergent world with the same global population, that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.
SRES B2	The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

TERM	DEFINITION
Sustainable development	Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.
Technology Transfer	Transmission of know-how, equipment and products to governments, organizations or other stakeholders. Usually also implies adaptation for use in a specific cultural, social, economic and environmental context.
United Nations Framework Convention on Climate Change (the Convention) (UNFCCC)	The Convention was adopted on 9 May 1992, in New York, and signed at the 1992 Earth Summit in Rio de Janeiro by more than 150 countries and the European Community. Its ultimate objective is the 'stabilization of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system'. It contains commitments for all Parties. Under the Convention, Parties included in Annex I aim to return GHG not controlled by the Montreal Protocol to 1990 levels by the year 2000. The Convention entered in force in March 1994.
World Business Council for Sustainable Development (WBCSD)	The World Business Council for Sustainable Development (WBCSD) is a CEO-led, global association of some 200 companies dealing exclusively with business and sustainable development.