

**Avoiding dangerous climate change - why financing for  
technology transfer matters**

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## Summary

With the countdown to the crucial climate change summit in Copenhagen now well underway, prospects for a breakthrough appear limited. Behind the increasingly intensive negotiating activity, familiar divisions continue to hamper progress. The deadlock between developed countries and the major developing countries over the timing, pace and distribution of commitments to cut greenhouse gas emissions has emerged as a potential deal-breaker in Copenhagen. Failure to resolve the deadlock will have grave consequences, calling into question prospects for avoiding dangerous climate change.

This paper argues that technology transfer holds the key to a substantive agreement in Copenhagen. It sets out the case for the creation of a Low Carbon Technology and Finance Facility (LCTFF) to mobilise around \$50bn annually by 2020 in public finance, with additional amounts leveraged through private investment. The facility would cover the incremental costs of financing national mitigation efforts in developing countries, enabling them to achieve carbon stabilisation targets without compromising national poverty reduction efforts. Mechanisms would include concessional finance, interest rate subsidies and risk guarantees.

Negotiations on technology transfer have been characterised by a mismatch between words and actions. Rich countries recognise that financing for technology transfer will have to be part of a final agreement package. Yet the proposals tabled to date fall far short of developing country expectations – and most lack substantive content. The upshot is that technology transfer remains a missing link in multilateral negotiations.

Basic carbon arithmetic helps to explain the critical importance of financing for technology transfer. Avoiding dangerous climate change – defined as an increase in global temperatures of 2°C – will require a halving of global emissions by 2050. Current projections point to a 45% *increase* by 2030. Over 90% of that increase is projected to originate in developing countries. Coal will account for one third of the total increase in developing country emissions, with China and India leading the surge. Transferring the most efficient low carbon technologies to the developing countries with the fastest growing emissions is one of the most efficient routes to lower global emissions.

In the absence of a step-decrease in the carbon content of energy generation in poor countries, there is no prospect of avoiding dangerous climate change. But for developing countries to stabilise and cut emissions without compromising national poverty reduction and economic growth goals, they will need support to adopt technologies that can decarbonise their energy systems.

We illustrate the problems and the potential for action by reference to coal. The best performing coal-fired power plants in rich countries achieve thermal efficiency levels that are 50% higher than the average plant operating in India and China. Closing that efficiency gap would make it possible to produce the same amount of energy with half the CO<sup>2</sup> emissions. Technological change holds the key to closing the efficiency gap – but technological change on the scale and at the pace required comes with a price tag.

Drawing on evidence from India we highlight some of the dilemmas facing policy makers in developing countries as they approach the Copenhagen negotiations. Measured on a per capita metric India's 1.2 tonne per capita carbon footprint puts the country in the minor league – per capita emissions in the US are over 20 tonnes. However, India is the world's fourth largest aggregate emitter and emissions are rising at 7% a year.

Current energy sector plans point to an increase in installed electricity generation capacity from 128GW today to 800GW by 2030. Under any plausible medium-term scenario coal-fired power generation, which currently accounts for 70% of carbon emissions, will remain the dominant source of commercial energy. Total demand for coal is projected to rise from 432m tonnes in 2005 to 670 million tonnes in 2011, with current plans implying an additional 500MW plant being built each week. While India has the potential to develop 'zero carbon' options on a large scale, the most pressing challenge for stabilising emissions is to reduce the carbon intensity of coal-fired power.

In a review of the technology options for the coal sector in India, we estimate the annual incremental costs of achieving 45% thermal efficiency levels at \$5.2bn to \$8.4bn per annum over and above currently planned investments to 2030. While some environmental groups argue that India should 'abandon coal' in favour of zero carbon alternatives, we reject this a viable medium-term policy option – and the medium-term is what counts in terms of the interim targets needed to frame a climate change agreement.

Our contention is that rich countries should finance the full incremental cost of the transition to higher efficiency under an arrangement such as the LCTFF. The patchwork quilt of current arrangements involving World Bank programmes, the European Union's Emissions Trading Scheme, and wider international efforts suffer from chronic under-financing, governance arrangements that are dominated by rich countries, and a project-based approach to delivery.

In the absence of an ambitious technology transfer strategy agreement there is little prospect of a credible deal emerging at the Copenhagen summit, or in post-Copenhagen negotiations. India alone has more people lacking access to modern electricity than the entire population of the European Union. With expanded energy provision a key to accelerated economic growth, poverty reduction and broad-based human development in developing countries, political leaders in developing countries are unlikely to sign-up for an agreement that involves trading-off current poverty reduction efforts against a contribution to future climate change mitigation.

Financing for technology transfer has the potential to convert potential trade-offs into win-win scenarios for development and climate security. Developing countries stand to gain from higher levels of energy efficiency. Global climate security stands to gain because technology transfer will make it possible for poor countries to countenance an agreement aimed at stabilising their emissions by 2020 as part of a wider international agreement involving deep cuts by rich countries. The case for developed countries financing a technology transfer deal is rooted in capability and responsibility. They have

the financial and technological resources to act – and their historic emissions have led to a large accumulated carbon debt.

## Introduction

In December 2009 the world's governments will gather in Copenhagen, Denmark for the United Nations Climate Change Conference (COP-15). The summit will mark the culmination of a protracted negotiating process aimed at reaching agreement on a successor to the Kyoto Protocol. Almost all governments have pledged their commitment in principle to forging an ambitious and effective international response to the threat posed by climate change. Yet there is little evidence of progress towards such a response. Differences between developed and developing countries threaten to consign the COP 15 negotiations to failure. An agreement of technology transfer is a precondition for resolving these differences.

The issues at the centre of tensions between developed and developing countries are familiar from the original Kyoto Protocol negotiations. Rich countries want a multilateral agreement that binds all major emitters of greenhouse gases (GHGs) to quantitative ceilings on future emissions. They point out that the global nature of the emissions problem demands a global response. For their part, major developing country emitters point out that historic responsibility for climate change, as measured by atmospheric stocks of GHGs, rests squarely with today's industrially developed nations. Beyond the issue of culpability, developing country governments insist that binding ceilings on emissions would necessitate energy sector reforms that will compromise economic growth, with damaging consequences for employment generation and poverty reduction. Put differently, they see a trade-off between the imperative to generate global public good through mitigation for a sustainable climate, and the imperative to eradicate the national 'public bad' in the form of low levels of human development.

Both sides are right. Without the participation of major developing country emitters in the successor regime to the Kyoto Protocol, it will not be possible to avoid dangerous climate change. While rich countries account for the bulk of atmospheric GHG *stocks*, developing countries now account for the bulk of current *flows*. They also account for over 90 per cent of the projected increase in energy-related carbon dioxide emissions to 2030. Whatever the issues of historic injustice, it is these future flows of GHGs not stocks that represent the part of the emissions problem amenable to multilateral action.

Yet developing countries are right to point to the threat of a mitigation-poverty reduction trade-off. Low levels of per capita energy consumption are both a symptom and a cause of low levels of average income and high levels of poverty. It is estimated that almost 2.5 billion people in developing countries lack access to modern energy sources – a deficit that imposes a major burden on the time of women and young girls, often keeping the latter out of school. Shortages of power are holding back the development of manufacturing in many countries, with damaging consequences for employment. Against this backdrop, there is an understandable resentment, reflected in public opinion in many developing countries, of people living in centrally-heated or air-conditioned homes and living in countries with abundant energy supplies demanding sacrifices of people who walk great distances to collect fuel for cooking.

Is the trade-off between climate change mitigation on the one side and poverty reduction on the other avoidable? The answer to that question is ‘yes’, but not without an ambitious agreement on technology transfer. Reconciling the competing objectives placed upon energy policy will require the introduction lower-carbon technologies and a range of clean-energy technologies. Making a low-carbon transition without a reduction in per capita energy use will require major advances in carbon efficiency. In a nutshell, developing countries will need to generate more energy with less carbon. Significantly lower-carbon growth paths are technically feasible and energy efficiency could produce deep cuts in GHG emissions. Scaling-up of emerging technologies could reduce their costs. However, most developing countries lack the financial, technological and human capabilities needed to achieve rapid efficiency gains and take the first steps towards low-carbon energy systems – hence the critical importance of technology transfer.

Rich countries have comprehensively failed to face up to the technology transfer challenge. To varying degrees, they are actively promoting measures aimed at the development and deployment of low-carbon technologies in their domestic markets. These range from firm-level incentives to regulatory intervention and direct public investment. Little attention has been paid to the problem of promoting the deployment of lower-carbon technologies in developing countries. The assumption appears to be that these countries will be swayed by the case for improving energy efficiency. This overlooks the fact that even ‘win-win’ reforms that might over the medium-term to long-term pay for themselves require multiple interventions and entail short-term costs for firms, consumers and government budgets. Transferring finance and technology can expand the range of technological choices open to countries by reducing these cost constraints, opening up new possibilities for low carbon transition in the process.

An agreement on technology transfer could pave the way for an ambitious global deal on climate change that does not compromise national poverty reduction efforts. It is not realistic to anticipate a commitment by developing countries to cut GHG emissions in the next Kyoto commitment period (roughly to 2016). However, with an effective multilateral plan of action in place on technology transfer, it is feasible for them to agree to the stabilisation of emissions by 2020, with significant cuts thereafter. Given the high global public goods content of action in this area (a more stable global climate for future generations) and the limited financing and technological capabilities of many developing countries, developed countries should meet a large part of the incremental cost associated with low-carbon technology. Our contention is that rich countries should meet the full incremental cost of achieving specified carbon mitigation goals over-and-above planned investment in the energy sector (which includes mitigation components).

In this paper we illustrate the case for international action on technology transfer by reference to India. The country-selection has a direct and immediate relevance to the COP-15 negotiations. While India has very low levels of per capita GHG emissions by international standards, it is one of the world’s largest aggregate emitters. The combination of a large population, rapid economic growth and – crucially – one of the world’s most carbon-intensive energy systems points unequivocally in the direction of rapid and sustained increases in emissions. Energy policy in India also provides a window

on wider climate change concerns. The country's carbon-intensity is in large measure a reflection of national dependence on coals – the most polluting of all carbon-based fuels. From a climate change perspective, coal is both an immense threat and a potential opportunity. The threat derives from its growing prominence in the global greenhouse gas emissions account. The opportunity lies in raising the efficiency of the coal-based power infrastructure in several major emitting countries – including India and China – as a transitional strategy before cleaner, renewables-based energy sources become commercially viable and scalable.

Raising efficiency levels through technological upgrading could dramatically lower projected CO<sub>2</sub> emissions. Many environmentalists, particularly in the United States, argue against this option. They point out that current clean coal technologies are still highly polluting, that zero-emission technologies are unproven, and that the focus for international action should be on renewable energy. While this perspective scores high on the scale of green purity, it is divorced from the real world choices facing policy makers in many developing countries. The problem is that coal *will* remain a central part of the energy systems of countries including India and China for the foreseeable future, and that there are limits to the pace at which renewable energy can be scaled up. As a transition strategy for stabilising emissions at more sustainable levels, making the coal sector more efficient is the only viable option.

There is another reason for focussing on India. Political leaders in the country have been particularly forthright in rejecting any demands for mitigation commitments. Citing the principles of rich country 'historic responsibility' and a national commitment to poverty reduction, India has raised the stakes in the run-up to the Copenhagen negotiations.

We view this approach as a mistake on three counts. First, India has much to gain from a multilateral agreement that incorporates financing for technology transfer – and much to lose from a failed negotiating process. The country is well placed to offer future commitments on mitigation in return for up-front commitments on technology transfer financing, not least given its growing weight in overall GHG emissions. Secondly, while political leaders are right to emphasise national poverty reduction commitments, it is difficult to square those commitments with *de facto* non-participation in climate change mitigation efforts. Whatever the attribution of historic responsibility for the problems, India's poor face immense threats from climate change impacts. The loss of Himalayan glaciers threatens irrigation and water supply for agriculture and national food security, and coastal flooding, the disruption of the monsoon, heat waves, and heightened vulnerability to drought threaten major reversals in human development. Thirdly, India is uniquely well-placed to influence the COP-15 negotiating process both by virtue of the country's standing, its leadership position as a member of the Group of 20, and experience of brokering developing country alliances in other multilateral negotiating processes.

On paper, the importance of technology transfer is widely recognised. It is an integral part of the United Nations Framework Convention on Climate Change (UN-FCCC) and appears in the Bali 'roadmap' – a set of priorities adopted in 2007 to facilitate a

successful climate change summit outcome. The problem is that such in-principle agreement has not been backed by practical strategies. Changing this picture is vital. An agreement on technology transfer is not the only deal-maker required for an ambitious climate change deal. But failure to reach such an agreement will be a deal breaker.

The paper is structured as follows. Part 1 provides an overview of the problem of climate change and its projected impact in the short to medium term. It focuses on coal and the scope for introducing technologies that may reduce the carbon-intensity of coal-fired power generation. Part 2 looks at the potential for more efficient energy technologies to reduce the carbon-intensity of economic growth in India. It also provides an assessment of the incremental costs that might be associated with a 50 per cent efficiency gain, and associated reduction in CO<sub>2</sub> emissions in the coal-fired power sector. International cooperation on technology transfer could help to create a win-win scenario for poverty reduction and greenhouse gas mitigation. However, current international arrangements fall far short of what is required. Part 3 looks at these arrangements and sets out an alternative.

## **I. Climate arithmetic adds up to dangerous climate change**

For reasons of simple carbon arithmetic a meaningful post-2012 multilateral regime for avoiding dangerous climate change has to include major developing country emitters. That does not mean that these countries should accept binding targets in the next Kyoto Protocol commitment period. But it does mean that they need to broadly stabilise emissions by 2020, after which the greenhouse gas emissions trajectory will have to bend downwards.

### *Defining 'dangerous'*

Under the terms of the United Nations Framework Convention on Climate Change (UNFCCC) governments are committed to avoiding dangerous change. What does this mean in practice?

In the absence of any international agreement on a metric for differentiating 'acceptable' from 'dangerous' climate change, a threshold of 2°C over pre-industrial levels has emerged by default as the target for the Copenhagen negotiations (currently, the world is 0.7°C warmer). There is no real scientific basis for this threshold and plenty of credible evidence to suggest that the bar has been set too high. For example, recent evidence suggests that the rate at which the world's major ice-packs are melting has been underestimated.

The social, economic and political case for the 2°C threshold is even more questionable. What may look safe from behind the climate defence systems of rich countries may look decidedly dangerous for, say, people living in a drought prone area of northern Kenya, the Mekong or Ganges deltas, or hurricane-prone areas in Central America. While these concerns are not the central focus of this paper, they do raise important questions about

whose priorities are reflected in multilateral negotiations. From a human development perspective, there are strong grounds for arguing that even a 2°C average increase in global temperatures would dramatically increase the exposure of vulnerable people to the effects of drought, floods, the collapse of irrigation systems fed by glacial melt, and ecological change.

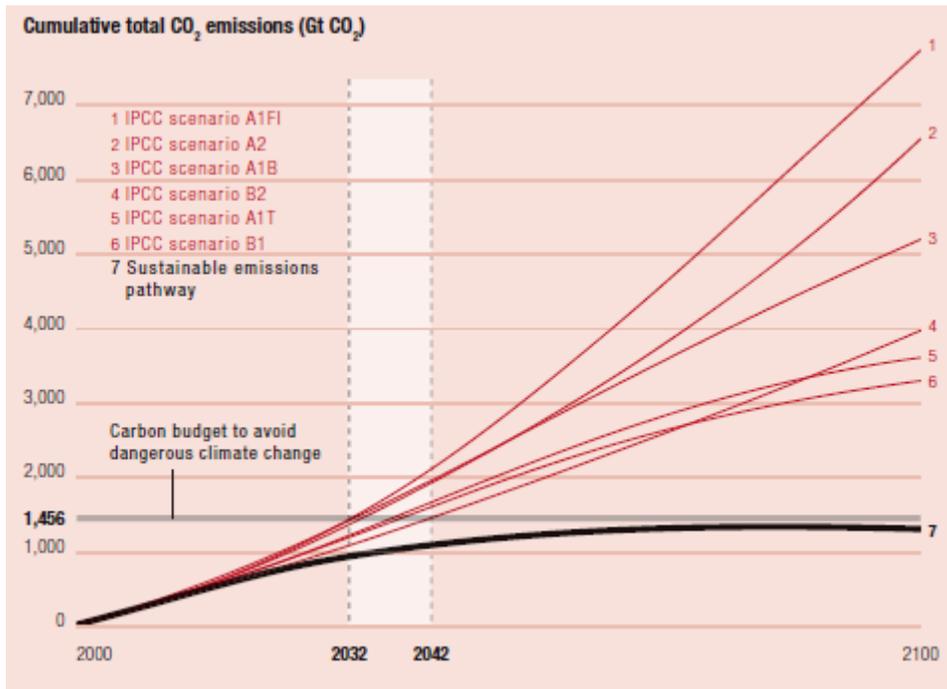
### *Working back to targets*

Endpoint climate targets are critical for any viable post-2012 multilateral agreement. The ultimate challenge is to realign the GHG pollution carrying capacity of the Earth's atmosphere with the energy systems that drive national economies. To be credible, the post-Copenhagen regime has to chart the first stage of a long pathway towards realignment. To be credible, that pathway has to take account of *cumulative* emissions and *current* emissions. Because many GHGs – including CO<sub>2</sub> – remain in the atmosphere for a long period, the pathway for reducing current emissions depends on when current emissions peak. Complex climate modelling exercises have been used to chart the relationship between emission reduction pathways and the probability of avoiding specified temperature increases.

One way of understanding these pathways is to think about long-term carbon budgets. Given the current level of GHG stocks, what flows are consistent with keeping below the 2°C threshold? Climate modelling work carried out for the 2007 *Human Development Report* estimated the 21<sup>st</sup> Century carbon budget at around 1,456 Gt of CO<sub>2</sub>, or 14.5Gt CO<sub>2</sub> on a simple annualised basis. Current emissions are running at roughly twice this level. To extend the budgetary analogy, the global community is behaving like a government bent on maintaining large fiscal deficit by running up public debts on the assumption that future generations will pick up the bill. The analogy is imperfect because, unlike climate change, the damage inflicted by reckless fiscal management can eventually be undone.

The bad news is that things are worse than they look. Driven by economic growth and population growth, GHG emissions are rising over time and pushing up stocks. Figure 1 compares a sustainable carbon budget threshold with six emissions scenarios developed by the Intergovernmental Panel on Climate Change (IPCC). Depending on the scenario, on current trajectories the entire 21<sup>st</sup> century carbon budget will expire somewhere between 2032 and 2040.

**FIGURE 1:** The carbon budget for the 21<sup>st</sup> century is expiring rapidly



Source: Meinshausen 2007, 1-22

Note: The A1 scenarios assume rapid economic and population growth combined with reliance on fossil fuels (A1FI), non-fossil energy (A1T) or a combination (A1B). The A2 scenario assumes lower economic growth, less globalisation and continued high population growth. The B1 and B2 scenarios assume some mitigation of emissions, through increased resource efficiency and technology improvement (B1) and through more localised solutions (B2).

Making the transition to a sustainable pathway implies radical adjustment. Climate science produces divergent assessments of the level of GHG concentration consistent with the 2°C threshold – with the allowable emissions becoming increasingly constrained. One recent study suggests that cumulative CO<sub>2</sub> emissions for 2000-49 would have to remain under 1,440 Gt of CO<sub>2</sub> for a 50 per cent chance of not exceeding 2°C.<sup>1</sup> To put this prospect in context, current emission pathways point to a stronger likelihood of the world overshooting a 4°C threshold than remaining within 2°C. Such an outcome would meet any reasonable criteria for potentially catastrophic climate change, including the collapse of a wide range of ecosystems.

Application of precautionary principles would lead to a more stringent assessment of the requirements for avoiding dangerous climate change. Aiming at a 50-50 chance of avoiding a highly undesirable outcome might reasonably be viewed as a cavalier approach to risk. Moreover, there is growing evidence that carbon-cycle feedback effects and climate-related environmental impacts are far stronger than predicted in some models.<sup>2</sup>

*The aggregation problem – and why it matters*

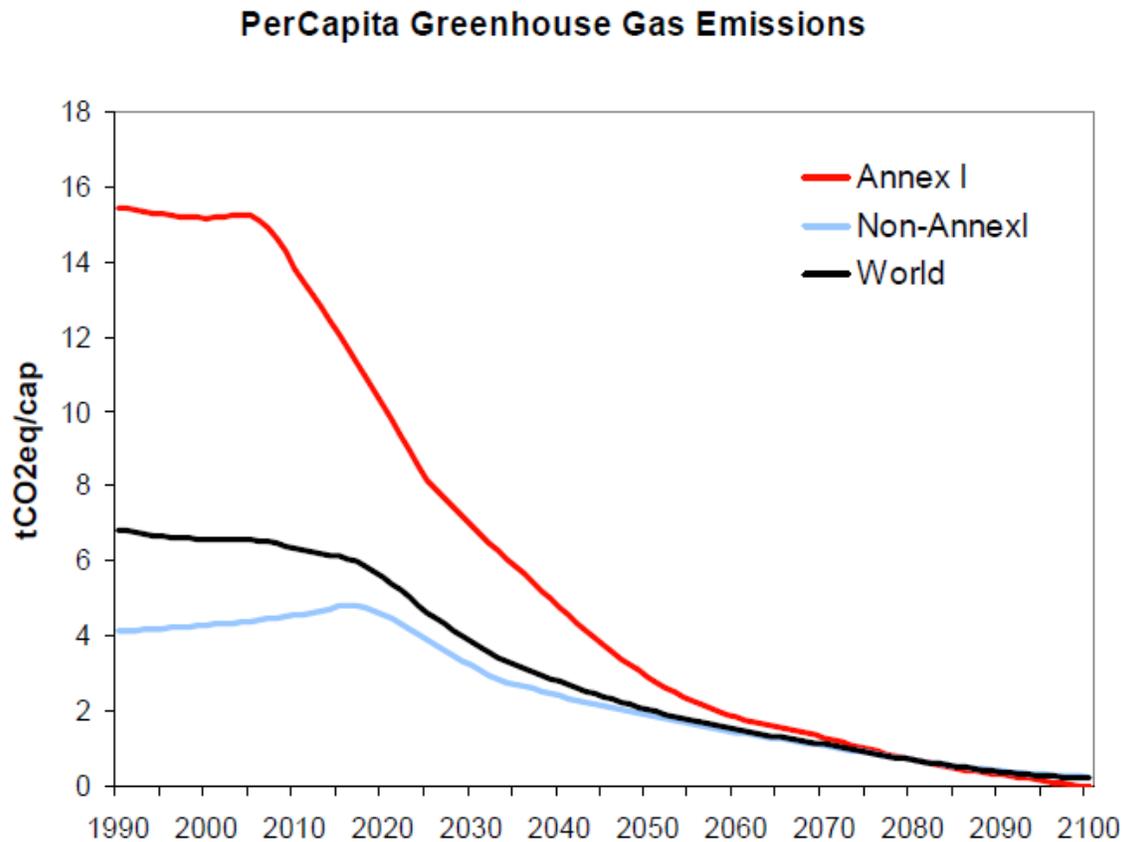
Avoiding dangerous climate change has been described as the ultimate challenge for global collective action. That assessment is both accurate and partially misleading. It is accurate in the sense that the scale of the challenge is beyond question. But the priority for collective action is not global. It is a shift in the greenhouse gas trajectories of around 20-30 major emitters – a group that spans both rich and poor countries.

Future emission pathways for avoiding dangerous climate change are shaped by past emissions. Today's rich countries account for the overwhelming bulk of the stock of GHG emissions. Current flows are more evenly divided. Developed and developing countries each account for around one half of the total, with a high level of concentration. As highlighted in Figure 2, just ten countries account for around two-thirds of total flows and the G8 for over 40 per cent. At the other end of the spectrum 50 LDCs account for around 3 per cent. While a global agreement and low-carbon energy policies may be desirable, the first order priority is clearly joint action between major emitters. Halving emissions in sub-Saharan Africa would have the effect of gutting global emissions by around 1 per cent – equivalent to just a 1.6 per cent reduction in the top 10 emitters. There are strong grounds, social and environmental, for energy policies in the region to prioritise low carbon options – but there is an obvious sense in which the global battle will be won or lost on the basis of actions taken by big emitters.



The scale of the action required can be illustrated through simple carbon footprint calculations. On average, each of the world's citizens today has a carbon footprint of around 5/t of CO<sub>2</sub>. Taking into account projected population increases to 2050, that footprint will need to fall to no more than 2/t CO<sub>2</sub> (and to less than 1/t CO<sub>2</sub> by the end of the 21<sup>st</sup> Century). For reasons of carbon arithmetic, no major emitter, or group of emitters, could breach this threshold. The implication is that most of the world's electricity production will have to be decarbonised by 2050, with emissions from transport, buildings, industry and land use declining to a fraction of today's levels.

**FIGURE 3:** Halving emissions by 2050 would require reductions by developed and developing countries



Source: Meinshausen 2007, 1-22

Adjustment to the threshold would have different implications for different countries. Taking 2004 emissions as a baseline, Canada and the United States would have to cut per capita emissions by around 90 per cent and countries in the European Union by around 80 per cent. Of the major developing country emitters, China's carbon footprint is around 5/t per capita and India's 2/t per capita. The implication is that by 2050 China would have to roughly halve current per capita emissions and India stabilise at 2004 levels, though it should be emphasised that the implied adjustment is non-linear. One plausible emissions pathway illustrated in Figure 3 would see developing country emissions peak around

2020 (reaching an average emissions level of 4/t per capita), with a reduction of 20 per cent in overall emissions to 2050. Such a pathway would imply reductions of at least 80 per cent by developed countries as a group.

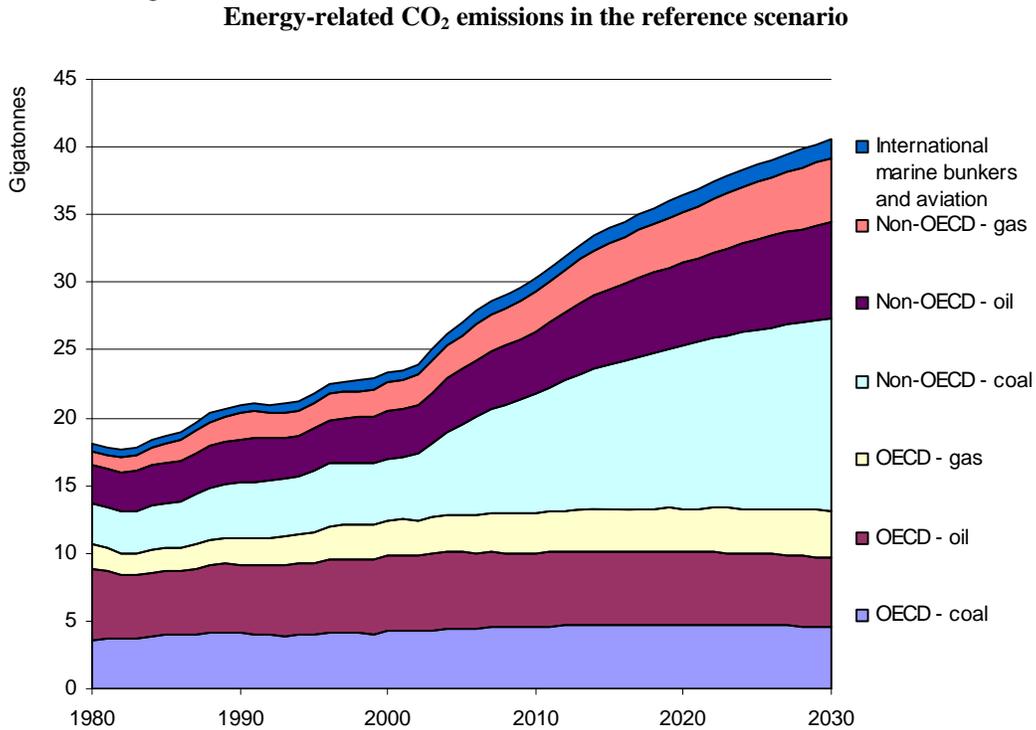
The equity questions implied by adjustment to a sustainable emissions pathway should not be under-stated. Rich countries have in effect ‘colonised’ a disproportionately large share of the biosphere, shifting adjustment costs to developing countries. There is a large North-South carbon debt that has received insufficient attention in multilateral negotiations. If developing countries were to converge on the per capita emission levels of the United States, the world would be exceeding its sustainable carbon budget not by a factor of two but by a factor of nine.

### *Heading for dangerous climate change – current emission pathways*

The misalignment between current patterns of energy generation and planet Earth’s ecological capacity is neatly encapsulated in simple energy projections. To have a break-even chance of staying within a 2°C threshold, greenhouse gas emissions will have to be cut by at least half by 2050. Current projections developed by the International Energy Agency (IEA) point to an increase of energy-related CO<sub>2</sub> emissions by 45 per cent between 2004 and 2030. These figures point unmistakably in the direction of a collision course between economy and ecology.

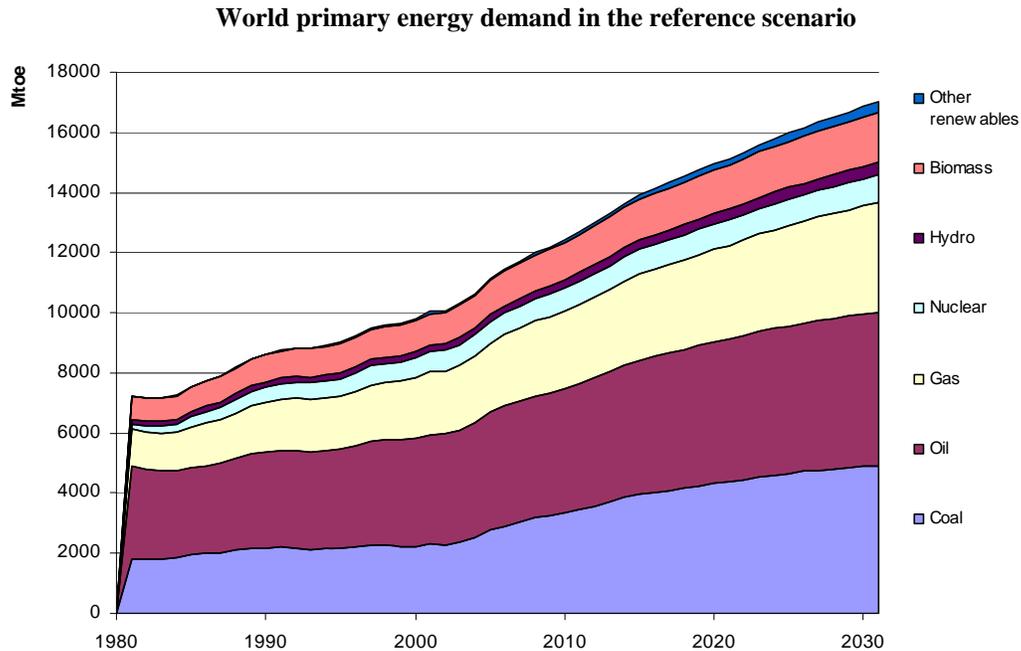
The drivers of that impending collision can be identified by breaking down the IEA projections. Two important currents can be readily identified. First, the overwhelming bulk of the increase in projected emissions – more than 90 per cent of the total - will originate in developing countries (Figure 4). The increase itself is highly concentrated: three-quarters will originate in China, India and the Middle East. Second, coal is playing an increasingly important role in global energy demand – and the global supply of CO<sub>2</sub> into the Earth’s atmosphere. Coal accounts for around one-third of the projected increase in emissions to 2030, driven by a surge in demand in developing countries (Figures 5 and 6). By 2030 coal-fired power generation in developing countries will account for just under half of all energy-related CO<sub>2</sub> emissions.

**FIGURE 4:** Non-OECD countries to account for more than 90% of projected increase in emissions during 2008-30



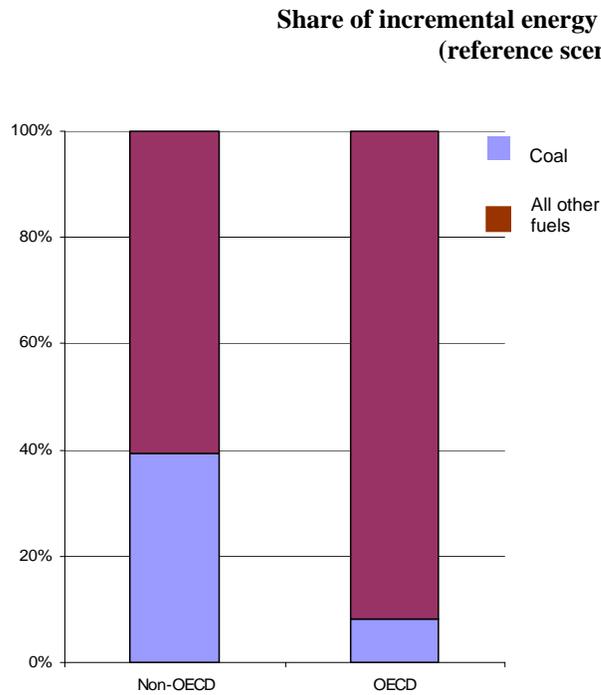
Source: Data from IEA 2008

**FIGURE 5:** Energy demand increases by 45% during 2008-30; coal accounts for a third of the rise



Source: Data from IEA 2008

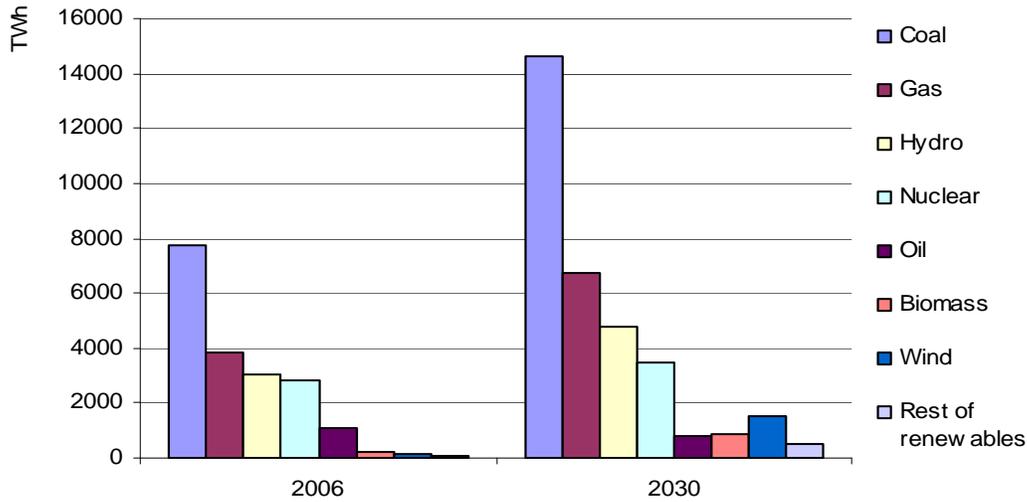
**FIGURE 6:** Growth in coal demand is highest and will account for a third of incremental energy demand until 2030



*Source:* Data from IEA 2008

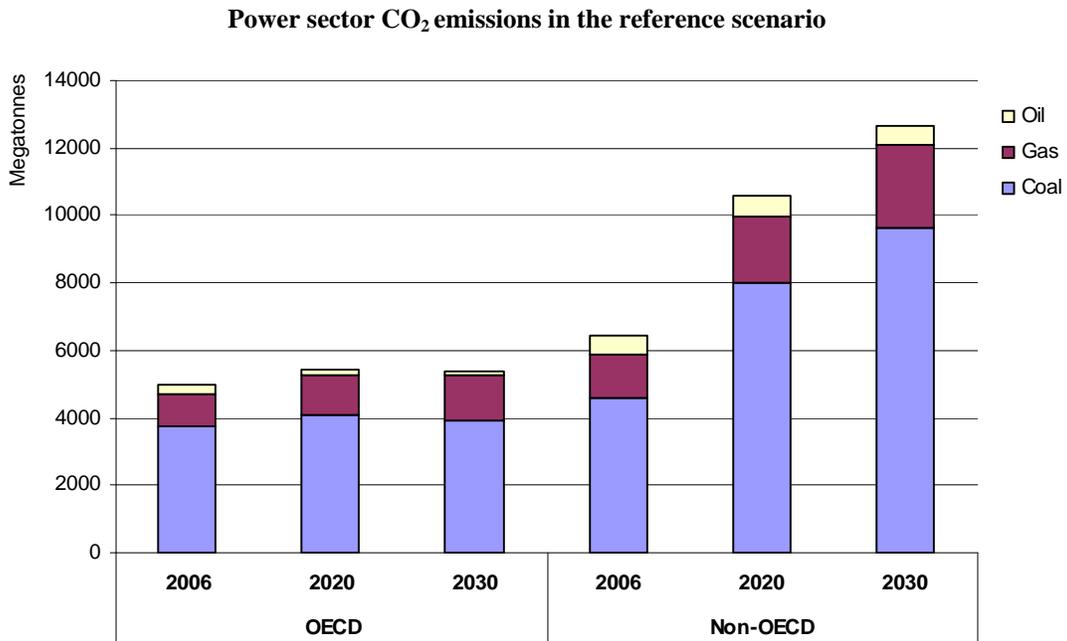
The dominant role of coal in future emission projections reflects its use in electricity generation (Figure 7). The power sector accounts for about 40 per cent of projected global CO<sub>2</sub> emissions by 2030 – and coal dominates power sector demand. Of course, any scenario for future demand is highly sensitive to assumptions about economic growth, carbon pricing, and technological development. But the IEA’s reference scenarios for both developed and developing countries suggest that coal is not heading for early displacement (Figure 8).

**FIGURE 7: Coal will remain the dominant source of electricity**  
**World electricity generation reference scenario**



Source: Data from IEA 2008

**FIGURE 8: Power sector will continue to dominate CO<sub>2</sub> emissions, accounting for 40% until 2030**



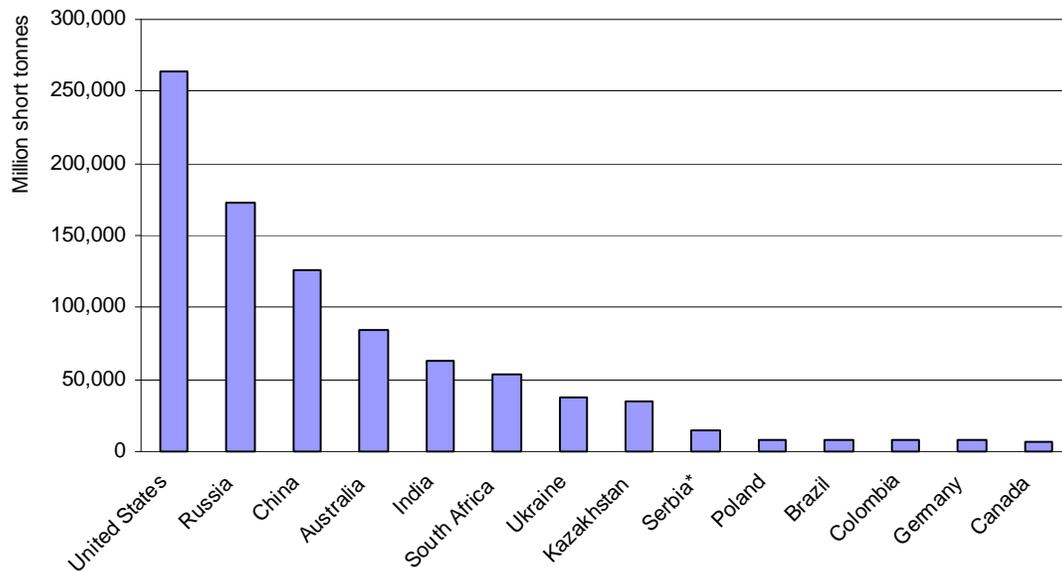
Source: Data from IEA 2008

There are good reasons to anticipate sustained high levels of demand for coal. Before the current recession and decline in oil prices, the ‘peak oil’ thesis enjoyed considerable currency. It is widely argued that the world is reaching, or may already have surpassed, the point at which discoveries of new oil reserves are falling behind current consumption. Whatever the accuracy of that assessment, it manifestly does not apply to coal. At current

production levels, the world has sufficient proven coal reserves to last for another 164 years. Those reserves are widely dispersed (Figure 9).

Rich countries have a range of options for early exit from their dependence on carbon-intensive coal-fired power generation, including a scaled-up effort to promote carbon-capture and sequestration (CCS) technologies. For developing countries, there are several factors that militate against such a transition. Apart from cost considerations, concerns over energy security have prompted a push towards enhanced reliance on domestic coal reserves in some countries. Moreover, energy infrastructures generate a strong path-dependence. Coals plants have a lifetime of 40-50 years, so that initial capital investments can lock countries into coal-dependence.

**FIGURE 9:** Coal reserves are plentiful and widely distributed



*Source:* Data from United States Energy Information Administration 2008

*Note:* Data for 2005 recoverable coal (anthracite, bituminous, lignite and sub bituminous); these countries account for 95% of total world reserves and another 54 have coal reserves.

\* Former Serbia and Montenegro

Future emission projections underline the highly carbon-intensive investment patterns emerging in global energy supply. In the period to 2030, it is projected that around \$20 trillion will be invested in energy development. The current annual capital investment by the global energy industry is \$300 billion. Much of this present and future investment is being directed into carbon-intensive infrastructure, notably coal. Once these investments are made, countries are effectively locked into emission trajectories that can only be changed either by writing off sunk costs, or through costly mitigation measures.

### *The key role of technology*

Technological change is the key to a low carbon transition. The challenge is to decarbonise economic growth by first weakening and then severing the link between energy generation and greenhouse gas emissions. Meeting that challenge will require a transformation in energy systems every bit as far-reaching as that which drove the first industrial revolution.

That transformation needs to encompass major technological breakthroughs in energy generation for homes, factories and transport. If the imperative is to stabilise carbon stocks and sustain economic growth, there is only one route: increased carbon productivity. The world needs to generate more energy with lower emissions. On a conservative estimate, productivity needs to rise by a factor of ten by 2050. To place this goal in historical context, it took the United States one hundred and twenty five years to increase labour productivity by a similar amount after 1830.<sup>3</sup>

Low-carbon technology is a shorthand depiction of a broad spectrum of approaches. One way of thinking about this spectrum is to differentiate between tracks for technological change.<sup>4</sup> The first track involves the diffusion of existing technology, with all sectors and countries ratchet-up to best-practice efficiency levels in order to lower emissions. On one estimate, achieving best practice standards with existing technologies could reduce global carbon emissions by 5-10Gt by 2030.<sup>5</sup> The second track covers accelerating the development and deployment of low-carbon technologies that are at or nearing commercial viability. Technologies falling under this heading would range from solar and wind power, to carbon capture and storage and second-generation bio-fuels. These technologies have the potential to reduce emissions by over 10Gt by 2030. The third track involves the creation of new breakthrough technologies for achieving zero emissions in power supply and transport, including options ranging from advanced solar power to more embryonic technologies such as nuclear fission.

Technological change is not just about the application of science to energy systems. The enabling – or disabling – environment for technological innovation is created through politics and economics. Making the transition to a low-carbon future will require far-reaching changes in public policy. Several long-standing and fundamental forms of market failure have to be addressed. The first, and most serious, is the failure to internalise the costs of greenhouse gas emissions in energy prices. The price of carbon cannot be determined by reference to the ‘value’ of the earth’s atmosphere, species loss, or the non-market costs associated with damage to habitat or malnutrition. But it can be approximated by the creation of a scarcity value linked to an emission ceiling consistent with avoiding dangerous climate change. Carbon taxation or cap-and-trade quota schemes are means to this end. Raising the price of carbon would create incentives for the accelerated development and deployment of low-carbon technologies. The total mitigation potential for a carbon price of US\$20/tCO<sub>2</sub> has been estimated at around 9-17 GtCO<sub>2</sub>/yr, rising to 13-26 GtCO<sub>2</sub>/yr at \$50/tCO<sub>2</sub> in the in 2030.<sup>6</sup> Governments have a key role to play in setting a long-term, predictable price for carbon because some

greenhouse gas-reducing technologies are not competitive unless energy prices are adjusted to reflect climate change externalities.

Regulatory measures which set and enforce standards, or which create markets for low-carbon energy, would have a similar effect. For example, governments can prohibit the building of new coal-fired power stations, raise fuel-efficiency standards, or require that energy utilities purchase a set proportion of supply from renewable sources.<sup>7</sup> The cost of energy produced by wind power or solar photovoltaic cells has been declining sharply over recent years, especially in countries that have created markets through regulatory intervention. In generating breakthrough technologies, price and regulatory action has to be backed by public research given the very large capital costs involved.

Coal-fired power generation demonstrates the critical role of technological choices. The widely-used term ‘clean coal technology’ is partially misleading in that no current technologies are clean in the strict sense of that term. However, there are large variations in their degree of ‘dirtiness’. Most installed coal-fired electricity-generating plants in both developed and developing countries are sub-critical, with typical efficiencies of between 29 per cent and 35 per cent. Best-performing technologies, like Integrated Gasification Combined Cycle plants, which convert coal into gas to remove impurities before burning, raise efficiency levels to above 45 per cent in the best performing plants. Basic arithmetic helps to explain why these efficiency differentials matter for CO<sub>2</sub> emissions. Plants operating at a conversion efficiency of 45 per cent produce half the level of emissions as a comparable plant operating at 30 per cent. Over the 40 year lifetime of a 1 GW plant, the cumulative effect is considerable – up to 310Mt of CO<sub>2</sub> for a plant with carbon capture compared with an average Chinese or Indian plant (Table 1).

**TABLE 1:** Carbon emissions are lower with more efficient coal plant technologies

Coal-fired plant	Approx. CO <sub>2</sub> emissions (g/KWh)	Reduction from average (%)	Lifetime CO <sub>2</sub> saving (Mt CO <sub>2</sub> )*
Chinese fleet average	1140	-	-
Global standard	892	22	73.3
Advanced cleaner coal	733	36	120.5
Supercritical coal with carbon capture	94	92	310.8

\* Assuming 1GW plant running at average capacity factor of 85%, compared with subcritical plant with 29% average efficiency.

Source: Watson et al 2007, 1-57

Until recently, clean coal technologies have been synonymous with gasification (integrated gasification combined cycle, IGCC) and a range of conversion technologies, including advanced super-critical boilers. More recently, the focus has shifted to carbon capture and storage (CCS) – a process that has the potential to reduce CO<sub>2</sub> emissions from coal-fired power generation to near zero. With global coal consumption set to double by 2030, CCS represents one of the most important technologies potentially available to stabilise emissions below the target threshold of 2 tons of CO<sub>2</sub> per capita. Briefly summarised, it involves a cluster of technologies with the potential to convert

CO<sub>2</sub> emissions into gas or liquid form, which can then be compressed and piped away. The key components of the technology already exist. They include the gasification of coal and the use of amine solvents for stripping carbon dioxide from gas streams. Continued development of IGCC systems is expected to reduce the costs of isolating CO<sub>2</sub>. More problematic is the question of storage. Potential methods include injection into underground geological formations, oil and gas reservoirs, disused coal mines, or deep oceans.

Tapping into the benefits of clean coal technologies and CCS will require action at many levels. In developed countries, the innovations required span Stern's Horizons 1-3. More stringent carbon pricing through cap-and-trade quotas or taxes aligned to specific emission reduction targets are an immediate priority. In the absence of a clear and consistent price signal, investors have no incentive to invest in operational low-carbon technologies – and no incentive to invest in research and development. Regulatory policies are also critical. Governments can use their position as 'grid managers' to set limits on the purchase of electricity generated through low efficiency technologies. Because of the high risks associated with CCS development and deployment, public-private partnerships in research and development, as well as commercial deployment, are also critical.

The record in these areas has not been encouraging. Carbon pricing policies have been too weak and erratic to influence investment decisions in the energy sector. Meanwhile, regulatory authorities have not used licensing rules or advance purchase commitment to create incentives for cleaner-coal technologies. One recent exception is an undertaking by the British government to withhold a license from a major coal-fired power plant unless it is equipped for CCS conversion. State action in developing CCS has been similarly unimpressive. The European Council has proposed that 12 full-scale CCS demonstration plants be built by 2015. However, no agreement has been reached on financing. In the United States, the major public-private initiative on CCS – Future Gen – has effectively been closed down. There is only one integrated CCS coal-fired power plant in operation today, in Germany, and this is relatively small scale.

To these serious domestic policy failures can be added failures of international cooperation. Some of the greatest efficiency gains from more efficient coal technologies could be reaped in developing countries. That is why the diffusion of these technologies on affordable and accessible terms is as important as their development. Consider the cases of China and India. Both countries have power-generation sectors dominated by small-scale, sub-critical plants operating at very low levels of average efficiency. Conversion rates for both countries are around 29-30 per cent. Given the weight of China and, to a lesser degree, India, in the energy scenarios outlined earlier, raising efficiency levels over the next decade towards the OECD average could generate major reductions in CO<sub>2</sub> emissions. Early adoption of CCS technologies would transform the scenarios, with obvious benefits for the stabilisation of greenhouse gas stocks at a level consistent with avoiding dangerous climate change. Yet there has been no concerted effort to forge the partnerships or develop the institutional mechanisms needed to facilitate technology transfer.

There are several reasons why such partnerships and institutions are important. The first is that the costs of developing and deploying low carbon technologies may be prohibitive for developing countries. To take one example, the incremental capital cost of building a supercritical coal-fired power plant equipped for CCS is estimated at around \$1 billion on and above the cost for conventional plants. Integrated gasification combined cycle plants with CCS, the most cost-effective application, is estimated to be between 75 per cent and 100 per cent more expensive than conventional power today (though these figures are highly sensitive to carbon pricing). Whereas developed countries may be in a position to pass these costs on to energy producers and consumers, developing countries with high levels of poverty, large deficits in access to energy, and a more limited revenue base are less well-placed.

There are many other barriers to the diffusion of low carbon technologies in developing countries. For some technologies – including those associated with coal-fired power generations – capital costs and foreign exchange costs are high. Commercial risk is another factor. The most advanced supercritical and ultra supercritical IGCC plants are still in the relatively early stages of commercial operation. Even in developed countries, operating problems continue to pose difficulties.<sup>8</sup> When it comes to CCS technologies the potential risks are even greater because the technologies involved are unproven. For energy operators in developing countries, increased risk is compounded by underlying constraints such as a lack of know-how, skills and technological capacity, and a host of domestic policy factors.

To the extent that technologies embody intensive research and development, there is also the potential for intellectual property rules to inflate costs. Evidence to date does not point to this as a major problem. In contrast to the pharmaceuticals sector, where patenting can create market prices that are large multiples of manufacturing cost, royalties on renewable energy technologies are very low.<sup>9</sup> In carbon-based energy sector, innovation has been slower and intellectual property is not major source of revenue. However, this picture could change with the development of IGCC and CCS technologies under public-private partnerships.

Technology transfer is not a panacea for carbon-intensive energy generation in developing countries. In the long-term, developing countries need to develop the technological capabilities needed for decarbonisation. Much has already been achieved in this area. Chinese and Indian companies have emerged as highly competitive players in renewable energies such as wind power and solar power. Brazil has been at the forefront of bio-ethanol technology development. However, the near-term challenges posed by dependence on inefficient coal-plants cannot be addressed through domestic resources alone – nor should they be. Developing country governments have a legitimate claim on support from rich countries to achieve international public policy goals in climate change. As we demonstrate by reference to India in the following section, aligning the domestic energy security agenda with a commitment to human development and participation in multilateral efforts to combat climate change poses immense challenges.

## **II. India – reconciling energy security, human development and climate sustainability**

The tension between global climate change goals and national development priorities is evident in many countries – and nowhere more so than India. While per capita emissions remain very low, the country ranks second only to China as a source of aggregate emissions. That fact alone makes India’s participation in a multilateral framework to reduce global greenhouse gas emissions an imperative – an international agreement devoid of quantitative reductions from India will not work. At the same time, national economic planning priorities in India are geared towards accelerated economic growth, rapid employment creation, and improved access to energy. Policy makers in India have been unequivocal in asserting that national goals for economic growth and poverty reduction will not be compromised by participation in a multilateral climate change agreement. As the National Action Plan on Climate Change (NAPCC) puts it: “Maintaining a high growth rate is essential for increasing living standards of the vast majority of our people and reducing their vulnerability to the impacts of climate change.”

National policy on climate change in India is underpinned by three distinctive political commitments. The first is a commitment to participate in global efforts to avoid dangerous climate change. Increasingly, this is seen as a priority for poverty reduction and environmental sustainability in India itself. Policy makers are increasingly aware that India is acutely vulnerable to the effects of global warming. The reliance of agricultural systems in northern India on river-based irrigation systems that depend on fast-retreating Himalayan glaciers, the dependence of the rural poor on rain-fed agriculture, and the exposure of large populations in river delta areas to the effects of more severe tropical storms and rising sea levels have all been highlighted as areas of concern. The Indian Prime Minister underlined the imperative to act when he launched the NAPCC in 2008. “Without a careful long-term strategy,” he warned, “climate change may undermine our development efforts, with adverse consequences, across the board, on our people’s livelihood, the environment in which they live and work and their personal health and welfare.”<sup>10</sup>

The second national policy commitment relates to the terms of Indian participation in climate change negotiations. There is a concern on the part of all mainstream political parties to ensure that burden sharing is based on ideas about fairness, international justice, and capability. Policy documents have consistently highlighted the problem of greenhouse gas stocks, historic responsibility for ‘colonisation of the biosphere’ by rich countries, and the depth of per capita footprints as distinct from overall national flows of greenhouse gases. The unsustainable lifestyles of people in the rich world, and the past and present failure of governments to slow the build-up of stocks, are seen as the defining features of the climate change problem. This approach has important practical implications for policy. The official Indian government approach to the post-2012 negotiations is that India will only undertake commitments rooted in the principles of equity and fairness. More specifically, the only commitment undertaken by the Indian governments to date is that it will ensure that per capita emissions in India will never exceed those of the rich world.<sup>11</sup>

The third commitment is to integrate approaches to climate change into wider national policy frameworks. More specifically, there is a broad view that energy-security should be geared towards sustained high-growth and poverty reduction. To date, five-year planning documents, including those dealing with energy, have had relatively little to say about climate change mitigation.<sup>12</sup> The emphasis is squarely on targets for economic growth, employment creation, and the energy generation needed to achieve these targets. At best climate change mitigation and the decarbonisation of growth has been a second- or third-order priority.

This picture is starting to change. The National Action Plan on Climate Change, published in 2008, sets out a wide-ranging vision for scaling-up renewable energy, strengthening energy efficiency, and reducing carbon intensity. While the plan itself is fragmented and lacking detail with respect to the costing of specific targets, it does recognise the central importance of technology and the scope for technology transfer to facilitate ‘leapfrogging’ to a low carbon system. In this context, the NAPCC calls for “...international cooperation for research, development, sharing and transfer of technologies enabled by additional funding and a global IPR that facilitates technology transfer to developing countries...”<sup>13</sup>

Relatively little domestic or international attention has been paid to this aspect of the NAPCC. Public policy debate has tended to focus on disputes over the setting of global emission reduction targets, and on differences between developed and developing countries over the depth and timing of cuts. These are important areas. Yet financing and technology transfer are central to any discussion of targets for quantitative reductions in greenhouse gas emissions – or they ought to be. Other things being equal, the stronger the international support for technological change and the decarbonisation of energy, the greater the scope for India to participate in an international agreement aimed at constraining future emissions without compromising wider national policy goals. To put the issue differently, policy-makers in India are less likely to embark on international commitments aimed at generating a global public good (enhanced climate security) if domestic producers and consumers have to bear the cost, than if a multilateral agreement opens the door to more equitable burden sharing.

The lack of attention paid to technology transfer and international cooperation on low carbon financing is striking. As we show below, the issue has not been taken up in a meaningful way in the negotiating process leading up to the 2009 summit in Copenhagen. By the same token, it has been largely absent from the domestic political debate on climate change in India itself. This has wider ramifications because India, along with China, Brazil, South Africa and other developing countries might have been expected to emerge as champions for such an agreement. What is clear is that, in the absence of institutionalised commitments on technology transfer, countries like India are highly unlikely to countenance participation in a post-2012 accord that involves developing countries taking on medium-term stabilisation targets. Such an outcome would weaken the prospects for the development of a verifiable and enforceable multilateral agreement for avoiding climate change, which would be bad for the world and bad for India.

### *Energy, growth and poverty reduction in India*

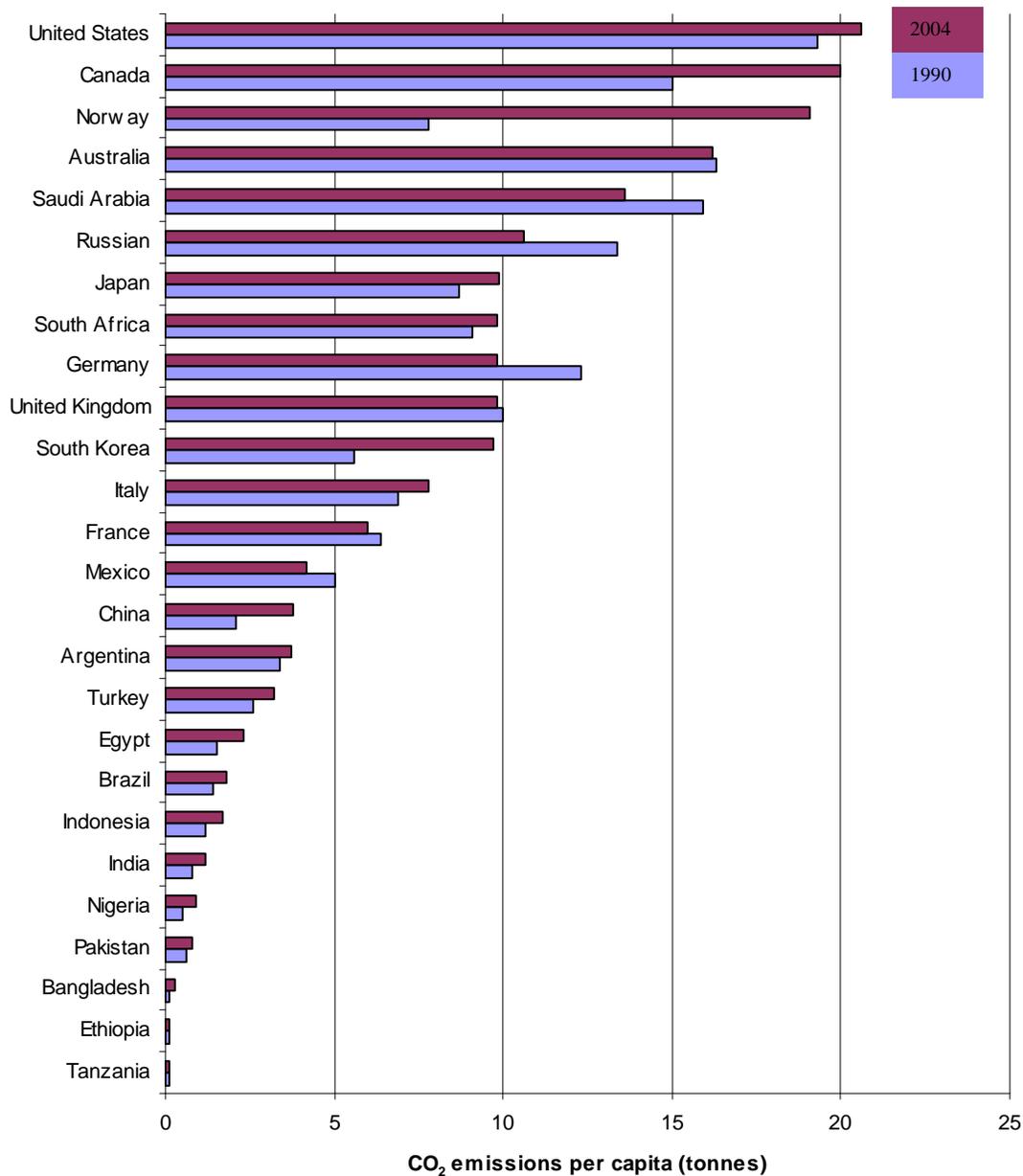
Commentators in the developed world often present India as an obstacle to a meaningful agreement on climate change. Viewed from India, developed country approaches to the post-2012 multilateral regime are widely interpreted as an exercise in self-interest and as a threat to national development efforts. These differences are rooted partly in Indian concerns over the potential for a trade-off between domestic human development goals and international climate change goals; and partly in the failure of developed countries to recognise the potential for such a trade-off.

The starting point for any assessment of these perspectives is the national greenhouse gas account. As a major source of CO<sub>2</sub> emissions, India is a critical player in climate change negotiations. The country is the world's fourth largest source of emissions and it has one of the highest growth rates for emissions, averaging 6.9 per cent annually from 1990 to 2004.<sup>14</sup>

Measured on a per capita metric, however, the picture looks very different. The average carbon footprint of an Indian citizen is 1.2 tonnes, which puts the country 109<sup>th</sup> in the international league table (Figure 10).

Behind the shallow carbon footprint are factors which serve to highlight national human development imperatives. By international standards, India has very low per capita levels of energy consumption – and the average figure obscures large gaps in provision. Over half of rural households and 12 per cent of urban homes do not have access to electricity. At the household level, inadequate access to energy impacts most directly on the well-being of women and girls because of their traditional role in cooking and fuel collection. Efficient energy generation is also critical to the attainment of national targets for creating millions of jobs and the creation of opportunities for the 280 million people living below the poverty line.

**FIGURE 10: Rich countries have deep carbon footprints**



*Source:* Calculated from UNDP, United Nations Development Programme 2007, Indicator Table 24.

The national energy infrastructure in India is under acute pressure. Some two decades of rapid economic growth have dramatically increased demand for energy. However, increases in supply and improvements in operational efficiency have been held back by under-investment, which has been linked in turn to problems in governance. The strains on the system are reflected in persistent shortages of electricity and disruptions to supply.

Ambitious targets have been set for overcoming energy bottlenecks. Compared to 2004-05, electricity consumption in India is expected to increase by six to seven times to 3600-4500TWh by 2030.<sup>15</sup> In order to meet the growing demand, the Planning Commission estimates that by 2031-32 (the end of the fifteenth five-year plan) India would need a total installed capacity of around 800GW, up from around 128GW today.<sup>16</sup> To put this figure in context, the increase is roughly equivalent to the total installed power generation capacity in China currently.

*Coal is set to remain king – but efficiency gains are possible*

This scenario has some obvious implications for climate change negotiations. Rapid expansion of electricity generation and energy supply capacity in India can be thought of as a non-negotiable national policy priority. The Government of India is not going to arrive in Copenhagen in 2009, or at any other event over the next decade or so, offering to sign-up for deep cuts in energy generation. The question is whether an expansion of energy supply seen as being consistent with national economic and human development priorities can be achieved *with* a simultaneous commitment to stabilise and then lower greenhouse gas emissions. The answer to that question will be determined by energy efficiency – and by the scope for technological change.

Scenarios for India's energy future are highly sensitive to assumptions about national policy and international cooperation. Approaches to the pricing of electricity and other forms of energy, including carbon-pricing, public investment decisions on infrastructure, regulatory decisions over efficiency standards, the mix of renewable and non-renewable sources, and incentives for low-carbon innovation will play a key role in determining the future profile of India's energy mix. International cooperation is important because it has the potential to enhance the affordability and broaden the range of low-carbon options open to policy-makers. While the energy sector has to be viewed in an integrated fashion, one sector – coal – stands out as being of particular importance.

Coal is the dominant primary source of commercial energy in India. This picture is not set to change in the near-term future. The coal sector currently accounts for over half of commercial energy consumption. Some three quarters of coal production is dedicated to power generation. At current levels of usage, India has an estimated 44 billion tonnes of coal reserves – sufficient for 30-60 years at current levels of consumption.<sup>17</sup> While imports are rising in the face of shortages of low-ash content coal, cost considerations and concerns over energy security make domestic supplies an attractive option.<sup>18</sup> Headline projections for supply tell their own story:

- Total demand for coal is projected to increase from 432 million tonnes in 2005 to 670 million tonnes in 2011. In order to meet this demand, India is planning to expand coal production by 60 per cent.
- Coal-fired power generation is forecast to increase from 461 TWh in 2004 to 836TWh in 2015.
- The Planning Commission expects the total coal-based capacity of power plants to rise from around 68 GW currently to 440 GW by 2032.

- This means India would need nearly 900 additional 500MW plants by 2032, or more than one new power plant being built every two weeks.

These projections have important implications for India's emerging CO<sub>2</sub> emissions profile. Coal accounts for 70 per cent of India's current emissions. With planned investments locking the country into a coal-dominated energy future, that share is set to fall only marginally over the next two to three decades.

However, this is not inevitable: any projection for energy generation and CO<sub>2</sub> emissions is highly sensitive to assumptions about the policy environment. Shifts in public policy would influence energy investments and the mix of sources for power generation. In principle, India could adopt policies which create strong disincentives for coal-based energy, such as a carbon tax or a stringent cap-and-trade regime. The locus for policy incentives could be shifted towards zero-carbon or low carbon options, ranging from solar power, to wind power, hydro-power or nuclear.

There is certainly enormous potential for a transition to a low carbon future. Located in the earth's equatorial belt and with most of the country experiencing 250-300 clear sunny days a year, India is well placed to exploit solar-power: just 1 per cent of land area attracts sufficient solar energy to meet the country's entire needs.<sup>19</sup> Wind power is already a growth industry, with Indian companies acquiring high levels of technological capability and emerging as a force in global markets. Enhanced energy efficiency is another potentially large source of greenhouse gas mitigation, especially in the industry sector.<sup>20</sup> It has been estimated that projected CO<sub>2</sub> emissions from fuel and electricity use in the industry sector could be lowered by 16 per cent against a business-as-usual scenario by 2030, although this would entail major incremental investment costs.<sup>21</sup>

Looking to the future, there is no question that India has the potential to reduce dependence on coal. With the right policy incentives and public investments put in place today, the country could be a world leader in wind and solar power by 2020. The NAPCC represents a first step towards this goal through the development of a strategy for tapping low-carbon energy potential. Targets have been set for raising photovoltaic production and increasing solar thermal power generation. At the same time, energy efficiency is being more effectively integrated into urban planning and residential building regulations.

From a climate change perspective the problem is that all of the above relates to medium-term and long-term potential. While much more could be done to decarbonise India's energy system, the barriers to a rapid low-carbon transition have to be acknowledged. Currently, renewable energy sources (excluding large hydro-power) account for around 9 per cent of the national energy mix.<sup>22</sup> While installed capacity for wind power is rising, capacity utilisation remains low due to wind speed variations. Technological innovation is needed to design and develop small wind energy generators that can generate power at very low wind speeds. While solar power technologies can be deployed through small scale grid systems, at current cost and efficiency levels they are unlikely to displace coal and petroleum on a large scale. Even with current expansion plans, nuclear power is

unlikely to account for more than 4-6.4 per cent of energy generation by 2031-32. In the most optimistic scenarios, hydro, nuclear and renewable-based power will contribute at most 10.9-14.6 per cent of India's energy mix by 2031-32.<sup>23</sup>

The upshot is that, under any credible scenario, coal will remain a major source of energy in India for the next two to three decades. This constitutes both a threat to the global climate and a small window of opportunity. The threats are readily evident from the emissions scenarios discussed in the previous section. With current technologies, the scaling-up of coal-fired power generation will inflict immense damage on the global climate and, by extension, on prospects for a viable post-2012 multilateral agreement on climate change. The opportunity derives from the potential for India to exploit more efficient coal technologies, thereby reducing carbon intensity.

Convergence towards best-standard international practices would set India on course for a very different carbon trajectory. If the global priority in climate change negotiations is deep cuts in future CO<sub>2</sub> emissions, India's coal sector offers an abundance of low-hanging fruit. Most of the country's plants use sub-critical pulverised coal (PC) technology and are relatively small. Current thermal efficiency is around 29 per cent - some 50 per cent below the best performing European plants. Raising this efficiency level to 45 per cent, in line with the best international standards, would cut emissions by 184 million tonnes in 2030, or 11 per cent of the projected coal-based emissions for that year. Further, if a fifth of the plants built during 2015-2030 incorporated CCS technology, the emission reductions would rise to 530 million tonnes in 2030.<sup>24</sup> On another estimate, if India were to construct only supercritical pulverised coal (SCPC) power plants from now on, it would reduce CO<sub>2</sub> emissions by 1 billion tonnes by 2025.<sup>25</sup> To set this in perspective, this compares with total emissions in 2004 which amounted to 1.3 billion tonnes. These reductions will not happen with the current profile for power generation, or with the continued domination of sub-critical plants envisaged under current expansion plans.<sup>26</sup> Raising efficiency levels in China would have even more marked impacts in terms of reduced CO<sub>2</sub> emissions (Box 1).

#### **BOX 1: Cleaner coal's potential to reduce emissions in China**

If coal is important to India, it is critical to China's rapid growth. It accounts for 60 per cent of the nation's energy consumption, half of which is devoted to power generation. Chinese coal is also of poor quality – high ash and sulphur content – and little of it is washed before combustion. The result is not only growing air pollution; this also creates public health hazard due to acid rain, which falls on a third of the Chinese landmass.

To meet growing demand, China has been adding coal-power capacity at breakneck speed. In just one year – 2005-06 – capacity increased by more than a quarter to 484GW. Yet, much of the infrastructure operates at low efficiency levels (29 per cent). In China's reference scenarios, the uptake of cleaner coal technology is not expected to be significant before 2020; the IEA expects efficiency levels to rise to 38-39 per cent by 2030.

If, instead, China adopted super-critical and IGCC technologies so as to increase efficiency levels to 45 per cent by 2030, CO<sub>2</sub> emissions for that year would be lower by 756-808 million tonnes, an amount greater than the total net emissions from the United Kingdom in 2006. If a fifth of Chinese plants were fitted with CCS technology during 2015-2030, then emissions in 2030 would be lower by 1.8 billion tonnes.

In order to attain these objectives, technology transfer would be essential. By 2004, China had 12.96 GW of supercritical plant capacity, only 4 per cent of the total. Combined with poor enforcement of environmental regulations and a large proportion of small-scale illegal equipment, domestic efforts have proved inadequate. Foreign collaborations can intensify the use of supercritical boilers and efficient gasifiers (including IGCC) in China.

*Source:* Watson et al 2007, p. 29; UNDP, United Nations Development Programme 2007, p. 149

How realistic is it to assume that the near-term efficiency gains can be exploited? The answer to that question is contingent on two related factors: domestic policy choice and international cooperation on technology transfer. With much of the existing coal-based energy plant and supply infrastructure due to be replaced in the near future, there is a window of opportunity for technological change. From a technological capacity perspective, the supercritical option is plausible.<sup>27</sup> The National Thermal Power Corporation (NTPC) is currently constructing the first supercritical plant with further plans to build at least seven ultra-mega power plants (4000 MW each) using supercritical technology.<sup>28</sup> India is also developing its domestic capacity in supercritical boiler technologies, suggesting a potential market for national firms. Wider measures to enhance efficiency can also be explored. For example, fluidised-bed gasifiers for Integrated Gasification Combined Cycle (IGCC) plants have the potential to increase the combustion of high ash-content coal (suitable to the Indian situation), thereby reducing emissions.<sup>29</sup> Were India to prioritise the construction of IGCC plants fitted for CCS, it would create the conditions for significant efficiency gains in the short-term while setting the scene for zero-emissions as new capture and storage technologies become available.

### *The limits to technological choice*

Technological choice does not happen in isolation. It is shaped by capacity and by incentive structures. To take an obvious example, the commercial viability of any energy technology is heavily influenced by assumptions about the future price of carbon, by regulatory considerations - such as the anticipated mix of renewable and non-renewable energy legislated for in the national grid - and by patterns of research and development. Cost is another major factor. It may be technologically feasible to lower CO<sub>2</sub> emissions with existing technologies, but financial feasibility for private and public investors is a different matter. Is India's coal sector open to early and far-reaching technological change?

The barriers to change are well known and widely debated in India itself. Low-levels of efficiency in the coal sector are symptomatic of wider problems. Indeed, the energy sector is beset by governance problems that are a source of tension between individual

states on the one side, and central government agencies – including the Planning Commission – on the other. State bodies have often prioritised low-cost electricity over commercial viability, allowing for electricity to be priced at levels below cost and tolerating the non-collection of payments. While these policies are often justified on the grounds that they enhance efficiency, this claim is far-fetched. The main beneficiaries include large farmers, who have been provided with low and sometimes zero cost electricity to pump groundwater – a practice that has contributed to severe ecological problems in several states. Capital-intensive industrial enterprises have also benefited on a large scale. Meanwhile, regulatory under-pricing of coal-fired energy generation has deterred private investors and deprived state agencies of the revenue streams needed to increase power generation capacity finance technological upgrading.

No strategy for technological change geared towards climate change mitigation is likely to succeed in the current policy environment. Reforms set out by the Planning Commission address many of the underlying causes of low-efficiency, though implementation has been uneven. However, under any reform scenario tapping into the potential efficiency gains will raise costs. From a planning perspective, these costs are clearly of critical importance both for the central government, for state governments, and for private investors. They also have a wider importance. If developed country governments want to see India embarking on ambitious moves aimed at lowering the national emissions trajectory, they also need to consider the financing implications. More than that, they need to turn their attention to the question of equitable cost-sharing and the development of multilateral mechanisms aimed at facilitating technological change.

We have attempted to develop ball-park figures for a technological change scenario in the coal sector. That scenario investigates the incremental capital costs for different technologies, which would be needed to shift India onto a higher efficiency, lower emissions trajectory. It is broadly consistent with achieving a 50 per cent reduction in CO<sub>2</sub> emissions through efficiency gains. We stress that the financing figures are indicative and that the scenario selected is both narrow (in the sense that it deals only with coal) and somewhat arbitrary.

Our starting point is the current national planning framework. As noted earlier, India's Planning Commission has an ambitious vision to increase the installed power generation capacity to 778 GW by 2032 (see Table 2). Assuming that the share of coal-power in total capacity remains steady at 57 per cent, coal-power capacity would have to reach more than 440 GW by 2032. This translates into roughly 900 additional plants of 500 MW capacity, or more than one new power plant being built every two weeks. Using an assessment of the total number of plants required in each planning period, we estimate the annual incremental cost of adopting lower-carbon technologies operating at higher levels of thermal efficiency.<sup>30</sup>

**TABLE 2:** Coal-power capacity needed in India

Five Year Plan	10th	11th	12th	13th	14th	15 <sup>th</sup>
End of plan year	2007	2012	2017	2022	2027	2032
Installed capacity needed (GW)	153	220	306	425	575	778
Required coal power capacity (GW)	87.21	125.4	174.42	242.25	327.75	443.46

*Source:* India 2006, p. 20, table 2.5.

*Note:* Planning Commission estimates based on demand projections to maintain GDP growth rates of 8 per cent per annum. Authors assume share of coal power in total capacity at 57 per cent.

Cost-estimates are highly sensitive to technological choices. Just as thermal efficiency levels differ by technology so do the incremental capital costs (see Table 3). In our scenario we estimate all incremental costs relative to the benchmark of capital costs for a conventional sub-critical PC plant (\$610 per KW), the dominant technology in use in India.<sup>31</sup> Building super-critical pulverised coal plants with flue gas desulfurisers (FGD) to remove sulphur dioxide emissions would increase thermal efficiency levels by around 5 per cent and plant costs by around 32 per cent per KW. This translates into an incremental capital cost of \$97.5 million for a single 500 MW plant. Adopting IGCC technologies would raise efficiency levels by around 50 per cent if the performance of the best-performing European plants could be duplicated in India. However, the incremental cost of an IGCC plant with the widely used entrained flow technology system would be almost three-times the level for a super-critical pulverised coal plant at \$397.5 million.

**TABLE 3:** Incremental capital costs of different coal-power technologies

Technology	Sub-critical Pulverised Coal	Sub-critical PC w/FGD	Super Critical PC w/FGD	Ultra SCPC	Circulating Fluidised Bed Combustion	Pressurised Fluidised Bed Combustion	Integrated Gasification Combined Cycle – Entrained-flow	IGCC – Fluidised-bed Gasifiers	IGCC – Moving-bed Gasifiers
Efficiency	29% <sup>#</sup>	–	5% above subcritical	–	Comparable to PC	40-47%	38-43%	44-48%	45%
Capital cost \$/KW	610	750	805 <sup>^</sup>	1130*	770	1240	1405*	1290	1350*
Incremental cost for a 500MW plant (\$mn)	–	70	97.5	260	80	315	397.5	340	370

*Source:* Calculations based on efficiency and capital cost estimates from Chikkatur and Sagar 2007, pp. 149, 152, 161, 165, 167, 196 (table 37).

*Note:* Where India-specific cost estimates were not available, we used the world estimates.

<sup>#</sup> Average fleet efficiency for India.

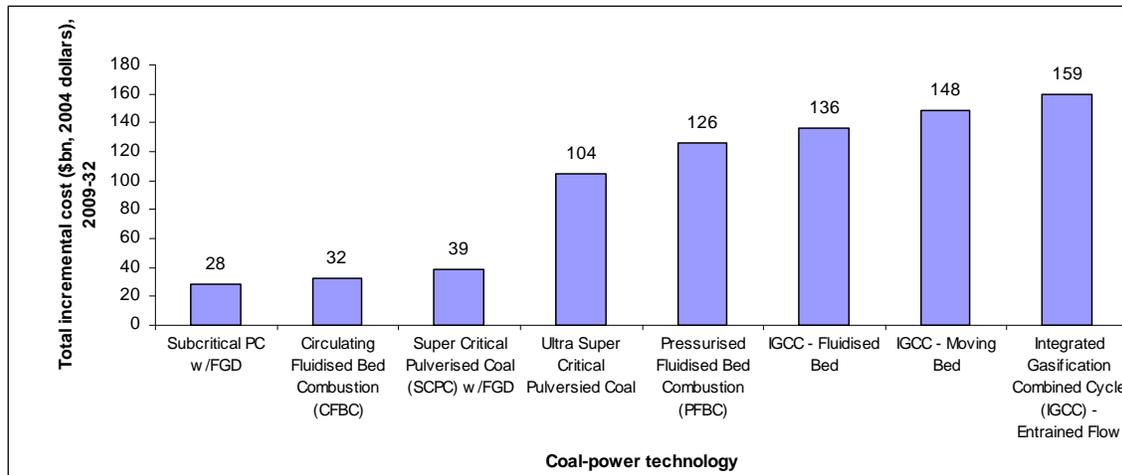
<sup>^</sup> This estimate is based on the claim that an SCPC plant with FGD would be 32 per cent more expensive than a sub-critical PC plant. Chikkatur and Sagar 2007, p. 149.

\* For these estimates we used the mid-points of the ranges.

What do these individual plant estimates mean for the national financing envelope? Applying a discount rate of 4 per cent for investments in future years, we estimate the

cost parameters for the period 2009-32 at between \$104 billion and \$159 billion. The technological options considered are set out in Figure 11. The lower end of the range is broadly consistent with cost estimates for super-critical pulverised coal technologies and the upper bound for IGCC plants. Annual incremental costs would range between \$5.2 billion and \$8.4 billion. At 45 per cent efficiency for a fluidised-bed IGCC plant, it would cost roughly \$36 to reduce each tonne of CO<sub>2</sub> emissions in 2030.

**FIGURE 11:** Incremental investments for higher efficiency, lower emissions technologies steadily rise



Source: Authors' calculations.

Carbon capture and storage would add to costs. Post-combustion capture of CO<sub>2</sub> in PC plants is more expensive and reduces plant efficiency to a greater extent than pre-combustion capture in IGCC plants.<sup>32</sup> But retrofitting plants with capture equipment is more complicated and expensive for IGCC-based technologies. In India, it is estimated that retrofits to existing plant stock could result in a third of the efficiency being lost.<sup>33</sup> From a cost and energy efficiency perspective, built-in CCS capacity makes sense. However, this would raise the capital costs of each additional IGCC plant by around \$300-\$800 per KW, pushing up the upper-bound estimate to \$1.14 billion for a 500 MW plant (or \$830 million more than a standard sub-critical plant).<sup>34</sup> In terms of the potential for CO<sub>2</sub> reductions, the potential returns on this investment are very high. Near-zero emissions from coal plants after 2020 would make it possible for India to embark on deep cuts in greenhouse gas emissions. By the same token, CCS technologies remain commercially unproven in developed countries – and India would face formidable technological and environmental challenges in adapting them. Even so, there are very strong grounds for India to make investments in CCS preparedness today in order to keep open future policy options. Given India's current CO<sub>2</sub> emissions trajectory, there are equally strong grounds for the rest of the world to support India in making these investments.

Costing exercises such as the one presented above serve a limited but important purpose. They provide a basis for understanding the financing implications of adopting the technologies that could change greenhouse gas emission trajectories. They are limited in the sense that they do not provide a basis for determining appropriate technologies. Indeed, the uncertainties surrounding specific technologies have to be recognised. It is not just CCS that is unproven in India. Legitimate questions have also been raised about whether or not entrained-flow IGCC technology is suitable to high ash-content Indian coal. In the absence of innovations to address this concern, the adoption of IGCC technology would require an increase in the supply of imported coal. Policy makers also have to consider wider questions. Some technologies – particularly those associated with IGCC – are still in a relatively early stage of application and come with commercial risks. Lack of clarity over the application of intellectual property rules and licensing arrangements adds another layer of uncertainty. Stringent enforcement of intellectual property rights over CCS technologies, to take one obvious example, would raise both import and operational costs.

Scenarios for India's energy future highlight some of the important issues at stake in climate change negotiations. Under current energy sector plans, India is becoming locked into a carbon-intensive energy infrastructure that will limit the scope for emission cuts over the next four-to-five decades – the life time of an average coal plant.<sup>35</sup> That is potentially very bad news for climate change. Improving energy efficiency in the coal sector would yield clear benefits for carbon mitigation. Viewed over the long-term, it would also hold out the potential for a range of social, environmental and economic benefits in India itself, including improved access to affordable and less unpredictable energy supplies. Supercritical plants, if fitted with desulfurisers and catalytic reducers, could also open the door to reduced emissions of sulphur dioxide and nitrous dioxide with attendant benefits for the environment and public health.

These potential benefits are sometimes overlooked. The threat posed by trade-offs between global climate change mitigation and domestic poverty mitigation is real. Yet there are win-win scenarios. What is good for the global climate does not have to be bad for India. However, India cannot unlock the win-win scenario by acting alone. What is required is concerted international action to support and accelerate the decarbonisation of energy through cooperation on finance and technology transfer.

That action would have to be based on a formula for cost-sharing. It could reasonably be argued by India that the entire *incremental* cost of raising efficiency over and above the level envisaged in current plans should be borne by developed countries. The implied financial transfer could be viewed both as a form of repayment for accumulated ecological debt, and as an investment in securing shared climate change goals. The argument could be couched in terms of greenhouse gas rights or the simple *realpolitik* of climate change arithmetic. The problem is that the world currently lacks a multilateral framework for exploiting win-win linkages. Such a framework would need to cover most of the incremental cost associated with low-carbon technological-upgrading, in effect creating a multilateral facility that invests in the global public good of enhanced climate security.

### **III. Technology transfer – a missing link in the multilateral framework**

Technology transfer has figured on the multilateral agenda for climate change for many years. The need for international action to facilitate the transfer of low carbon technology is explicitly recognised in the United Nations Framework Convention on Climate Change (UN-FCCC), which calls on governments to “take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies” (Article 4.5). The Marrakech Accords adopted at the Conference of the Parties (COP-7) in 2001 established a framework for enacting this principle. An Expert Group on Technology Transfer was created to undertake technology needs assessments and identify mechanisms for technology transfer. Yet apart from a large number of resolutions adopted by working groups, COP sessions, and high level meetings, nothing of any substance has emerged under the UN-FCCC’s auspices.

Hopes that this picture might change in the run-up to the 2009 climate change summit have not so far been realised. The Bali ‘Road Map’ calls for “enhanced action on technology development and transfer to support action on mitigation.” Here, too, encouraging words have been delinked from quantifiable and verifiable outcomes. This has been a major concern for developing countries, many of which arrived at the Poznan COP in 2008 having tabled proposals for multilateral action on climate change (see Annex I). While many proposals lacked clarity, the failure of developed countries to respond has been one factor in a protracted deadlock that now threatens to undermine an effective post-2012 climate change treaty.

It is not difficult to see why the issue of finance and technology transfer is so important. Building on the scenario for avoiding dangerous climate change outlined earlier, it is possible to sketch the broad parameters for a multilateral agreement with the potential for averting dangerous climate change. Developed countries will need to cut emissions by over 80 per cent by 2050 against 1990 levels. Near-term cuts in the range of 20-30 per cent by 2020 would be consistent with this goal. Were developed countries to deliver on these reductions, developing countries would need to stabilise emissions by 2020-2025, with cuts of around 20 per cent by 2050.

The post-2012 treaty needs a two-phase framework that mirrors this sustainable carbon budget scenario. In the first phase, corresponding to the next Kyoto commitment period, developed countries will have to undertake clear quantitative reduction commitments, while at the same time accepting far stronger monitoring and verification of performance. In the second phase, from around 2017, developing countries will have to undertake similar commitments geared towards stabilisation. The aggregation problem discussed earlier means that all major developing country emitters will have to be covered. Given the financing implications discussed in the previous section, this is unlikely to happen in the absence of strengthened international support.

In this section we examine the current framework for technology transfer. For practical purposes, that framework is a patchwork of fragmented and uncoordinated initiatives.

These vary in scale and effectiveness, though none provides a systemic response to the technology transfer challenge. The following are among the major initiatives in place:

- The Clean Development Mechanism (CDM)
- The Global Environment Facility (GEF)
- Bilateral and regional initiatives
- The Clean Technology Fund

After examining each of these in turn we consider what a more ambitious and effective multilateral system might look like.

#### *The Clean Development Mechanism (CDM)*

Established under Article 12 of the Kyoto protocol, the CDM provides developed countries with the flexibility to meet greenhouse gas reduction commitments by buying-in credit for emissions from projects implemented in developing countries.<sup>36</sup> The CDM is important because it creates a vehicle for transferring carbon finance to developing countries. Sales of emission credits amount to \$6 billion,<sup>37</sup> with estimates for emission reductions ranging from 300 million to 1.2 billion CO<sub>2</sub> equivalent in 2012.

Although the CDM does not have an explicit technology transfer mandate, it may contribute by financing emission reductions that use technologies not available in the host country.<sup>38</sup> Only around 39 per cent of all CDM projects are estimated to involve technology transfer, though there are large variations between countries.<sup>39</sup> In India, just 16 per cent of CDM projects involve a technology transfer component – a far lower share than in countries like Mexico or Bolivia.<sup>40</sup>

The more serious problem with the CDM framework is its project focus. Carbon finance provided through the scheme is typically linked to verifiable actions by firms, rather than to whole sectors or energy programmes. Currently, around 400 projects are approved annually, with each process of validation and registration taking almost one year. The combination of high transaction costs and relatively small financial flows remains a major handicap.<sup>41</sup> Modifying the CDM approach to allow for the financing of large-scale technology transfer in coal-fired power generation, to take one example, would enhance its effectiveness. However, prices for CDM credits have to be high enough to generate demand in rich countries and a strong flow of carbon finance.

There is also uncertainty about the net effect of the CDM on international emissions because of the informational problems associated with credibly establishing ‘additional’ emissions reductions. Further, stakeholders claim that the procedures for approving CDM projects are ‘unclear, impractical, and resource intensive,’ thus driving away legitimate projects. In other words, although the CDM reduces compliance costs, it is not necessarily cost-effective for achieving emissions cuts in poor countries thanks to the high transaction costs.<sup>42</sup>

### *The Global Environment Facility (GEF)*

In institutional terms the GEF has been a lynch-pin in the UN-FCCC framework for technology transfer. Yet the overall record is been unimpressive. Since 1991 the GEF has allocated \$2.5 billion to climate projects and claims to have leveraged another \$15 billion in co-financing. The financing portfolio is project-based, with an average project size in renewable energy of less than \$6 million. While some projects have been highly innovative, the GEF has clearly not financed technology transfer or capacity building on the scale required.

This picture is not set to change. At Poznan in 2008 the COP adopted a ‘strategic programme’ proposed by the GEF, which envisages three funding windows: on needs assessments, piloting priority technology projects, and disseminating GEF experience with technology transfer. The ‘strategic programme’ plans to devote only \$50 million to scale-up transfers of technology.<sup>43</sup>

Scale is not the only problem. During recent climate change negotiations, the GEF has been at the centre of protracted and largely unresolved disputes between developed and developing countries. Developing countries view GEF with considerable suspicion. Many governments claim that its governance structures give undue weight to the influence of developed countries and institutions – such as the World Bank – in which these countries are major shareholders.

Several developing country governments have also questioned the degree to which the GEF is providing ‘new and additional’ funds, as envisaged under the UN-FCCC mandate, as distinct from providing a channel for the reallocation of existing funds. More broadly, most developing countries have rejected the GEF as a financial mechanism, choosing to treat it only as an operational entity.<sup>44</sup> While developed countries have supported the GEF’s strategic orientation towards technology needs assessments, for developing countries the priority has been financial transfers from rich countries.<sup>45</sup>

### *Bilateral and regional initiatives*

There is no shortage of initiatives purporting to support technology transfer. The US Technology Cooperation Agreement Pilot Program (TCAPP, 1999) and the Climate Technology Partnership (CTP, 2001) both incorporate technology transfer options. The same is true of the EU-led Climate Technology Implementation Plan (CTIP, 1995).<sup>46</sup> CCS technology is being demonstrated in China under the EU-sponsored Near Zero Emissions Coal Initiative (NZEC). In India a joint project of the National Thermal Power Corporation and the U.S. Agency for International Development established a Centre for Power Efficiency and Environmental Protection (CenPEEP) to demonstrate and disseminate technologies to reduce GHG emissions from power stations. The Asia-Pacific Partnership on Clean Development and Climate brings together a large group of countries, including the US, Australia, Japan, India and China. Many other initiatives could be mentioned.

Most of these diverse arrangements have one feature in common: they have to date failed to substantially transfer either technology or finance. Finance is one reason for the gap between aspiration and delivery. Each of the initiatives mentioned above operates through very small budgets. Another problem is that the processes involved in programme development are geared towards learning, rather than technology transfer. For instance, the first phase of the NZEC programme involves establishing links between British and Chinese experts, modelling future energy requirements, building capacity to evaluate CO<sub>2</sub> storage potential and developing a roadmap.<sup>47</sup> The final aim of the programme is a limited one. It is envisaged that one demonstration plant will have been built by 2014, with a view to demonstrating the viability of near zero emission technology by 2020.<sup>48</sup> From a climate change perspective this is far too little, far too late.

### *The World Bank's Clean Technology Fund (CTF)*

One of the few concrete outcomes of the Bali Action Plan was the establishment of a Clean Technology Fund (CTF). In operational terms, the new facility will be managed and administered by the World Bank but co-finance projects with regional development banks and the private sector.<sup>49</sup> The stated aim was to use the new facility to support 'country-owned' strategies that have the potential to lead to the "demonstration, deployment and transfer of low carbon technologies with a significant potential for long-term greenhouse gas emissions savings." The CTF was supposed to be 'technologically neutral', supporting options ranging from solar and wind power, to nuclear and 'clean coal'. In February 2008, the US and the UK announced plans for financing for the CTF, with the Bush Administration seeking Congressional approval for \$2 billion in appropriations.

It had been hoped that the CTF would emerge as the prototype for a clean technology delivery mechanism. Outcomes to date have been disappointing. During the initial negotiations differences over approaches to governance threatened to derail agreement. Most developing countries had pressed for a new facility to be managed through an institutional framework that gave developing countries a stronger voice than they enjoy in the Bretton Woods institutions.<sup>50</sup> Under a compromise agreement, the management board for the new facility will comprise an equal number of developing and developed country representatives.<sup>51</sup>

Other problems have been less amenable to solutions and could have serious long-term consequences. Serious question marks continue to hang over CTF financing, notably on the part of the United States. Congressional authorisation and appropriations are required for any US contributions to the new fund,<sup>52</sup> and requests by the Administration have so far been rejected.

The factors behind congressional opposition are instructive. The creation of the new facility generated a wide-ranging debate in the United States over whether 'technological neutrality' is an appropriate principle. Critics of the facility in Congress, the non-government organisation community and development research institutes have raised several concerns, notably over the potential role of the CTF in financing coal-fired power

stations. Several commentators have argued that the technologies supported should be ‘transformational’, with an emphasis of ‘zero carbon’ renewable technologies.<sup>53</sup> The World Bank’s involvement through the International Finance Corporation (IFC) in helping to finance a 4,000 MW supercritical coal plant in Gujarat, India was cited as evidence of a bias towards coal.<sup>54</sup> Critics claim that such plants do little to reduce emissions, and that supercritical facilities will lock countries such as India into a carbon-intensive pathway that is inconsistent with a commitment to mitigating climate change. It has also been argued, albeit on the basis of limited supporting evidence, that the private sector would finance construction of supercritical plants without multilateral support.<sup>55</sup> Supporters of the CTF counter these arguments by pointing out that the alternative to these technologies is not wind power or solar power, but another generation of sub-critical reactors. In the case of the Gujarat plant, the IFC claims that the project would result in 70 per cent fewer greenhouse gas emissions by comparison with typical coal plants in India, and that it is the first project in India to use 800 MW-sized units with supercritical technology and would likely be the most energy efficient coal-based thermal power plant in the country.<sup>56</sup>

The early experience of the CTF highlights some wider issues in the financing and governance of technology transfer arrangements. Concerns raised by developing countries in the negotiating process point to questions over the perceived legitimacy of the World Bank and its Board in framing priorities, determining resource allocation, and more broadly shaping the CTF agenda. The legitimacy problem is related not to the technical competence of World Bank staff, but to the weak voice of developing countries in the institution’s governance system.

There are wider governance concerns. The Gujarat dispute has served to highlight the strength of civil society lobbies, notably in the United States, relative to developing country governments. Under its operating mandate, the CTF is required to respond to country-owned strategies and proposals from governments in developing countries. Many of these governments are concerned that what northern environmental organisations see as ‘transformational’ renewable energy options may not meet rapidly rising demand for electricity at an affordable price and in a reliable manner. As highlighted earlier in this paper, the Government of India’s energy plans, which would fulfil most criteria for ‘national ownership’, continue to attach priority to the development of coal-fired power generation in the near-term, while building renewable capacity over the medium-term.

None of these questions can be entirely separated from the specific institutional context in which the CTF operates. The World Bank is viewed with suspicion by many environmentalists. One reason for this is that World Bank projects and policy guidelines do not systematically incorporate measures to assess climate risks and mitigation opportunities.<sup>57</sup> Whatever the merits or demerits of the Gujarat coal-fired power station project, it also remains the case that the World Bank has yet to develop a transparent carbon accounting system through which it might be possible to assess the relative costs and benefits of different mitigation options.

*Low-carbon technology transfer and finance – moving from principle to practice*

Technology transfer has the potential to emerge as a deal breaker in multilateral negotiations towards a post-2012 multilateral agreement on climate change. It has the potential to become a deal maker. Backed by an international commitment to finance a transition to low carbon technologies, developing countries are far more likely to sign-up for quantitative restrictions of carbon emissions.

There is a partial precedent. When the Montreal Protocol was negotiated in 1987 its provisions included a loose undertaking to ‘facilitate access to environmentally safe alternative substances and technology’ to developing countries and provide them with ‘aid, credit, guarantees or insurance programmes’ (Article 5). Three years later, the London Amendment to the Protocol included a specific provision to compensate developing countries for the ‘incremental costs’ of participation. Provisions were made for the transfer of \$160-\$240 million for the initial period 1991-93. By 2001, contributions to the Multilateral Fund amounted to \$1.22 billion.<sup>58</sup> The financing covered the costs, including the implicit intellectual property costs, of adopting technologies for screening out ozone-depleting substances.

We emphasise that the precedent is only partial. Whereas the Montreal Protocol targeted one specific set of pollutants, the UN-FCCC covers a wide range of greenhouse gases. Moreover, the technologies required for combating ozone depletion were relatively simple, low cost, and – crucially – already developed. When it comes to greenhouse gas mitigation, many of the key technologies are complex, high-cost and still under research and development. The scale of activity involved is also very different. Tackling ozone depletion involved focused interventions in identified industrial plants. By contrast, climate change requires strategies that touch every area of energy generation and consumption. Yet for all of these differences, the incorporation of technology transfer provisions in the Montreal Protocol reinforced cooperation partly through financial transfer; and partly by creating an institutional mechanism perceived as fair and legitimate.<sup>59</sup> As the chief U.S. negotiator for the Montreal Protocol has argued, many of the practices underpinning the treaty retain a powerful resonance for climate change.<sup>60</sup>

That assessment is reflected in the negotiating process for the post-2012 climate agreement. Developing countries have set out a broad agenda for technology transfer through UN-FCCC process and at high-level negotiations (see Annex 1).<sup>61</sup> At Accra in August 2008, the G-77 and China proposed a new technology mechanism, complete with an Executive Body on Technology under the UN-FCCC, a Multilateral Climate Technology Fund, and a provision for three-year Technology Action Plans to support research, development, and transfer and diffusion.<sup>62</sup> The proposal envisaged an Executive Body supported by a Strategic Planning Committee, Technical Panels, Verification Group and a Secretariat.

Financing has figured prominently in several proposals. The G-77 and China have called on the industrialised nations to divert as much as 1 percent of their gross national product (GNP) to help finance emissions-reducing technology projects in the developing world.<sup>63</sup>

More broadly, a recurrent theme in developing country proposals is that multilateral mechanisms are needed to cover both the full incremental cost for mitigation actions involving the transfer of low carbon technologies, research and development, patent fees, and other measures.<sup>64</sup> Another recurrent theme is that the multilateral process for technology transfer should be demand-driven, with developing countries having an effective voice in allocation decisions.

Developed countries have been resistant to this approach. Many have concerns over the effectiveness of UN-FCCC mechanisms, notably in the area of verification and enforcement. If rich countries were to finance a large-scale technology transfer facility geared towards quantitative reductions in greenhouse gas emissions, how would compliance with the targets be measured? What enforcement mechanisms would be put in place in the event of non-compliance? These questions are hardly distinctive to climate change: they are found in discussions of a wide range of environmental treaties, international trade governance, and development assistance. However, technology transfer for climate change mitigation does pose some distinctive problems. Current governance systems under the UN-FCCC do not provide a foundation for effective monitoring, verification and enforcement. Moreover, there are inherent difficulties in separating the timing and impact of technology transfer effects of greenhouse gas emissions from wider factors, including economic growth and structural change in the economy.

These difficulties can be overcome. However, breaking the deadlock in negotiations will not be easy. The recent history of multilateral negotiations in areas marked by far lower levels of complexity gives little cause for optimism, as witnessed in the torturous demise of the Doha Round of world trade talks. Developments in successive rounds of UN-FCCC negotiations also point in a worrying direction. No substantive agreements emerged during two successive rounds of negotiations in Bali in 2007 or Potsdam in 2008. Given the complexity of the issues at stake and the number of actors involved, it is unlikely in the extreme that summit brinkmanship at the end of 2009 in Copenhagen will produce meaningful results. Levels of trust remain low and common ground is conspicuous by its absence.<sup>65</sup>

#### *Moving towards a multilateral framework*

The challenge of aligning energy sector policy in India with climate stabilisation is a microcosm of a far wider challenge. There are no reliable global estimates of the costs associated with developing countries achieving the broad goal of stabilisation by around 2020. The UN-FCCC's Expert Group on Technology Transfer puts the additional global cost of achieving a 50% cut in global emissions by 2050 at between \$262-670 billion. That estimate highlights both the high levels of uncertainty involved and the scale of investment required.<sup>66</sup> Estimates for the additional costs of deployment and diffusion of mitigation technologies to developing countries are placed by the UN-FCCC in a range from \$160-\$305 billion.

It is important to recognise that ‘additional costs’ are not the same as the incremental cost analysis set out in this paper for India. It is our contention that rich countries should meet the full incremental cost of achieving specified carbon mitigation goals over-and-above planned investment in the energy sector (which includes mitigation components). The distinction is important in terms of incremental resource mobilisation. Most energy financing will continue to come from public and private investments, with the mix determined by national policy. However, the bulk of incremental financing for technology transfer to developing countries will have to come from public finance, mainly in the form of new and additional aid.

Mechanisms for delivering development assistance for mitigation could take a variety of forms. For example, bilateral aid could be used to subsidise the interest bearing component of International Development Association loans, converting them into grants, or of International Finance Corporation investment risk guarantees. New and innovative financing measures could be used more widely to supplement aid flows.

Carbon markets provide one potential source of revenue to finance technology transfer. In 2008, the global carbon market reached a value of \$126 billion.<sup>67</sup> Imposing a 3 per cent tax on transactions in that market could mobilise \$3.6 billion. If all developed countries adopted the more stringent cap-and-trade regimes required to stay within the 2°C target *and* auctioned the bulk of permits, the combination of a higher carbon price and increased trade could generate far larger revenues. A proposal from the Norwegian government estimates potential revenue of \$20-30 billion. Much will depend on the degree to which the EU and the United States lower the ceiling for emission quotas (or Assigned Amount Units) and increase the share of quotas subject to auction. The strength of the Norwegian proposal is that it would create a mechanism that mobilises finance for technology transfer independently of budget decisions in developed countries by directly tapping carbon mitigation markets.<sup>68</sup>

Another proposal from Mexico envisages all governments investing in a global fund for climate financing, with levels of transfer determined by a formula based on GDP, emissions and population size (with exemptions for the poorest states in Africa).<sup>69</sup> Such a fund would be difficult to negotiate. However, it does offer the prospect of a predictable, rules-based revenue scheme.

Developed country governments could also consider a range of options developed under wider aid programmes. One way of financing a global public good is to tax the public bad that creates it. Extending the levy imposed on air tickets by France to cover the costs of immunisation is one potential avenue for exploration. Another is the International Financial Facility for Immunisation (IFFIm) developed under the GAVI Alliance. Briefly summarised, governments supporting the IFFIm issue bonds to generate up-front capital that can be used to front-load investments and maintain a predictable stream of financing. The mechanism has mobilised \$1.2 billion to date is projected to mobilise around \$4 billion over the next ten years.<sup>70</sup>

Creating a viable multilateral mechanism will require more than innovative financing proposals. Breaking out of the current impasse will require a critical mass of countries to forge a common understanding. These countries will have to include major emitters in the developing world – including India and China – along with members of the G8, including the United States. The G20 provides one possible negotiating structure for forging a deal. More important than the locus for negotiations are the principles and practical measures required. There are seven make or break elements for a deal:

***A clear mission:*** The starting point is to create a dedicated new facility – the Low Carbon Technology and Finance Facility (LCTFF) - charged with mobilising resources and building capacity to cover the incremental cost of achieving specified greenhouse gas reduction goals. ‘Incremental’ would be defined as costs over and above those envisaged in current energy strategies with an explicit target of lowering the emissions trajectory. Detailed metrics and verification procedures would be developed to compare current emission pathways with lower carbon pathways, with the LCTFF financing the costs of transition.

***Legitimacy:*** Developing countries are unlikely to accept a governance and decision-making structure dominated by rich countries. Locating technology transfer within the World Bank, even with modified governance rules for the relevant trust funds, is unlikely to be considered as acceptable by major developing countries. The UN-FCCC provides an obvious alternative. However, for developed countries the legitimacy of the UN-FCCC will hinge critically on perceptions of its capacity for overseeing compliance (see below). The proposed LCTFF would be overseen by an Executive Board comprising equal numbers of developed and developing countries with additional expert representation. The Executive Board would be headed by a respected international figure.

***Scale:*** Financing for low carbon technology transfer has to be commensurate with the cost of achieving targets specified in any international agreement. According to the International Energy Agency (IEA), an additional investment of \$9.3 trillion would be needed between 2008 and 2030 to keep atmospheric CO<sub>2</sub> emissions below a concentration below 450 ppm (an approximation for the 2 degrees Celsius dangerous climate change threshold). Much of that investment will have to take place in developing countries. It has been estimated that climate stabilisation will require annual carbon flows of \$20-75 billion a year by 2020 and up to \$100 billion by 2030. These can be considered as ball-park figures for LCTFF financing requirements. An important principle is that the financing provided through the LCTFF would be *additional* and not be counted towards the fulfilment of carbon reduction commitments by developed countries.<sup>71</sup>

***Flexibility:*** Countries vary in the type of finance and support they require for making a low carbon transition. Low-income countries are likely to need highly concessional finance, including grants. For middle-income countries, especially those with high levels of private investment in the energy sector, trade finance and commercial risk mitigation through loan guarantees, insurance and other instruments may be more relevant. For energy utilities, whether public or private, subsidised risk insurance, advance payment guarantees, and performance bonds can significantly reduce the costs of construction and

technology. This is an area in which the World Bank's International Finance Corporation has extensive experience. One option might be for the IFC to manage the subsidy element in commercial risk provision. Note that over time a more efficient power infrastructure would yield cost savings and higher revenues. The proposal outlined here does not place the burden of financing entirely on donor funding. Instead, the primary role of the LCTFF would be to tap into public financing to subsidise and/or insure the upfront capital expenditure, without which cost-sensitive utilities in developing countries (whether in the public or private sectors) would end up adopting cheaper but more polluting technologies.

***Transparent and efficient processes.*** Eligibility for financing should be determined through a three step process. First, developing countries would review existing energy sector strategies with a view to estimating the technology and financing requirements of moving towards a well-defined mitigation target (for example, stabilisation of emissions by 2020). Detailed proposals would be drawn-up to identify the incremental costs of achieving the target, over and above current plans for efficiency gains. Second, the proposals would be submitted to a technical panel constituted under the LCTFF which would make recommendations to the Executive Board for the release of finance, linked to proposals for monitoring and evaluation. Third, resources would either be released (in the event of a positive proposal) or withheld subject to further clarification (in the event of a negative proposal). The Global Fund for HIV/AIDS, malaria and tuberculosis provides a working version of this model.

***Monitoring and verification:*** One way of reconciling the positions of developing and developed countries' concerns is to constitute a credible measurement, reporting and verification (MRV) system for technology transfer. MRV is meant to be part of the negotiations under the Bali Action Plan,<sup>72</sup> but most of the discussions have focused on mitigation actions and emissions trading. In 2009 negotiations are expected to develop metrics to review and assess the effectiveness of the implementation of provisions for technology transfer under the UN-FCCC (Article 4, paragraphs 1(c) and 5).<sup>73</sup> Any system that develops metrics for plant performance and not financial transfers would not be credible in the eyes of developing countries. Any system that measures and reports financial flows and not the efficiency of new plants would not get the support of developed countries. Only a partnership model of joint implementation and monitoring can satisfy the demands and concerns of all groups of countries.

***Equitable intellectual property management:*** It is not clear that intellectual property rights (IPRs) currently represent a major barrier to technology transfer.<sup>74</sup> However, this picture could change as new technologies come on stream. There is already some evidence that firms in India and China have struggled to gain access to cutting edge IGCC technology in coal-fired power generation, with leading firms unwilling to license technologies to potential competitors.<sup>75</sup> Such practices could restrict the access of local firms to the 'tacit knowledge' embodied in licensed technologies, something that Indian firms have expressed concerns about.<sup>76</sup> Where the objective of the recipient country is to strengthen domestic technological and absorptive capacity, strict IPR regimes may prove restrictive.<sup>77</sup> The danger is that more stringent enforcement of intellectual property rules

will increase the costs of technology transfer, hold back the introduction of breakthrough technologies, and disadvantage firms in developing countries. Against this backdrop, there may be a need for a provision analogous to the 2001 Doha Declaration allowing public health concerns to override certain claims of patent holders. Other approaches could include exploiting the flexibilities already available in the WTO TRIPS Agreement for compulsory licensing to facilitate access to low carbon and renewable technologies.<sup>78</sup> Further, firms in developed countries could also be pressed to forego patents on publicly-funded research.<sup>79</sup> In the case of climate change, there is a clear public interest in ensuring that low carbon technologies come on-stream as quickly as possible and that they are widely disbursed. The LCTFF could also be used to ‘buy-out’ patents and facilitate the public acquisition and licensing of low carbon technologies.

## **Conclusion**

Climate change negotiations have reached a critical point. There now appears to be a strong likelihood that negotiations scheduled to end in 2009 will spill-over into 2010. Delaying a deal comes at a price. The longer that it takes governments to agree binding multilateral targets for cutting greenhouse gas emissions, the deeper the subsequent cuts required to avoid dangerous climate change – and the stronger the likelihood of irreversible damage to the Earth’s climate system. While there are many elements required for a post-2012 framework, low carbon finance and technology transfer is a vital component. Developing countries have to be part of any global agreement. But in the absence of a commitment by rich countries to meet part or all of the incremental costs of lower emissions, developing countries face strong disincentives to enter a rules-based regime that enshrines commitments cuts and provisions for monitoring of compliance. Concerns over potential trade-offs between economic growth and poverty reduction on the one side and climate change mitigation on the other must be taken seriously. Creating a LCTFF of the type outlined in this paper would help to avoid the trade-offs and create incentives for developing countries to enter a post-2012 agreement.

The global financial crisis has pushed climate change down the political agenda. Yet the climate crisis poses a threat that is at once more systemic and more urgent. The threat is more systemic because of the scale and severity of the risks facing the Earth’s ecosystems. And it is more urgent because the underlying problem is cumulative and irreversible. Once emitted, many of the greenhouse gases that are driving climate change remain in the atmosphere for more than one hundred years. In effect, they constitute a non-negotiable carbon stock. Preventing that stock from reaching a critical threshold is arguably the defining challenge of the 21<sup>st</sup> Century. Failure to meet that challenge will have grave long-term consequences for the planet, along with more immediately adverse consequences for the world’s poorest countries and their most vulnerable citizens.

<b>ANNEX 1: Major proposals from developing countries on technology transfer and financing</b>				
<b>Date</b>	<b>Country</b>	<b>Document</b>	<b>Title</b>	<b>Key features</b>
13 August 2008	Mexico	<a href="#">FCCC/AWGLCA/2008/MIS C.2</a>	Enhanced action on the provision of financial resources and investment to support action on mitigation and adaptation and technology cooperation	World Climate Change Fund
13 August 2008	Korea	<a href="#">FCCC/AWGLCA/2008/MIS C.2</a>	Market-based Post-2012 Climate Regime: Carbon Credit for Nationally Appropriate Mitigation Actions	Selling NAMA credits
13 August 2008	Turkey	<a href="http://unfccc.int/files/meeting_s/ad_hoc_working_groups/lca/application/pdf/turkey_bap_100908.pdf">http://unfccc.int/files/meeting_s/ad_hoc_working_groups/lca/application/pdf/turkey_bap_100908.pdf</a>	Information, views and proposals by Turkey regarding paragraph 1 of the Bali Action Plan of the Ad Hoc Working Group on Long term Cooperative Action under the Convention	Technology Transfer Fund; sectoral approach
25 August 2008	G-77 and China (Philippines)	<a href="#">FCCC/AWGLCA/2008/MIS C.2/Add.1</a>	Financial mechanism for meeting financial commitments under the Convention	'New and additional' resources (0.5 to 1% of GNP); operate under COP, administered by trustees
26 August 2008	Ghana	<a href="#">FCCC/AWGLCA/2008/MIS C.2/Add.1</a>	Proposal on options for effective mechanisms and enhanced means for technology development and transfer	Incentives for adding value and credits; Technology Development and Transfer Board; Multilateral Technology Fund
26 August 2008	African Group (South Africa)	<a href="#">FCCC/AWGLCA/2008/MIS C.2/Add.1</a>	Adaptation and means of implementation	Financing and capacity building
27 August 2008	G-77 and China (Antigua and Barbuda)	<a href="http://unfccc.int/files/meeting_s/ad_hoc_working_groups/lca/application/pdf/technology_proposal_g77_8.pdf">http://unfccc.int/files/meeting_s/ad_hoc_working_groups/lca/application/pdf/technology_proposal_g77_8.pdf</a>	Proposal by the G77 & China for A Technology Mechanism under the UN-FCCC	Executive Body on Technology; Multilateral Climate Technology Fund; Technology Action Plan
28 September 2008	China	<a href="http://unfccc.int/files/kyoto_protocol/application/pdf/china_bap_280908.pdf">http://unfccc.int/files/kyoto_protocol/application/pdf/china_bap_280908.pdf</a>	China's views on enabling the full, effective and sustained implementation of the Convention through Long-term Cooperative Action now, up to and beyond 2012	Subsidiary Body for Development and Transfer of Technologies; Multilateral Technology Acquisition Fund
30 September 2008	Korea	<a href="http://unfccc.int/files/kyoto_protocol/application/pdf/korea_bap300908.pdf">http://unfccc.int/files/kyoto_protocol/application/pdf/korea_bap300908.pdf</a>	Proposals for AWG-LCA	Recognise carbon credits for NAMA

30 September 2008	Brazil	<a href="http://unfccc.int/files/kyoto_protocol/application/pdf/brazil_bap300908.pdf">http://unfccc.int/files/kyoto_protocol/application/pdf/brazil_bap300908.pdf</a>	Views and proposals on paragraph 1 of the Bali Action Plan	
30 September 2008	Argentina	<a href="http://unfccc.int/files/kyoto_protocol/application/pdf/argentinabap300908.pdf">http://unfccc.int/files/kyoto_protocol/application/pdf/argentinabap300908.pdf</a>	Enabling the Full, Effective, and Sustained Implementation of the Convention through Long-Term Cooperative Action Now, Up To, and Beyond 2012	Support for sectoral approaches
30 September 2008	Panama on behalf of Costa Rica, El Salvador, Honduras, Nicaragua, Panama	<a href="http://unfccc.int/files/kyoto_protocol/application/pdf/cehnp_anamasuggestion300908.pdf">http://unfccc.int/files/kyoto_protocol/application/pdf/cehnp_anamasuggestion300908.pdf</a>	The Bali Action Plan: Suggestion to move forward	Quota of technology and financial transfer; bidding for developing country projects; independent verification
17 October 2008	India	<a href="http://unfccc.int/files/kyoto_protocol/application/pdf/indiafinancialarchitecture171008.pdf">http://unfccc.int/files/kyoto_protocol/application/pdf/indiafinancialarchitecture171008.pdf</a>	Financing Architecture for Meeting Financial Commitments under the UN-FCCC	'new and additional grants'; 0.5% of GDP; international travel levy; funding verticals – Technology Acquisition and Transfer Fund; Climate Research Fund; Adaptation Fund
17 October 2008	India	<a href="http://unfccc.int/files/kyoto_protocol/application/pdf/indiatechtransfer171008.pdf">http://unfccc.int/files/kyoto_protocol/application/pdf/indiatechtransfer171008.pdf</a>	<a href="#">Technology Transfer Mechanism</a>	Full costs and full incremental costs; Executive Body on Technology; MCTF; TAP
2 December 2008	Alliance of Small Island States	<a href="http://unfccc.int/files/kyoto_protocol/application/pdf/aosisssharedvision021208.pdf">http://unfccc.int/files/kyoto_protocol/application/pdf/aosisssharedvision021208.pdf</a>	Shared Vision	
4 December 2008	India	<a href="http://unfccc.int/files/kyoto_protocol/application/pdf/indiafinancialarchitecture241208.pdf">http://unfccc.int/files/kyoto_protocol/application/pdf/indiafinancialarchitecture241208.pdf</a>	Financing architecture for meeting financial commitments under the UN-FCCC	
6 December 2008	Algeria	<a href="http://unfccc.int/files/kyoto_protocol/application/pdf/algeriasharedvision061208.pdf">http://unfccc.int/files/kyoto_protocol/application/pdf/algeriasharedvision061208.pdf</a>	An equity-oriented proposal for a shared vision for long term cooperative action	
6 December	Madagascar	<a href="http://unfccc.int">http://unfccc.int</a>	Shared Vision	0.5% of GDP for

2008		<a href="http://unfccc.int/files/kyoto_protocol/application/pdf/madagascarsharedvision061208.pdf">t/files/kyoto_protocol/application/pdf/madagascarsharedvision061208.pdf</a>		climate change in developing countries; international tax
6 December 2008	Pakistan	<a href="http://unfccc.int/files/kyoto_protocol/application/pdf/pakistansharedvision0606008.pdf">http://unfccc.int/files/kyoto_protocol/application/pdf/pakistansharedvision0606008.pdf</a>	<a href="#">Ideas and Proposals on para 1 of the Bali Action Plan</a>	Compulsory licencing; patent pools; limited time patents; Commission on Innovation, Intellectual Property Rights and Access to Climate Technologies
6 December 2008	Venezuela	<a href="http://unfccc.int/files/kyoto_protocol/application/pdf/venezuelabap060608.pdf">http://unfccc.int/files/kyoto_protocol/application/pdf/venezuelabap060608.pdf</a>	<a href="#">Ideas and Proposals on para 1 of the Bali Action Plan</a>	
6 December 2008	Turkey	<a href="http://unfccc.int/files/kyoto_protocol/application/pdf/turkeybap060608.pdf">http://unfccc.int/files/kyoto_protocol/application/pdf/turkeybap060608.pdf</a>	Information, Views and Proposals by Turkey Regarding Paragraph 1 of the Bali Action Plan	Technology transfer mechanism; technological information transfer agreement; technological information system and data pool
6 December 2008	Trinidad and Tobago	<a href="http://unfccc.int/files/kyoto_protocol/application/pdf/trinidadtobagotechnology061208.pdf">http://unfccc.int/files/kyoto_protocol/application/pdf/trinidadtobagotechnology061208.pdf</a>	Technology Transfer Framework and Modality under the Ad-Hoc Working Group on Long Term Cooperative Action	Technology objective; adaptation through climate proofing' projects; financial additionality; additionality verification
6 December 2008	Indonesia	<a href="http://unfccc.int/files/kyoto_protocol/application/pdf/indonesiainplementation061208.pdf">http://unfccc.int/files/kyoto_protocol/application/pdf/indonesiainplementation061208.pdf</a>	Means of implementation	Collaboration on technology transfer programmes; transparency; participation of SMEs
6 December	Federated States of Micronesia	<a href="http://unfccc.int/files/kyoto_protocol/application/pdf/micronesiabap061208.pdf">http://unfccc.int/files/kyoto_protocol/application/pdf/micronesiabap061208.pdf</a>	Ideas and proposals on paragraph 1 of the Bali Action Plan	Energy efficiency; carbon soot; sequestration
6 December	Bolivia	<a href="http://unfccc.int/files/kyoto_protocol/application/pdf/boliviabap08122008.pdf">http://unfccc.int/files/kyoto_protocol/application/pdf/boliviabap08122008.pdf</a>	Ideas and proposals on paragraph 1 of the Bali Action Plan	Integral Financial Mechanism for Living Well (1% of GDP)
6 December	Alliance of	<a href="http://unfccc.int">http://unfccc.int</a>	AOSIS Input into the Assembly Paper on	Assessed and

	Small Island States	<a href="http://unfccc.int/files/kyoto_protocol/application/pdf/aosisfinance061208.pdf">t/files/kyoto_protocol/application/pdf/aosisfinance061208.pdf</a>	Financing	voluntary contributions; auctioning; central fund for mitigation; international levies; IFIs; Multi-Window Mechanism to Address Loss and Damage from Climate Impacts
6 December	Alliance of Small Island States	<a href="http://unfccc.int/files/kyoto_protocol/application/pdf/aosistechology061208.pdf">http://unfccc.int/files/kyoto_protocol/application/pdf/aosistechology061208.pdf</a>	AOSIS Input into the Assembly Paper on Technology	
6 December	Chile	<a href="http://unfccc.int/files/kyoto_protocol/application/pdf/chilebap061208.pdf">http://unfccc.int/files/kyoto_protocol/application/pdf/chilebap061208.pdf</a>	Ideas and proposals on paragraph 1 of the Bali Action Plan	
6 December	China	<a href="http://unfccc.int/files/kyoto_protocol/application/pdf/chinasharedvision071208.pdf">http://unfccc.int/files/kyoto_protocol/application/pdf/chinasharedvision071208.pdf</a>	Shared Vision	Equitable allocation of carbon space
6 December	Guatemala on behalf of Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, Belize, Panama and Dominican Republic	<a href="http://unfccc.int/files/kyoto_protocol/application/pdf/guatemalaadaptation091208.pdf">http://unfccc.int/files/kyoto_protocol/application/pdf/guatemalaadaptation091208.pdf</a>	Compensation-Mechanism based on Adaptation. An approach for vulnerability reduction	
12 December 2008	Maldives on behalf of the group of LDCs	<a href="http://unfccc.int/files/kyoto_protocol/application/pdf/maldivesadaptation131208.pdf">http://unfccc.int/files/kyoto_protocol/application/pdf/maldivesadaptation131208.pdf</a>	International Air Passenger Adaptation Levy	Could raise \$8-10bn annually
<i>Source:</i> Compiled and analysed by authors				

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- <sup>1</sup> Meinshausen et al, 2009, 1158-1162. Also, Allen et al, 2009, 1163-1166
- <sup>2</sup> McKibben, 2009, 32-38
- <sup>3</sup> McKinsey Global Institute, 2008, pp. 11-12
- <sup>4</sup> Stern, 2008, pp. 32-34; Stern, 2009, pp. 111-115, 147
- <sup>5</sup> IPCC, Intergovernmental Panel on Climate Change, 2007,
- <sup>6</sup> IPCC, Intergovernmental Panel on Climate Change, 2007, p. 9
- <sup>7</sup> UNDP, United Nations Development Programme, 2007,
- <sup>8</sup> Watson, MacKerron, Ockwell, and Wang, 2007, 1-57
- <sup>9</sup> Barton, 2007, 1-35
- <sup>10</sup> Available at: <http://pmindia.nic.in/lspeech.asp?id=690>
- <sup>11</sup> India, 2008, p. 2
- <sup>12</sup> In 2006, an Expert Committee on an Integrated Energy Policy for India devoted only one and half pages to climate change in a 137-page report
- <sup>13</sup> India, 2008, p. 2
- <sup>14</sup> UNDP, United Nations Development Programme, 2007, p. 312; Chikkatur, 2008, p. 2
- <sup>15</sup> Chikkatur, 2008, p. 4
- <sup>16</sup> India, 2006, pp. xiii, 20-21
- <sup>17</sup> Chikkatur, 2009, p. 26. New technologies can enhance the coal extraction potential, an assumption on which some argue that India's reserves can last 200 years.
- <sup>18</sup> Rising demand combined with low efficiencies in extracting coal mean that coal imports could account for up to 45 per cent of coal demand by 2030. India, 2006, i-148
- <sup>19</sup> India, 2008, p. 20
- <sup>20</sup> 42% of commercial energy use in 2004/05.
- <sup>21</sup> India, 2008, pp. 3, 22-23. The ongoing 11<sup>th</sup> Five-Year Plan expects to save 10,000 MW of energy thanks to policies also already implemented since the Energy Conservation Act was enacted in 2001.
- <sup>22</sup> 11.27 GW of grid-interactive renewable power (bio-fuels, wind, small hydro, cogeneration-bagasse, waste-to-energy, solar) and 205.23 MW of captive renewable power. Calculation based on data from India, 2006, i-148 and India, 2008, 1-112.
- <sup>23</sup> India, 2006, pp. xxii-xxiii
- <sup>24</sup> Watson, MacKerron, Ockwell, and Wang, 2007, p. 38; UNDP, United Nations Development Programme, 2007, p. 152
- <sup>25</sup> MIT, Massachusetts Institute of Technology, 2007, p. 170; Watson, MacKerron, Ockwell, and Wang, 2007, p. 40
- <sup>26</sup> The potential to increase efficiency with the current plant stock is only 1-2 per cent with each percentage point increase in efficiency reducing coal use and CO<sub>2</sub> emissions by 3 per cent. Deo Sharma, 2004, 1-32. Despite the installation of a few demonstration plants, most future plants will continue to be based on subcritical PC technology. Chikkatur, 2008, p. 2
- <sup>27</sup> A comprehensive rating of available technologies can be found in: Chikkatur and Sagar, 2007, pp. 202-208
- <sup>28</sup> India, 2007, 1-480
- <sup>29</sup> Fluidised bed gasifiers were used in an IGCC pilot plant in the late 1990s, built by Bharat Heavy Electricals Limited (BHEL). Efficiency estimates of a new IGCC 100 MW plant being built by BHEL and NTPC range between 33 and 40 per cent, much higher than the current industry average in India. Chikkatur, 2008, p. 34
- <sup>30</sup> We assume that the building of plants would be evenly distributed each year during a particular plan period.
- <sup>31</sup> Chikkatur and Sagar, 2007, p.196. All estimates are in 2004 dollars.
- <sup>32</sup> Chikkatur and Sagar, 2007, p. 179
- <sup>33</sup> Sonde, 2005, 1-105
- <sup>34</sup> Calculated on the basis of Chikkatur and Sagar, 2007, Tables 33 and 34. Note that the costs are expected to reduce over the next decade, but would still remain significantly high.
- <sup>35</sup> A recent assessment ranks supercritical PC and CFBC as the best options 'in the present circumstances'. Chikkatur and Sagar, 2007, p. 206. IGCC and PFBC are rejected on account of low commercial maturity

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and high costs. Also, Ghosh, 2005, 1-104. Another study, which is heavily influenced by cost factors, lists sub-critical PC as the best technology for India (the environmental impact is ignored). Nexant Corporation, 2003, . This is why alternative options for financing the incremental capital costs of such efficient future technologies needs to be part of the calculus for Indian policymakers.

<sup>36</sup> There are currently over 4200 CDM projects in the pipeline, of which 1693 have been approved.

<sup>37</sup> Zenghelis and Stern, 2009, p. 309

<sup>38</sup> To take the Indian example again, an expert working group on the CDM had recommended that the government should approve projects not only based on contributions to national priorities and sustainable development, but also take account of the provisions for technology transfer, development assistance and foreign direct investment. India, 2003, pp. xxv, 69, 74

<sup>39</sup> UNFCCC, United Nations Framework Convention on Climate Change, 2008, para. 33

<sup>40</sup> By June 2008, India had already approved 969 projects, more than any other country (32 per cent of the global total registered with the CDM Executive Board). It ranked second only to China in the quantity of CERs issued (28.16 per cent of the global total). India, 2008, p. 47. But technology transfer provisions were included in 55.1 per cent of projects in China. Ockwell, et al, 2007, p. 8

<sup>41</sup> Ellis and Kamel, 2007, 1-50

<sup>42</sup> Government Accountability Office, United States, 2008, p. 7

<sup>43</sup> UNFCCC, United Nations Framework Convention on Climate Change, 2008, para. 60

<sup>44</sup> Hoffmaister and Ling, 2008

<sup>45</sup> Lin and Hoffmaister, 2008, 1-2. The G-77 representative claimed that the Least Developed Countries Fund could also be called the Least Developed Fund. Hoffmaister and Ling, 2008

<sup>46</sup> Barton, 2007, p. 3

<sup>47</sup> NZEC, 2007

<sup>48</sup> Carbon Capture & Sequestration Technologies @ MIT, 2009

<sup>49</sup> The CTF is one of two Climate Investment Funds approved by the World Bank Board of Directors in July 2008. The other is the Strategic Climate Fund, aimed at financing new development approaches.

<sup>50</sup> Müller and Winkler, 2008, 1-6

<sup>51</sup> The CTF Trust Fund Committee includes eight representatives from contributor countries and eight from eligible recipient countries.

<sup>52</sup> Requests for the authorisation of \$400m were included in the FY 2009 budget.

<sup>53</sup> Werksman, 2008, pp. 1-2

<sup>54</sup> Wheeler, 2008, pp.7-8

<sup>55</sup> Wheeler, 2008, p. 8; Werksman, 2008, p. 6

<sup>56</sup> IFC, 2008

<sup>57</sup> Nakhoda, 2008, p. 14

<sup>58</sup> Barrett, 2005, pp. 347, 349

<sup>59</sup> Barrett, 2005, p. 357

<sup>60</sup> Benedick, 2001, 71-76

<sup>61</sup> Other submissions can be found at:

[http://unfccc.int/meetings/ad\\_hoc\\_working\\_groups/lca/items/4578.php](http://unfccc.int/meetings/ad_hoc_working_groups/lca/items/4578.php)

<sup>62</sup> G-77 and China, 2008

<sup>63</sup> ICTSD, International Centre for Trade and Sustainable Development, 2008

<sup>64</sup> India, 2008

<sup>65</sup> Ghosh and Woods, 2009,

<sup>66</sup> UNFCCC, United Nations Framework Convention on Climate Change, 2009, p. 31

<sup>67</sup> World Bank, 2009, 1-73

<sup>68</sup> Norway, 2008, 1-3; Amb-Norwegia.pl, 2009

<sup>69</sup> Gomez Robledo, 2008, 1-8; Doyle, 2009

<sup>70</sup> GAVI Alliance, 2008, 1-68

<sup>71</sup> G-77 and China, 2008

<sup>72</sup> Paragraphs 1(b)(i) and 1(b)(ii). The latter is for ‘nationally appropriate mitigation actions’ by developing countries ‘*supported and enabled by technology, financing and capacity-building, in a measurable, reportable and verifiable manner*’ (emphasis added).

<sup>73</sup> Decision --/CP.14, paras. 2(a-d) and 3.

<sup>74</sup> Ockwell, 2008, 1-11

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<sup>75</sup> Lewis, 2007, 208-232. Barton (2007) finds that loosely structured industries are more conducive to the entry of new firms and offer more incentives for technology diffusion in developing countries. Barton, 2007, 1-35

<sup>76</sup>Ockwell, et al, 2007, . Wind power technology seems to be the most restricted, with GE pursuing litigation against infringements of its patents. Barton, 2007, p. xi

<sup>77</sup> Lewis, 2007, 208-232

<sup>78</sup> The flexibilities include: exemptions from patentability, exceptions to patent rights, and compulsory licences. Oliva, Meléndez-Ortiz, Roffe, Latif, and Gueye, 2008, pp. 5-7

<sup>79</sup> Barton, 2007, p. 20

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