Global Climate Network

Breaking Through on Technology

Overcoming the barriers to the development and wide deployment of low-carbon technology

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The Global Climate Network

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The Global Climate Network is a collaboration of independent, influential and progressive research and policy organisations in countries key to tackling climate change. Together, members of the Network are committed to addressing the constraints faced by sovereign governments in agreeing international action.

The Network aims to help governments clear a pathway towards an effective and fair international agreement for avoiding dangerous climate change by proposing bold low-carbon policies and using data and analysis to persuade policymakers that climate change mitigation is in their interest.

The Network is working to:

- Address the political (economic, social and cultural) constraints barring the way to action by bridging the divide between domestic and international policy
- Promote equitable solutions that take into account the huge development, financial and energy challenges countries face
- Champion ideas and innovations to help construct a new political narrative that links action on climate change with enhanced economic and social well-being.

Alone, each Global Climate Network member has significant credibility and influence. By producing joint research, staging events together and seeking to influence policy, the Network can help bridge the dangerous divide that exists and is currently widening between international negotiations and national politics.

The Network's members are:

- **Institute for Public Policy Research (ippr),** London, also acting as the secretariat for the Network: The UK's leading progressive think tank with a strong track record on research and policy.
- **Center for American Progress,** USA: Founded by John Podesta, former Chief of Staff to President Clinton.
- **Research Centre for Sustainable Development,** China: An institute of the Chinese Academy of Social Sciences. Dr Jiahua Pan, its director, is one of 12 members of the Chinese Experts Committee for Climate Change.
- **The Energy and Resources Institute,** India: The country's leading climate and energy research institute whose director, Dr Rajendra Pachauri, chairs the UN's Intergovernmental Panel on Climate Change and is a close adviser to the Indian government.
- **Wuppertal Institute for Climate, Environment and Energy,** Germany. Wuppertal Institute's ground-breaking climate change work is led by Dr Hermann Ott.
- **Vitae Civilis,** Brazil. Dr Rubens Born, Vitae Civilis's director, has had significant input into the Brazilian government's recent climate change plan.
- **International Centre for Energy, Environment and Development,** Nigeria. ICEED has expertise in climate change and energy policy.
- **The Climate Institute,** Australia. Set up in 2005, the Institute is a leading Australian voice in climate research and advocacy, pioneering clean technology and investment solutions with government and business.
- **IMBEWU Sustainability Legal Specialists Pty Ltd,** South Africa. An influential Johannesburg-based legal consultancy specialising in sustainability law with a strong climate change focus.

Dr Rajendra Pachauri (see above) and Lord Chris Patten of Barnes, former European Commissioner for External Affairs, are the Network's first patrons.

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Executive summary

Technology is critical for human development and progress. The fight against climate change will not be won without a revolution in the use of existing low-carbon technology and a tidal wave of new inventions. Yet the importance of doing that, especially in healing the rifts in international climate negotiations, is not yet being recognised.

The Global Climate Network asked more than 100 experts from government, private sector firms, academic institutes and non-governmental organisations in eight countries (Australia, Brazil, China, Germany, India, Nigeria, South Africa and the United States) for their views on the barriers to the 'development and transfer' of low-carbon technology. Their responses are detailed and complex but below we draw together our key findings, conclusions and recommendations.

Success at the United Nations Framework Convention on Climate Change Conference of the Parties meeting in Copenhagen in December depends on agreement being reached in each of the five areas currently under negotiation. But without a firm commitment to develop and transfer new technologies, with industrialised countries taking the lead on financing these endeavours, consensus will be difficult to reach and, in practical terms, emissions will be hard to reduce, at least without unacceptable penalties to human development, social cohesion and economic wellbeing.

Low-carbon technology development and transfer

Technologies, of all types, developed in one jurisdiction are regularly transferred to another but there is a long and largely unhappy history to the debate concerning technology transfer from developed to developing countries. This has been evident in climate negotiations. The challenge for an international negotiation in which technology transfer is an existing legal obligation on the part of developed countries is how such a process can best facilitate, support and enable strong domestic policies. For many developing countries building indigenous capacity to innovate, manufacture and export is as important as buying in equipment and skills.

Finance has a crucial role. It is perhaps through the financing agenda that the negotiations can make the most difference to the development and transfer of low-carbon technology by helping to support developing countries to meet the cost of low-carbon technology policies and minimise the potential trade-offs, such as increased taxation, changes in energy tariffs and regulation, all of which will increase costs ultimately levied on the taxpayer or consumer.

Intellectual property (IP) law can also act as a barrier and measures to encourage companies to use or relinquish IP (and in some circumstances to use the flexibility already available through the World Trade Organisation's TRIPs agreement) may be necessary. Yet IP is central to innovation and important to vertical transfer as it provides competitive advantage to technology developers.

Key findings

1. The importance of technology

The emphasis in the technology debate should be placed not only on mitigating and adapting to climate change but also on sustainable human development and, in particular, on poverty alleviation. Low-carbon technology should therefore be celebrated as a means by which countries can address human needs and reduce poverty, develop new economic opportunities and markets and create good quality jobs.

2. Finance goes hand in hand with technology development and transfer

Participants in the study from both developed and developing countries identified lack of access to finance, both private and public, as a barrier to technology development and deployment. Most low-carbon technologies require high up-front investment and may be more costly to deploy than carbon-intensive alternatives. Therefore while the focus on finance in the negotiations has been on either establishing carbon markets or on new funding mechanisms, other, often government-led, financing initiatives may be necessary. Although in the longer term the private sector will be

the major source of low-carbon finance, government money is needed early on to make new technologies cheaper and less risky.

3. Domestic low-carbon policies are woefully inadequate

While no government is building from scratch, in all eight countries, the absence of a long-term low-carbon policy framework or coherent set of policies appears to be a major impediment to the development and deployment of low-carbon technology. Interviewees in all countries were in favour of government intervention to address technology barriers and most felt that domestic low-carbon strategy with strong political support, often lacking in some quarters, was essential. Consequently, more keenly focused government policies are desperately needed, including regulating on carbon standards and providing clear, targeted incentives and tax breaks.

4. Knowledge and capacity are as important as equipment

Technology transfer is not wholly or perhaps even mostly about the movement or licensing of equipment from jurisdiction to jurisdiction (although clearly some early climate and political victories might emerge from ensuring this happens). It also concerns the development of skills and know-how in order to use equipment and to innovate in the future. In developing countries in particular, interviewees identified a lack of skills and know-how to deploy low-carbon technology.

5. Intellectual property rights need careful attention

In some cases stronger observance and enforcement of IP rights might encourage technology developers to roll out new technology in more jurisdictions more quickly. In others, the costs of licensing (as distinct from wholesale purchase of IP by governments) could be another focus of financial support by developed country governments, a *de facto* subsidy to developers of low-carbon technology.

Recommendations

1. Put technology at the heart of climate negotiations

More emphasis should be placed on technology in the climate change debate especially in the ongoing UNFCCC negotiations: recognising its role in enabling countries at all stages of development to reach environmental and sustainable development goals simultaneously is critical.

2. Create focused incentives for technology deployment

The key technologies identified in this study require focused incentives. These might include new tariff structures, the removal of established energy subsidies and government-led finance to reduce the higher risks associated with large scale low-carbon technology deployment.

3. Link technology and finance in international talks

International processes, such as the UNFCCC, should focus on how developed country governments and private sector financiers can support the development of incentives in developing countries, such as meeting the cost of feed-in tariffs and helping to reduce the negative social impacts of removing fossil fuel subsidies.

4. Develop national low-carbon technology strategies

Beyond the UNFCCC negotiations, leadership countries at different levels of development should establish low-carbon technology strategies. Such initiatives could attract formal recognition and finance within a future international framework.

5. Give an urgent boost to R&D initiatives

Calls for an increase in low-carbon R&D spending must be taken seriously. Governments should increase their support for R&D at the national level as part of their national low-carbon technology strategies and increased R&D finance. A major, International Technologies Initiative to accelerate R&D should be a key part of any new international framework for action.

6. Pilot joint learning and capacity-building

One clear area that could benefit from international agreement is in the sharing of technical knowledge, through capacity-building and mutual learning programmes.

7. Establish joint innovation for future technologies

The GCN believes a new International Technologies Initiative is necessary, in which regional and global innovation 'hubs' would provide a focal point for collaboration on the development of breakthrough low-carbon technology. An international network of low-carbon research, development and demonstration initiatives could also help in future to overcome the barrier posed by IP.

8. Reward technology risk-takers with strong IP

The developers of existing technology, some of which is subject to patents restricting its generic manufacture and use, should be assured of strong enforcement of their IP if they license and do so at reasonable cost. Conversely, patents could be withdrawn if developers who are guaranteed protection do not seek to deploy technology.

9. Develop new technology collaboratively

In future, low-carbon innovation could be driven by collaborative initiatives, such as the International Technology Initiative above. Technology might therefore be open access, with an emphasis on a sharing of equipment, but also on the development of locally appropriate versions.

1. Introduction

Technology is central to human progress and economic development (Stiglitz 1994). Facing up to the climate and development crises simultaneously requires technological innovation to be driven rapidly in the direction of low-carbon and high efficiency (Stern 2006) and for access to the benefits of this process to be widespread. Governments, acting at the national level and through international collaboration have a significant role to play in this process.

Market failure (Hutton and Schneider 2008, inertia in public policy and a reliance on carbon-based energy are constraining technological innovation and its widespread use, especially at the global level (Perez 2002). Attempts over two decades to stimulate the development and transfer of low-carbon technology (to developing countries in particular) through the UN Framework Convention on Climate Change (UNFCCC) process have been largely unsuccessful. This is perhaps not the fault of the climate talks per se but of public policy in general, often at the domestic level, and of markets.

The faltering nature of technology processes in the UNFCCC is also the result of a long-standing political divide between developed and developing countries over the very process of development (Ockwell *et al* 2008). Developed countries – Japan, the United States and Germany in particular[1] – are the main inventors and largely, therefore, owners of 'climate-friendly' technologies[2]. These countries, listed in Annex II of the UNFCCC, have an obligation under its Article 4 to transfer technologies to developing countries.

The legal obligation of developed countries to transfer technology is beyond dispute. However, many of those exposed to this obligation argue that it is best fulfilled through the creation of robust markets in which goods can move freely, intellectual property rights are upheld in each jurisdiction and carbon-intensive production is crowded out by pricing emissions. However, there is a strong correlation between the countries in Annex 1 that have this legal obligation and the jurisdictions in which low-carbon technologies are owned (Sangeeta 2009), suggesting that they are well placed to gain from the development of free markets.

Developing countries, on the other hand, argue that substantial, global intervention is necessary to ensure developed countries fulfil their obligations, for instance through intellectual property buy-outs and the establishment of a global technology fund under the Conference of the Parties to the UNFCCC. Parallel World Trade Organisation negotiations and the failure of other global processes have eroded trust. Thus, developing countries want tangible proof of the willingness of developed country governments to enable technology transfer and, perhaps most importantly, the development and production of new technologies in developing countries.

This study, drawing on primary research and reviews of national policies in eight countries and additional, international analysis where necessary, suggests that effective development and 'transfer'[3] of low-carbon technology requires a complex combination of factors that lie both inside and outside of the aegis of the UNFCCC. Its findings emphasise the importance of technology to all countries, underlining an urgent need to place technology 'front and centre' of the negotiations and to find the means and mechanisms to support and enable strong national policymaking through an international framework.

Findings from the eight national studies also emphasise the importance of finance. Without finance, innovation and technology deployment, especially through the infamous 'valley of death' between research and development and commercial use, will be constrained. This intrinsically links the technology and finance pillars of the current UNFCCC negotiations; finance will be needed to ensure key technologies are pushed through these phases and deployed globally. Indeed, financing through a post-2012 climate agreement and through much-needed reforms in global institutions, appears fundamentally linked to the sustainable and progressive deployment of new technology (Perez 2002).

Through the lens of the climate change negotiations, the barriers to the development and transfer of low-carbon technology are also somewhat distorted. The research underlines the obvious but

1. These three countries hosted more than two-thirds of climate friendly inventions between 1998 and 2003. See Dechezleprêtre *et al* 2008.

2. In this study, specific climate-friendly technologies are identified in each country by interviewees and national strategies and policies but in general are those that lead to the mitigation of greenhouse gas emissions, particularly low-carbon technologies.

3. In interviews in many of the case study countries, the term 'transfer' was challenged many times as being inadequate and sometimes inaccurate as a means of describing the complex, dynamic process of low-carbon innovation, or at least how such a process might be made to work.

important point that low-carbon technology faces similar transfer and deployment barriers as other forms of new or emerging technology.

2. The Global Climate Network's methodology

One of the key strengths of the Global Climate Network is its access to a range of policy- and decision-makers in countries in which its members are based. Thus, its methodological approach to collaborative work is focused on interpreting and summarising at the global level a body of qualitative data from authoritative domestic sources.

The research underpinning this paper took place in eight countries – Australia, Brazil, China, Germany, India, Nigeria, South Africa and the US – supplemented by a review of the literature and policy at the international level.

This project was approached in three stages:

1. The GCN's secretariat, based at ippr in London, reviewed the literature on low-carbon technology transfer and innovation (see Section 3 below for a summary of this review).

2. GCN members in each participating country reviewed similar literature at the national level and also reviewed existing relevant government policy frameworks.

3. Between January and March 2009, more than 100 people in eight countries were interviewed about their views on barriers to and policies that would encourage low-carbon technology development and transfer. Representatives from government departments (including industry, finance, business and planning ministries), state and private sector enterprises, academic institutions and non-governmental organisations took part in interviews. Views and specific responses are not attributed in either this paper or national summaries of it, but a list of all interviewees is available.

Throughout, the team of researchers – one in each of the participating GCN member organisations and one in the secretariat – took part in regular teleconferences at which interview questions and common approaches were agreed and progress and interim findings were discussed. The agreed question areas can be found in Section 4 below.

There are limitations to the scope of this study. While more than 100 individuals were interviewed across the eight different countries in which research took place, the population of the survey in each country is small at 10 to 15 people. It is the knowledge of the people interviewed and the quality of their response that the GCN sought to gain rather than an exhaustive quantitative approach. Nevertheless, the findings represent the views of those interviewed and are indicative of the challenges facing the development and transfer of low-carbon technology.

Participating members are individually publishing and disseminating a summary of national findings, a précis of which is compiled in Section 4 of this paper.

3. Low-carbon technology development and transfer

There is a wide-ranging debate – particularly pertinent in the current global economic climate – surrounding the importance of innovation and technology to economic development and governments' role in facilitating technological progress versus the role of the free market. Classical economic theory assumes that access to necessary technology is unrestricted, but in practice, as many have observed, the innovation process – research and development, demonstration and deployment – requires intervention (Stiglitz 1994, Stern 2006, Hutton and Schneider 2008).

This paper is concerned with low-carbon technologies and their widespread transfer to help mitigate greenhouse gas emissions at the same time as enabling economic and human development to

continue, especially in developing countries. However, as many of those interviewed during the course of the GCN's research have argued (see Section 4 below), there is little effective difference between the development and transfer of low-carbon and other new technologies. The barriers faced are similar (see GCN national summaries at www.globalclimatenetwork.info).

There are, therefore, arguably three layers to consider in assessing barriers to the development and transfer of low-carbon technology:

1. **In practice.** A whole range of technologies – low-carbon or otherwise – developed in one jurisdiction are regularly transferred to another through trade, inward investment, licensing, mergers and acquisitions, pirating and by other means. Many lessons regarding the faster and wider deployment of low-carbon technologies and the policies required to direct technology may be learnt from examples beyond the low-carbon group of technologies.

2. **In principle.** There is a long and largely unhappy history of debates in international processes concerning technology transfer in general, which tend to be split along developed-developing country lines. For instance, the Doha Round of World Trade Organisation negotiations established a Working Group on Trade and Transfer of Technology at the request of developing countries. Like the Expert Group on Technology Transfer, its equivalent in the UNFCCC process, it has faced questions as to its effectiveness (South Centre 2005).

3. **In international climate law.** Under Article 4.5 of the UNFCCC, developed countries have an international legal obligation to '… take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how' to developing countries. This places the debate about low-carbon technology transfer firmly within the political context of the UNFCCC process.

While much attention in the low-carbon technology debate has been focused on the third of these layers, the lessons of the first and second along with the wider debate about innovation and technology are of high importance. This is underlined in Section 4 below and particularly in the interviews GCN member conducted with private sector representatives. The argument is supported by the data on the transfer of low-carbon technologies to date, which suggests that its rate of transfer, measured as a percentage of low-carbon inventions that are patented in more than one country (25 per cent), is not significantly different from the rate of transfer of other technologies (Dechezleprêtre *et al* 2008).

It is also important to clarify the concept of 'transfer'. Technology transfer takes place both vertically through the innovation chain and horizontally from one user to another (see Ockwell 2008b), often crossing jurisdictions 'for the purposes of economic gain' (Schnepp *et al* 1990, Ockwell 2008b). Both types involve not only equipment, but also the means to use the equipment, know-how and skills (UNCTAD 2007). For many developing countries and companies, there is also an important distinction between importing equipment and know-how and developing homegrown capacity to innovate, manufacture and export. In essence, then, the debate surrounding technology transfer is as much about pure economic competitiveness – of firms and of whole economies – as it is about a desire to deploy technology in the public interest (Tomlinson *et al* 2008). It is also as much about know-how and skills as it is about equipment.

Ahead of its *Third Assessment Report*, the Intergovernmental Panel on Climate Change (IPCC) produced a comprehensive review of low-carbon technology literature. It defines technology transfer as:

> 'a broad set of processes covering the flows of know-how, experience and equipment for mitigating and adapting to climate change among different stakeholders such as governments, private sector entities, financial institutions, NGOs [non-governmental organisations] and research/education institutions' (IPCC 2000).

The report's *Summary for Policymakers* illustrates how moribund the UNFCCC technology transfer debate has been since. Thematically, it covers all the areas – capacity-building, enabling

environments, different industrial sectors, governance – that are currently looming large in the negotiations and being debated by the Expert Group on Technology Transfer (EGTT). The EGTT was first constituted in 2001 at COP 7 in Marrakech. It is now one year into a new, five-year mandate, which includes helping to implement technology needs assessments (UNFCCC 2007a). More than 50 non-Annex 1 countries (developing countries and economies in transition) have either completed technology needs assessments (TNAs) or have published interim or partial studies.[4] Typically, these assessments list the technologies seen as important by governments for mitigation, adaptation and developmental needs and estimate their potential and cost. The purpose of this process is to 'assist in identifying and analysing priority technology needs' so that Article 4.5 of the UNFCCC can be implemented.

4. See http://unfccc.int/ttclear/jsp/CountryReports.jsp for a list of countries and to read the TNAs or interim studies and UNFCCC 2006 for a synthesis of TNAs.

However, as Third World Network (2008) observes: 'Despite the central role of technology transfer [in negotiations], there has been in fact very little, if any, practical transfer of climate-friendly technology under the UNFCCC. The operation of the principles, the establishment of mechanisms, and the actual transfer of technologies have yet to be put into effect. These are now urgent tasks.' While perhaps over pessimistic, as the Clean Development Mechanism (CDM) has led to wider use of some technologies, technology is nevertheless one of the issues in the negotiations that has eroded trust between developed and developing countries.

Some have attempted to articulate how the UNFCCC technology deadlock might be broken (E3G 2008) and to identify the need to link measures taken inside the negotiations and outside (Egenhofer *et al* 2007). However, there is still an evident disconnection between the transfer of technology in practice and of governments' role in this process on the one hand and the politics of technology transfer between developed and developing countries, particularly within the UNFCCC, on the other. Aside from the developed-developing country politics, the significance of which cannot be underestimated, one of the key reasons for this is that there 'is no "one policy fits all" solution to facilitating low carbon technology transfer' (Ockwell *et al* 2008). The GCN research summarised in Section 4 below supports this view and underlines the importance of domestic policy and political support for low-carbon technology – in developed and developing countries – as well as the implementation of the UNFCCC through enabling measures on technology.

The importance of domestic policy in the innovation process, including in deployment of technologies, is underlined by an increasing number of real world experiences. That of California in, for instance, imposing 'tailpipe' (exhaust pipe) standards to encourage the development of low-carbon (zero emissions) vehicles is one such example (Bird 2008). In Europe, Germany, Spain and Denmark have built offshore wind industries off the back of strong, clearly directed domestic regulation and economy-wide policy (Bird 2009).

Thus an absence of a strong domestic policy frameworks (either sector specific, such as feed-in tariffs, or across sectors, such as carbon pricing) and accompanying regulations and incentives to encourage the development and widespread use of low-carbon technology in any one economy is one of the most profound barriers of all (GCN national summaries, 2009). The challenge for an international negotiation in which technology transfer is an existing legal obligation on the part of developed countries is how such a process can best facilitate, support and enable strong domestic policies in key countries.

One key area is finance. Both cross-economy policies, such as taxation or changes in energy tariffs, and regulations will increase costs, which will ultimately be levied on the taxpayer or consumer. This makes low-carbon technology policy potentially unpopular and therefore politically unattractive (Lockwood and Pendleton 2009). This is likely to be the case in developing countries where public expenditure is highly constrained and consumers are profoundly sensitive to price increases.

The GCN research strongly supports this view and links the financing pillar of the negotiations very strongly with low-carbon technology. It is perhaps through the financing agenda that the negotiations can make the most difference to the development and transfer of low-carbon technology by helping to support developing countries to meet the cost of low-carbon technology policies and other measures, such as support for research and development (R&D).

Intellectual property

A further barrier to technology transfer that merits mention is intellectual property (IP) law. There is little doubt in the literature that IP is a barrier constraining horizontal transfer of technology. Yet IP is central to innovation and important to vertical transfer as it provides competitive advantage to technology developers; it is, in effect, a government-led intervention to support developers of technology to obtain a return on their investment (Stiglitz 1994).

Some argue that IP plays a limited role in some low-carbon technologies because it is a low proportion of the costs of production relative to other technologies, such as pharmaceuticals. They argue too that key sectors – wind, solar PV, biofuels – are reasonably competitive and so royalties are unlikely to be high (Barton 2007). Others point to the fact that limited transfer of low-carbon technology has taken place and that IP may be a barrier because many of the technologies concerned are patented, and that IP owners may find ways to limit or increase the cost of licensing (Third World Network 2008).

In fact, it is likely that there is no hard and fast rule, as the behaviour of patent holders and the proportionate cost of IP will vary from technology to technology and from market to market. The few studies focusing on IP as a barrier to the transfer of Environmentally Sound Technologies (ESTs) published hitherto do not provide the data required to draw a definitive conclusion (Ockwell 2008a).

The issue of competitiveness is the key to the IP conundrum (E3G 2008). So while Barton (2007) may be correct in observing that R&D is a small proportion of eventual costs in some key technologies and that competition between firms in these technologies is sufficient to keep the cost of licensing low, IP remains a means by which firms can maintain a competitive edge and prevent new entrants to their markets. And as long as the majority of new patents in low-carbon technologies are registered in developed countries, in particular the EU and Japan (Sangeeta 2009), IP is likely to remain an issue of political significance in international climate negotiations and processes.

The GCN's research underlines some of these conclusions, illustrating that IP is important in some cases and some countries and that measures to encourage companies to use or relinquish IP (and in some circumstances to use the flexibility already available on IP through the World Trade Organisation's Trade-Related Aspects of Intellectual Property Rights [TRIPs] agreement) may be necessary. However, in other cases, it appears either that IP is relatively unimportant in comparison with other material factors discussed above (which include the availability of local skills, know-how and ongoing capacity to maintain and upgrade technology along with associated soft technologies) or more robust IP protection is required at the national level before patent owners will invest themselves or license (GCN national summaries 2009).

For the UNFCCC to have influence the issue of IP needs to be taken into consideration, both in the case of existing technologies whose widespread use will reduce greenhouse gas emissions immediately, and in the case of innovation, which could have far greater mitigation potential in the future. Alongside providing finance to increase low-carbon R&D by between two and five times globally (Stern 2006), technology negotiations should examine how best to ensure IP is not obstructive once its fruits are brought to market. Collaboration among governments appears the best way to achieve this (Ockwell 2008a, E3G 2008). The GCN's research also suggests that there is disagreement on IP between public and private sector interviewees.

4. Low-carbon technology: findings from Global Climate Network interviews

More than 100 key figures from relevant government departments (trade, industrial, planning, development and environment), private sector firms, academic institutes and non-governmental organisations were interviewed by the GCN in eight countries (Germany, China, India, Australia, United States, Brazil, South Africa and Nigeria). Researchers from each of the eight GCN member

organisations followed an interview format and areas of inquiry that were agreed collectively beforehand. The brief summary of findings below is grouped into the areas of inquiry.

Question 1: Key sectors

In what key sectors are clean/low-carbon innovation and technology development and deployment envisaged?

Responses

- Not surprisingly, the **energy sector** (primary energy and electricity production) was identified in all eight countries as a top priority for development and deployment of low-carbon technology.
- Within the energy sector, many of the national studies identified **carbon capture and storage and clean coal** to enable the continued use of fossil fuels as being key and a primary candidate for rapid development and early deployment.
- Interviewees from Nigeria, out of the eight the country the most dependent on revenues from **oil and gas**, also unsurprisingly identified this sector as having 'important potential for reducing emissions'.
- As a corollary of the above, **renewable energy** was seen in all the countries as being of key interest although with some reservations (from India[5]). This broad category included the usual suspects – in particular wind and solar PV (photovoltaic) – in most cases. In addition there was interest in hydropower – small hydropower (Brazil) and hydropower in general (India, Nigeria).
- Other sectors mentioned by interviewees included the manufacturing, transport and automotive industry, waste management, mining, chemical, metal and cement industries, and agriculture.
- **Energy efficiency** was almost universally highlighted as a key priority in the building and transport sectors (by Germany, China, India, Brazil in particular), and in industry, agriculture and forestry. Greater energy efficiency was seen as a 'low hanging fruit' which could be achieved with comparative ease in the short term (US).
- In Brazil, indirect technologies for the processing and industrialisation of tropical forestry products, direct seeding in the Amazon and new diets for cattle herds to reduce methane emissions were also raised as options.
- 'Supportive sectors' including the **mechanical, electronic and IT** sectors were highlighted as also being worth of attention (South Africa).

Question 2: Government policy

Is there a guiding industrial or economic policy in which these key sectors are identified and, if so, what are its objectives?

Responses:

One of the overriding findings of this study is that adequate domestic policy to steer and provide certainty to capital investments in low-carbon technologies is lacking in all countries. However, each has a variety of policies and legislation either to set direct strategy for action on low-carbon technology or to influence technology development and transfer indirectly through measures to increase energy efficiency and renewable energy or to reduce emissions. These are set out by country below.

- **Germany:** The 'Ecological Industrial Policy' sees Germany as a forerunner in climate policymaking and a global provider of environmental technology and services. To date, policies for transfer of technology to other countries are less developed.
- **China:** Policies are in place setting out plans for energy mix, emissions reduction, energy conservation and renewable energy targets/measures. In addition, technology development policies were outlined in the National Climate Change Programme including to increase spending on R&D from US$2.5 billion for 2001–2005 to $7 billion for 2006–2007.

5. Even though all the Indian interviewees noted the significance of renewable energy, it was stressed that for the next 20 to 30 years their contribution to the energy supply might not be adequate.

- **India:** The country's 'Vision 2020' has a strategic goal of transforming India into a developed nation and a knowledge economy, and includes policies to promote industrial R&D investment in renewable energy and energy efficiency sectors.
- **Australia:** Policy initiatives at the local and state level have been constrained by inaction at the federal level. Recent government commitments include short- and long-term emissions reduction targets, a renewable energy target, emissions trading scheme, energy efficiency strategy and fiscal support for low-carbon technologies. However, significant legislative uncertainty exists around many of these measures.
- **United States:** Despite the perceived importance among interviewees of a comprehensive national energy policy, such ideas remain at a nascent stage. Industrial policy is being developed at state level, with California particularly active in pushing new energy technologies such as solar. A cap and trade bill (the Waxman-Markey bill), which contains many other measures, is beginning its journey through Congress.
- **Brazil:** Brazil has only recently started to think once again in terms of short-, medium- and long-term planning policies (the sugar cane ethanol programme, which began in the 1970s, is a good example of this type of planning in the past). Interviewees indentified a lack of government policy to guide private sector investment in most renewable sectors (except biofuels and hydro), and a lack of policy on technological development for the forest sector. New government plans (Programme for Accelerating Growth, Productive Development Policy and Technology and Innovation) prioritise R&D. The country has plans of action that present lines of thought but do not identify specific needs, policies and priorities.
- **South Africa:** It is the government's stated goal to 'develop a plan of action which is economically risk-averse and internationally aligned to the world effort on climate change' (Long Term Mitigation Scenario: Strategic Options for South Africa, 2007). The policy mix is to include command-and-control, market-based and voluntary instruments by 2012, with a related fiscal, legislative and regulatory package.[6]
- **Nigeria:** The African country suffers from a vertically integrated and centralised energy market that is dependent on centralised fuels; and from weak market development policies and regulatory frameworks.

Question 3. Objectives of low-carbon technology development and transfer

In key sectors, what are the objectives of innovating and demonstrating new technologies and deploying existing technology?

Responses

- Many interviewees (especially those from China, South Africa and Nigeria) identified economic growth as the key objective in developing and deploying low-carbon technology, particularly to decouple growth from emissions and a reliance on fossil fuels (in the case of Nigeria, this was to address over-reliance on crude oil exports).
- Many (especially China, India, South Africa and Nigeria) therefore felt that clean technology development and transfer had to be aligned with macro-economic (and social) objectives, including: sustainable development, economic competitiveness, job creation, poverty alleviation, energy access and security, poverty alleviation, modern energy access and food security.
- In the US the focus for clean technology development is more on maintaining economic competitiveness and spurring job creation in the clean energy sector.
- Indian interviewees identified energy security as a primary driver: 'a cleaner environment is seen as a co-benefit instead of the main objective.'
- For Germany, the objective is achieving a 'zero carbon energy economy' at home by 2050, and promoting the model abroad, as well as economic development and competitiveness.

6. Cf. Final National Climate Change Response Policy Discussion document (2009). The South African government 'is committed to ensuring on-going and increased support for new and ambitious research and development initiatives in the field of carbon-friendly technologies – with the focus on the renewable energy and transport sectors' (p 19).

- Australian interviewees saw developing new, low-emissions export industries as being equally as important as domestic carbon abatement objectives.
- Some private sector interviewees (from South Africa) saw technology as the principle means for firms and sectors to comply with environmental legal requirements, and to improve performance, efficiency and cost effectiveness.
- Exploiting opportunities through the Clean Development Mechanism and other market-based initiatives was highlighted by South Africa and Nigeria.
- National environmental concerns (for Nigerians the pollution of the Niger Delta and desertification in the North, for instance), domestic adaptation to climate change and consideration of the need to reduce emissions to remain competitive economically (South Africa) were also important.

Important technologies for early deployment: *Which new and already developed technologies are most important between now and 2020?*

- **Solar PV and thermal** (South Africa, India, China, Australia, US, Nigeria and Brazil) was the most cited technology; seen as relevant, cost-effective and with most energy/emissions abatement potential; 'one of the most important sources of clean power generation in the country' (Indian interviewee). Some governments (South Africa, Australia and China) have a desire to build a 'new competitive advantage' in solar technology in order to become a 'market leader, with government providing supporting measures' (South Africa).[7] Most interviewees in the US cited the potential of solar technologies and acknowledged that they were attracting a significant amount of venture capital. Brazil is considering the best way to implement feed-in tariffs and has one of the world's largest silicon reserves. Purifying silicon to solar grade could be a way to put Brazil into the global solar market.
- **Wind** (China, India, Brazil, US, Australia, Germany and – with mixed views – South Africa) was also often cited as important in the short term, with developing countries using it widely (India is 'fast becoming one of the pioneers in manufacture of [wind] technology' and China is looking for '[L]ow-cost and scale exploitation and utilization'). Wind power is the fastest growing energy sector in the US and now employs more people than the coal sector.
- **Clean coal, carbon capture and storage and IGCC** (integrated gasification combined cycle) (China, India, Australia, US, South Africa, Germany, Nigeria) is another indispensible technology, which is seen as 'necessary' (China) and as 'an area for Australian leadership'[8], and is already the focus of R&D (South Africa). The importance of related infrastructure was also mentioned, including pipelines to transport CO2 away from coal-reliant areas that cannot sequester carbon due to local geological characteristics (US). In addition US interviewees stressed the need to solve liability questions around the storage of CO2 as a necessary precondition for successful implementation of the technology. In India, clean coal and IGCC technology was seen as a high priority by all interviewees, while some expressed security and cost concerns with CCS and one participant questioned whether it would even serve as a barrier to the development of more efficient technologies.
- **Energy efficiency** is mentioned by many interviewees in most national summaries, but covers a very wide range of technologies, from buildings design and components (India) to co-generation in agricultural processing (South Africa) and in other sectors (Brazil) and use of geothermal devices (China and Australia).
- **Biofuels** (India, South Africa and Brazil) are seen as offering considerable potential, either to meet domestic energy demand (India) or for export. Brazil has developed a strong bio-ethanol industry as a result of government industrial policy in the oil crises of the 1970s, which others seek to emulate and innovation in the production of algae for biofuel is also mentioned (Australia). Advances in biofuels in the US are currently ensnared in disputes about federal subsidies for some fuels (especially corn ethanol) over others. Second generation biofuels have

7. South Africa's 'National Climate Change Response Policy', Discussion Document, 2009.

8. One Australian interviewee noted: 'if Australia wants to keep expanding coal exports, then it has a moral obligation to make CCS [carbon capture and storage] a viable technology.'

potential to achieve significant greenhouse gas emissions reductions, increase the volume of biofuels to internal and external markets and facilitate the production of biofuels in more areas.

- **Electric vehicles, battery technology** (India, China and South Africa) and hydrogen fuel cell innovation (India and South Africa) are already being pursued, while battery storage technology is receiving increasing state and federal funding (US).
- In addition, interviewees mentioned **wave power** technology (US, South Africa), **small-scale hydro-power** (India, South Africa and Brazil), specific technologies for energy-intensive industries (China) and **nuclear power** (China, India and South Africa).

Question 4: Barriers to innovation

What are the barriers to the development of new technology (including existing examples of new technologies in development and the policies that support these or problems and challenges faced in development)?

Responses:

- Overwhelmingly, interviewees in all countries – especially those from the private sector – felt that the lack, described as 'appalling' by Nigeria, of 'strong, well coordinated and well financed' (Australia) government R&D strategy was the principle barrier to low-carbon innovation (that is, invention and vertical transfer of technology).
- A **lack of domestic capacity** and of an innovation culture (Brazil), of skilled technicians and engineers in low-carbon sectors (China), inadequate technological capability and poor R&D facilities (India) and a significant decline in R&D (South Africa) were all identified as resulting from the absence of government policy and strategy on innovation.
- R&D appears now largely the preserve of large, private sector companies or to be undertaken on *ad hoc* basis by private and public entities, with a lack of integration between different players (as reported by South Africa). Interviewees in the US and India felt that there was limited federal assistance and inadequate incentives for R&D.
- In the worst case, **poor political commitment** and a view of technology as being only equipment rather than skills, knowledge and processes has led to a 'brain drain' in some locations – for example, Nigeria – as specialised researchers have moved to the US or Europe.
- In addition, Australia, Brazil and South Africa pointed to a **lack of government innovation strategy** and policy having led to a lack of certainty for investors, which is perceived as a significant barrier to, *inter alia*, the financing of the innovation process, from invention to commercialisation.
- In Australia, the proposed Carbon Pollution Reduction Scheme (CPRS) seeks to establish a carbon price, but in the short term will provide 'little impetus for technologies still in the earlier stages of development', according to interviewees. Also in the short term, the renewable energy target will drive substantial levels of renewable energy deployment.
- In the US potential implementation of a national renewable energy standard was suggested by several people as one way to build on the fragmented attempts to solve this problem by the individual states.
- In Brazil, there is a perceived lack of policies to support the establishment of a renewable energy market and industry and a lack of government interest.
- Across all eight countries, **financing is seen as a major obstacle** to commercialisation of low-carbon technological innovations. There is perceived to be a lack of available financing and a need for new, customised funding mechanisms, such as low-carbon venture capital (South Africa, China and India). Financiers are highly risk averse – especially since the recent finance crisis – and there is very little venture capital or speculative finance available (Australia).
- **High costs** – of R&D (highlighted by South Africa), capacity-building and capital (Brazil) and the relatively low cost of conventional technologies were also highlighted as a barrier.

- Another constraint is the **lack of information exchange** between developers, leading to higher costs for all (for China and India) and a lack of innovation hubs through which technology could be co-developed (mentioned by South Africa).
- Opinions varied on **intellectual property rights** being a barrier. Some interviewees – especially those from the private sector, argued that more certainty around IP is necessary to provide 'investment security' (South Africa) and that poor enforcement/lack of observance of IP rights in developing countries was a problem (China and Germany).
- Some mentioned the distinction between technology transfer at the non-commercial level (that is, in the public interest and by governments) and at the commercial level where 'it is perceived only as a cost component' (Indian interviewee). Some foresaw the need for IP-related costs to be met by government or through intergovernmental agreement (India). The creation of international research centres supported by public funds and that could develop technology free of IP restrictions was considered by Brazil. However, a 'few multinational companies have created a monopolistic market in these technologies' according to an Indian interviewee.
- For many, competitiveness is the core issue in the IP debate, with companies fearing new competitors emerging from developing countries, spurred by easy access to new technologies and poor IP (Germany and Australia).
- China's **Multilateral Technology Acquisition Fund** proposal was suggested as a means by which some of the costs of IP in key technologies, *inter alia*, could be met.

Question 5. Barriers to deployment

What are the barriers to the deployment of existing or breakthrough technologies (including existing examples of new technologies in development and the policies that support these or problems and challenges faced in development)?

Responses

- **Financial constraints** were seen by most countries as the principle barrier to deployment. Issues include high upfront capital costs as compared with fossil fuel-based alternatives (India[9], Brazil and Australia), return on investments not always being sufficient (Australia), low levels of foreign investment in low-carbon sectors (South Africa), greater levels of risk associated with clean technologies (China, US, Australia) and relatively high operational and maintenance costs (China).
- There were perceived to be huge uncertainties surrounding the future effects of climate change and the magnitude of the policy responses required (China).
- A **lack of awareness** within industry of low-carbon technologies and their availability and costs was seen as a barrier (by South Africa, Australia, India and Brazil).
- There is also still a lack of confidence in renewable energy at a commercial level (India, US and South Africa) and a concern about the visual impacts of wind farms, including its impact on tourism (Brazil).
- As with barriers to technology development, a **lack of domestic policy** was seen as a significant barrier to deployment in most countries, with a lack of efficiency-driven incentives and a need for government support in the form of procurement to create a market (India). Weak regulatory frameworks and institutional capacity (Nigeria and India), an absence or inadequacy of longer-term policy frameworks or policy environments to support scale-up (Australia, US, South Africa, India and Brazil), bureaucratic hurdles for renewable energy projects, liability issues (US) and a lack of supportive infrastructure (India) were all mentioned by interviewees.
- Allied to this, political support for low-carbon technology and policy was seen as lacking (by Brazil and India): 'the issue of clean technologies… is not yet keyed into the decision making circle' (Indian interviewee).

9. Some Indian interviewees pointed out that in some cases high initial costs are not real barriers but the manifestations of the irrational prices of inefficient technologies.

- In countries already positioned to export technology, there was also a **lack of awareness** and know-how in low-carbon industries to deal with some of the barriers to transfer and a lack of awareness, or scepticism, concerning the comparative advantage of some low-carbon industries (Germany, US).
- International cooperation mechanisms within the UNFCCC, especially the Expert Group on Technology Transfer and the Global Environment Facility, function inadequately (China).
- Tensions between climate change law and policy and international investment law may become a barrier issue, as may potential tensions between international trade law and efforts to support domestic clean technology industries (Australia).
- Many interviewees also spoke of a **lack of market-based incentives** (see Question 7 below) in the form of carbon pricing policies, subsidies or preferential tariffs, to employ cleaner technologies (South Africa, US, Brazil and India). In Australia, while providing long-term signals, the forthcoming Carbon Pollution Reduction Scheme was perceived by some interviewees as unlikely to provide a strong enough price incentive to drive significant deployment in the short term, especially for more expensive technologies that still need to be proven commercially.
- Some interviewees mentioned the relative ineffectiveness of the Clean Development Mechanism, suggesting there has been a slow take-up of CDM opportunities (South Africa), inefficiencies and delays in the process (Australia) and that it requires reform (Brazil, India).
- In some countries, subsidies in carbon-intensive sectors were perceived as being a significant barrier to low-carbon technologies (South Africa, Brazil, US, India), with large, often state-owned companies dominating decision-making and the market (South Africa).
- Another significant barrier, especially in developing countries, is a **shortage of domestic skills and know-how**, with significant dependence on foreign expertise (South Africa, Nigeria, Germany and Brazil) and subsequent difficulties in integrating new knowledge areas and technologies (Brazil).

Question 6: Market barriers

What are the particular demand-side/market barriers to development, demonstration and deployment of technologies and what domestic and international policies and policy frameworks are needed to overcome these?

Responses

- Once again, many interviewees felt that **domestic policy is the major constraint**. In some cases, wider economic and other factors (such as conflict in Nigeria), high levels of bureaucracy and lack of long-term political stability were a barrier (Nigeria, and Germany as an exporter). More generally, political priorities in many countries are not aligned with climate change (or low-carbon technology development and deployment), which inhibits investment opportunities and increases risk (Germany). In the US 'uncompromising domestic politics' was cited as a particular barrier to technology development and deployment. Interviewees noted congressional attachments to state industries and the former Bush Administration's 'overall policy bias toward fossil fuels' as serious impediments. One US interviewee went so far as to pronounce a 'failure of domestic politics' in this arena.
- In particular, there is a **lack of government 'policy support'** – fiscal, industrial, trade and taxation policies – to overcome market barriers to low-carbon technology development (China, US). An unsupportive commercial and economic environment for low-carbon technologies demands investment incentives to scale up the market and provide clear signals for industry (South Africa, Nigeria, Brazil and India), but public project financing for clean technologies is highly limited (India).
- The **global economic crisis** is also constraining demand hugely and therefore investment (Australia) and limiting the economic growth required for technological renewal/innovation to

occur (Nigeria). Now more than ever developing countries lack 'economic pull' for investors (Germany).

- Many interviewees in developed countries focused on the **need to put a price on carbon** to improve market competitiveness of clean technologies (Australia, Germany, US).
- Meanwhile in developing countries, **subsidies for carbon-intensive sectors** – or 'negative subsidies' for low-carbon technology – were seen as a huge constraint (South Africa, Brazil, China and India). This came alongside the perception that the up-front, incremental and transaction costs of low-carbon technology are relatively high (India, China, South Africa, Brazil).
- High interest rates reduce the average person's capacity to invest in decentralised energy generation, for example, in solar photovoltaic sources (Brazil).
- Interviewees in countries with smaller domestic markets (Australia, South Africa, Nigeria) inevitably saw limited potential based on demand only at the domestic level and therefore limited attraction for companies as manufacturing bases.
- Direct deployment of imported technology is not always possible, according to some interviewees. Technologies need to be 'adapted' to better suit domestic needs and conditions (South Africa, India). There is also a lack of supporting infrastructure in developing countries (according to Germany, India and Australia).
- Markets might develop faster through deployment/transfer via public-private partnerships (South Africa, China and India). While R&D requires federal funding, deployment 'should be driven by the market' (US).

Question 7: Required domestic policy changes

What domestic policy changes are required for developing and existing technologies to accelerate their development, demonstration and wider usage and what are the limits of domestic policymaking to this end?

Responses

- **Clear and politically supported domestic low-carbon strategy and policy** was the top priority for most interviewees. Identifying priority technologies (South Africa), a clear articulation of the need to link growth to low-carbon technology (Nigeria), a renewable energy policy with a shift in policymaking and good 'enabling environments' (India) and a national portfolio of key low-carbon products (Brazil) were all seen as essential.
- In the US, despite acknowledging an 'American ideological aversion to centralised economic or energy policies', interviewees cited the need for policy to set standards and to instigate broader behavioural changes among producers and consumers. Setting time frames was also deemed necessary for strategising the development and implementation of new energy technologies (US). Particular emphasis was placed on the need for long-term policy innovations in order to 'mitigate uncertainty and assure investors and developers of a continuous, relatively stable investment environment'.
- **Capacity-building** was also seen as important: for example, proactive capacity-building to sustain scaling-up of the market, and implementation of educational programmes (South Africa) and investment in capacity-building to create and maintain scientific teams working on specific technologies (Brazil).
- **To stimulate R&D and demonstration** there is a need to develop national and regional centres of excellence and information hubs (South Africa and China), to share and transfer knowledge (India), to bring R&D 'from university research bunkers to the mainstream of economic policy making' (Nigeria), to increase funding (South Africa, Germany) through grants, tax incentives and risk-sharing arrangements (China, India, Australia, US), to provide incentives to private companies that invest in R&D (Brazil, US) and to provide finance and infrastructure for the commercial testing and demonstration of technology (India).

- **Financing in general is key**: all countries' interviews reflected the need to scale up financing for low-carbon technology, especially using state-funded programmes to trigger private sector interest (China). Specific financing policies were called for by some interviewees, such as feed-in tariffs (Australia, US), investment in a smart grid (US) and a scaling-up of the CDM and the international carbon market (South Africa), an enlargement of existing incentives and an introduction of tradable renewable energy certificates (India).
- Interviewees also emphasised the **importance of clearer price signalling**, through emissions trading or by offering tax incentives in the form of subsidies, tax holidays and so on (India), bringing down the cost of low-carbon technologies and regulations (India, US), the review of subsidies for carbon-intensive sectors (South Africa, Brazil), import and export policies to reduce tariff barriers on high-priority low-carbon technologies (China), direct export subsidies and guarantees (Germany) and mandatory standards, guidelines and targets to stimulate market scale-up (South Africa).
- **Stronger IP regimes** in developing countries were also seen as being important by many private sector interviewees both in developed and developing countries (Germany, India, China, South Africa). However, government interviewees in some countries were concerned that IP might restrict the building of technological capability.

Question 8: Required international policy changes

What policies are required at the international level – especially with regard to the UN climate negotiations, but referring to other international processes where appropriate – to foster the wider usage of developing and existing technology?

Responses:

- Many interviewees argued for a new approach to the UNFCCC negotiations, in which **technology is placed 'front and centre'** (Australia), with a focus on facilitating and incentivising the commercial deployment of clean technology (Australia, India).
- **Financing at the international level** is as key as it is at the national level: developed countries should commit large-scale public sector financing for clean technology RD&D (research, development and demonstration) in developing countries (Australia) or give national tax incentives to companies that take their best technologies to developing countries (Brazil). A global financing mechanism is needed for R&D (India).
- Some identified a need to set up **carbon market development programmes** to help countries break existing barriers to accessing the carbon market (Nigeria) and saw a further need to expand the international carbon market, striking a balance between 'efficiency' and 'rigour' (Australia).
- It was suggested that negotiations should seek to **incentivise international research, funding and coordination** of low-carbon technology development and transfer through a UNFCCC Multilateral Technology Acquisition Fund (MTAF) and related national technology action plans, roadmaps and action programmes (South Africa, China, Nigeria, Australia, US).
- There was a strong view expressed by interviewees for developing countries to benefit from projects to demonstrate new technologies (South Africa) and to increase knowledge through international strategic partnerships and exchange programmes (South Africa).
- Related to this, interviewees in many countries emphasised the need for future international (global and regional) **collaboration through technology research and application networks** to enable knowledge and skills transfer and best practice development (South Africa, Nigeria, Germany, India).
- Many saw potential in the International Renewable Energy Agency as the main international hub for clean technology information (South Africa, Germany) or the creation of a secretariat under the UNFCCC, 'responsible for the centralisation of information regarding available technology around the world' and for the development of IP-free technologies (Brazil).

- Existing institutions should be used – United Nations Energy Programme (UNEP), Global Environment Facility (GEF), the World Bank – and quotas of finance dedicated to investment in low-carbon technologies (Brazil), although interviewees from Germany and the US expressed scepticism as to these institutions' ability to implement an overarching technology regime.
- Other than or in addition to emissions reduction targets, countries should adopt **differentiated renewable energy targets** (Brazil) or 'renewable energy production targets' (India). Developed countries should introduce 'compulsory carbon emissions reduction policies'; developing countries should introduce 'climate friendly policies and measures for promotion of climate friendly technologies' (China).
- Official development assistance needs to balance short-term aid with long-term R&D priorities (Nigeria), but commitments to assist developing countries in clean technology development must be new and additional and funds should not be diverted from other development assistance (Australia).
- On IP, some interviewees emphasised the importance of flexibility in the WTO trade regime to ensure that IP does not hinder the dissemination of knowledge and diffusion of technologies (India). Some, though, felt that seemingly intractable debates about IP at the international level were blocking the immediate use of many technologies that were already off patent (Nigeria).[10]
- **Bilateral agreements** between developed and developing countries were also mentioned by interviewees as a means to accelerate the diffusion of low-carbon technology (South Africa, China, US, Germany), including through dual implementation demonstration projects with jointly held IP (US).

Conclusions and recommendations

Despite the diversity of the interviewees involved in this study, a common set of barriers to the development and application of low-carbon technology can be identified from their responses. There was also some consensus on the policies required to address them. We are therefore able to make a number of recommendations under the five themes of:

1. The importance of technology
2. Finance, technology development and transfer
3. The inadequacy of domestic low-carbon policies
4. The importance of knowledge and capacity
5. Intellectual property rights.

1. Technology should be at the heart of climate negotiations

In the climate change debate, technology has often been rendered a poor relation of the grand concerns of setting targets and establishing economy-wide price signals. Yet no country, industrialised or developing, can achieve its targets and maintain or improve people's quality of life without deploying low-carbon technologies at an early stage in the development of climate change policy. Thus, technology is an essential building block to the practical achievement of mitigation (and adaptation) and is therefore an indispensible element of the international negotiations. It is also critical to the politics of climate change: a climate policy narrative that does not have a strong technology story at its heart is likely to prove politically unsustainable.

Technology is also salient to the current UN negotiations. Its transfer to developing countries is an overhanging and largely unfulfilled obligation of developed country parties to the UNFCCC and it falls directly under the critical Paragraph 1b (ii) of the Bali Action Plan (UNFCCC 2007b). Not only is technology critical but measures to accelerate its development and transfer cannot be avoided if there is to be a successful outcome to the current process.

10. According to one interviewee, over 95 per cent of the technologies required to make major progress in developing countries are in the public domain unencumbered by patents (Nigeria).

The emphasis in the technology debate should be placed not only on mitigating and adapting to climate change but also on sustainable human development and, in particular, on poverty alleviation. The focus of policymakers must therefore be on developing and deploying low-carbon technologies that are aligned with countries' broader development goals. In this respect, technology should be celebrated as offering the win-win opportunity of enabling development goals to be achieved through environmentally sustainable means.

Low-carbon technology should also be celebrated as a means by which countries can develop new economic opportunities and markets and create good quality jobs. The development in recent years of information technology perhaps provides an insight into how low-carbon technology development should be viewed. The IT sector has been of benefit to most countries, with developed and developing countries alike taking advantage of its many opportunities.

GCN recommendation 1.1: Put technology at the heart of climate negotiations

More emphasis should be placed on technology in the climate change debate, especially in the ongoing UNFCCC negotiations. Its role in enabling countries at all stages of development to reach environmental and sustainable development goals simultaneously is critical.

2. Finance goes hand in hand with technology development and transfer

Almost universally, participants in this study raised access to finance as being a primary barrier to both the transfer and deployment of existing technologies and to low-carbon technology research and development. Again, there is an obligation in the text of the Bali Action Plan (also in paragraph 1b [ii]) for developed countries to transfer finance to developing countries. This study emphasises the importance of linking technology and finance in the negotiations.

However, participants in this study from both developed and developing countries identified lack of access to finance as a barrier to technology development and deployment. Most low-carbon technologies require substantial up-front investment and may be more costly to deploy than carbon-intensive alternatives. Therefore while the focus on finance in the negotiations has been on either establishing carbon markets or new funding mechanisms, other financing initiatives may be necessary. It is likely that these will need to be government-led until incentives for private sector investors are much clearer and better established. Nevertheless, the objective of government-led finance for low-carbon technology should be providing incentives to leverage private sector finance and help crowd out investment in carbon-intensive alternatives.

GCN recommendation 2.1: Create focused incentives for technology deployment

While economy-wide incentives may help in the longer term and with the winning of commercial hearts and minds, the key technologies identified in this study require market transformation through more focused incentives. These might include tariff structures that favour low-carbon power generation, the removal of established energy subsidies, government-led finance to steer key technologies safely through the valley of death and instruments to reduce the higher risks associated with large-scale low-carbon technology deployment.

GCN recommendation 2.2: Increase finance for R&D

All governments, individually and in collaboration – preferably the latter – must dramatically increase the supply of finance to support a new International Technologies Initiative (see Recommendation 4.2 below), using public money (in highly constrained quantities) to draw in private investors. Proposals already tabled in the negotiations for a government-led, collaborative venture capital fund and the development of low-carbon R&D hubs should be pursued as vigorously as other key aspects of the talks.

GCN recommendation 2.3: Link technology and finance in international talks

In all countries in this study there is a lack of up-front finance and financial incentives to spur greater deployment of low-carbon technologies. What is needed is market transformation through government activism, which at the international level means financing to support policy reforms, promotional activities, capacity-building, and, in particular, the diffusion of technology that is important and of direct material benefit to poor people in developing countries.

3. Domestic low-carbon policies are woefully inadequate

In all eight countries, the absence of a long-term low-carbon policy framework or sets of policies was identified – especially by private sector interviewees – as a major impediment to the development and deployment of low-carbon technology. This is clearly closely linked to Recommendations 1 and 2 above and is leading to a chronic lack of confidence in the technologies that will deliver climate change mitigation, especially renewable energy.

However, no government is starting from scratch. Each country in the study has exciting examples of success in low-carbon technology development and deployment and the policies that have helped support these successes need to be analysed and, where appropriate, scaled up and replicated. However, the lesson of this study is that domestic policy – reinforced by a strong international regime – is of absolutely critical importance to the development and deployment of low-carbon technology.

On the deployment side, and linked to Recommendation 2, countries must focus on putting financial incentives in place through policy initiatives and by removing existing positive incentives for fossil fuels (while paying careful attention to the negative social impacts that this may bring). Similarly, the development of new low-carbon technology, according to the findings of this study, requires urgent government attention. New initiatives to promote and support innovation and significant new collaboration between governments are needed.

GCN recommendation 3.1: Develop national low-carbon technology strategies

Beyond the UNFCCC negotiations, leadership countries at different levels of development should establish low-carbon technology strategies that interlock with their industrial development and energy security policies and aim to accelerate the deployment of key technologies. Such initiatives should attract formal recognition and finance in a future international framework. National strategies should be the building blocks of agreement with their probable impact on emissions registered internationally and then measured and verified.

GCN recommendation 3.2: Give an urgent boost to R&D initiatives

Calls for an increase in spending on low-carbon R&D must be taken seriously. Governments should increase their support for R&D at the national level as part of their national low-carbon technology strategies and increased R&D finance. A major International Technologies Initiative to accelerate R&D should be a key part of any new international framework for action (see 4.2 below).

4. Knowledge and capacity are as important as equipment

Technology transfer is not wholly or perhaps even mostly about the movement or licensing of equipment from jurisdiction to jurisdiction (although clearly some early climate and political victories might emerge from ensuring this happens). It also concerns the development of skills and know-how in order to use equipment and to innovate in the future, to develop and manufacture indigenous low-carbon technologies, and to grow economic opportunity out of the low-carbon seedbed.

In addition, knowledge of good policymaking to promote low-carbon technology development and transfer is important. The paucity of domestic low-carbon strategies highlighted in this study points to a very significant need for learning among governments and public servants in the area of developing and introducing policy to accelerate low-carbon technology. Enhancing countries' capacity and knowledge of low-carbon technologies and low-carbon technology policy is therefore of high importance.

GCN recommendation 4.1: Pilot joint learning and capacity-building

One clear area that could benefit from international agreement is in the sharing of technical knowledge, through capacity-building and mutual learning programmes. International cooperation will be more robust if governments agree to collaborate – either inside or outside a formal agreement – on technology deployment, focusing on a shortlist of key technologies, including measures to increase energy efficiency.

GCN recommendation 4.2: Establish joint innovation for future technologies

The GCN believes a new International Technologies Initiative is necessary, in which regional and global innovation 'hubs' provide a focal point for collaboration on the development of breakthrough low-carbon technology. This initiative could deliver open access technologies and knowledge, borrowing ideas from the emerging open innovation movement, thereby reducing the future cost of deployment.

5. Intellectual property rights need careful attention

Private sector interviewees in this study, in both developed and developing countries, tended to underline the importance of observing intellectual property rights as a spur to innovation. However, government interviewees in developing countries saw IP as obstructive in the deployment of low-carbon technology; the literature supports both points of view, because without strong IP, technology developers will be reluctant to deploy but also because deployment may remain slow as a result of the costs of licensing.

The GCN therefore concludes that there is no easy answer on IP but that it should not become obstructive. Therefore, in some cases stronger observance and enforcement of IP rights might encourage technology developers to roll out new technology in more jurisdictions more quickly. In others, the costs of licensing (as distinct from wholesale purchase of IP by governments) could be another focus of financial support by developed country governments, a de facto subsidy to developers of low-carbon technology.

GCN recommendation 5.1: Reward technology risk-takers with IP rights

The developers of existing technology, some of which is subject to patents restricting its generic manufacture and use, should be assured of strong enforcement of their IP if they license and do so at reasonable cost. Conversely, patents could be withdrawn if developers seek inappropriately high rents from their IP protection or use IP to restrict a technology's use.

GCN recommendation 5.2: Develop new technology collaboratively

In future, low-carbon innovation could be driven by collaborative initiatives, such as the International Technology Initiative proposed in 4.2 above. Technology might therefore be open access, with an emphasis on a sharing of equipment, but also on the development of locally appropriate versions.

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Appendix: List of interviewees

Dr Y.P. Abbi, Distinguished Fellow, The Energy and Resources Institute (TERI) and Former Executive Director of Bharat Heavy Electricals Limited (BHEL), India

Dan Adler, President, California Clean Energy Fund Innovations, USA

Obioma Aduku-Brown, National Office for Technology Acquisition and Promotion, Nigeria

Dr Ramgopal Aggrawal, Senior Adviser, Research and Information System for Developing Countries (RIS), India

Dr A. Ajakaye, Director General, National Oil Spill Detection and Response Agency, Nigeria

Dr Emma Archer, Senior Researcher, Council for Scientific and Industrial Research (CSIR), South Africa

Dr Guilherme Ary Plonsky, Scientific Coordinator, Center for Policy and Technological Management, University of Sao Paulo (PGT/USP), Brazil

Wang Baiyu, Senior Manager, Climate Change Capital, China

Dr Ayo Balogun, Group General Manager, Nigeria National Petroleum Corporation

Ruth Brand, Head of Berlin Office, Enercon, Germany

Chandra Brown, Vice President, Renewable Energy Program Manager, Oregon Iron Works, USA

Liu Caifeng, National Institute of Standardization, China

Eduardo Canepa, Amazon Fund Management Department, Environmental Department, Brazilian Development Bank (BNDES)

Dr Koshy Cherail, President, Alliance for an Energy Efficient Economy, India

Christopher Clarke, Executive Director and Principal, Inspired Evolution Investment Management, South Africa

Huang Dai, Senior Manager, Guangdong Development Bank Co. Ltd, China

Qiu Donggang, Vice Manager General, Beijing Jingneng Energy Technology Investment CO, China

Maosheng Duan, Associate Professor, Institute of Global Climate Change, Tsinghua University, China

Peter Ekweozoh, Assistant Director and Head of Climate Change Desk, Federal Ministry of Science & Technology, Nigeria

Dr A. A. Esan, UNIDO Regional Centre for Small Hydropower, Nigeria

Dr Rosemary Falcon, Director of the Fossil Fuel Foundation of Africa and Professor at the University of the Witwatersrand, South Africa

Min. Luiz Alberto Figueiredo Machado, Vice-chair of the AWG-LCA and Director of the Department of Environment and Special Issues, Ministry of External Relations (MRE), Brazil.

Dr Victor Fodeke, Head of the Special Climate Change Unit, Federal Ministry of Environment, Nigeria

Paul Frankel, Managing Director, California Clean Energy Fund Innovations, USA

Ian Fry, Environment Department, Government of Tuvalu, Australia

Dr Collins Gardner, Chairman of the Presidential Implementation Committee for the Clean Development Mechanism, Nigeria

Mark Craft, Director of Executive and Financial Communication, Duke Energy, USA

Rajiv Garg, Energy Economist, Bureau of Energy Efficiency, Ministry of Power, Government of India

Professor Ross Garnaut, University of Melbourne, Australia

Valerie Geen, Director, National Business Initiative (NBI), South Africa

David Gibson, Renewable Energy Program Manager, Oregon Iron Works, USA

Dr Prodipto Ghosh, Negotiator for the Indian Delegation to the UNFCCC

Dr Jose Goldemberg, Professor, University of Sao Paulo (USP), Brazil

Dr José Domingos Gonzales Miguez, General Coordinator on Global Climate Change, Ministry of Science and Technology (MCT), Brazil

Dr Dan Gwary, Senior Lecturer, University of Maiduguri and Chair of IPCC WG, Nigeria

Qin Haiyan, Secretary General, Chinese Wind Energy Association

Emma Herd, Westpac Banking Corporation, Australia

Rainer Hinrichs-Rahlwes, Board Member of the German Renewable Energy Federation (BEE) and Vice-President of the European Renewable Energy Foundation (EREF), Germany

Stephen Howes, Professor, Crawford School of Economics and Government, The Australian National University

Dr. Martin Jänicke, Founding Director and Prof. Emeritus, Environmental Policy Research Centre, Freie Universität Berlin, Germany

Yu Jie, Senior Manager, Climate Change Capital, China

Kejun Jiang, Senior Research Fellow, Energy Research Institute (ERI), National Development and Reform Commission (NDRC), China

Muyi Kazim, Executive Director, United Bank for Africa, Nigeria

Kevin Knobloch, President, The Union of Concerned Scientists, USA

Sangeet Kumar Dave, National Thermal Power Corporation Limited, India

Dr Thelma Krugg, Head of the International Affairs Office, INPE, Brazil

Kevin Leahy, Managing Director of Climate Policy, Duke Energy, USA

Ang Li, Climate and Energy Programme, World Wide Fund for Nature (WWF) China

Gao Li, Director, Climate Change Department of the National Development and Reform Commission (NDRC) and Acting Head of the Chinese Delegation to the UNFCCC

Liyan Li, Deputy Head, Climate Change Department of National Development and Reform Commission (NDRC), China

Holger Liptow, Head of Energy and Transport, GTZ, Germany

Xuedu Lu, Deputy Head, Office of Global Environmental Affairs, Chinese Ministry of Science and Technology and Member of the Chinese Delegation to the UNFCCC

Dr Thembakazi Mali, Senior Manager, Clean Energy Solutions, South African National Energy Research Centre (SANERI).

Dr P.C. Maithani, Director, Ministry of New and Renewable Energy, Government of India.

Kate Miles, Sydney Law School, University of Sydney, Australia

Rohit Modi, President (India Operations), Suzlon, India

Kapil Mohan, Director, Ministry of Power, Government of India.

Huzi Mshelia, Executive Director, Clean Energy and Safe Environment Initiative, Nigeria

Volker Munster, Director, Aldus Capital, South Africa

Dr Carlos Nobre, Head, Centre for Earth System Sciences, INPE, Brazil

Anil Patni, Head of Communications and External Affairs, TATA BP Solar, India

Sizhen Peng, Project Officer, The Administrative Center for China's Agenda 21

Klaus-Peter Pischke, Leiter Kompetenzcenter Energie, KfW, Germany

Peet du Plooy, Trade and Investment Programme Advisor, World Wide Fund for Nature (WWF), South Africa

Wendy Poulton, General Manager for Sustainability and Innovation, Eskom, South Africa

Dr Krishnan S. Raghavan, Technology Transfer Services Group, Asian and Pacific Centre for Transfer of Technology (APCTT), India

Ndivhuho Raphulu, Director, National Cleaner Production Center (NCPC), South Africa

Bernd Reinhard, Department III C5 'Grundsatzfragen der rationellen Energienutzung und Energieeffizienz', Federal Ministry of Economics and Technology (BMWi), Germany

Dr Aminu Saard, Managing Director, Terrasolar, Nigeria

Professor A.S. Sambo, Director General, Energy Commission of Nigeria

Samantha Scott, Australian Coal Association

Wayne Smith, Ausra Pty Ltd, Australia

Daniel Soeiro, Manager, Amazon Fund Management Department, Environmental Department, Brazilian Development Bank (BNDES)

Dr Osvaldo Soliano Pereira, Director of the Brazilian Centre of Energy and Climate Change and Professor at the University of Salvador (UniFacs), Brazil

Nicole St. Clair, Associate Director (DC Office), Nicholas Institute for Environmental Policy Solutions, Duke University, USA

Charlie M. Stringer, Principle and General Counsel, The Renewable Resources Group, USA

Maria Tarrant, Policy Director, Business Council of Australia

Dr Kelly Thambimuthu, Chief Executive Officer, Centre for Low Emissions Technology, Australia

Dr Elsa du Toit, Director of Energy Efficiency and Environment, Department of Minerals and Energy (DTI), South Africa

Julian Turecek, Cleantech Ventures, Australia

Johan van den Berg, Founder, CDM Africa, South Africa

Marba Visagie, Deputy Director of Environment, Department of Trade and Industry (DTI), South Africa

Dr Shaun Vorster, Special Advisor, Department of Environmental Affairs and Tourism (DEAT), South Africa

Gang Wen, Head of Project Management Division, China CDM Fund, Ministry of Finance, China

Martijn Wilder, Baker & McKenzie, Australia

Tony Wood, The Clinton Foundation, Australia

Oliver Yates, Macquarie Capital, Australia

Alex Zapantis, Rio Tinto, Australia

Wang Zheng, Vice Manager General, Tsinghua Coway International TechTrans Co. Ltd, China

Peng Zhiyuan, Director, China Beijing Environment Exchange

Dr. Roberto Zilles, Professor, Institute of Electrotechnics and Energy, University of Sao Paulo (USP / IEE), Brazil

Plus:

Government officials from the Department of Climate Change and the Department of Resources, Energy and Tourism, Australia

Government officials from the Federal Ministry of the Environment and the Federal Ministry of Economy and Technology, Germany

Government officials from the Energy and State Departments, USA

Adviser to the Executive Office on Technology policy, USA

Executive Office Staffer on Clean Energy policy, USA

Senior representatives of RWE, Germany

Energy Company Lobbyists, USA