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Enhancing Developing Country Access to Eco-Innovation: The Case of Technology Transfer and Climate Change in a Post-2012 Policy Framework

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ENHANCING DEVELOPING COUNTRY ACCESS TO ECO-INNOVATION

THE CASE OF TECHNOLOGY TRANSFER AND CLIMATE CHANGE IN A POST-2012 POLICY FRAMEWORK

By
Dr. David Ockwell, with contributions from Dr. Jim Watson, Alexandra Mallett, Ruediger Haum, Professor Gordon MacKerron, and Anne-Marie Verbeken

JEL classification: O19, O31, O33, O34, O38, Q54, Q55, Q56, Q58

Keywords: eco-innovation, green tech, technology transfer, absorptive capabilities, innovation capabilities, multilateral environmental agreements

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ABSTRACT

The deployment of eco-innovations in developing countries is a key driver of their contribution to efficiently addressing global environmental challenges. It is also a key driver of markets for eco-innovation and sustainable economic development.

This report explores the barriers developing countries face in accessing markets for eco-innovation. It outlines the key considerations policy needs to address to overcome these barriers and discusses the extent to which selected existing policy mechanisms and organisation have achieved this.

The key finding of the report is that the majority of existing policy mechanisms fails to recognise the critical importance of developing indigenous eco-innovation capabilities amongst developing country firms. Indigenous eco-innovation capabilities are essential to facilitating *both* the diffusion of existing eco-innovations within developing countries *and* sustainable economic development based on the adoption, adaption and development of environmentally sound technologies that fit with the bespoke conditions faced by developing countries.

Building up eco-innovation capabilities in developing countries requires a shift away from the current focus on large project based approaches which emphasise the transfer of the hardware aspects of clean technologies, towards approaches that emphasise flows of codified knowledge (know-how and know-why) and tacit knowledge. Policy also needs to be improved to better respond to the context-specific technological and cultural requirements which vary inter- and intra-nationally.

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Keywords: eco-innovation, green tech, technology transfer, absorptive capabilities, innovation capabilities, multilateral environmental agreements

RÉSUMÉ

La diffusion des éco-innovations dans les pays en développement est un facteur clé de la contribution de ces pays à une lutte effective contre les grands enjeux environnementaux. C'est aussi un déterminant essentiel des marchés pour l'éco-innovation et le développement durable.

Le présent rapport identifie les barrières auxquels les pays en développement sont confrontés pour accéder aux éco-innovations. Il souligne les enjeux clés que les politiques publiques doivent prendre en compte pour contourner ces barrières. Il évalue la réussite dans ce domaine de certains des mécanismes et organisations existants.

La principale conclusion de ce rapport est que la majorité des mécanismes existants n'accordent pas suffisamment d'importance au développement des capacités locales à innover dans le domaine de l'environnement. Ces capacités, dans les pays concernés, contribuent de manière décisive à la fois à la diffusion des éco-innovations dans les pays en développement et à un développement durable fondé sur l'adoption, l'adaptation et le développement de technologies favorables à l'environnement qui soient adaptées aux contextes particuliers des pays en développement.

Renforcer la capacité à innover dans les pays en développement suppose de renoncer partiellement à la priorité accordée actuellement au soutien aux grands projets ; cette priorité met l'accent sur le transfert des aspects purement technologiques. Le rapport plaide pour des approches qui mettent l'accent sur les flux de connaissance codifiés (pourquoi, comment) et tacites. Il convient également d'améliorer les politiques publiques de sorte qu'elles prennent mieux en compte les besoins technologiques et culturels propres aux contextes et qui varient au sein d'un même pays et entre les pays.

Codes JEL : O19, O31, O33, O34, O38, Q54, Q55, Q56, Q58

Mots clés : éco-innovation, technologies vertes, transferts de technologies, capacités à innover, accords multilatéraux sur l'environnement

FOREWORD

This report was commissioned by the OECD Environment Directorate and prepared by Dr. David Ockwell, with contributions from Dr. Jim Watson, Alexandra Mallett, Ruediger Haum, Professor Gordon MacKerron, and Anne-Marie Verbeken, all based at the University of Sussex, UK, and affiliated with SPRU (Science and Technology Policy Research). It is based on a brief desk review of existing theory and available empirical evidence and of recent research developed by the author in this area. The report was commissioned in the context of the preparation of the OECD Global Forum on Environment focused on eco-innovation, held on 4-5 November, 2009, at the OECD Conference Centre in Paris (for more information, visit www.oecd.org/environment/innovation/globalforum).

The report was presented at the Global Forum on Environment focused on eco-innovation. Comments received at and after the Global Forum have been take into account. The opinions expressed in this paper are the sole responsibility of the author(s) and do not necessarily reflect those of the OECD or the governments of its member countries.

ACKNOWLEDGMENTS

The project is funded by a grant from the European Commission under the ENRTP, a thematic programme for the environment and sustainable management of natural resources.

The report draws considerably on work conducted over the last 43 years on science, technology and innovation policy within SPRU (Science and Technology Policy Research) at the University of Sussex. It benefits directly from the theoretical and heuristic developments, underpinned directly by empirical observation and policy application, of several scholars at SPRU. In particular the report owes a depth of gratitude to the researchers of the Sussex Energy Group and the Tyndall Centre for Climate Change Research (based at SPRU).

As well as the listed contributors to this report, Dr. Ockwell would especially like to acknowledge the benefits he has accrued from being exposed to the work of Professor Martin Bell, Dr. Adrian Ely and Oliver Johnson. Particular insights have been afforded from the recent development of "Innovation, Sustainability, Development: A New Manifesto" which readers of this report are strongly urged to consult.[1]

[1] Available at www.anewmanifesto.org

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EXECUTIVE SUMMARY

The deployment of eco-innovations[2] in developing countries is a key driver of their contribution to efficiently addressing global environmental challenges. It is also a key driver of markets for eco-innovation and sustainable economic development. This report explores the barriers developing countries[3] face in accessing markets for eco-innovation, outlines the key considerations policy needs to address to overcome these barriers and discusses the extent to which selected existing policy mechanisms and organisation have achieved this. There is a strong focus on low carbon technologies, reflecting the authors' backgrounds and empirical experience. The report therefore uses this high profile subset of eco-innovations to illustrate some broader points and arguments. The existing mechanisms and organisations analysed in the report are Multilateral Environmental Agreements [including the Montreal Protocol and the Expert Group on Technology Transfer (EGTT), Clean Development Mechanism (CDM) and the Global Environment Facility (GEF) under the auspices of the UNFCCC], information sharing initiatives (including the Environmental Technology Verification Programme), and more targeted international collaborative initiatives along the research, development, demonstration and deployment spectrum (including the UK Carbon Trust's Low Carbon Technology Diffusion and Innovation Centres, and Fundacion Chile).

The report identifies the following key barriers to developing countries accessing eco-innovation:

- **Lack of international policy focus on indigenous eco-innovation capabilities:** There is a strong tendency for policy discussions at the international level to focus on the idea of providing developing countries with access to existing eco-innovations on the basis of them consuming existing technological hardware. In other words it is seen as sufficient that developing countries become consumers of eco-innovations rather than producers and eco-innovators in their own right. This fails to recognise the central need to foster the development of indigenous eco-innovation capabilities in developing countries. Indigenous eco-innovation capabilities are essential to facilitating both the diffusion of existing eco-innovations within developing countries and sustainable economic development based on the adoption, adaption and development of environmentally sound technologies that fit with the bespoke conditions faced by developing countries.

[2] In accordance with the Environmental Technology Action Plan of the European Commission, the term "eco-innovation" is used here to refer to "all forms of innovation activities resulting in or aimed at significantly improving environmental protection. Eco-innovation includes new production processes, new products or services, and new management and business methods, whose use or implementation is likely to prevent or substantially reduce the risks for the environment, pollution and other negative impacts of resources use, throughout the life cycle of related activities."

[3] Note that the term "developing countries" is adopted for ease of use in this report to refer to both developing and emerging economies. This is not intended to obscure the important contextual differences between, for example, the BRICS countries and countries in Sub-Saharan Africa, and these differences are considered in detail in this report relation to the context specific nature of appropriate policy approaches to facilitating access to, and access to markets for eco-innovation.

- **Characteristics of eco-innovation:** Eco-innovations are often not yet at commercial stages in their development. Instead they span the full range of the RDD&D spectrum thus raising a range of issues that many commercial innovations are not subject to. These include increased risks to investors, lack of available sources of venture capital, lack of knowledge of operation (particularly in new geographical and cultural contexts) and higher incremental costs.

- **Incremental costs and market failures:** As well as the increased costs associated with new technologies noted above, the incremental costs of eco-innovations are exacerbated by the failure of markets to capture the environmental benefits of eco-innovations, or the environmental costs associated with non-eco innovations.

- **Intellectual property:** Evidence available to date suggests a complex picture in relation to IP for eco-innovation. Whilst access to IP might be necessary in some cases, it is unlikely to be sufficient in itself to enable developing country firms to become producers of eco-innovations. Firms also need access to tacit and other related knowledge (e.g. trade secrets) which are often not patent protected. These are also important factors in developing indigenous eco-innovation capabilities. Nevertheless, the fact that evidence suggests patents can sometimes slow the rate at which developing country firms can become producers of eco-innovations, or produce at the cutting edge, suggests that international policy mechanisms do need the capacity to be able to address IP in specific instances[4].

The key finding of the report is that the majority of existing policy mechanisms fail to recognise the critical importance of developing indigenous eco-innovation capabilities amongst developing country firms. Indigenous eco-innovation capabilities are essential to facilitating *both* the diffusion of existing eco-innovations within developing countries *and* sustainable economic development based on the adoption, adaption and development of environmentally sound technologies that fit with the bespoke conditions faced by developing countries. Building up eco-innovation capabilities[5] in developing countries requires a shift away from the current focus on large project based approaches which emphasise the transfer of the hardware aspects of clean technologies, towards approaches that emphasise flows of codified knowledge (know-how and know-why) and tacit knowledge. Policy also needs to be improved to better respond to the context-specific technological and cultural requirements which vary inter- and intra-nationally.

There is a need to address the shortfall of current international policy processes by putting in place institutional and funding structures that achieve maximum leverage from public investment, both in terms of maximising the impact on indigenous eco-innovation capabilities, and maximising the potential to attract sustained private sector investment in eco- innovation. Precedents do currently exist, such as the Carbon Trust's proposed network of Low Carbon Technology Innovation and Diffusion Centres, and Fundacion Chile (a not for profit organisation geared towards facilitating access to relevant international innovations and increasing indigenous innovation capabilities) reviewed in this report. These provide potentially viable models for a more focussed, needs based approach to developing eco-innovation capabilities in developing countries than can be achieved by the centralised, large project based approach that tends to characterise current international efforts. For an example of how these principles might be operationalised, refer to the University of Sussex's proposal to the UNFCCC negotiations in Copenhagen, December 2009. This proposed a new network of low-carbon 'Innovation Centres' in developing countries,

[4] For an up to date review of options for managing IP in relation to climate relevant technologies see Maskus, K. (2009) Differentiated *Intellectual Property Regimes for Environmental and Climate Technologies* Report to OECD Environment Directorate Working Party on National Environmental Policies ENV/EPOC/WPNEP(2009)6 – 21 October 2009

[5] Eco-innovation capabilities refer to the capabilities to adapt, develop, deploy and operate relevant technologies effectively within specific developing country contexts.

managed via regional and international hubs. Building on work by the Carbon Trust, activities of the Centres (see Carbon Trust, undated) would include, for example:

- Applied research and development: Grant funding, open and/or directed at prioritised technologies;
- Technology accelerators : Designing and funding projects to evaluate technology performance e.g., field trials;
- Business incubator services: Strategic and business development advice to start-ups;
- Enterprise creation: Creation of new low carbon businesses by bringing together key skills and resources;
- Early stage funding for low carbon ventures: Co-investments, loans or risk guarantees to help viable businesses attract private sector funding;
- Deployment of existing energy efficiency technologies: Advice and resources (e.g. interest-free loans) to support organisations to reduce emissions;
- Skills / capacity building: Designing and running training programmes;
- National policy and market insights: Analysis and recommendations to inform national policy and businesses.

The report concludes by focussing on the negotiations under the UNFCCC in Copenhagen in December 2009 and uses the analysis from the paper to set out some guiding principles for informing the post-2012 approach to technology transfer[6] to developing countries. These principles are as follows:

Guiding principles for post-2012 technology transfer to developing countries[7]

1. Low-carbon technology transfer can facilitate sustained low-carbon development in developing countries. This can only be achieved by developing indigenous innovation capabilities in developing countries – i.e. the capabilities to adapt, develop, deploy and operate low-carbon technologies effectively within specific developing country contexts.

2. Diffusion and development of low-carbon technologies are facilitated by incremental *and* adaptive innovation processes[8] within developing countries. This requires sufficient innovation capabilities amongst developing country firms, universities and research institutes, and appropriate links with public-sector actors.

[6] Note that technology transfer in this report is understood in a broader sense than acknowledged in the conventional technology transfer literature. This broader conception, as explored later in this report, acknowledges the central role of innovation within the process of technology transfer, particularly with reference to eco-innovations.

[7] For more details on Sussex's policy proposal for delivering low carbon technology transfer under the UNFCCC see http://www.sussex.ac.uk/sussexenergygroup/documents/tech_transfer_prop.pdf

[8] Incremental innovations are seen as occurring more or less continuously as economic agents strive to improve quality, design and performance. Adaptive innovation describes processes where existing technologies are adapted in ways that can be applied in new contexts.

These capabilities are essential to allow developing country actors to work with existing low-carbon technologies, identify opportunities to improve and adapt them for application in new contexts, and to develop brand new technologies suited to specific developing country needs. Policy should therefore, not treat the diffusion and development of low-carbon technologies separately.

3. Technology transfer includes: the traditional notion of 'hardware' (physical equipment); the often ignored, yet vital, 'software' element of technology (knowledge and processes), including both underlying knowledge (e.g. engineering and manufacturing processes, or new farming techniques) and tacit knowledge (knowledge acquired by doing, e.g. applied engineering & systems integration skills). The software aspect is often most important.

4. As low-carbon innovation capabilities build up in developing countries a snowballing effect takes place where we observe increasingly more rapid uptake and development of low-carbon technological applications. This will yield benefits for developed and developing countries by accelerating development, opening up new market opportunities, and mitigating against future climate change.

5. International technology-leading firms and industrialised countries might have concerns regarding intellectual property protection and their competitive advantage. However, these concerns are likely to be outweighed by the significant economic benefits of accessing new markets via carefully negotiated collaborative initiatives with firms and other institutions within developing countries.

6. The private sector – through investment, research and expertise – will play a pivotal role developing and diffusing low-carbon technologies in developing countries.

7. Policy must be designed to respond to the context-specific social, economic, ecological and technological needs of different regions, countries and areas within countries.

   - The needs of the rural-poor differ greatly from those of urban populations.

   - Rapidly-emerging economies' needs are very different from those of least-developed countries.

   - Countries reliant on hydropower face different climate challenges to those dependent on coal-fired power.

   - Individual technologies raise context-specific issues: this may relate to their stage of commercial development (e.g. investor risk is higher at earlier stages of technology development), or to hardware and software components involved (e.g. Carbon Capture and Storage (CCS) involves more complex systems management requirements than small scale solar photovoltaics). Policy must take account of context specific issues.

8. Sussex University's work in India[9] shows that access to Intellectual Property Rights (IPRs) do not ensure developing country access to low-carbon technologies. Access to other knowledge, particularly tacit knowledge, is often a more important barrier. In some cases, lack of access to IPRs slows the rate at which developing country firms can produce low-carbon technologies and

[9] See http://www.sussex.ac.uk/sussexenergygroup/1-2-9.html

also prevents firms producing at the cutting edge. Policy should therefore include provision for international arbitration in such cases.

Analyses developed in this paper lead to recommendations for further research. For instance, it would be both timely and valuable to conduct an assessment of the Technology Mechanism, proposed in the context of the UNFCCC to deliver on commitments for technology transfer to developing country. In a different vein, work is needed to identify and articulate the benefits to international technology leading companies of engaging in collaborative, capacity building initiatives in developing countries.

INTRODUCTION

The deployment of eco-innovations[10] in developing countries is a key driver of the environmental performance of these countries and of their contribution to efficiently addressing global environmental challenges. It is also a key driver of markets for eco-innovation and for sustainable economic development. Low-carbon technologies are a particular case in point.

The objective of this report is to scope the barriers developing and emerging countries (hereafter referred to as "developing countries" [11]) face in accessing markets for eco-innovation, to explore the policy relevant issues and to discuss the relevance of selected mechanisms to overcome them. There is a strong focus on low carbon technologies, reflecting the authors' backgrounds and empirical experience. The report therefore uses this high profile subset of eco-innovations to illustrate some broader points and arguments.

As stated above, the focus of this report is on international mechanisms that might be put in place in order to overcome barriers developing countries face in accessing eco-innovation. However, this focus on "barriers" is not intended to obscure the significant opportunities that the pursuit of eco-innovation in developing countries present for both developed and developing countries. Neither is the focus on "international mechanisms" intended to obscure the key role that domestic policy has to play in developed and developing countries alike in encouraging and facilitating access to eco-innovation. Developing countries face significant opportunities from eco-innovation in terms of economic development via access to new technologies, as well as economic, environmental and social benefits from more sustainable and resource efficient economic activities. Concurrently, technology leading firms, often based in developed nations, stand to gain from access to new markets, whilst the global environmental benefits of the adoption of eco-innovations in developing countries will accrue benefits to international civil society now and in the future. Therefore, whilst the scope of this report requires a focus on barriers to, and international mechanisms for overcoming access to eco-innovation in developing countries, the intention is not to belittle the opportunities and national policy solutions that are of equal relevance to this area of contemporary policy debate.

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[10] In accordance with the Environmental Technology Action Plan of the European Commission, the term "eco-innovation" is used here to refer to "all forms of innovation activities resulting in or aimed at significantly improving environmental protection. Eco-innovation includes new production processes, new products or services, and new management and business methods, whose use or implementation is likely to prevent or substantially reduce the risks for the environment, pollution and other negative impacts of resources use, throughout the life cycle of related activities."

[11] Note that the term "developing countries" is adopted for ease of use to refer to both developing and emerging economies. This is not intended to obscure the important contextual differences between, for example, the BRICS countries and countries in Sub-Saharan Africa, and these differences are considered in detail in this report in relation to the context specific nature of appropriate policy approaches to facilitating access to, and access to markets for, eco-innovation.

The report is structured around three sections as follows:

1. Barriers to accessing markets for eco-innovation[12]: Section 1 summarises the key barriers faced by developing countries in accessing markets for eco-innovation. It combines theoretical insights with empirical observations to produce a sound underpinning of the policy relevant issues set out in Section 2. Relevant lessons from other industries (e.g. pharmaceuticals) are also summarised in order to highlight any policy relevant parallels or important differences.

2. Policy relevant issues: Building on the analysis in the Section 1, Section 2 sets out the key issues that must be addressed by policies that aim to facilitate developing country access to markets for eco-innovation.

3. Potential of existing mechanisms to overcome barriers: The final section of the report assesses the potential of existing mechanisms to overcome the barriers outlined in Section 1 in a way that addresses the issues summarised in Section 2. It focuses mainly on international mechanisms as opposed to domestic policy in developing countries and includes analysis of Multilateral Environmental Agreements and other international cooperation initiatives involving developing countries.

The report concludes by using the negotiations under the UNFCCC in Copenhagen in December 2009 to make forward looking, constructive suggestions as to ways in which the issues highlighted in Sections 1 and 2 might be operationalised into guiding policy principles. It also includes a section highlighting areas for future work.

[12] Note that the idea of "accessing markets for eco-innovation" is an artefact of the original terms of reference for this report. In reality, as unpacked within this report, access to eco-innovation is fostered via a mix of policy, training, and market access.

BARRIERS TO ACCESSING MARKETS FOR ECO-INNOVATION

In this section a focussed analysis of theory and evidence is conducted in order to facilitate a summary of the barriers developing countries face in accessing eco-innovation. The key emerging message is that the central focus of policy efforts needs to be on the development of indigenous eco-innovation capabilities amongst firms in developing countries. This is necessary in order to facilitate *both* the diffusion of existing eco-innovations within developing countries *and* sustainable economic development based on the adoption, adaption and development of environmentally sound technologies that fit with the bespoke conditions faced by developing countries.

The analysis begins by considering the different levels of innovation that exist and articulating the central importance of incremental and adaptive innovation in relation to eco-innovation, and to developing, as opposed to developed, country contexts. It then considers the unique barriers faced in the adoption of eco-innovations and why developing countries might be motivated to adopt the former. The centrality of knowledge flows, including tacit knowledge, during processes of technology transfer is then explored. This serves to demonstrate the importance of fostering indigenous eco-innovation capabilities amongst firms in developing countries. Explicit consideration is then given to the role of intellectual property. The section concludes by summarising the key barriers developing countries face in accessing eco-innovation.

Different levels of innovation

Before commencing with a discussion of eco-innovation it is first important, particularly within a developing country context, to understand what we mean when we talk about "technology" and "innovation". The term "technology", when used in this report, is understood as an inclusive term that refers as much to "software" (knowledge and processes) as it does to "hardware" (physical equipment). This software includes both the codified knowledge (e.g. engineering and manufacturing processes, or new farming techniques) and tacit knowledge (i.e. human-embodied knowledge acquired by doing, e.g. applied engineering & systems integration skills) that underpin existing eco-innovations.[13]

"Innovation" can be characterised on the basis of the OECD Oslo Manual (OECD, 2005) (as cited by Bell, 2009) as including points 1, 2 and 3 in the following typology:

- **Innovations 'new to the world'**: Where a firm is the first to introduce innovation for all markets & industries, domestic and international.
- **Innovations 'new to the market'**: Where a firm is the first to introduce innovation in its particular market.
- **Innovations 'new to the firm'**: Where a firm introduces a product, process or method new to that firm, or significantly improved by it, even if it has already been implemented by other firms.

[13] See the discussion further below on the centrality of knowledge flows for a more in depth description of what constitutes these knowledge flows.

It is often only type 1 (innovations new to the world) that captures the focus of policy discussions on eco-innovation (e.g. new strains of drought resistant crops, new ways of generating electricity, new energy-efficient end use technologies like LED lighting). However, in a developing country context, and in the context of eco-innovation, types 2 (innovations new to the industry) and 3 (innovations new to the firm) are often most important. In this sense, a farmer's selection of specific rice varieties and locally appropriate soil management methods is equally as important and innovative as the development of new strains of drought resistant rice within centralised research and development (R&D) laboratories (ibid.).

The importance of type 2 and 3 innovations in developing country contexts can be further appreciated in terms of their relation to radical, incremental and adaptive innovations. Type 1 innovations (innovations new to the world) are more likely to be associated with more radical innovations (although, as noted below, they may also result from incremental or adaptive innovation processes). Radical innovations are characterised by the emergence of new inventions, often as a result of deliberate R&D, that lead to a radical departure from previous production practice. An example of this is hybrid cars. Whilst hybrid cars utilise two existing technologies, the internal combustion engine and battery-driven electric motors, the combination of these technologies in the production of a new, significantly more energy efficient vehicle could be seen as representing a radical innovation (Gallagher, 2006).

In a developing country context, however, the kind of incremental and adaptive innovations that are often underpinned by type 2 (innovations new to the market) and 3 (innovations new to the firm) innovations, are often of more importance. This is particularly true in relation to facilitating the more widespread use of existing innovations within new country contexts, and is therefore of critical interest in the context of eco-innovation where rapid adoption and diffusion is a central concern.

Incremental innovations are seen as occurring more or less continuously as economic agents strive to improve quality, design and performance. This emphasises the importance of learning by using, doing and interaction between suppliers and users of technology (Lundvall, 1988; Freeman, 1992). Incremental innovation has often played a critical role in instances of assumed technology "leapfrogging" in developing countries,[14] where countries have moved towards, and then surpassed the international technological frontier. For example, Gallager (2006) cites the case of the Korean steel industry which eventually emerged as international technology leaders as a result of the adoption of internationally established technology followed by a continuing process of incremental improvements. Here, a continuum of type 2 (innovations new to the industry) and 3 (innovations new to the firm) innovations eventually led to what could be seen as constituting a type 1 (innovations new to the world) innovation in terms of new steel production processes. As with adaptive innovation below, the emphasis shifts away from centralised R&D further along the continuum of technology demonstration, revision and commercial deployment at the decentralised firm level.

Adaptive innovation describes processes where existing technologies are adapted in ways that can be applied in new contexts. This is a particular concern in relation to eco-innovation. For example, carbon capture and storage technologies will need to be adapted to suit both local fuel sources and geological storage options (Tomlison et al., 2008); new strains of drought resistant crops need to be viable within local ecological and environmental management contexts; energy efficiency or clean, decentralised energy options need to work within the context of existing cultural (behavioural) practices and existing infrastructure; and so on.

[14] For a comprehensive discussion on leapfrogging see Sauter, R. and Watson, J. (2008) Technological Leapfrogging: A Review of the Evidence Report for UK Department of International Development. SPRU, University of Sussex, December. Available at http://www.sussex.ac.uk/sussexenergygroup/documents/dfid_leapfrogging_reportweb.pdf

These kinds of context specificity and the associated need for adaptive innovation might also be observed in regional differences in existing levels of absorptive capacity i.e. the ability of firms, societies or individuals to adopt new technologies, including technological capabilities, knowledge, skills and supportive institutions – all central considerations when assessing the extent to which developing country firms can work with existing formulations of clean technologies. Context specificity might also apply to the suitability of different technological options for communities with different wealth levels. In poor rural areas, for example, it might be more viable to explore adaptive innovation around low maintenance configurations of solar and LED (light emitting diode) technology, as opposed to clean options for centralised energy generation which might better suit urban industrial interests. Some commentators have also highlighted the potential importance of the related concept of "below the radar" innovation (Clark et al., 2009) where, rather than new technologies diffusing from a unitary technological frontier, locally-adapted innovations increasingly emerge as a result of incremental tinkering and adaption of external technologies in order to address local needs and environments. In some (but not all) cases these locally-adapted innovations find application elsewhere.

As with incremental innovation, adaptive innovation is heavily weighted towards type 2 (innovations new to the industry) and type 3 (innovation new to the firm) innovations. Type 2 and 3 innovations can therefore be considered as central to technological development in developing country contexts. They underpin the kind of incremental and adaptive innovation processes that better characterise technological transitions than radical innovation, which is much rarer. It follows that in developing countries, policy which seeks to underpin a transition to, or industrial development paths based upon, clean technology is likely to be most effective if targeted at facilitating type 2 and 3 innovations at the decentralised firm level. This contrasts with the traditional dominant focus in developed countries on encouraging type 1 innovation (via undue concentration on innovation as something which occurs in centralised R&D labs)(Bell, 2009).

A more successful policy approach is likely to emphasise instead the development of indigenous innovation capabilities in developing countries, as well as the need to often focus on later stages of the research, development, demonstration and deployment (RDD&D) spectrum – support for this argument is central to the issues unpacked later in this report. There is also a need for knowledge flows (both know-how and know-why), as well as tacit knowledge flows (knowledge developed from hands on experience with clean technologies and related design and engineering processes) as part of providing developing country access to eco-innovations. This is not to say that there is no role for publicly funded R&D in developing countries which will remain important in supporting the training of engineers in working with state of the art products and processes, and underpinning adaptive innovation in some instances. Instead the point is that a shift in emphasis needs to occur away from a sole focus on R&D towards a relative and absolute increase in public spending on developing eco-innovation capabilities amongst developing country firms.

The centrality of knowledge flows and developing eco-innovation capabilities in developing countries is dealt with in more detail further below. Before tackling this issue, however, it is first necessary to take a moment to understand both why eco-innovation is distinct, and the nature of developing countries' likely motivations for being interested in it.

Why is eco-innovation unique?

To understand the barriers developing countries face in accessing eco-innovations it is first necessary to appreciate the distinct nature of eco-innovation. Under normal circumstances technological innovations often tend to make their way into usage within developing country contexts over varying time periods. These time periods relate to actions within the private sector, often underpinned by demand pull or supply push pressures emanating from normal market pressures, domestic or international policy and/or the strategic actions of technology supplier or recipient firms. This usually involves technologies that are already in commercial use in certain countries. Their uptake is usually unrelated to policy imperatives and therefore the time dimension is unimportant.

Eco-innovations are distinct for two reasons. Firstly, they span a whole range of stages of technological development, from the research and development stage (e.g. next generation biofuels), to the demonstration stage (e.g. Integrated Gasification Combined Cycle, IGCC, based coal fired power stations), to the supported commercial stage (e.g. wind and solar power supported by feed-in tariffs). Secondly, the rapid uptake of eco-innovations in developing countries will yield global benefits by addressing critical environmental problems (e.g. climate change and biodiversity loss). This implies that their uptake within developing country contexts needs to be encouraged over as short a time period as possible. In other words, whilst the uptake of innovations tends to take place over varying (and often long) time periods, the uptake of eco-innovations needs to be achieved as a matter of urgency if catastrophic local, regional and global environmental, economic and social impacts are to be avoided.[15] Moreover, these environmental and social costs and benefits are not usually captured by markets, thus contributing to higher incremental costs of eco-innovations relative to non-eco innovations.

Importantly, when considering the choices developing countries face in choosing to focus on eco-innovations, the early stages of development of many eco-innovations present a number of barriers, such as increased costs of new technologies (before economies of scale and efficient production processes can be realised), increased investor risks, lack of practical experience working with these technologies, lack of information on their use in the face of geographically or culturally determined variables (see the discussion on adaptive innovation above), and so on. These are similar (although, due to wealth related factors, more acute) to barriers faced in many developed country contexts where eco-innovations are not yet in widespread use. Policy is therefore often simultaneously required to encourage the transition of eco-innovations along the research, development, demonstration and deployment (RDD&D) spectrum *at the same time as* encouraging access in different geographical contexts. In the parlance of the technology transfer literature, eco-innovation must deal with both horizontal (from one country context to another) *as well as* vertical (from R&D to commercial deployment) transfer – a problem that is only likely to be overcome via targeted policy intervention (Ockwell et al., 2008). Additionally, even where technologies are already commercially deployed in one country, they often need to undergo processes of adaptive innovation before they can usefully be produced or utilised within another country context.

It is also worth noting here that the traditional notion of horizontal transfer of eco-innovations from developed to developing country contexts (north-south transfer) does not always apply. Many emerging economies (in particular Brazil, Russia, India, China, South-Africa, the BRICS countries) are now producers and suppliers of eco-innovations in their own right. For example, India and China have firms that rank in the top ten within the global wind power industry, and Brazil has been identified as a globally significant supplier of sugar cane based biofuels and related technologies. This means that technology transfer is now often observed both between developing nations (South-South transfer) as well as occasionally from developing nations to developed nations (South-North transfer). For a more detailed exploration of this see Brewer (2008).

Eco-innovation: why should developing countries care?

A policy approach that aims to provide access to eco-innovation in developing countries is likely to be most effective if tailored to respond simultaneously to the interests of both developing nations and industrialised countries. Developed countries have an interest in encouraging the uptake of eco-innovations in developing countries due to their public good nature and related potential to reduce and adapt to the impacts of global environmental problems. International firms also potentially stand to gain as

[15] For an economics based rationale for this claim in relation to low carbon technologies see Stern (2007).

a result of new market opportunities in developing countries for existing or new clean technologies. This might apply particularly where developing country engagement at the local level might lead to adaptive innovation that opens up new variants of technologies specifically applicable within developing country contexts. Nevertheless, it should be noted that many international firms have concerns relating to engaging with developing countries. This often focuses on fears related to contributing to the technical expertise of potential competitors in developing countries, essentially creating future competitors that might challenge the market dominance of existing international leading firms. This is a key barrier that must be addressed if international firms are to perceive incentives to engage with developing countries.

In the face of pressing concerns relating to poverty and economic development, however, the incentives for developing countries to actively pursue eco-innovations is sometimes less clear. Two key motivations exist for developing countries to pursue eco innovation. Firstly, developing countries are often most vulnerable to the impacts of environmental problems. For example, climate change stands to impact hardest in some of the world's poorest nations, as well as the larger emerging economies like India and China, significant parts of which are particularly vulnerable to impacts such as drought and flooding. It is therefore in their interest both to access eco-innovations relevant to both adapting to the impacts of climate change and reducing emissions of greenhouse gases to mitigate against future climate change. It should be noted, however, that adaptation technologies are not necessarily 'eco' (although they may be e.g. more efficient irrigation techniques) – they need to deal with local circumstances as required, and more concrete on a flood barrier is not 'eco', but could be essential.

Secondly, and perhaps more importantly in terms of immediate concerns with economic development, access to technology is a key determinant of levels of economic development. A north-south gap historically exists in terms of technology ownership (Missbach, 1999), with industrialized countries having a clear technological advantage. Increased access to technology is one of the pre-requisites of economic growth, self-reliant development, and poverty alleviation. By accessing eco-innovations developing nations therefore open up the potential for technological change within existing industries, thus improving their competitive advantage through increased factor productivity and/or the development of new, competitive products and broadening the industrial base of a country via the establishment of new industry sectors with associated employment benefits, profits and public income through taxes (Lall, 1998; Gereffi, 2001). Access to new technology not only offers the possibility of moving up the value chain, it also provides opportunities to diversify into new products similar to the ones originally imported (Bell, 1997). Eco-innovations are a key area where developing countries might access new technologies with the support of international policy incentives. It must be acknowledged, however, that this is a source of concern for industrialised country firms which sometimes fear that this will result in them losing their competitive advantage.

The centrality of knowledge flows and indigenous innovation capabilities

Thus far we have established the nature of eco-innovation and the reasons for developing countries' potential interest in accessing the clean technologies that eco-innovation underpins. Within this context, understanding what policy approach is most likely to encourage the uptake of eco-innovations in developing countries requires a more in depth analysis of what constitutes flows of technology from one country context to another, and what part of these flows is most likely to facilitate rapid and sustained uptake of eco-innovations within developing countries. Central to this is the knowledge that is associated with new, clean technologies.

As mentioned above, 'technology' needs to be understood as both 'hardware' (physical equipment) and 'software' (knowledge and processes). This software includes both codified knowledge (e.g. engineering and manufacturing processes) and tacit knowledge (i.e. human – embodied knowledge acquired by doing, e.g. applied engineering & systems integration skills). Bell (1990) offers a useful typology for understanding the qualitatively different flows associated with the transfer of technology from a technology owner or supplier to a technology recipient (see Table 1). He breaks these down into three flows – A, B and C.

Flow A comprises the capital goods and services needed to create the physical facilities of a new production system. Flow B refers to the skills and know-how needed to operate and maintain the newly installed production facility. Some of these skills might already exist in the host country, but usually, as Bell highlights, if transfer projects involve elements of flow A, at least some elements of the whole transfer process fall into category B. Flow C refers to the skills and knowledge necessary in order for recipient firms to build the expertise necessary to become producers of new technologies, and innovators in their own right, as opposed to just being consumers of new technology dependent on continued imports. As well as expertise and access to codified knowledge that might either be patented, or known only to the technology owners, this knowledge flow also includes experiential, non-codified, or tacit knowledge. The centrality of tacit knowledge, or experience with working with the technology and processes in question (or related technologies), is often overlooked. As discussed below this failure to recognise the importance of tacit knowledge is characteristic of some views on the role of intellectual property in technology transfer.

Table 1.The technological content of international technology transfer

TECHNOLOGY SUPPLIERS		TECHNOLOGY TRANSFERRED		TECHNOLOGY IMPORTERS
Supplier firms' engineering, managerial and other technological capacities	Flow A >>>>>>	Capital goods Engineering services Managerial services Product designs	>>>>>	Creation of new production capacity
	Flow B >>>>>>	Skills and knowledge for operation and maintenance (know how)	>>>>>	
	Flow C >>>>>>	Knowledge, expertise and experience for generating and managing indigenous eco-innovation (know why)	>>>>>	Accumulation of technological capacity

Source: Based on Bell (1990)

Whilst, as Bell points out, there is no sharp distinction between C- and B-type flows, C-type flows are significantly different from, and additional to, the knowledge needed to operate a production facility. While flows A and B lead to the creation of new production capacities in the recipient country, C-type flows enable the additional benefit of augmenting indigenous eco-innovation capabilities. This includes the capacity to adapt the technology to local, changing needs, to replicate it, enhance it and eventually create new technology.

As discussed above, the uptake of new technologies, and eco-innovations in particular, within a developing country context relies centrally on processes of incremental and adaptive innovation. Bell's typology implies that in order to become technology producers and innovators technology recipients first need to access the knowledge (including codified and tacit knowledge) that underpins the superior innovation capabilities that enabled supplier companies to produce these new technologies in the first place. It is these superior innovation capabilities and the knowledge that underpins it that defines the competitive advantages of technology leading firms, not the possession of pieces of hardware.

The key message to take on board here is that it is the development of new eco-innovation capabilities amongst developing country firms that will *both* improve their capacity to absorb new eco-innovations *and* enable them to become innovators in their own right, thus underpinning sustainable economic development.[16] Bearing in mind the critical need for adaptive and incremental innovation by developing country firms, both these considerations imply that policy aimed at encouraging sustainable development in developing countries will be most effective if targeted at fostering the development of new eco-innovation capabilities. Ways in which this might be achieved are outlined in section 2 in relation to key policy considerations. First let us take a moment to consider the role of intellectual property in all this.

A note on intellectual property (IP)

Much debate has tended to focus on the role that intellectual property (IP - by which most commentators in relation to eco-innovation tend to mean patents[17]) might play in facilitating access to eco-innovations in developing countries. The G77 coutnries under the UNFCCC negotiations, for example, have proposed the creation of a multilateral fund to buy up IP in relation to low carbon technologies. In the context of the UNFCCC process, developed (Annex I) nations have tended to be resistant to this proposal, arguing that developing countries having access to IP will not necessarily equate with developing country firms being able to work with new technologies[18]. It is, however, important to acknowledge the influence here of industrialised country firms' desire to protect IP, and the motivations of developing country governments that wish to avoid excessive IP-related costs – neither view being well represented by empirical evidence, as discussed below.

Empirical evidence to date on the role of IP in facilitating access to eco-innovations is both limited and mixed. Various studies (e.g. Barton, 2007; Lewis, 2007), including our own as yet unpublished work at Sussex University on low carbon technology transfer to India, have shown that the picture is more complicated than the political debate implies. The analysis below represents a synthesis both of an in depth review of existing literature in this area and Sussex University's own empirical findings from working with partners in India (for a detailed discussion see Ockwell, in press)[19]. The lack of extensive empirical study on the role of IP in relation to developing country access to eco-innovations should be taken as an indicator of a lack of ability at this stage to make any firm conclusions. Nevertheless, the observations below do lend themselves to useful policy insights.

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[16] This is also often referred to as the "absorptive capacity" of developing country firms – their ability to absorb and work with new technologies and is increasingly recognised as integral to facilitating the transfer of eco-innovations – see e.g. Nick Johnstone and Ivan Haščič (2009); Ockwell et al. (2008); Mallett et al. (2009). For more details contact David Ockwell d.g.ockwell@sussex.ac.uk

[17] Other IPRs include copyrights, which could be particularly relevant in the case of software used for low carbon energy technologies, and Plant Variety Protection, relevant for both climate change mitigation (e.g. biofuels) and adaptation (e.g. drought-resistant varieties of crops) – see Abbott, F. (2008) '*Innovation and Technology Transfer to Address Climate Change: Lessons from Global Policy Development on Intellectual Property and Public Health'* United Nations Framework Convention on Climate Change, Conference of the Parties 14 (COP14). Poznan.: 6

[18] See, for example, HM Government (2009); UNCTAD-ICTSD (2003)

[19] Sussex gratefully acknowledges its collaborators in this work, The Energy and Resources Institute (TERI), Margaree Consultants and the Institute for Development Studies (IDS).

When discussing IP in the context of eco-innovation, it is first important to make some clarifications. First is the distinction between consumers, or users, of low carbon technologies, and producers of these technologies. Consumers of new technologies are unlikely to experience any specific IP related barriers to accessing these technologies. The barriers consumers face are more likely to be related to costs (although a part of these higher costs can be due to IP), which, as outlined above, are often higher for eco innovations. For example, it could be imagined that once the technology becomes commercial an integrated gasification combined cycle (IGCC) power plant (a clean coal technology) might cost 25-30% more than a supercritical coal-fired power plant. But it is difficult to say exactly how much of this extra cost would be related to patents, e.g. it may only be a small percentage. For firms wishing to become producers of such technologies, on the other hand, the existence of and access to patents is likely to play a much more significant role in terms of the rate at which they are able to access the knowledge necessary to start manufacturing these technologies. For example, in India we observed a situation where negotiating existing patents seemed to be slowing down the rate at which Indian firms are able to develop commercial hybrid vehicle technologies without infringing existing international patents owned by industry leaders.

Another important aspect to keep in mind is the distinction between the incremental cost of eco-innovations and the potential cost of the IP. New technology often costs more than existing technology until the time that demand increases to the level where economies of scale can be realised. This is further compounded in the case of eco-innovations due to the failure of markets to reflect the environmental benefits associated with eco-innovations and the environmental costs associated with many technologies. In many cases there will be virtually no demand for eco-innovations in developing countries unless the incremental cost is addressed via international policy mechanisms, or by domestic policies such as renewables targets or energy efficiency standards (which can yield cost savings to the equipment users). This can also be related to different remedies – free IP will only make eco-innovations competitive if the incremental cost is less than the cost of the IP. In the case of IGCC for example, where IP may only account for about 2% of the incremental costs of IGCC over conventional coal technologies, free IP would still make IGCC more expensive than conventional coal technologies. Compulsory licensing might (or might not) be needed, but a way of funding the incremental cost would also be required.

This cost consideration, together with the sheer number of patents that often relate to environmentally sound technologies, such as low carbon energy generation technologies like wind turbines, or more efficient end use technologies like hybrid vehicles, make comparisons with other sectors difficult. Parallels are often drawn, for example, with the treatment of IP in relation to anti-retroviral drugs in the pharmaceuticals sector. Pharmaceuticals, however, are often characterised by innovations protected by a smaller numbers of patents where the cost of IP contributes to a large proportion of the costs of being able to manufacture new medicines.

With all clean technologies studied to date (by ourselves and by the other studies cited), firms in emerging economies (India and China being the two countries most studied) have been seen to be active at some point along the research, development, demonstration and deployment (RDD&D) spectrum. At the time of study (2007/08), however, none were producing at the cutting edge. Lack of access to IP also seemed to have the potential to slow the rate at which firms in developing economies could begin to reach the cutting edge. For example, successful Indian photovoltaic technology firms predicted difficulties in moving to produce thin film grade silicon, and, as noted above, Indian automotive firms and related public sector organisations were, despite a successful public-private Indian collaborative partnership, taking time to negotiate the IP that exists in relation to hybrid vehicles. This suggests that in some instances developing country access to IP might indeed need to be addressed via international policy mechanisms in order to expedite the rate of diffusion of eco-innovations in developing countries (for an up to date review of options for managing IP in relation to climate relevant technologies see Maskus, 2009).

But simple access to IP is only part of the picture. In cases where affordable access to patents is possible, this is often not enough for developing country firms to begin producing these technologies. A huge amount of knowledge is often protected by companies in the form of trade secrets and tacit knowledge relating to, for example, the management and manufacturing systems that underpin the ability to apply these patents within the production process. For example, in 2006 when researchers from Sussex University spoke to Indian Light Emitting Diode (LED) manufacturers these firms emphasised that access to IP relating to white LEDs would not enable them to start manufacturing this technology. Instead, what they wanted most was access to existing manufacturers' knowledge and experience of the manufacturing processes involved. Similarly, a far more important barrier than IP for Indian companies wishing to work with IGCC has been difficulties related to accessing knowledge on the practical experiences of global leaders in this technology, compounded by the fact that there are few suppliers and only semi-commercial plants in operation worldwide – thus again emphasising the importance of tacit knowledge, and the need to adapt IGCC to use local high ash coal.

IP also does not necessarily provide knowledge of the processes of innovation that lay behind the development of new low carbon technologies to which the IP relates. Before developing country firms can make use of knowledge tied up in patents they first need to possess certain competences that will enable them to work with particular technologies (Hammond, Stapleton, 2001). Or, in other words, they need to possess sufficient absorptive capacity to work with the technology in question. This is influenced by a wide range of factors, including tacit knowledge, the internal organisation of the firm, interactions via inter-firm linkages, supply chains and networks, past learning efforts, investments in human capital and 'learning by doing', market structure and competitive pressure, government interventions to correct the failure of markets for knowledge (education, R&D training), government led institutional arrangements to facilitate innovation (R&D labs, technology intermediaries), and finally access to finance (Bell, Pavitt, 1993). Without any of this, providing access to the IP for a new eco-innovation would be similar to giving a standard mechanic access to the blueprints to a new design of formula one racing car – it is highly unlikely that the mechanic would be able to successfully build the car without access to the engineering, design and mechanical experience of specialised formula one development and manufacturing teams. All this implies that access to IP alone might have little impact on the key goal of developing new indigenous eco-innovation capabilities in developing countries. Policy options that focus simply on providing access to IP are therefore unlikely to be successful in fostering long term access to eco-innovations in developing countries.

Similarly, however, while a single focus on IP ignores the additional aspects necessary to build new eco-innovation capabilities, a narrow policy focus that ignores IP related issues and looks instead towards providing developing countries access to new eco-innovations on the basis of them as "consumers" rather than "producers" ignores the vital role that indigenous eco-innovation capabilities play in achieving the adoption and diffusion of eco-innovations. As discussed above, new innovations will often not diffuse in a new environment unless they are adapted to local conditions. Diffusion may often involve the ability of indigenous firms to replicate a technology, enhance it and eventually create a new product (Bell, Pavitt, 1993). Where the relevant knowledge and processes for such replication are patent protected it may therefore be necessary to facilitate access to patents. Whilst access to IP may therefore not be the one and only concern for international policy, it nevertheless cannot be ignored.

Summarising barriers to eco-innovation in developing countries

On the basis of the above discussion it is possible to summarise a number of key barriers that developing countries face in accessing eco-innovations. They can be summarised as follows.

Lack of international policy focus on indigenous eco-innovation capabilities

There is a strong tendency for policy discussions at the international level to focus on the idea of providing developing countries with access to existing eco-innovations on the basis of them consuming existing technological hardware. In other words it is seen as sufficient that developing countries become consumers of eco-innovations rather than producers and eco-innovators in their own right. This fails to recognise the central need to foster the development of indigenous eco-innovation capabilities in developing countries. Indigenous eco-innovation capabilities are essential to facilitating *both* the diffusion of existing eco-innovations within developing countries *and* sustainable economic development based on the adoption, adaption and development of environmentally sound technologies that fit with the bespoke conditions faced by developing countries.

Characteristics of eco-innovation

Eco-innovations are often not yet at commercial stages in their development. Instead they span the full range of the RDD&D spectrum thus raising a range of issues that many commercial innovations are not subject to. These include increased risks to investors, lack of available sources of venture capital, lack of knowledge of operation (particularly in new geographical and cultural contexts) and higher incremental costs.

Incremental costs and market failures

As well as the increased costs associated with new technologies noted above, the incremental costs of eco-innovations are exacerbated by the failure of markets to capture the environmental benefits of eco-innovations, or the environmental costs associated with non-eco innovations.

Intellectual property

Evidence available to date suggests a complex picture in relation to IP for eco-innovation. Whilst access to IP might be necessary in some cases, it is unlikely to be sufficient in itself to enable developing country firms to become producers of eco-innovations. Firms also need access to tacit and other related knowledge (e.g. trade secrets) which are often not patent protected. These are also important factors in developing indigenous eco-innovation capabilities. Nevertheless, the fact that evidence suggests patents can sometimes slow the rate at which developing country firms can become producers of eco-innovations, or produce at the cutting edge, suggests that international policy mechanisms do need the capacity to be able to address IP in specific instances.

POLICY RELEVANT ISSUES

Building on the analysis in Section 1, and particularly focussing on the barriers summarised at the end of the Section, a central goal for policy aimed at facilitating developing country access to eco-innovation can be articulated together with a number of guiding criteria and key policy considerations.

Central policy goal: maximising leverage

The central policy goal in any attempt at facilitating developing country access to eco-innovations is to maximise leverage from public spending in two senses:

- **Maximise impacts on indigenous eco-innovation capabilities.** This will encourage the uptake and rapid diffusion of existing eco-innovations, as well as the development of new eco-innovations relevant to specific developing country contexts. It is also necessary in order to facilitate a process of long term, sustainable economic development in developing countries based on clean technology;

- **Maximise leverage of private finance.** The vast majority of the new investment required to fund a transition to an economy characterised by widespread adoption of eco-innovations will come from the private sector. It is therefore vital to establish approaches to investing public finances that are likely to have maximum impact in terms of attracting and sustaining private investment in relevant technologies.

By focussing on leverage in these two senses it may be possible both to mobilise sufficient finance to deliver widespread adoption of eco-innovations, and to do so in a way that ensures developing countries develop indigenous innovation capabilities as a result. In this way critical thresholds of eco-innovation capabilities might be met in developing countries hence facilitating long-term, sustained development along more environmentally sustainable trajectories.

Guiding criteria and considerations

Developing indigenous eco-innovation capabilities

In order to maximise leverage in terms of developing indigenous eco-innovation capabilities, any effective policy response must ensure two things:

- Imports of existing eco-innovations to developing countries have maximum impact on developing new indigenous eco-innovation capabilities (e.g. by requiring the use of host country suppliers & parts manufacturers; requiring the use and training of host country engineers, designers, building contractors etc.; including knowledge sharing and training agreements in any international initiatives related to the transfer of clean technology);

- **Specific mechanisms for developing eco-innovation capabilities in developing countries are established** (e.g. exchange/placement schemes for developing country engineers and designers with technology leading firms; international collaborative research, development, demonstration and deployment (RDD&D) initiatives at appropriate points along the RDD&D spectrum based on in depth analysis of existing capabilities within the relevant country).

Intellectual property

The political acceptability of any international policy mechanism aimed at fostering access to eco-innovations requires explicit mechanisms to address IP. The evidence reviewed above suggests that such a requirement has empirical support. However, it will not be sufficient in itself to foster access to eco-innovations. Emphasis should be placed on the acquisition of tacit knowledge and other experiential knowledge rather than just knowledge tied up in patents. It is these other types of knowledge that are essential to developing indigenous eco-innovation capabilities.

Engaging international involvement

In order to be politically acceptable to international technology owning firms and developed country governments, policy proposals must also address the following two concerns:

- **International competitive advantages** should not be seen as significantly threatened by participation in / agreement to the proposed mechanisms;

- In order to achieve point 1, the **benefits to international firms** need to be clearly articulated and communicated (e.g. accessing new markets for existing technology, creating new markets by either adapting technology to new conditions or developing new bespoke technology). This must be pursued with due recognition of international firms' concerns regarding the potential for developing country firms to become future competitors.

There may also be important opportunities for research partnerships along the lines of the triple helix model in innovation studies where industry, the academic sector and governments at various levels (nation, region / state, and local) work together to innovate, but with the added requirement for international components of any partnerships. Such collaborations should aim to strengthen links across different sectors of the domestic economy within developing countries, especially industry/academia/government connections, and to engage international involvement in these partnerships. Each of these players can bring different skills and expertise to the table. The argument is that projects with more sources of leadership and support will be more likely to succeed.

Context specificity

The need for context specificity must be both recognised and facilitated. This refers to differences in circumstances and needs between countries (e.g. emerging vs. least developed) and within countries (e.g. urban vs. rural, rich vs. poor). It also refers to differences in the technological characteristics of different technologies (e.g. large energy generation technologies vs. improved farming methods) and the appropriate stage of collaboration along the RDD&D spectrum that is most likely to optimise the benefits to developing country firms. This latter consideration is dependent upon the level of existing innovation and absorptive capabilities across different sectors in different countries. Facilitating context specificity, within an overarching international framework that delivers real environmental benefits may require a combination of a top-down strategic framework with bottom-up needs based assessment frameworks linked in to relevant local, national and international centres of knowledge and expertise.

International collaborative RDD&D

One of the most promising ways in which developing country access to eco-innovations could be fostered is via the establishment of international collaborations at the appropriate points along the RDD&D spectrum. This has the potential to foster the development of indigenous eco-innovation capabilities by facilitating access to tacit and other relevant knowledge and skills. Such collaborations also heighten the potential for adaptive innovation specific to individual developing country contexts. They also offer potential in the longer term for overcoming IP related issues if collaborations are established at early stages in the innovation process with explicit agreements as to how IP will be treated.

Three considerations are particularly important in the establishment of collaborative RDD&D initiatives. Firstly, they need to be developed on the basis of bespoke approaches that carefully consider the existing innovative and absorptive capabilities of firms within developing countries. This requires bottom up engagement with firms, which are often the actors that possess the most sophisticated understanding of practical technological areas with most potential for development. They are also usually aware of which international firms possess the relevant knowledge, and which point along the RDD&D spectrum it would be most beneficial to target collaboration.

Relatedly, the second consideration is the need to shift the emphasis of policy away from the traditional focus on centralised R&D capabilities towards the development of skills and capabilities at the decentralised firm level. This might benefit most from bespoke initiatives that focus on knowledge sharing at later stages along the RDD&D spectrum. It also requires an emphasis on facilitating underlying and tacit knowledge sharing, as well as follow-on funding to ensure that the benefits of collaborative initiatives can be communicated throughout an industry, as opposed to only benefiting those companies directly involved in the initiatives. This opens up opportunities for cross-fertilization and flourishing of otherwise isolated innovations. It does, however, raise issues for large developing countries in that it opens up issues of domestic competition issues (who receives help, who doesn't) and WTO rules.

The third consideration, as mentioned above in relation to international engagement, is the need to demonstrate the benefits to international firms of engaging in such collaborations. This includes communication of potential new market opportunities, properly negotiated and enforced IP agreements, and possibly financial or other incentives for participation.

The types of interventions that such collaborative interventions need to focus on are well articulated by the Carbon Trust (see Carbon Trust, undated) in relation to low carbon technologies, as set out below:

- Applied research and development: Grant funding, open and/or directed at prioritised technologies;
- Technology accelerators : Designing and funding projects to evaluate technology performance e.g., field trials;
- Business incubator services: Strategic and business development advice to start-ups;
- Enterprise creation: Creation of new low carbon businesses by bringing together key skills and resources;
- Early stage funding for low carbon ventures: Co-investments, loans or risk guarantees to help viable businesses attract private sector funding;

- Deployment of existing energy efficiency technologies: Advice and resources (e.g. interest-free loans) to support organisations to reduce emissions;
- Skills / capacity building: Designing and running training programmes;
- National policy and market insights: Analysis and recommendations to inform national policy and businesses.

This highlights the need for collaboration across the full RDD&D spectrum, including ways of reducing risks to industries in using new technologies, as well as targeted interventions focussed on skills and capacity building.

Incremental costs

In parallel with initiatives that are explicitly focussed on developing indigenous eco-innovation capabilities, policy mechanisms need to be put in place, both nationally (see below) and internationally to reduce the higher incremental costs of eco-innovations. This requires two things. Firstly the increased costs and investor risks associated with new technologies need to be addressed, for example by creating funds and initiatives that can share the cost and risk of investment in eco-innovation. Secondly, market-based mechanisms that aim to internalise environmental externalities (e.g. markets for carbon, environmental taxes and subsidies) need to be introduced.

Domestic policy

Whilst the emphasis of international policy debates tends to be on international interventions, it is also important to recognise the essential role that domestic policy plays in creating markets for, and encouraging the development and diffusion of eco-innovations (Johnstone, Hascic, 2009) – a fact that applies as much in developed countries as it does in developing countries. National emissions limits on new vehicles, for example, or feed-in tariffs for renewable energy, provide significant incentives for the development and diffusion of clean technologies. This has positive knock-on effects both in terms of creating demand and enabling the realisation of economies of scale. The high cost of batteries for hybrid vehicles, for example, is unlikely to decrease without more large scale production, which needs to be driven by increases in national demand for hybrid and/or electric vehicles.

POTENTIAL OF EXISTING MECHANISMS TO OVERCOME BARRIERS

This final section of analysis considers the success of some existing Multilateral Environmental Agreements (MEAs) and other collaborative initiatives in addressing the key policy considerations outlined above.

The key message to emerge from this analysis is that an important gap exists at the level of context-specific approaches to generating indigenous capabilities at the firm level in developing countries and sustaining long term development around eco-innovation. Instead international initiatives have, to date, tended to favour large, centralised project based initiatives with a strong bias towards rapidly emerging economies. The section concludes by analysing two initiatives (The Carbon Trust's proposed network of Low Carbon Technology Diffusion and Innovation Centres, and Fundacion Chile) which provide models for a potentially more effective approach that is able to bridge this gap.

Selection of initiatives for analysis

There are a wide range of different international initiatives of relevance to this analysis. The scope and timescale of this report excludes consideration of all of them. The report is also constrained by the availability of either existing literature reviewing existing initiatives or the authors' own direct experience or access to relevant primary empirical evidence.

Selection of initiatives for analysis has been designed to cover both different spatial scales and different types of technology-oriented initiatives. Coverage was therefore sought of broad international initiatives as well as more targeted nationally/locally oriented initiatives, and a range of types of initiatives from MEAs and information sharing initiatives to approaches to brokering international collaborations along the RDD&D spectrum. The following initiatives are reviewed:

- MEAs: the Montreal Protocol and the Expert Group on Technology Transfer (EGTT) under the UNFCCC; relatedly, consideration is given to the two key funding initiatives that support the remit of the EGTT, namely the CDM and GEF climate programme;
- Information sharing: the Environmental Technology Verification initiative;
- International collaborative RDD&D: the UK Carbon Trust's proposed network of Low Carbon Technology Diffusion and Innovation Centres, and Fundation Chile (a Chilean not for profit organisation geared towards facilitating access to relevant international innovations and increasing indigenous innovation capabilities).

Multilateral Environmental Agreements (MEAs)

MEAs represent the highest level of intervention considered here being based at the international level, usually with a high degree of political negotiation underpinning their remit and administration. Two initiatives have been selected for analysis here. The Montreal Protocol on Substances that Deplete the Ozone Layer, formed in 1987, is widely regarded as a successful example of an MEA that provided developing countries with access to eco-innovations. The EGTT under the UNFCCC has met with more limited acclaim with low carbon technology transfer being broadly regarded by many developing countries as one of the key areas that the UNFCCC has failed to deliver. By considering these two MEAs in turn, this section is therefore able to give some consideration to the aspects of, and conditions under which, MEAs facilitate access to eco-innovation.

The Montreal Protocol

The Montreal Protocol on Substances that Deplete the Ozone Layer is widely regarded as a successful example of an MEA that provided developing countries with access to eco-innovations. Whilst developed nations were quick to ratify the Protocol, which included binding reduction targets for all parties, developing nations initially objected due to the costs of compliance. Developing nation participation was finally secured in 1990 via an amendment to the Protocol which established a Multilateral Fund (US$2.1 billion between 1991-2005 with replenishment levels of US$400 million for 2006-08)(Coninck et al., 2008a; UNEP, 2005) geared towards meeting the incremental costs of compliance faced by developing nations. This is delivered in the form of grants and loans via four implementing agencies: United Nations Development Programme (UNDP), United Nations Industrial Development Organization (UNIDO), the World Bank and UNEP (see http://www.multilateralfund.org/about_the_multilateral_fund.htm). The establishment of this multilateral fund for financing technology transfer to developing nations, and the equal voting powers given to developing nations in relation to its application, are unique features of the Montréal Protocol relative to other MEAs (Zao, 2005).

The result was significant reductions in global emissions of Ozone Depleting Substances (ODSs), together with substantial increases in developing country access to eco-innovations in the form of non-ODS technologies. Importantly, the multilateral fund includes provision not just for paying the costs of acquiring access to relevant technologies and manufacturing process and their related costs such as royalties and patents, it is also able to fund the training of personnel (UNEP, UNCTAD, 2007) and the establishment of national Ozone Units which act as focal points for implementation. This provision for funding training in developing country firms potentially goes some way to fulfilling the need to ensure that the transfer of hardware is accompanied by software flows, and in particular the less well attended issue of access to tacit knowledge. Analysis of the exact nature of these training initiatives and their knock-on benefits for developing indigenous eco-innovation capabilities would constitute a useful addition to the existing evidence available on the Montreal Protocol and the extent and nature of its successes in facilitating developing country access to eco-innovation. In particular information is required in relation to the extent to which information flows have included flows of knowledge relating to what underpinned relevant innovations (i.e. know-why type knowledge flows).

The perceived success of the Montreal Protocol in providing developing countries with access to new environmentally sound technologies led to suggestions that a similar MEA-based approach might work for addressing other global environmental problems such as climate change (see for example, Victor, 2001). After all, similar to ODSs, greenhouse gases share the characteristics of deriving from locally distributed sources but contributing to a global atmospheric problem (climate change). This comparison has, however, been widely dismissed due to the far greater scale of changes required to address climate change (Coninck et al., 2009). Zhao (2005, p.77) lists the factors underpinning the success of the Montreal Protocol as including "… the limited number of industries involved, the availability of substitutes for ODS, the lack of any coherent and sustained industrial or public opposition, the relative certainty of scientific research, and the relatively low compliance costs." These are not shared in the case of the climate change problem, characteristics of which include the far greater number of and widespread sources of greenhouse gases (GHGs), the greater costs involved, and the much deeper social and systemic changes (e.g. behaviour change, addressing existing technological lock-in to high carbon infrastructure) that would be required to facilitate a shift to a low carbon society.

The Expert Group on Technology Transfer (EGTT) under the UNFCCC

International efforts to facilitate developing country access to low carbon technologies under the UNFCCC were, until recently, nominally coordinated by the EGTT. Since this report was originally drafted, proposals were put forward at the UNFCCC Convention of the Parties in Copenhagen (in December 2009) which led to a draft decision, noted in the currently (at time of writing) non legally binding Copenhagen Accord, to replace the EGTT with what is viewed by many commentators as a more ambitious "Technology Mechanism" (FCCC/AWGLCA/2009/L.7/Add.3 – see http://unfccc.int/resource/docs/2009/awglca8/eng/l07a03.pdf). The analysis in this report was conducted prior to this draft decision and focuses on the experience of the EGTT pre-Copenhagen with the aim of drawing out relevant lessons for future ways forward.

The EGTT operates within the context of the UNFCCC's technology transfer framework[20]. Membership is limited to nineteen experts from the following parties to the UNFCCC:

1. Three members from each of the non-Annex I (developing countries) Party regions (Africa, Asia and the Pacific, and Latin America and the Caribbean);

2. One member from the small island developing States;

3. Eight members from Annex I (developed country) Parties;

4. One member from other non-Annex I Parties

Members are nominated by respective parties and sit for a two year term serving a maximum of two terms. Members can also invite experts from resourcing organisations such as the GEF and the UNDP.

On the face of it, the UNFCCC technology transfer framework appears to address some of the key policy considerations outlined in Section 2 above. The key elements of the framework and how they might address the key policy considerations set out in this report are examined below:

- Technology needs and needs assessments. This attempts a bottom-up approach whereby developing nations are encouraged to prepare technology needs assessments (TNAs) highlighting the key technologies they require access to. This has the potential to facilitate the assessment of existing indigenous innovation capabilities and absorptive capacities in developing countries and engage with private sector actors to identify opportunities for strategic international partnerships at appropriate points along the RDD&D spectrum.

- Technology information. The EGTT has overseen the establishment of TT:CLEAR, an online resource where countries' TNAs are shared as well as information on available climate relevant technologies and initiatives. This touches on the relevance of knowledge-sharing highlighted by this report.

- Enabling environments for technology transfer. Much emphasis in discussions of technology transfer under the UNFCCC is given to the idea of creating "enabling environments", interpreted as the need to address national policy environments to remove barriers to technology transfer in areas such as trade, economic policy, legal barriers and so on. This speaks to the importance of national policy environments highlighted in this report.

[20] Formally the "framework for meaningful and effective actions to enhance the implementation of Article 4, paragraph 5, of the Convention"

- Capacity-building for technology transfer. This relates to a desire to "enhance and improve existing scientific and technical skills, capabilities and institutions" (see http://unfccc.int/ttclear/jsp/CB.jsp) in developing countries to enable them to adopt climate friendly technologies. This seems to speak to the idea of building innovative capabilities and increasing absorptive capacities amongst developing country firms as highlighted above.

- Mechanisms for technology transfer. This focuses on identifying relevant financing mechanisms for facilitating technology transfer, which would seem to address the need for funding the kind of collaborative initiatives the analysis in this report suggests would be highly effective, as well as meeting the higher incremental costs of eco-innovations.

In addition to the above aspects of the UNFCCC technology transfer framework, in 2008 the need was highlighted for consideration by the EGTT of additional elements which included attending to the importance of endogenous development of technology through provision of financial resources and joint research and development – again key issues highlighted by the analysis in this report.

Despite the well conceived nature of the framework under which the EGTT operates, however, technology transfer to developing countries is one of the key areas that the UNFCCC is seen as having failed to deliver on to date (Khor, 2008). This is particularly controversial as access to clean technologies was represented as a key reason for developing nations becoming party to the Convention (Grubb et al., 2001; Gupta, 1997). The failure to deliver on technology transfer is reflected in the language used in a recent decision under the UNFCCC asking the EGTT to prepare a two year work programme, which it was stated "could benefit from becoming more focused on practical actions" (http://unfccc.int/ttclear/jsp/EGTTWP.jsp ; see UNFCCC, 2008).

Independent reviews of activities by parties to the UNFCCC, guided by the EGTT, are currently not available in the literature. However, by looking at the actions against the UNFCCC's technology transfer framework above it is easy to make several observations of how actions to date fall short of meeting the key policy considerations highlighted in this report. For example, whilst some countries have prepared TNAs to date, by no means all of them have. And those that have, despite the careful guidance manuals commissioned by the EGTT, read more like technology "wish lists" as opposed to carefully guided documents that can identify opportunities for strategic international partnerships at appropriate points along the RDD&D spectrum.[21] They are certainly nothing like the detailed analyses of indigenous capabilities that is required to ensure maximum leverage from public spending on international technology collaborations. They also contain little evidence of private sector engagement in their preparation, despite the critical knowledge that private firms in developing countries are likely to possess in terms of identifying relevant international partnerships.

Furthermore, whilst as demonstrated above the different elements of the UNFCCC technology transfer framework could be interpreted as touching upon several of the key policy considerations highlighted in this report, in practice their interpretation seems more limited. For example, the idea of capacity building (as related to the idea of developing indigenous innovation capabilities discussed above) is never discussed in UNFCCC documentation as something that reaches down to the level of individual developing country firms or employees. There is certainly nowhere that explicitly recognises the importance of developing innovative capabilities. Even the mention of endogenous development of technology reads more as something that happens in isolation within developing countries, as opposed to a dynamic process of knowledge flows, tacit experiences and adaptive innovation.

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[21] This observation is based on the authors' own personal interaction with other professionals like involved with the technology transfer process under the UNFCCC, including developing country TNA preparation processes.

One reason for the constrained impact of the EGTT is that, as a politically negotiated text, the UNFCCC's strategic technology transfer framework does not provide a clear basis for action on the ground. This is borne out by the consistent, seemingly intractable disagreements between Annex I countries and the G77. These conflicting positions seem to come into their own when technology transfer is on the table – see, for example, the US's recent statement in Bonn in August 2009 that it wants IPRs "off the table" in any deal negotiated in Copenhagen, a position clearly unacceptable to developing nations.[22]

Another reason that might be seen as constraining the impact of the EGTT is its limited practical involvement in finance and spending. There are two key financing mechanisms under the UNFCCC which are seen as being of relevance to investment in technology transfer related initiatives, namely the Clean Development Mechanism (CDM) and the Global Environment Facility (GEF). The EGTT has no remit in relation to the CDM. It can contribute to recommendations made to the GEF in relation to spending on climate mitigation. However, any recommendation made by the EGTT must first be approved by the parties to the UNFCCC (e.g. via the Conference of the Parties, or by the Subsidiary Bodies for Scientific and Technological Advice and for Implementation). This implies they will be subject to extensive political negotiation rather than being communicated to the GEF as clear guidelines based on expert analysis. The roles played by the CDM and the GEF in financing technology transfer under the UNFCCC, and the limited remit of the EGTT to influence this spending, imply that these two mechanisms warrant explicit consideration here.

The Clean Development Mechanism

The CDM is widely viewed as the key mechanism under the UNFCCC for financing investment in clean technology in developing countries. As highlighted in another paper in this series by David Popp (Popp, 2009), the fact that host country governments, via their ability to approve CDM projects, can stipulate (as, for example, China and South Korea currently do) that projects contain some level of technology transfer (either hardware or knowledge), means that the CDM is nominally able to deliver some level of technology transfer. This emphasis on national approval has, however, resulted in marked differences between countries in the percentage of CDM projects claiming elements of technology transfer (Haites et al., 2006). For example, 12% of projects in India include technology transfer, compared to 40% in Brazil and 59% in China (Dechezlepretre et al., 2008). Popp also points to analysis by Dechezleprêtre *et al*. (2008) that breaks down technology transfer by hardware and knowledge flows. This finds that of the 43% (277) that involve technology transfer, 57 transfer equipment, 101 transfer knowledge, and 121 transfer both equipment and knowledge.

There is, however, a need for caution in interpreting the results of meta analyses such as those that yielded the figures cited by Popp above. These analyses rely on CDM project registrations and project design documents for their data. They are not in any way based on analyses of whether in reality these projects delivered any form of technology transfer on the ground. They certainly cannot comment on the extent to which projects were managed in ways that maximized knowledge flows and associated impacts on indigenous innovation capabilities. Coupled with the lack of any international requirement for CDM projects to conform to relevant guidelines that either require technology transfer, or would ensure projects were designed and implemented in ways that maximize impacts on indigenous capabilities, the extent to which it can be concluded that the CDM facilitates developing country access to eco-innovations is therefore limited.

[22] This view was expressed at the session of the working group on technology transfer during the Inter-sessional Informal Consultation of the ad hoc working group on long-term cooperative action of the UN Convention on Climate Change – see http://www.tebtebba.org/index.php?option=com_content&view=article&id=69:technology-us-proposal-to-remove-iprs-from-the-table-arouses-developing-countries-objections&catid=68:news-and-other-articles

Another point that needs to be highlighted in relation to the CDM's ability to achieve the transfer of eco-innovation is the fact that it is a market-based mechanism. As such it can provide a financial incentive for investing in projects involving clean technology. However, whilst this could potentially encourage the horizontal transfer of technologies to new developing country contexts, it is unlikely to provide incentives to opt for less proven technologies. As with market-based renewables policy options like the UK's Renewables Obligation Certificate system, market-based instruments encourage the use of clean technologies that are already, or close to being, commercially viable. It does not encourage or facilitate investment in earlier stages along the innovation chain, which is of concern considering the importance of adaptive innovation in rendering technologies suitable for developing country contexts.

As Coninck *et al*. (2008b) highlight, CDM project finance has also been observed to follow flows of foreign direct investment (FDI). As such it is seen to disproportionately benefit large emerging economies. Marginalised economies, especially in Africa, have little access to CDM funding in practice. The monitoring and evaluation processes associated with CDM projects, and the requirement to demonstrate additionality, also favour large, centralised projects. This goes against the need highlighted above for mechanisms to be able to work on a context-specific basis.

The Global Environment Facility

Unlike the CDM, the GEF, under the guidelines set out by the UNFCCC, is able to explicitly engage in financing projects that aim to facilitate technology transfer. Its efforts are split between technologies for adaptation (via the Climate Technology Initiative) and technologies for mitigation. As a fund rather than a market-based mechanism, the GEF is also able, should it wish, to target initiatives at earlier stages of the RDD&D spectrum. Indeed, the GEF has been seen to invest in many capacity building initiatives which have had knock-on benefits in terms of boosting the number of CDM projects that have been undertaken in countries where the GEF has undertaken capacity building activities (Coninck, 2009).

Similar to the CDM, the GEF is subject to biases towards large emerging economies in its spending. The provision of specific funding for least developed countries (LDCs), however, implies slightly better consideration of the need for context specificity. It also seems better equipped than the CDM to engage at the level of projects, such as improving energy efficiency, that require more engagement at the level of national regulatory and market reform (ibid.) Nevertheless, the level of reductions of greenhouse gases under the GEF (approximately 92.5 MtCO2 over fifteen years) is significantly less than the CDM has achieved in two years (340 MtCO2) (figures based on UNEP figures cited by Coninck, 2009, p.144). Neither of these levels of reductions, however, is on a scale able to respond to the magnitude of the climate change problem.

The GEF approved its operational strategy on climate change in 1995. The OS maps out two key goals for future activity: wider diffusion for selected low-carbon technologies and cost-reductions. Diffusion shall be achieved through project-based transformation of markets and removal of barriers to the establishment and management of such markets. Cost-reduction shall be achieved through the formation of markets and direct-technology transfer to support local manufacturing capacity and development of industrial infrastructure. Over time, projects supporting technology transfer directly e.g. through the acquisition of licenses ceased to be funded by the GEF. Likewise, technology transfer ceased to be a direct goal of GEF projects but was reconceptualised as a secondary outcome of projects aiming at increasing demand for low-carbon technology through market creation and expansion. Private actors, in the understanding of the GEF, will transfer low-carbon technology to developing countries, in case demand for such technologies was successfully increased through GEF activities supporting underlying markets (Haum, 2009). The reasons for the shift from direct to market-based technology transfer is found in limited GEF funds, a general perception of GEF staff that market based mechanisms work more efficiently in transferring technology, lacking guidance from GEF donors as well as the UNFCCC to do otherwise.

Despite the long period over which the GEF has engaged with the transfer of climate related technology, there has to date been little attempt to properly interrogate the GEF's project base in order to analyse and learn from the fund's available information and experience. Recent work by Verbeken (2009) and Haum (2009) in this area, however, affords a number of important insights. Firstly, while there is ample evidence that GEF climate change projects have aimed at technology transfer, it is difficult to draw broad conclusions about their outcomes because of the paucity of implementation information. However, the projects reviewed provided an indication of what is not working, and what may work. The very valuable but limited insights produced by the few project evaluations and reviews Verbeken conducted shows that a more systematic and broader review would generate the kind of evidence required for up-scaling technology transfer efforts under the GEF.

By the GEF's own admission, its approach to the transfer and diffusion of technologies has been piecemeal. On the other hand, the reviewed evidence showed the difficulties the GEF has experienced with transferring technologies, in particular when they are pre-commercial. Equally apparent is the learning that took place over its 18 years of existence, and the growing recognition in GEF of its limitations as "technology transfer agent". The GEF came to the conclusion that more efforts should be targeted at the market level, as well as at developing absorptive capacity at all levels – which comes close to the recommendations made in this report.

Haum investigated one GEF project aiming at the diffusion of off-grid photovoltaic systems in India through market expansion. While the project has been relatively successful in PV systems diffusion no evidence of technology transfer was found. The reasons were insufficient demand creation as a result of limited projects funds for market expansion and lacking incentives for private actors to actually transfer technology as a reaction to increased demand. The results indicate that the GEF market-based strategies aiming at technology transfer need the commitment of substantially increased funding if local demand should serve as an incentive for private actor technology transfer or must be complemented with elements that facilitate technology transfer directly.

Verbeken's and Haum's review of the GEF supports the stipulations made in this report of the need for a multi-faceted approach tailored to each technology and implementation context. GEF projects that did not benefit from or help to create a supportive complementary organizational and policy context failed to achieve their technology objectives. This highlights the failure of the GEF to recognise the importance of engaging in supporting indigenous activities along the whole of the RDD&D spectrum (as opposed to supporting near commercial technologies) and the related need to develop innovation capabilities in developing countries. The GEF was seen to have paid little attention to R&D, except in some of the targeted research projects it supports. The GEF was observed in its internal document to recognize the importance of supporting national innovation systems of countries, but this recognition did not seem to be carried through to influence project design.

Capacity development was seen to be an integral part of nearly all GEF projects. Yet despite its central role in technology adoption, it has not been subject to a systematic study or evaluation in the GEF. Due to the lack of baseline information related to in-country capacity and lack of assessment of post-project impacts, Verbeken was unable to contribute on the GEF's overall impact on capacity development. Nor could much be said about the GEF's approach to capacity building: although it is present in all projects, it was perceived to be a side issue for the GEF, rather than a central one.

Another aspect which emerged from the analysis, and which GEF also recognized, is the role of technology alliances, networks and partners for the success of projects. Much could be learned from project experience, in terms of approaches, models, and constraints of partnerships with private companies, industry associations, industries and research organizations. There may be valuable lessons learnt from GEF's development of a private sector strategy which took many years to formulate. The role of GEF *vis-*

a–vis project partners is a subject which deserves analysis in view of the importance of collaboration in the transfer of technologies.

The GEF follows in project design the principle of the market transformation approach and currently speaks of five pillars of market transformation that are supported by GEF funded projects. While this indicates a strong focus on demand side measures, very little analysis was identified at the level of the different approaches and instruments used by the GEF to influence the conditions of technology adoption and diffusion. It seemed a variety of policy, market and financial instruments, mechanisms and approaches have been used in GEF projects, but there was no codification of experience gained beyond the elementary level, which precluded drawing conclusions on what has worked and what has not. The absence of a knowledge management system to extract and codify insights gained at the project level, to analyse and share lessons learnt, both positive and negative, prevented more effective and in-depth learning, as well as replication and sharing of experiences with countries and other organizations.

Finally, Verbeken's analysis highlighted the inadequacy of project-based systems like the GEF for supporting technology transfer and diffusion, which require a long-term approach. Projects with a 4-5 year duration will achieve some goals but often fail to sustain achievements, except where host country governments have both the resources, policies and the commitment to continue efforts after GEF funding ends.

The GEF has very limited funds, and demand far exceeds available resources. This has forced it to target resources where it can have the most impact, as measured in GHG emission reductions, within the duration of a project. This, combined with the standard management fee implementing agencies receive, regardless of the complexity and transaction cost of a project, and a system of narrow performance management, may also have contributed to a growing share of fairly standard energy efficiency market transformation projects.

Information sharing

From the perspective of firms considering investing in new environmentally sound technologies, an important issue is access to information regarding relevant technologies. This can relate to the need for information on what technologies are available, such as is attempted via the EGTT's TT:CLEAR initiative mentioned above. Equally, there is also a need to reduce the risk to firms by ensuring minimum standards of performance. The US Environmental Protection Agency is currently coordinating the Environmental Technology Verification (ETV) Programme which "… develops test protocols and verifies the performance of innovative technologies that have the potential to improve protection of human health and the environment" (see http://www.epa.gov/etv/basic.html).

This can play an important role in reducing the risk to investors in eco-innovations, including firms in developing countries. The fact that the ETV is not a private company (it operates on the basis of a not-for-profit public/private partnership) gives a certain level of independence from the commercial interests of technology owning firms. However, independent analysis to verify the level of independence that is achieved could not be found during the literature review for this report.

The ETV has attracted considerable international interest. Canada, the European Union (EU), Japan, Korea, the Nordic countries and the Philippines have now developed similar pilot or fully operating programmes, and Bangladesh, India and Singapore have expressed an interest in following suit. The EU is also currently sponsoring an initiative (AdvanceETV) which will attempt to involve technology vendors in a scheme where technologies receive joint verification under all three of the US, Canadian, and European verification programmes, thus increasing the international standardisation of the verification process and the potential access to international markets for technology vendors.

The ETV approach clearly represents a valuable initiative in bridging potential information related barriers for private sector firms, an issue that is of equal relevance to firms in developing and developed countries. There are at least two considerations that such an approach does not address, however. Firstly, many eco-innovations of relevance to developing countries, particularly LDCs and poorer regions of emerging economies, are unlikely to represent the kind of advanced technologies that an initiative like the ETV, or other information initiatives like TT:CLEAR, tend to focus on. In these cases more rudimentary technologies, like efficient cooking stoves, or new irrigation techniques, might represent far more relevant innovations. With a significant proportion of the world's population living in poor conditions, the environmental and social benefits of such rudimentary eco-innovations should not be underestimated. There is therefore a need for information sharing initiatives that focus at this level, far away from the cutting edge. At a more advanced technological level, although still far from the cutting edge, Sussex University's work in India with TERI (The Energy Resources Institute, New Delhi) has highlighted the significant energy savings that can be achieved by introducing well established production technologies within the small and medium-sized enterprise (SME) sector in India which is characterised by large numbers of firms often working with very old, inefficient technologies.

It is also important to recognise that, especially in larger emerging economies, firms are also interested in accessing information on demonstration projects relating to technologies that may be some way from commercialisation (ETV only deals with near commercial technologies). For example, Sussex University's research in India identified considerable frustrations within a private sector company that was seeking to innovate around a particular clean coal technology in order to adapt the technology to work with high-ash Indian coal. The company was experiencing considerable difficulties in accessing information from several public sector funded demonstration projects that had been run in the US. Bearing in mind the extent to which developing countries like India and China are likely to rely on their significant indigenous reserves of coal in the short to medium term, addressing these kinds of information blocks could be of critical importance to future carbon savings.

International collaborative RDD&D initiatives

A key area identified in Section 2 as having high potential to contribute to the development of innovative capabilities in developing countries is internationally collaborative RDD&D initiatives. A number of such initiatives can be identified. In the climate technology field these include (for further details on these initiatives see the web links provided):

- The International Energy Agency's (IEA) Implementing Agreements[23], and, relatedly, Networks of Expertise in Energy Technology[24];
- The Photovoltaic Market Transformation Initiative[25];
- The EU's Seventh Framework programme[26];
- Asian Pacific Partnership on Clean Development and Climate[27];

[23] http://www.iea.org/Textbase/techno/index.asp

[24] http://www.iea.org/textbase/neet/index.asp

[25] http://www.pvmti.com/

[26] http://cordis.europa.eu/fp7/

[27] http://www.asiapacificpartnership.org/english/default.aspx

- C40 Cities Climate Leadership Group[28];
- The Climate Technology Initiative[29];
- The Asia Pacific Partnership[30];

All of these initiatives represent welcome attempts to facilitate international cooperation and knowledge sharing. At present little analysis exists pertaining to the relative success of such initiatives, particularly at the level of transferring knowledge, including tacit knowledge, to developing country firms. For example, the IEA's Implementing Agreements, which provide knowledge sharing and R&D cooperation opportunities around several environmentally sound technologies, are hailed by many as successful examples of the benefits of international collaboration. The analysis upon which such claims rest, however, tends to remain at a rather superficial level which focuses on reporting activities under different Implementing Agreements, or describing the structural basis around which the Agreements operate.[31] [32]The literature review conducted for this study was unable to locate any analysis that goes any further than this, other than Holtinnen's analysis of the R&D Task (Holtinnen, 2008) entitled 'Design and Operation of Power Systems with Large Amounts of Wind Power Production' (formed within the 'IEA Implementing Agreement on the Cooperation in the Research, Development and Deployment of Wind Turbine Systems'), which was written before the Agreement had progressed further than its initial scoping stage.

Anecdotal evidence (from the authors of this report's own personal involvement in this policy field and conversations with policy makers and experts involved with several of the initiatives listed above) suggests that the level at which initiatives such as the IEA Implementing Agreements tend to focus is fairly centralised, often with a focus at the level of established national R&D centres, as opposed to a firm level focus, or an emphasis on later stages along the RDD&D spectrum. This leaves a gap at the level of initiatives in developing countries that might better be able to harness the knowledge and experience of developing country firms to articulate what kind of relationships (e.g. where along the RDD&D spectrum, which technologies etc.) and with whom (e.g. which international firms) the respective industries might best benefit from collaborating with. For example, our research in India highlighted the example of the National Hybrid Propulsion Platform (NHPP) – a public-private collaboration which aims to create an indigenous demonstration fleet of hybrid cars. This provides an excellent example of the kind of collaborative initiative that can be established with the direct involvement of developing country firms. However, the initiative currently lacks any engagement from international players.

Whilst the establishment of national initiatives like the NHPP demonstrates the potential for harnessing collaborative initiatives in developing counties, it is nevertheless based on a large and economically powerful industry (the automobile industry) in a rapidly emerging economy (India). This leaves a gap at the level of brokering relationships and levering industry knowledge of appropriate

[28] http://www.c40cities.org/, supported by the Clinton Climate Initiative

[29] http://web.archive.org/web/20080209202956/http://www.climatetech.net/

[30] http://www.asiapacificpartnership.org/english/default.aspx

[31] See, for example, Brito-Melo, A., G. Bhuyan, K. Nielsen, K. Polaski, T. Pontes, G. Shanahan, and Isope (2007) Koch, H. J., H. J. Neef, I. Walker, and K. Nakamura (2001)

[32] It should be noted that exceptions to this critique are noted by some commentators. For example, the NEET (see above) was an effort to target government and private sector organisations in developing countries. Some of the Implementing Agreements have strong private sector participation e.g. the IEA GHG and IEA Clean Coal Implementing Agreements.

technology within less centralised contexts, such as energy efficiency initiatives amongst SMEs or within LDCs. It is at this level that, based on the analysis above, one might expect to have the most impact on innovation capabilities and maximise opportunities for adaptive innovation.

Some of the key areas where it seems little international attention has been paid to date, and which are crucial for maximising opportunities for increasing eco-innovation capabilities in developing countries, include:

- Engagement at the firm level within developing countries – both in terms of the foci of existing initiatives, and in terms of bottom up approaches to harnessing firms' knowledge of potential opportunities for collaborations;
- Shifting emphasis towards later stages of the RDD&D spectrum;
- Explicit focus on the acquisition of tacit knowledge;
- Harnessing opportunities amongst SMEs;
- Exploring opportunities for adaptive innovation;
- Responding to context specific issues, such as inter- and intra-national differences in needs, suitable technologies, or the potential for, and nature of adaptive innovation.

The lack of more bottom-up, locally focused and context specific approaches that would address these issues is perhaps not surprising due to the political significance of many of the international collaborative initiatives that have been established to date. This political significance can often shift attention towards more visible, large centralised initiatives. In view of the current political attention afforded to eco-innovation in the area of low carbon technologies within the context of current negotiations under the UNFCCC, it is pertinent to take some time to outline two initiatives that operate at a level better able to address the gaps in existing international efforts outlined above. These initiatives represent models upon which MEAs such as the UNFCCC could build in an effort to shift the emphasis towards more context sensitive approaches better geared to foster eco-innovation capabilities in developing countries.

The first, the UK Carbon Trust's Low Carbon Technology Innovation and Diffusion Centres initiative, provides the potential to broker developed-developing country relationships at the firm level, with public financial and knowledge support from international sources. The second, Fundacion Chile, provides an example of how indigenous institutions could be established in developing countries with appropriate levels of knowledge and capabilities that could manage in-country the kind of processes that the Carbon Trust's Low Carbon Technology Innovation and Diffusion Centres manage at a more international level.

The UK Carbon Trust's Low Carbon Technology Diffusion and Innovation Centres

The Carbon Trust's proposed network of Low Carbon Technology Diffusion and Innovation Centres is explicitly designed to address exactly the kind of need for development of indigenous eco-innovation capabilities proposed in this report. The Carbon Trust recognises that most international efforts emphasise large demonstration projects around "big ticket" technologies in the developing world. On this basis they identify a need for "…publicly funded organisations that can work on the ground in individual countries across a wide range of technologies appropriate to the needs of those countries, and engage national as well as multinational companies to overcome the local barriers to the development and deployment of these technologies" (Carbon Trust, undated) . They explicitly aim to "catalyse domestic capacity to develop, adapt and diffuse beneficial innovations….” and include a host of context specific interventions “… including field trials, business incubation, capacity building and seed capital.” The proposed interventions, as mentioned above include (ibid.):

- Applied research and development: Grant funding, open and/or directed at prioritised technologies;
- Technology accelerators : Designing and funding projects to evaluate technology performance e.g., field trials;
- Business incubator services: Strategic and business development advice to start-ups;
- Enterprise creation: Creation of new low carbon businesses by bringing together key skills and resources;
- Early stage funding for low carbon ventures: Co-investments, loans or risk guarantees to help viable businesses attract private sector funding;
- Deployment of existing energy efficiency technologies: Advice and resources (e.g. interest-free loans) to support organisations to reduce emissions;
- Skills / capacity building: Designing and running training programmes;
- National policy and market insights: Analysis and recommendations to inform national policy and businesses.

One of the key aims is to leverage private funding via carefully targeted public spending. They therefore address both aspects of the concern articulated earlier with maximising leverage.

This initiative is currently in its infancy. It has already, however, encountered some limitations in accessing international public funding sources. For example, the initiative does not qualify for funding under the World Bank's new Climate Investment Funds as these funds have to meet overseas development goals and as a consequence can only be offered to organisations in a developing country where 100% of the benefits accrue to the country receiving the aid. As the international collaborations set up under the Carbon Trust's initiative necessarily have multiple international benefactors (a key factor in enabling successful leverage of funding and international private sector participation) the Centres do not fulfil the World Bank's criteria. This is an issue that should be addressed under multilateral negotiations if the transfer of clean technologies to developing countries is to be accelerated.

Fundacion Chile

Another example of how indigenous institutions geared towards delivering the kind of activities that the Carbon Trust's Centres aim to develop might look is Fundacion Chile. This is a not-for-profit Chilean organisation that works across a range of key industrial sectors, several of which are of explicit environmental relevance e.g. forestry, agriculture, marine resources, environment and chemical metrology. It receives funding from the Chilean government and ITT Corporation (based in the US) and has been highly successful in sustaining its funding base via a process of levering private sector funding and involvement. This has the knock-on benefit of more sustained private sector adoption of the innovations Fundacion Chile promotes.

Fundacion Chile's key aim is to identify innovations internationally that might be of relevance to improving the performance (including environmental performance) of Chilean industry. It then uses a number of methods to adapt, demonstrate and roll out these innovations thus reducing risk and encouraging uptake amongst Chilean firms. The approach Fundacion uses is based on three stages. First opportunities for innovation (often adaptive innovation) are identified based on careful assessments of international and domestic capabilities and in close consultation with the private sector. The next stage involves obtaining, developing or adapting the technology via three approaches. These include:

- Transferring and adapting a technology obtained from an outside supplier;
- Developing a technology using Fundacion's own in house R&D capabilities;
- Developing a technology via collaboration with an established network of indigenous R&D institutions.

The third stage involves scaling up and disseminating the technology via a number of approaches which include:

- Creation of innovative companies, always with strategic partners (usually private sector). Fundacion usually sells its share in these companies once they are self sustaining and then reinvests the funds in new initiatives;
- Sale and licensing of technologies (when new technologies become available via its in-house R&D or its collaborations with external, indigenous R&D centres);
- Supply of technological services across the different key areas that it works;
- Certification and implementation of standards;
- Broad dissemination through training, seminars, publications and internet websites.

Fundacion Chile also has a unit that specifically focuses on human resources. It therefore fully recognises and operationalises the requirement for facilitating the transfer of knowledge, including tacit knowledge, as part of the technology transfer process. Fundacion Chile is widely seen to have had a profound influence on increasing innovative capabilities within the Chilean economy and has had some large successes with developing new industries, including the Chilean salmon industry, and remains proactive in developing potential new clean initiatives such as biomass pelletisation from Chilean forestry waste. The approaches outlined above all conform to best practice in terms of meeting the criteria set out in this report for maximising impacts on indigenous eco-innovation capabilities and leveraging private funding. Fundacion Chile therefore provides practical evidence of the likely success of the approach adopted by the Carbon Trust in their network of Low Carbon Technology Diffusion and Innovation Centres.

CONCLUSION: CONSTRUCTIVE WAYS FORWARD

This report has identified an important shortfall in international efforts to facilitate access to and to encourage eco-innovation in developing countries. This shortfall centres around a failure to recognise the critical role of indigenous innovation capabilities amongst developing country firms. Indigenous eco-innovation capabilities are essential to facilitating *both* the diffusion of existing eco-innovations within developing countries *and* sustainable economic development based on the adoption, adaption and development of environmentally sound technologies that fit with the bespoke conditions faced by developing countries. Particularly within the context of the negotiations under the UNFCCC in Copenhagen in December 2009 and thereafter, there is a need to address this shortfall. The lack of any binding agreement post Copenhagen, and the proposal for a new Technology Mechanism under the Copenhagen Accord presents an important opportunity to ensure that the issues raised in this report are properly integrated into any post-2012 approach to climate relevant eco-innovations in particular. This requires new institutional and funding structures that are better able to meet the need for context-specific technology oriented initiatives that achieve maximum leverage from public investment. This should be understood both in terms of maximising the impact on indigenous eco-innovation capabilities, and maximising the potential to attract sustained private sector investment in eco-innovation.

As demonstrated in the analysis above, precedents do currently exist, such as the Carbon Trust's proposed network of Low Carbon Technology Innovation and Diffusion Centres, and Fundacion Chile, which provide potentially viable models for a more focussed, needs based approach to developing eco-innovation capabilities in developing countries than can be achieved by the centralised, large project based approaches of existing MEAs. Using the UNFCCC as an example and drawing on the analysis above, this report therefore concludes by focussing on the negotiations under the UNFCCC in Copenhagen in December 2009 and setting out some guiding principles for informing the post-2012 approach to technology transfer to developing countries.

Guiding principles for post-2012 technology transfer to developing countries[33]

1. Low-carbon technology transfer can facilitate sustained low-carbon development in developing countries. This can only be achieved by developing indigenous innovation capabilities in developing countries – i.e. the capabilities to adapt, develop, deploy and operate low-carbon technologies effectively within specific developing country contexts.

2. Diffusion and development of low-carbon technologies are facilitated by incremental *and* adaptive innovation processes[34] within developing countries. This requires sufficient innovation capabilities amongst developing country firms, universities and research institutes, and appropriate links with public-sector actors.

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[33] For more details on Sussex's policy proposal for delivering low carbon technology transfer under the UNFCCC see http://www.sussex.ac.uk/sussexenergygroup/documents/tech_transfer_prop.pdf

[34] Incremental innovations are seen as occurring more or less continuously as economic agents strive to improve quality, design and performance. Adaptive innovation describes processes where existing technologies are adapted in ways that can be applied in new contexts.

These capabilities are essential to allow developing country actors to work with existing low-carbon technologies, identify opportunities to improve and adapt them for application in new contexts, and to develop brand new technologies suited to specific developing country needs. Policy should therefore, not treat the diffusion and development of low-carbon technologies separately.

3. Technology transfer includes: the traditional notion of 'hardware' (physical equipment); the often ignored, yet vital, 'software' element of technology (knowledge and processes), including both underlying knowledge (e.g. engineering and manufacturing processes, or new farming techniques) and tacit knowledge (knowledge acquired by doing, e.g. applied engineering & systems integration skills). The software aspect is often most important.

4. As low-carbon innovation capabilities build up in developing countries a snowballing effect takes place where we observe increasingly more rapid uptake and development of low-carbon technological applications. This will yield benefits for developed and developing countries by accelerating development, opening up new market opportunities, and mitigating against future climate change.

5. International technology-leading firms and industrialised countries might have concerns regarding intellectual property protection and their competitive advantage. However, these concerns are likely to be outweighed by the significant economic benefits of accessing new markets via carefully negotiated collaborative initiatives with firms and other institutions within developing countries.

6. The private sector – through investment, research and expertise – will play a pivotal role developing and diffusing low-carbon technologies in developing countries.

7. Policy must be designed to respond to the context-specific social, economic, ecological and technological needs of different regions, countries and areas within countries.

   - The needs of the rural-poor differ greatly from those of urban populations.
   - Rapidly-emerging economies' needs are different from those of least-developed countries.
   - Countries reliant on hydropower face different climate challenges to those dependent on coal-fired power.
   - Individual technologies raise context-specific issues: this may relate to their stage of commercial development (e.g. investor risk is higher at earlier stages of technology development), or to hardware and software components involved (e.g. Carbon Capture and Storage (CCS) involves more complex systems management requirements than small scale solar photovoltaics). Policy must take account of context specific issues.

8. Sussex University's work in India[35] shows that access to Intellectual Property Rights (IPRs) do not ensure developing country access to low-carbon technologies. Access to other knowledge, particularly tacit knowledge, is often a more important barrier. In some cases, lack of access to IPRs slows the rate at which developing country firms can produce low-carbon technologies and also prevents firms producing at the cutting edge. Policy should therefore include provision for international arbitration in such cases.

[35] See http://www.sussex.ac.uk/sussexenergygroup/1-2-9.html

Recommendations for future work

The analysis of theory and practice within this report highlights a number of areas that would benefit from future attention. These include:

- In light of recent progress made under the UNFCCC to negotiate a proposed Technology Mechanism to deliver on commitments for technology transfer to developing country, it would be both timely and valuable to conduct an assessment of the proposed mechanism. This should develop a framework for analysis that draws on criteria set out in this and other reports to assess the likely success of the proposed Mechanism in delivering sustained, low carbon development in developing countries.

- More in-depth review of lessons learned from previous/existing international and national efforts to facilitate collaborative initiatives around the transfer of technology, both in terms of hardware and software. For example, the analysis above suggests that the experiences of the GEF are as yet under assessed and much could be gained from an interrogation of project reports and interviews with project personnel to draw out lessons learned. Analyses of initiatives such as those under the Carbon Trust's proposed innovation centres and the work of institutions such as Fundacion Chile could prove equally valuable. An emphasis should be put on interrogating grounded case studies where both successful and unsuccessful international collaborative initiatives have been attempted. Particular care must be given to understanding the extent to which any technology transfer has included the components necessary to develop indigenous innovation capabilities (as discussed in this report). The aim of such analysis should be to inform the development of innovative models by which the two-way transfer of hardware and software between developing country firms and technology leading firms has been and might in future be facilitated.

- Work is needed to identify and articulate the benefits to international technology leading companies of engaging in collaborative, capacity building initiatives in developing countries. This should include a focus on identifying examples where incremental and adaptive innovation processes may have opened up new market opportunities and the resulting distribution of benefits accruing from this.

- In undertaking the work proposed in point 1 above, it is important that bespoke mechanisms which deal with the transfer of tacit knowledge, and capacity building in the sense of human-embodied knowledge are given sufficient attention. In other words the focus should not simply be on hardware, or codified knowledge such as IP, but also on knowledge transfer, with explicit attention to mechanisms by which knowledge has been successfully transferred to the benefit of both developing countries and international technology leading firms.

- Building on the identification of lessons learned from the analysis proposed in point 1 above, and any appropriate technology transfer models they may suggest, attention needs to be given to the kind of institutional structure that might facilitate more widespread and systematic replication of such models in future. A useful starting point is provided by the institutional structure suggested within Sussex University's proposal on technology transfer under the UNFCCC (Ockwell et al., 2009).

All these areas of research should focus on grounded, case study based analysis. This should emphasise engagement with private sector actors in developed and developing countries in order to properly appreciate the likely success of any resulting proposals from the perspective of levering private sector funding. For an example of such a methodological approach refer to the UK-India collaborative study on technology transfer (Mallett et al., 2009).

References

Barton, J. H. (2007), *Intellectual Property and Access to Clean Technologies in Developing Countries. An Analysis of Solar Photovoltaic, Biofuel and Wind Technologies*, International Centre for Trade and Sustainable Development (ICTSD), Geneva, Switzerland

Bell, M. (1990), *Continuing Industrialisation, Climate Change and International Technology Transfer*, SPRU, University of Sussex

Bell, M. (1997), Technology transfer to transition countries: are there lessons from the experience of the post-war industrializing countries? in D. A. Dyker, editor, *The Technology of Transition: Science and Technology Policies for Transition Countries*, Central European University Press, Budapest

Bell, M. (2009), *Innovation Capabilities and Directions of Development*, Domain Paper for Innovation, Sustainability, Development: A New Manifesto, University of Sussex, UK, available at http://anewmanifesto.org/wp-content/uploads/bell-paper-33.pdf

Bell, M., and K. Pavitt (1993), *Technological Accumulation and Industrial Growth: Contrasts between Developed and Developing Countries Industrial and Corporate Change*, 2:157 - 210

Brewer, T. (2008), Climate change technology transfer: a new paradigm and policy agenda, *Climate Policy* 8: 516–526

Brito-Melo, A., G. Bhuyan, K. Nielsen, K. Polaski, T. Pontes, G. Shanahan, and Isope (2007), Ocean energy systems implementing agreement: An international collaborative programme in *17th International Offshore and Polar Engineering Conference* (ISOPE 2007) Lisbon, Portugal, pp. 463-466, International Society Offshore& Polar Engineers

Carbon Trust (undated), *Low Carbon Technology Innovation and Diffusion Centres. Accelerating low carbon growth in a developing world*. Carbon Trust, London available at http://www.infodev.org/en/Document.680.pdf)

Clark, Norman, Chataway, Joanna, Hanlin, Rebecca, Kale, Dinar, Kaplinsky, Raphael, Muraguri, Lois, Papaioannou, Theo, Robbins, Peter and Wamae, Watu (2009), *Below the radar: What does innovation in the asian driver economies have to offer other low income economies.* Economic and Social Research Council, http://oro.open.ac.uk/15241/1/Innogenwp69.pdf, accessed 12th May 2009

Coninck, H., de (2009) *Technology rules! Can Technology-oriented Agreements Help Address Climate Change?* Vrije University, Netherlands

Coninck, H., de, C. Fischer, R. Newell and T. Ueno (2008a), International Technology-oriented Agreements to Address Climate Change. *Energy Policy* 36: 335-356

Coninck, H, de, Haake, F., N.H. van der Linden (2008b) Technology Transfer in the Clean Development Mechanism, *Climate Policy* 7(5): 443-455

Dechezleprêtre, Antoine, Matthieu Glachant, and Yann Ménière (2008), The Clean Development Mechanism and the international diffusion of technologies: An empirical study, *Energy Policy*, 36, 1273-1283

Freeman, C. (1992), *The Economics of Hope*, Pinter Publishers, London, New York, p.77

Gallagher, K. S. (2006), Limits to leapfrogging in energy technologies? Evidence from the Chinese automobile industry. *Energy Policy* 34:383-394

Gereffi, G. (2001), Beyond the producer-driven/buyer-driven dichotomy - The evolution of global value chains in the Internet era. *Ids Bulletin-Institute of Development Studies* 32:30

Grubb, M., C. Vrolijk, and D. Brack (2001), *The Kyoto Protocol. A Guide and Assessment*, 2nd edition. The Royal Institute of International Affairs, London

Gupta, J. (1997), *The Climate Change Convention and Developing Countries: From Conflict to Consensus?* Kluwer Academic Publisher, Dordrecht

Haites, Erik, Maosheng Duan and Stephen Seres (2006), Technology transfer by CDM projects, *Climate Policy*, 6, 327-344

Hammond, G. P., and A. J. Stapleton (2001), Energy analysis of the United Kingdom energy system. Proceedings of the Institution of Mechanical Engineers, Part A, *Journal of Power and Energy* 215 (A2):141-162

Haum R. (2009), *Technology Transfer under the UNFCCC: The case of the GEF market transformation approach in India*. Unpublished PhD Thesis, SPRU-Science and Technology Policy, University of Sussex, UK

HM Government (2009), *The Road to Copenhagen: The UK Government's Case for an Ambitious International Agreement on Climate Change*. London: The Stationery Office

Holttinen, H. (2008), Estimating the impacts of wind power on power systems - summary of IEA Wind collaboration, *Environmental Research Letters* 3:6

Johnstone, N., I. Haščič (2009), *Environmental Policy Framework Conditions, Innovation and Technology Transfer*. OECD project on "Environmental Policy and Technological Change". ENV/EPOC/WPNEP(2009)2/FINAL, 13-Nov-2009

Khor, M. (2008), *Access to Technology, IPRs and Climate Change*, Day One Session, European Patent Forum. http://www.epo.org/about-us/events/epf2008/forum/details1/kohr.html

Koch, H. J., H. J. Neef, I. Walker, and K. Nakamura (2001), The IEA's collaborative programme on energy technology developing a bridge to a low-carbon future, in D. J. Williams, B. Durie, P. McMullan, C. Paulson, and A. Smith, editors, *5th International Conference on Greenshouse Gas Control Technologies*, pp. 1038-1043. Cairns, Australia: CSIRO

Lall, S. (1998), Investment, technology and international competitiveness. in J. H. Dunning and K. A. Hamdan, editors. *The New Globalism and Developing Countries*. United Nations University, Tokyo, New York, Paris

Lewis, J. I. (2007), Technology Acquisition and Innovation in the Developing World: Wind Turbine Development in China and India, *Studies in comparative international development* 42:208-232

Lundvall, B.-A. (1988), Innovation as an inter-active process: from user-producer interaction to the national system of innovation, in G. Dosi, editor, *Technical Change and Economic Theory*, Pinter Publishers, London

Mallett, A., David G. Ockwell, Prosanto Pal, Amit Kumar, Y P Abbi, Ruediger Haum, Gordon MacKerron, Jim Watson, Girish Sethi (2009), *UK-India collaborative study on the transfer of low carbon technology: Phase II Final Report,* University of Sussex, UK. Available at http://www.sussex.ac.uk/sussexenergygroup/1-2-9.html

Maskus, K. (2009) Differentiated *Intellectual Property Regimes for Environmental and Climate Technologies*, Report to OECD Environment Directorate Working Party on National Environmental Policies, ENV/EPOC/WPNEP(2009)6, 21 October 2009

Missbach, A. (1999), *Das Klima zwischen Nord und Süd. Eine regulationstheoretische Untersuchung des Nord-Süd-Konflikts in der Klimapolitik der Vereinten Nationen*, Westfälisches Dampfboot, Münster

Ockwell, D., Alexandra Mallett, Rüdiger Haum and Jim Watson (in press) Intellectual property rights and low carbon technology transfer: the two polarities of diffusion and development, *Global Environmental Change*, earlier version available at http://www.sussex.ac.uk/sussexenergygroup/documents/ockwell_et_al_conflicting_discourses_of_dev_diffusion.pdf

Ockwell D., Jim Watson, Anne Marie Verbeken, Alexandra Mallett and Gordon MacKerron (2009), *A blueprint for post-2012 technology transfer to developing countries*, University of Sussex, UK. Available at http://www.sussex.ac.uk/sussexenergygroup/documents/techo_briefingweb.pdf

Ockwell, D., Jim Watson, Gordon MacKerron, Prosanto Pal and Farhana Yamin (2008), Key policy considerations for facilitating low carbon technology transfer to developing countries, *Energy Policy* 36 (11): 4104-4115

OECD (2005), *Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data*, OECD, Paris

Popp, D. (2009), *Policies for the Development and Transfer of Eco-Innovations: Lessons from the Literature*, OECD Environment Working Paper No. 10

Stern, Nicholas (2007), *The Economics of Climate Change, The Stern Review*, Cambridge: Cambridge University Press

Tomlinson, S., Zorlu, P. and Langley, C. (2008), *Innovation and Technology Transfer. Framework for a Global Deal,* E3G and Chatham House, London

UNCTAD-ICTSD (2003), *Intellectual Property Rights: Implications for Development*, International Centre for Trade and Sustainable Development (ICTSD) and United Nations Conference on Trade and Development (UNCTAD), Geneva, Switzerland: 86

UNEP (2005), *Multilateral Fund for the Implementation of the Montreal Protocol. Policies, Procedures, Guidelines and Criteria*, Secretariat of the Multilateral Fund, Quebec, Canada

UNEP-UNCTAD (2007), *A Preliminary Analysis of MEA Experiences in Identifying and Facilitating the Transfer of Technology What Insights Can Be Drawn for the WTO EGS Negotiations?,* United Nations Environment Programme (UNEP) and United Nations Conference on Trade and Development (UNCTAD)

UNFCCC (2008), *Work Programme of the Expert Group on Technology Transfer for 2008–2009*, *Note by the Chair of the Expert Group on Technology Transfer*, FCCC/SB/2008/INF.1 http://unfccc.int/resource/docs/2008/sb/eng/inf01.pdf

Verbeken, Anne-Marie (2009), *Low Carbon Energy Technology Transfer: A Review of GEF Experience*., Dissertation submitted as part of an MSc at SPRU, University of Sussex, UK

Victor, D.G. (2001), *The collapse of the Kyoto Protocol and the struggle to slow global warming,* Princeton University Press, Princeton NJ, USA

Zhao, Jimin (2005), Implementing International Environmental Treaties in Developing Countries: China's Compliance with the Montreal Protocol, *Global Environmental Politics* 5:1