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CRIBs (Climate Relevant Innovation-system Builders): An effective way forward for international climate technology policy

Dave Ockwell and Rob Byrne

Climate Technology

STEPS centre

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National systems of innovation (NSIs) provide the context within which all processes of technology development, transfer and uptake occur - they refer to the network of actors (e.g. firms, universities, research institutes, government departments, NGOs) within which innovation occurs, and the strength and nature of the relationships between them. Nurturing NSIs in relation to climate technologies provides a powerful new focus for international policy with potential to underpin more sustained and widespread development and transfer of climate technologies. This working paper builds on an invited presentation by one of the authors at a workshop on NSIs convened by the Technology Executive Committee (TEC) of the United Nations Framework Convention on Climate Change (UNFCCC). It identifies policy recommendations for consideration of the TEC. The intention is both to inform possible recommendations by the TEC to the UNFCCC Conference of the Parties (COP) and to highlight potential areas for future work that the TEC could undertake on this issue.

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Contents

Acronyms

ADB	Asian Development Bank
AfDB	African Development Bank
CDM	Clean Development Mechanism
CICs	Climate Innovation Centres
COP	Conference of the Parties
CRIBs	Climate Relevant Innovation-system Builders
CTCN	Climate Technology Centre and Network
EBRD	European Bank for Reconstruction and Development
EE	Energy Efficiency
EPO	European Patent Office
GEF	Global Environment Facility
IADB	Inter-American Development Bank
ICTSD	International Centre for Trade and Sustainable Development
IPRs	Intellectual Property Rights
NDEs	National Designated Entities
NGO	Non-Governmental Organisation
PV	Photovoltaics
R&D	Research and Development
TEC	Technology Executive Committee
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organisation
NSI	National System of Innovation
UNFCCC	United Nations Framework Convention on Climate Change

Executive summary

National systems of innovation (NSIs) provide the context within which all processes of technology development, transfer and uptake occur – they encompass the network of actors (e.g. firms, universities, research institutes, government departments, NGOs) within which innovation occurs, and the strength and nature of the relationships between them. Nurturing NSIs in relation to climate technologies provides a powerful new focus for international policy with potential to underpin more sustained and widespread development and transfer of climate technologies.

This working paper builds on an invited presentation by one of the authors at a workshop on NSIs convened by the Technology Executive Committee (TEC) of the United Nations Framework Convention on Climate Change (UNFCCC). It provides an overview of the relevance of NSIs to international climate technology policy and identifies policy recommendations for consideration of the TEC. The intention is both to inform possible recommendations by the TEC to the UNFCCC Conference of the Parties (COP) and to highlight potential areas for future work that the TEC could undertake on this issue.

Following the structure of the TEC's workshop, the three core sections of the report cover:

1. Building blocks necessary to understand the nature and importance of NSIs for fostering climate technology development and transfer
2. Key issues climate policy needs to address/contend with in order to nurture NSIs across different country and technological contexts
3. Key policy recommendations (including a gaps analysis of existing international policy in relation to building NSIs)

Building blocks necessary to understand the nature and importance of NSIs for fostering climate technology development and transfer

Essentially, insights from two related fields provide the bedrock upon which an understanding of NSIs for climate technology development and transfer can be developed:

1. Decades of empirical research in the field of *Innovation Studies* have shown that the astounding levels of technological and economic development observed across many developing country sectors (e.g. the Korean steel industry), and countries as a whole (e.g. the Asian Tiger economies), can be understood as the result of processes that strengthened NSIs. These provided the enabling environment in which indigenous firms could boost their technological capabilities, often through a slow, deliberate process of technological capability building and from low to increasingly sophisticated levels of capabilities, leading eventually to more widespread processes of technological change and economic development. An NSI perspective can also explain the success of OECD economies (OECD 1997). Importantly, the Innovation Studies literature emphasises the knowledge-based nature of technology and technology transfer, with technological hardware understood as mere embodied artefacts of knowledge flows and related capabilities.

2. More recently, insights from the field of *Socio-Technical Transitions* has expanded on the *Innovation Studies* perspective to focus beyond firms and consider technology users and the social practices which form the context within which innovation happens. It is able to define, via a co-evolutionary relationship, directions of technological innovation and change (e.g. climate compatible, or non-compatible, directions of innovation and development).

   Simply put: from a socio-technical perspective, innovation, technological change and the creation of new markets for technology are not merely technical challenges. They are also processes that shape, and are shaped or constrained by, social practices and evolving local knowledge. Taking energy as an example: cultural practices around cooking might define which alternatives to kerosene will be viable and sustainable; but dominant institutions and vested interests in kerosene supply might also create a powerful inertia against change.

   This perspective has also helped to illuminate how new technologies (like climate technologies) might, through an NSI-based approach, be introduced in ways that maximise the chances of such technologies moving from being niche technologies to challenge established technology regimes (and their attendant vested interests and stable trajectories) in order to become more widely adopted. This is particularly powerful in the context of international climate policy as it opens up space to consider the directions in which such change might happen and how it might be nurtured in more climate-compatible, sustainable directions.

Key issues climate policy needs to address in order to nurture NSIs across different country and technological contexts

Two key issues need to be addressed in order for international climate policy to effectively implement an NSI-based approach to climate technology development and transfer:

1. Do not focus entirely on codified knowledge – tacit knowledge is often more important

There has been a tendency within the international climate negotiations to fix attention on codified knowledge as opposed to tacit knowledge. In fact, however, tacit knowledge is of far greater importance to building technological capabilities and underpinning technological change and development. Tacit knowledge is human-embodied knowledge acquired through experience of doing things, and extends to more institutionally-embodied knowledge where firms and other organisations develop capabilities around, for example, management systems and approaches which are passed on through generations of employees. Tacit knowledge is a prerequisite for codified knowledge to have any use or relevance to a firm or industry. Think, for example, of giving a standard, local car mechanic access to the patents for core components of a new design of Formula 1 racing car engine – 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 1 development and manufacturing teams (the latter being tacit and neither codified nor legally protected in any way). It is often these tacit processes of knowledge acquisition that more accurately characterise learning by firms and other actors as NSIs increase in levels of sophistication and scale and lead towards processes of innovation and change.

Knowledge flows are critical to building these capabilities. However, the qualitative type of knowledge that is relevant and likely to have most impact on host-country technological capabilities will vary according to a wide range of context-specific considerations. In some cases knowledge will be codified, and in some cases this codified knowledge will be in the form of Intellectual Property Rights – IPRs – (as opposed, for example, to trade secrets). But IPRs are only a small part of a much bigger picture. Access to IPRs does not ensure developing-country access to climate technologies. Access to other knowledge, particularly tacit knowledge, is often a more important barrier. In many cases (and indeed all the case studies considered in this report – e.g. the Kenyan photovoltaic (PV) sector and the Korean steel industry), tacit knowledge and knowledge acquired through working with technologies, most often under license and protected by patents, has played a far more significant role than access to IPRs *per se*. IPRs are only likely to be prohibitive once developing-country firms reach the technological frontier. IPRs are thus never sufficient as a focus of policy mechanisms that aim to build NSIs.

2. Be sensitive to the context-specific nature of appropriate climate technologies, national and local needs and the nature of appropriate interventions

The extent to which different types of knowledge and technology are likely to be appropriate depends on a range of context-specificities, such as their applicability within different socio-technical circumstances and their applicability within different physical, cultural and economic contexts. For example, the technological needs of communities with different wealth levels need to be understood – poorer communities might perhaps have a greater need for technologies related to subsistence needs, whereas wealthier communities might have priorities around transport, or processing goods to add value. We need to understand, therefore, the extent to which climate technologies facilitated under existing international policy mechanisms are pro-poor. In poor rural areas, for example, it might be more viable to explore adaptive innovation around low-maintenance configurations of solar PV and LED technologies, as opposed to clean options for centralised energy generation which might better suit urban industrial interests. And in adapting to climate change, technologies such as drought-resistant strains of crops, or knowledge regarding new farming methods in increasingly flood prone areas, might be of more relevance to poor people than advanced engineering solutions for strengthening coastal flood defences.

At a higher level, different countries will have NSIs at different levels of development. And these levels of development are likely to vary according to different technologies. For example, Kenya has a highly developed market for off-grid solar PV, but has only just begun to enter into industrial activities in relation to solar PV, whereas China has both a large domestic market and domestic manufacturing capabilities. This and the other context-specificities listed above have consequences for the nature of effective policy interventions.

To some extent this focus on context-specificities might be interpreted as confounding policy efforts, especially those at the national and multilateral levels which characterise actions under the UNFCCC. Some observers might push instead for the identification of non-context-specific issues so that more generic policy approaches might be developed and applied. Indeed, there has been, and still is, a tendency for international climate policy to focus at the generic (non-context-specific) level. In fact, however, a policy focus on nurturing NSIs is the key way in which these past policy shortcomings can be overcome. Interventions that aim to play an "innovation system builder" role in developing countries (i.e. facilitate the development and strengthening of NSIs) provide the basis for designing policy approaches characterised by non-context-specific (generic) processes/interventions (e.g. network building, fostering learning, experimentation, etc.) which are able to still respond to context-specificities. These interventions can nurture change by developing and strengthening NSIs, precisely because they are pursued within, and with inclusive and reflexive consideration of, specific contexts.

Key policy recommendations

The core aim of policy should be to support interventions which enable actors and institutions to act as *Climate Relevant Innovation-system Builders (CRIBs).* The key is to do so via nationally-nested, demand-driven interventions that are internationally-networked, facilitating learning across different contexts in order to build indigenous technological capabilities and well-functioning, context-sensitive NSIs.

Policy should focus on achieving four overarching goals:

1. Build networks of diverse stakeholders that work together in projects, programmes and other interventions;
2. Foster and share learning from research and experience;
3. Promote the development of shared visions amongst stakeholders;
4. Support diverse experimentation with technologies and practices.

A range of detailed policies and actions that Parties might implement to achieve these goals are detailed in Section 3.5 of the report.

It is recommended that these be achieved via adoption under the Convention of two complementary proposals:

1. Proposal 1: Strengthen the capacity of National Designated Entities (NDEs) under the Climate Technology Centre and Network (CTCN) by funding and supporting the establishment of national level Climate Relevant Innovation-system Builders (CRIBs) within developing countries.
    a. CRIBs would play a strategic, facilitating role, linking up relevant national actors, targeting and coordinating project and programme level interventions to maximize benefits to NSIs.
    b. CRIBs (through NDEs) would coordinate with the CTCN to communicate national priorities (with due knowledge of national policy priorities and local realities).
    c. The CTCN (as per its existing remit) would then act to network CRIBs internationally, facilitating knowledge flows and access to international technological capabilities based on a more detailed understanding of national/local capabilities and needs.

2. Proposal 2: Use climate technology projects and programmes explicitly to build climate innovation systems.
    a. If pursued jointly with Proposal 1, this role can be facilitated by CRIBs, in coordination with the CTCN.
    b. If pursued in isolation, this can be achieved by revising the remit and approach of the CTCN to integrate a climate innovation system building approach into projects, programmes and related interventions, and to provide advice, via NDEs, on how Parties can bolster their own NSIs.

Proposal 1 should be highlighted as the preferred option with most potential to foster the development of NSIs around climate technologies in developing countries. Proposal 2 would be best used to augment the remit of the CTCN, mainstreaming a focus on NSIs. Proposal 2, could, however, be pursued on its own if Proposal 1 were seen as too ambitious.

It should be emphasised to the COP that both proposals (particularly Proposal 1) would support nationally-driven and nationally-appropriate actions. Both proposals would increase Parties' agency to foster climate technology development and transfer in ways that respond to their own nationally-determined needs and priorities. The report concludes with possible recommendations for further work by the TEC on this issue.

1. Introduction

1.1 Aim of this report

This report builds on a recent invitation by the TEC for the authors to present at a workshop in Bonn on "*Strengthening national systems of innovation in developing countries*"[1]. The aim of this paper is to elaborate on the material presented at the workshop, providing a written source for members of the TEC and other stakeholders to refer to as thinking and action progresses on this subject, both under the UNFCCC and under other related initiatives.

Following the structure of the TEC's workshop, the report is divided into three sections, respectively providing:

- An overview of the relevance of national systems of innovation ("NSIs") to fostering the development, transfer and uptake of climate technologies[2] in developing countries whilst simultaneously supporting economic and human development.
- Analysis of some key issues that policy interventions designed to nurture NSIs must address.
- Concrete policy approaches that can be adopted at the national and multilateral levels in order to foster NSIs in ways that might effectively nurture the development, transfer and uptake of different climate technologies in different developing-country contexts.

1.2 A "pathways" perspective

We start from an explicit recognition that there is no single, uncontested pathway towards achieving climate technology transfer and development, nor is there any single outcome or development trajectory that such pathways might support. Rather, multiple possible pathways exist and multiple potential end points, all of which have material consequences in the distribution of benefits – who wins, who loses, whose interests are represented and whose marginalised – that result along the way. The societal services and functions that climate technologies facilitate (e.g. energy production via low-carbon technologies to serve the needs of poor rural communities) are realised dynamically out of the interplay of various

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[1] Details of the workshop and Ockwell's presentation are available on the UNFCCC website: http://unfccc.int/ttclear/templates/render_cms_page?s=events_ws_nsi

[2] The report focuses on climate technologies, i.e. technologies of relevance to climate change adaptation and mitigation. Developing NSIs is a way of fostering the development and uptake of the full suite of climate-relevant technologies, from the low-carbon energy sector, through the agricultural sectors, water, health, coastal management, environmental monitoring, and so on – as well as technologies which cut across, or operate at the nexus between, these sectors (e.g. distributed renewable energy technologies that are low-carbon whilst simultaneously contributing to the adaptive capacities of poor rural households and regions through, for example, providing new economic opportunities via access to modern energy, or powering irrigation). The examples used in this report tend to be from the energy sector because of the authors' research foci (low-carbon energy and development), but the policy approaches proposed are equally applicable across the full suite of climate technologies (i.e. they are not technology-specific, rather they propose a systems approach to technology development, transfer and uptake that would work with any technology).

co-evolving complex systems (social, technological, environmental) and any particular unfolding of these dynamics constitutes a specific development pathway amongst multiple possibilities (Leach *et al*. 2007).

Each of these complex systems themselves, and their combination, can be framed in different ways. And each framing informs – and is informed by – a narrative that interprets the world in a particular way, reflecting and reinforcing the perspective of the narrator. As understood here, a narrative is used to "suggest and justify particular kinds of action, strategy and intervention" (Leach, Scoones and Stirling 2010a: 3) and so attempts to enrol actors and their resources into particular ways of achieving development goals. If this enrolment is successful then a particular direction of development is privileged, the result of which is an unfolding pathway co-evolving contingently and uncertainly in the interplay between these privileging forces and the various complex systems noted above.

Implicit in this description is the notion that multiple framings, narratives and pathways are possible. Different groups of actors will interpret the world in different ways; arising from their own experiences, situations, understandings, values and interests. Favouring certain framings over others, they will seek to promote narratives that would help to create their preferred development pathways. Some narratives will be more dominant than others, perhaps because they are promoted by powerful actors, and are likely to become manifested in interventions. Other narratives remain marginalised, perhaps because they are promoted by groups who are themselves marginalised or powerless (Byrne *et al.* 2012b).

This means there are material consequences to how we frame problems and solutions. It is therefore critical to start by addressing how international policy on climate technology transfer is framed, and to reflect on the limitations of the framing that currently dominates.

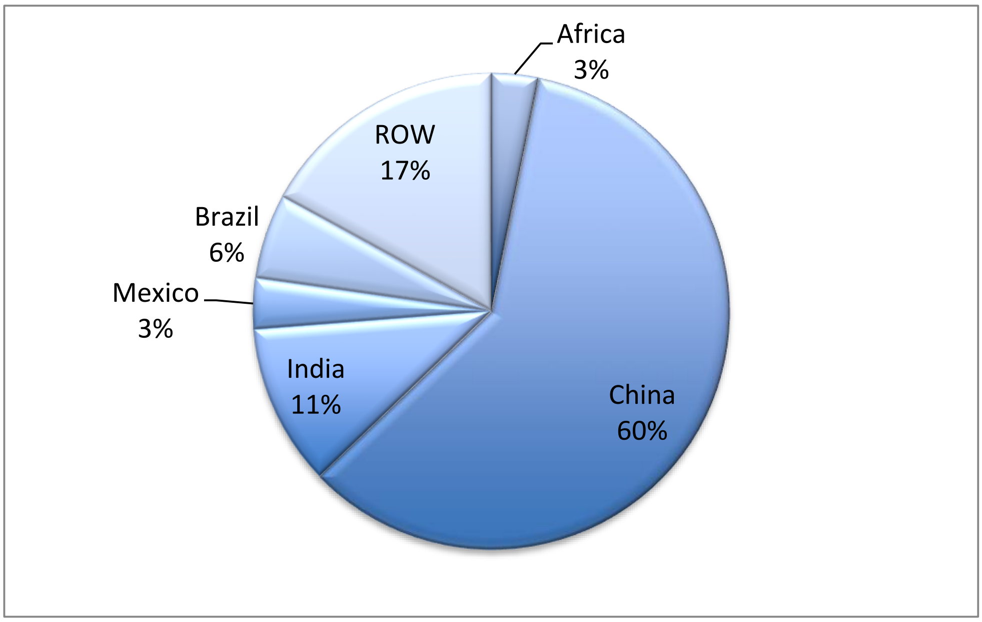
1.3 Why do we need to reframe international policy on climate technology transfer?

Climate technology development and transfer forms a core commitment under multiple articles of the UNFCCC. In support of this commitment, there are two mechanisms that provide significant levels of support for technology transfer to developing countries: the Global Environment Facility (GEF, which has been in operation since 1991) and the Clean Development Mechanism (CDM, which is one of the flexible mechanisms of the Kyoto Protocol). To date, the GEF has provided finance to developing and transition economies totalling around USD 3.6 billion plus USD 23.7 billion in additional co-funding (GEF 2012). Whilst this is a significant amount of finance, the CDM has facilitated about USD 350 billion of investment[3]. However, despite these commitments and policy efforts, the extent to which meaningful levels of technology transfer and development have been achieved, and the distribution of associated finance, has been uneven and focussed around a limited number of technologies. For example, Figure 1.1 illustrates the distribution by country or region of cumulative investment to date under the CDM. Here we see that the vast majority of investment has accumulated in a small number of countries. Figure 1.2 illustrates how these relative funding streams do not correspond to the relative emissions levels of these countries. In particular, Africa stands out as receiving disproportionately lower levels of finance compared to its emissions. Figure 1.3 illustrates how the majority of investment related to

[3] See the CDM pipeline, available via: http://www.cdmpipeline.org

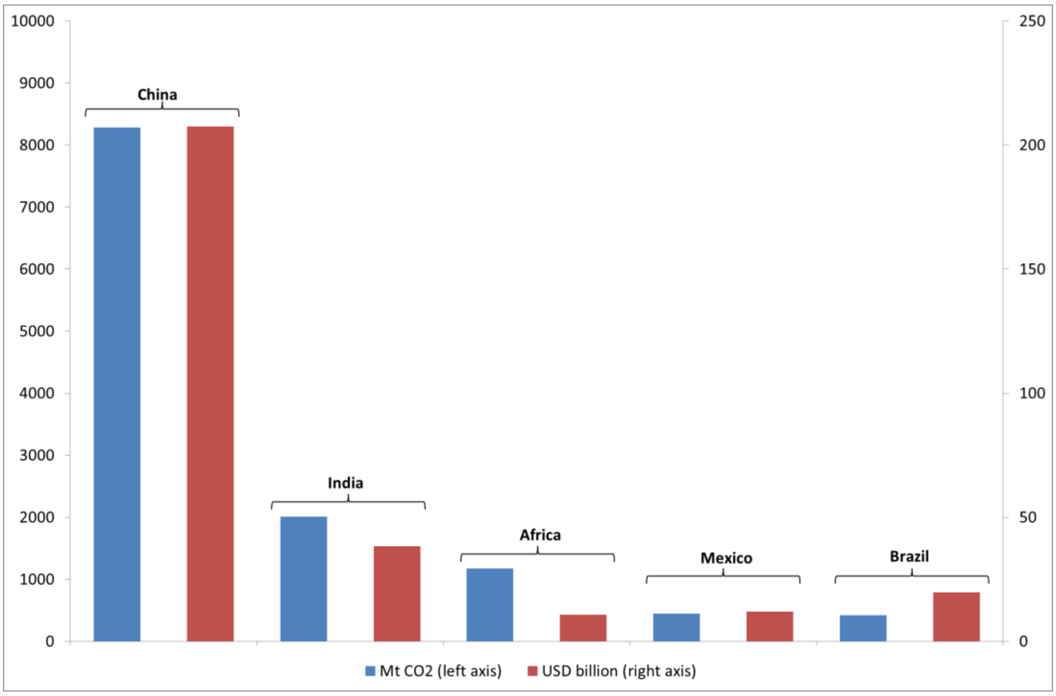
renewable energies has been in a small number of well-established technologies – only wind and solar PV being remotely towards the scale of "new" renewable energy technologies.

Figure 1.1. Distribution of cumulative investment under the CDM



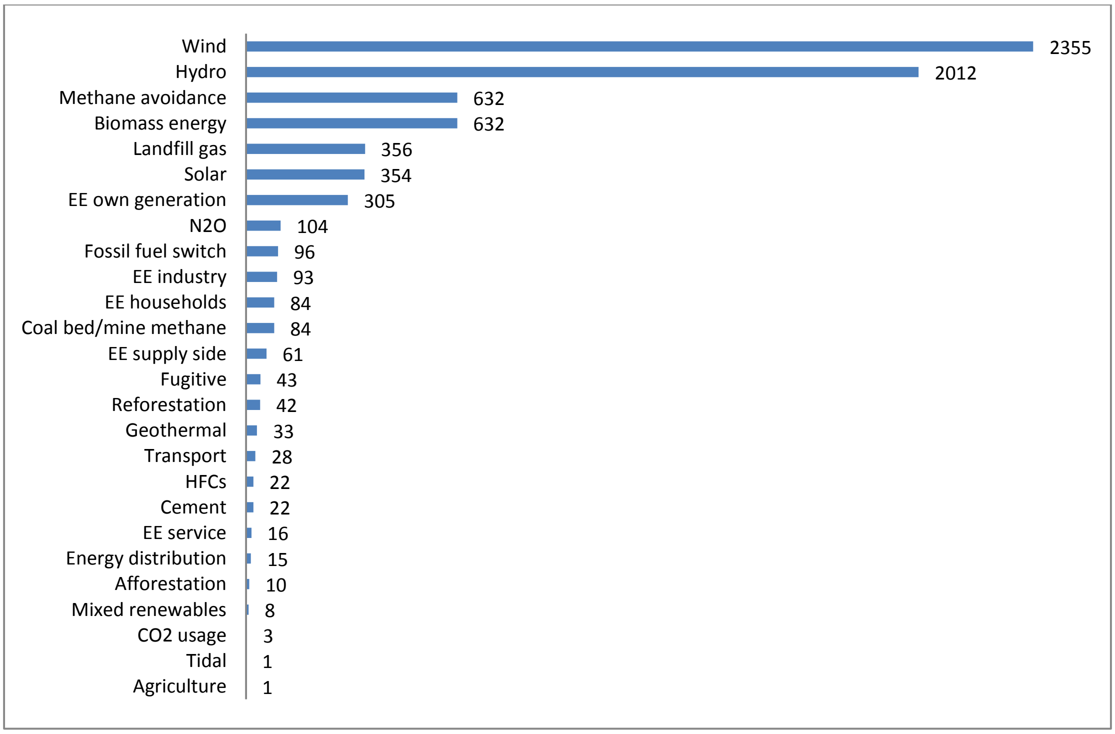
Notes: ROW = Rest of World; Figures represent % of total accumulated investment by the end of January 2014
Source: Authors, based on analysis of the CDM pipeline (http://www.cdmpipeline.org)

Figure 1.2. CO2 emissions and CDM project investment



Notes: Figures represent national or regional CO2 emissions (million tonnes) and CDM investment received (in USD billion) by the end of January 2014.
Source: Authors, based on World Development Indicators and analysis of the CDM pipeline (http://www.cdmpipeline.org)

Figure 1.3. Number of registered CDM projects as at end of January 2014, by project type (7412 total registered projects)



Source: Authors, based on analysis of the CDM pipeline (http://www.cdmpipeline.org)

There is, then, clearly a need to revisit the way in which international climate policy understands the problem of climate technology transfer and development. As will become clear in subsequent sections, the first step is to move beyond the traditional understanding of the problem as being one of 'hardware financing'. This is based on the erroneous assumption that climate technologies (understood as pieces of hardware, or 'kit') will be widely developed and transferred if the positive externalities of climate mitigation and adaptation can be internalised through market mechanisms.

Finance is most certainly part of the picture. The argument in this report is certainly not that finance or market mechanisms that seek to rectify market failures are not necessary parts of the solution. They are definitely necessary; but they are certainly not sufficient. As we will explain, based on decades of research in the fields of Innovation Studies and recent advances in the field of Socio-Technical Transitions, technological hardware is merely an artefact resulting from a combination of social practices, knowledge and capabilities. Once this is recognised, we begin to see why a simple hardware financing approach to international climate technology policy is insufficient. *Social practices* co-evolve with technologies and define directions of innovation and broader processes of technical change (climate-compatible or otherwise). *Knowledge* (amongst firms and other actors) of many kinds forms the basis from which to develop technologies and innovations. And *technological capabilities* (of firms, users and other actors) incorporate the knowledge, skills and other resources required to realise technical and innovative change.

An NSI connects together relevant actors and provides the environment within which these capabilities are nurtured and put to use. Those countries that have benefited most from the CDM, for example, are also those that have developed important new technological capabilities of relevance to various climate technologies, nurtured via the development of functioning NSIs in these key climate technology areas (e.g. bioethanol in Brazil, solar and wind in India and China). As well as realising the necessary but insufficient role of hardware financing mechanisms, we are therefore introduced to a fruitful new way to understand the problem of climate technology transfer, development and uptake. Furthermore, this understanding points to a vital way in which policy interventions might be refocused on nurturing NSIs with potentially profound long term impacts on widespread, climate-compatible technological change and development.

To some extent, recent moves under the Convention and elsewhere – most notably the establishment of a Climate Technology Centre and Network (CTCN) under the new Technology Mechanism (and similar centre-based approaches being implemented by other actors, such as the Climate Innovation Centres led by InfoDev, the UK Department for International Development (DFID) and Danida, and the various GEF funded initiatives) – have potential to act as innovation system builders, nurturing and learning across NSIs. But, as Section 4 of this report sets out, careful attention is needed to a number of other policy priorities beyond those which these centres are currently considering or implementing. It is the intention of this report to set out the nature of tangible policy interventions that might mainstream a focus on nurturing NSIs and (slowly but surely) achieve exactly the kind of widespread climate-compatible technological change and sustainable development that is at the heart of the UNFCCC and efforts to tackle climate change across the globe.

1.4 Structure of this report

This report is structured as follows. Section 2 introduces the building blocks necessary to understand the nature and importance of NSIs for fostering climate technology transfer, development and uptake. Section 3 articulates some of the key issues which climate policy needs to address in order to nurture NSIs across different country and technological contexts. Section 4 summarises the key overarching goals that policy interventions need to fulfil and provides a short review of some key relevant existing initiatives and the extent to which they could be or are delivering against these goals. It then articulates two proposals through which actions under the Convention (and beyond) could proactively nurture NSIs to significantly boost the development, transfer and uptake of climate technologies in developing countries. Finally, we conclude with specific recommendations for the TEC.

2. Setting the scene: National systems of innovation

NSIs provide the context within which all processes of technology development, transfer and uptake occur. Many different definitions exist of NSIs, but the term is often associated with the work of authors like Freeman and Lundvall (e.g. Freeman 1997, Lundvall 1992). Essentially, in the Innovation Studies literature, NSIs are defined as the network of actors (e.g. firms, universities, research institutes, government departments, NGOs) within which technology development, transfer and uptake occurs, and the strength and nature of the relationships between them. As expanded on below, decades of empirical research in the field of Innovation Studies have shown that the astounding levels of technological and economic development that have been observed across many developing country sectors (e.g. the Korean steel industry), and countries as a whole (e.g. the Asian Tiger economies), can be understood as the result of processes that strengthened NSIs, and provided the enabling environment in which indigenous firms could boost their technological capabilities. An NSI perspective is equally able (and has been applied via extensive empirical research) to explain the success of OECD economies (OECD 1997).

Sections 2.1 to 2.3 outline the main insights from the Innovation Studies literature. However, these insights are mainly drawn from a focus on the technical and economic aspects of the supply side of innovation, and the formal institutional environment within which supply-side actors operate. More recently, insights from the field of Socio-Technical Transitions research have usefully expanded on the traditional Innovation Studies perspective to include consideration of technology users and the social practices which form the context within which innovation happens and define, via a co-evolutionary relationship, the directions of technological innovation and change. This perspective has also helped to illuminate how new technologies (like climate technologies) might, through an innovation systems based approach, be introduced in ways that maximise the chances of such technologies moving from being niche technologies to challenge established technology regimes (and their attendant vested interests and stable trajectories) in order to become more widely adopted. This has opened up space to consider the directions in which such change might happen and how it might be nurtured in more climate compatible or sustainable directions. A socio-technical transitions perspective is also better able than traditional innovation studies to attend to institutional considerations (formal and informal) and broader political economy considerations (although there is still work to do to better incorporate political economy considerations into socio-technical transitions approaches). Sections 2.4 and 2.5 elaborate on these insights, laying the foundations for a broader definition of an NSI than we would draw from the traditional Innovation Studies literature.

Taken together, these insights provide powerful purchase for policy aimed specifically at boosting the development, transfer and uptake of climate technologies in developing countries. In this section we therefore focus on introducing the building blocks necessary in order to understand the key insights from the Innovation Studies and Socio-Technical Transitions literatures and draw these together to demonstrate the importance of an NSI approach to policy. We conclude the section with some case studies from China and Kenya to bring these insights to life and show how they can work in practice.

2.1 What is ‘innovation’?

Innovation is a broad term that is used to describe both the process and outcome of developing technologies and techniques that are put to use in the world. A comprehensive understanding of innovation goes beyond the common assumption of inventing technologies that are new to the world, i.e. radical innovations that emerge from highly technical scientific research and development (R&D). First, it is important to make a distinction between invention and innovation. Fagerberg (2005, 4), for example, states that invention is considered to be the first occurrence of an idea (e.g. how to harness certain technical principles for making a touchscreen interface), while innovation is considered to be the first implementation of that idea in practice (e.g. the incorporation of a touchscreen into a new mobile phone released on the market). Second, not all innovations are radically new technologies based on scientific R&D. As the OECD's Oslo Manual asserts (OECD 2005, 46-47), it is also innovative when a firm is the first to introduce a new (or improved) piece of hardware – e.g. a product or piece of production equipment – or a new (or improved) technique – e.g. a production process or marketing strategy. Likewise, even if other firms have already introduced new hardware or techniques, it remains innovative to a firm when it adopts these itself for the first time. Indeed, as Arnold and Bell (2001, 288) note, in discussing product innovation in OECD-country firms, "considerable efforts are devoted to monitoring competitors' products and reverse engineering – both as a source of ideas and in order to benchmark the company's own processes". Moreover, Arnold and Bell report that these kinds of efforts constitute the dominant form of innovation activity, contrasted with the "vanishingly small" contribution of publicly-funded R&D. This does not provide an argument against public sector research; rather, it provides a perspective on the direct contribution of such research – particularly basic science – to innovations in economic activity.

However, where publicly-funded scientific R&D does appear to be more useful to an economy, according to Arnold and Bell (2001), is in the provision of highly-trained researchers who can then work in private firms to further innovative activities. One of the reasons for this benefit is that such researchers are able to understand the knowledge created from scientific R&D and so raise the chances of applying that knowledge in the firms' innovative activities. The ability of a firm to understand and make use of scientific R&D, and of the stock of knowledge more generally, is referred to as absorptive capacity[4] (Cohen and Levinthal 1990, 128). This ability to use scientific knowledge is likely to be more important in those areas of economic activity that are – broadly speaking – at the frontiers of technology: e.g. bio- and nanotechnology, amongst others. Indeed, in such frontier areas, where the risks to investment are high, publicly-funded research (basic and 'applied') can be critical to the initial development and future success of those technologies as well as the firms that work in their respective sectors. As Mazzucato (2013, 13) argues:

"From the development of aviation, nuclear energy, computers, the Internet, biotechnology, and today's developments in green technology, it is, and has been, the State – not the private sector – that has kick-started and developed the engine of growth, because of its willingness to take risks in areas where the private sector has been too risk averse."

Once innovations are introduced or adopted by firms, there often follows a continuous process of improvement (e.g. in efficiency) or adaptation (e.g. to meet the regulatory requirements of another country) in which each implemented change is also considered an innovation. Again, as with innovation activity described above, these incremental or adaptive

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[4] Cohen and Levinthal (1990, 128) specify absorptive capacity as the ability of a firm to "recognize the value of new information, assimilate it, and apply it to commercial ends".

innovations constitute much of ongoing economic activity and development. Incremental changes can add up to significant improvements over time, as Barnett (1990, 543) observes:

"[…] much of the increase in productivity in industrialized countries is achieved through the aggregation of myriads of minor changes to existing production processes (rather than from individual massive jumps in productivity through investment in new vintages of technology)."

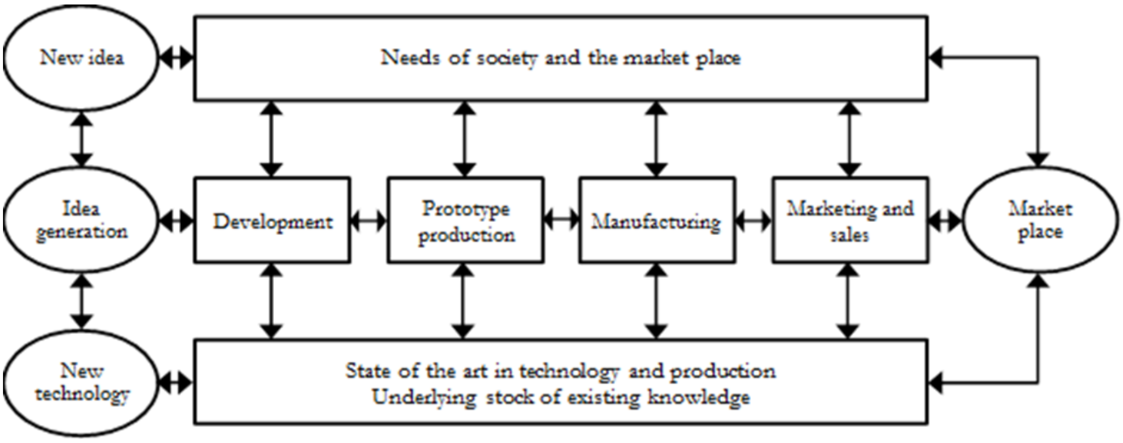
And adaptive innovations are often required in order to ensure an existing innovation better 'fits' the context into which it is introduced – a new country, industry, firm, farm, household, etc. – such that it is more likely to be adopted or that it performs better in that new context. For example, many adaptive innovations have been made to mobile phone handsets being sold to poor consumers in Kenya. Foster and Heeks (2013, 343) describe the innovation responses of Chinese mobile handset firms to suggestions from Kenyan intermediaries working close to low-income consumers for modifications to handsets:

"[Innovations included] dual sim card phones (allowing users to choose the lower-cost network to phone particular contacts), translation of the phone interface into Swahili, and addition of a single-button-enabled new interface for the popular M-Pesa mobile money service."

It should be clear from this brief discussion that there is a wide spectrum of outcomes that can be described as innovations. When focussing on firms, as the Oslo Manual does (OECD 2005, 46), innovations can emerge in products (goods and services), processes, marketing methods, organisational arrangements and management of external relations. Furthermore, innovations can range from the highly novel (or radical) to the more incremental. In terms of day-to-day economic activity, incremental forms of innovation are by far the most important, even in the OECD countries. Science-based R&D is in general of little direct relevance to these day-to-day activities but researchers trained under such conditions can help improve absorptive capacity when working in firms. Nevertheless, science-based R&D can be critical to certain kinds of innovation, particularly at the leading edge of technology development.

Innovation is also used to refer to the process of innovating, and it is understanding this process that is of fundamental concern in the Innovation Studies literature (Fagerberg 2005, 9). The outcomes of innovation are inherently uncertain and therefore unpredictable except in broad terms. However, it is clear that innovation outcomes do not occur simply by chance and decades of research into innovation processes have given rise to many useful insights. At a general level, one of the most important of these insights has been the recognition of the systemic nature of innovation, which has driven the development of increasingly sophisticated 'models' of innovation. Within the literature, the so-called Linear Model has long been discredited. This model assumes that innovation begins with scientific research, which leads to innovations of various kinds via a sequence of steps through engineering, manufacturing and marketing. During the 1960s, this 'science push' understanding of innovation gave way to a 'market pull' model, which emphasises the importance of needs expressed in the market place as motivators of innovation, although it too is a linear representation of the innovation process (Rothwell 1994). Based on the findings of many detailed empirical studies of innovation in practice, which revealed the inadequacies of both these linear conceptualisations of innovation, Kline and Rosenberg (1986) introduced a coupling model (which forms the basis of the innovation chain, now widely cited). The coupling – or chain-linked – model is shown in Figure 2.1 with the addition of the existing stock of knowledge available to firms, which Arnold and Bell (2001, 287) argue continues to constitute the vast majority of knowledge used during innovation activities.

Figure 2.1. The "interactive", "coupling" or "chain-linked" model of innovation



Source: Based on Kline and Rosenberg (1986, 290), Arnold and Bell (2001, 287) and Conway and Steward (2009, 68)

Although this interactive model emerged from empirical analysis of firms, its arrangement of different kinds of functional activities in innovation – linked to the market place and to the available stock of knowledge – suggests not all activities need be performed within any one firm. Instead, the empirical studies revealed the reality of multiple feedbacks between these functional activities and the available stock of knowledge and society, where the feedbacks are represented by the two-way arrows in the model. Moreover, innovations could emerge from any one of the activities – say, marketing and sales – or any combination of some or all of the activities. From this perspective, the nature and quality of the feedbacks and links between activities become as important as the activities themselves, regardless of whether the activities are located in a single firm or in many specialised firms. For example, the manufacture of a product could be excellent in terms of quality, and it might be skilfully marketed, but if few in the marketplace are interested in that product then it is likely to be a failure. Conversely, a poorly-made product, even if it in principle answers a widespread need in society and is well-marketed, is likely in time to fail. In the first case, we might surmise that poor understanding of particular needs in society (because of weak feedbacks and links) led to poor design and manufacturing choices. In the second case, despite strong feedbacks and links that enabled a clear understanding of needs, the manufacturing ability was too weak to answer those needs satisfactorily.

So, we can see that the concept of innovation encompasses both the process of innovating and the outcome of this process. We also see that the outcomes – innovations – are not always radically new technologies or techniques; indeed, the majority of innovations are incremental or adaptive, emerging from interactive processes anywhere in the innovation 'chain', not just from – or even necessarily involving – basic R&D. This more sophisticated model of innovation activities, together with an appreciation of the wide spectrum of innovation outcomes, provides some of the essential features that need to be understood in order to make sense of what we now call innovation systems. But there are other foundational ideas to highlight before we can draw the various insights together into a broad definition of an NSI. First, we need to explore the relationship between knowledge and technology (and, more generally, innovation), which has important implications for understanding the role of technology transfer in innovation and the building of NSIs. And, second, we need to consider more carefully how society plays a much more integrated role in innovation than the discussion has so far examined. The literature that helps us understand this more integrated role also provides insights on how we might better foster the building of innovation systems, particularly in least developed countries, and how we might better focus innovation activities to benefit poor and marginalised groups within those countries.

2.2 Technology as knowledge not hardware – building technological capabilities to underpin technological change

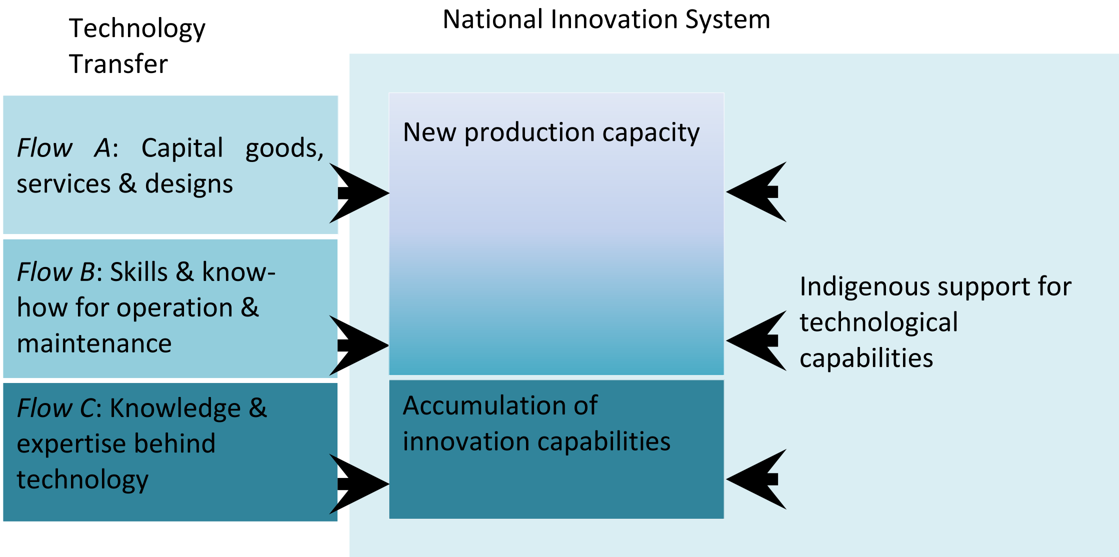
Another important insight from the innovation studies literature is that technology is not simply hardware. Embedded in the hardware is a reflection of the knowledge required to create it; and knowledge and skills are needed to adopt, use and adapt it – sometimes referred to as the software (Bell and Pavitt 1993, Ockwell *et al.* 2010b). An essential characteristic of this 'software' is tacit knowledge – a fundamental aspect of knowledge and skills that is difficult or impossible to articulate (or codify) but can be cultivated through practice and experience (Polanyi 1966) (see section 3.1 for an elaboration on codified versus tacit knowledge). Taking these insights together with those discussed in the previous section, we can begin to craft a more holistic understanding of how technologies are created, adopted, used and adapted. And, from this holistic perspective, we can see that understanding technology (and, more broadly, innovation) in terms of knowledge has profound implications for how technology development and innovation can be more successfully – and sustainably – encouraged than the currently dominant approaches of hardware-financing.

The chain-linked model discussed above (see Figure 2.1) derives from the recognition of the importance of inter-linkages between firms, and their inter-linkages with the social context. This already suggests interdependent relationships between firms, innovations and society. Innovations succeed, in part, because they respond to well-understood 'needs' (or demands) in the relevant social context and so we can see that the behaviour of firms (and the nature of innovations) is to some extent dependent on that social context. But as innovations become more widely adopted they enable new choices, behaviours, and so on, in society (including amongst innovating firms). So the context is also dependent to some extent on the behaviour of firms and the innovations they produce. And, of course, all this happens within an environment of institutions constituted by policies, laws, regulations and norms. Furthermore, these institutions evolve as responses to, or intentions to influence, developments in technology and other innovations. In other words, technologies (innovations) are part of a system, and a key *dynamic* element of that system is evolving knowledge (including scientific, technical, social, cultural, political, etc., forms of knowledge). Particular technologies and innovations can be understood as specific distillations of combinations of these different knowledge domains, including what can be codified and what is inherently tacit. Within the traditional innovation studies literature, many of these ideas have been thoroughly analysed and there is, in particular, a wealth of evidence concerned with the relationships between evolving knowledge, firms' behaviour and the formal institutional environment (e.g. see Katz 1987, Kim, Kim and Lee 1989, Bell 1990, 1997, 2009, Freeman 1992, Lundvall 1992, Bell and Pavitt 1993, Hobday 1995a, 1995b, Radošević 1999, Ockwell *et al.* 2008, Watson *et al.* 2014).

One way to understand the significance of these ideas in relation to technology transfer and innovation is depicted in Figure 2.2, especially in regard to innovation systems and the ways in which the knowledge and skills required for self-directed development can be accumulated. Based on Bell (1990), the diagram shows three types of technology transfer flows (A, B and C) into a local context. Flow "A" includes hardware, as well as the engineering and managerial services that are required for implementing such transfer projects. Flows of type “B” consist of information about production equipment – operating procedures, routines, etc. – and training in how to operate and maintain such hardware. Bell (1990, 77) describes these flows as “paper-embodied technology” and “people-embodied knowledge and expertise”. Both flows “A” and “B” add to or improve the production capacity of a firm or economy, but do little for developing the skills needed for generating new technology. The CDM tends to result in these kinds of flows: for example, it might facilitate the installation of wind farm projects that increase the capacity for electricity production. Flows of type “C”, however, are those that help to create the capability to generate new technology. In other words, they help to build innovation capabilities (see Bell 2009). These flows have not occurred through the CDM without the active leveraging of project opportunities through the implementation of additional national policy interventions such as those used in China (Stua 2013, Watson *et al.* 2014, and see the case study on China below). Offering some contrast, the GEF funds or finances projects that help to foster broader knowledge and capacity building. Whilst not directly building the capabilities for creating new technologies, they are to some extent building the capabilities for innovating in other ways such as adaptive innovation (see, for example, GEF 2012). And Byrne (2011) includes an analysis of a GEF-funded solar PV project in Tanzania that saw innovations along the supply chain as well as in new uses for PV systems.

Within the context of a concern with climate-compatible development, this idea of technology flows building local capabilities to generate broader technological change is of central importance – in this case, building capabilities to generate technological changes that facilitate more climate-compatible social and economic practices. In other words, efforts need to focus on building technological capabilities to move from basic production capabilities towards innovation capabilities. The existing technological capabilities in the local context could also be considered as absorptive capacity, broadening Cohen and Levinthal’s (1990) original definition beyond the capacity of a single firm. Indeed, this broader concept has been used to demonstrate the impact of individual firms’ absorptive capacities on the ability of clusters of firms to adopt and adapt new technologies (Giuliani and Bell 2005), and to explain the ability of countries to achieve technological learning through the CDM (Doranova 2010).

Figure 2.2. Technology transfer and indigenous innovation



Source: Watson *et al.* (2014) based on Bell (1990)

The diagram in Figure 2.2 does not show explicitly the importance of the institutional environment, although the innovation literature does so, especially with regard to formal national and international institutions. Used carefully, these can help to enhance existing industrial activity – for example, to raise the level of capabilities to increase competitiveness – but are also important for fostering new industrial activity that would otherwise not be pursued (e.g. see Cimoli, Dosi and Stiglitz 2009). In the case of climate technologies – and a concern with broader processes of climate-compatible technological change – this latter point is particularly relevant (Ockwell *et al.* 2010b). Many existing climate-compatible alternatives are not yet competitive with climate-incompatible technology options and so market demand for many climate technologies tends to be weak or marginal. But it is likely that we will need a range of such technologies, and the need is becoming increasingly urgent. In principle, appropriate policies could foster their competitiveness, and the local capabilities (and innovation systems) that can sustain and develop them.

It should be clear from this discussion that achieving large-scale climate-compatible technological change is an inherently long-term endeavour, involving multiple actors engaged in many interdependent processes. The literature that analyses these changes – particularly the literature on the so-called 'catching-up' countries – demonstrates convincingly that making the transition from a least-developed country to even a middle-income developing country status requires targeted strategic policy interventions implemented over decades (e.g. Fagerberg and Godinho 2005). Whilst there are many context-specificities that mean each country implemented particular policies that might not be suitable elsewhere, the general strategy has been to ensure the development of technological and innovation capabilities and to build innovation systems (Cimoli *et al.* 2009). As we have highlighted, central to this endeavour is the exploitation of knowledge flows. This has been a huge challenge for those countries that have – at least to some extent – 'caught up' but the challenge is now compounded by the need to build *climate-compatible* innovation systems, a constraint that did not trouble the previous 'latecomers' (Byrne, de Coninck and Sagar 2014a).

Nevertheless, there is evidence in the literature that suggests many practical policy interventions to achieve such development are available, although we should also expect that there will be an ongoing need for experimentation and learning (Chaminade *et al.* 2009).

2.3 The incremental nature of technological capability building

Section 2.1 has emphasised the importance of incremental innovation in processes of widespread technological change. Here we expand on this issue with reference to some empirical examples in order to clearly illustrate its policy relevance. In line with the popular conception of innovation as science-based radical invention, there is a tendency to assume that the promotion of innovation capabilities will be readily achieved through the strengthening of science-based R&D. However, experiences reported in the literature suggest that this strategy is unlikely to work unless more foundational capabilities are built first. For example, Bell (1997) argues, with reference to a number of studies – from as early as the 1970s – focussed on a range of countries in Latin America and East and South East Asia, that knowledge acquisition and capability-building are better achieved through incremental improvements that begin with simple engineering and managerial competences. Citing the work of Katz and colleagues (Katz 1987), and research conducted by Hobday (1995a, 1995b) and Kim *et al.* (1989), Bell discusses two different sets of approaches to establishing inter-firm and organisation linkages; one based on centralised R&D services and the other more sequenced along a 'simple' to 'complex' trajectory. The Latin American countries used a centralised approach in which specialised R&D organisations were expected to conduct research on behalf of private firms. This was unsuccessful, largely because the R&D organisations and private firms were unable to communicate with each other. That is, private firms, without sufficient existing technological capabilities, were unable to articulate their technical needs in a form that the R&D organisations could use to focus their research. For their part, the R&D organisations were not necessarily interested in the technologies that the firms were using, especially as they were attracted to the prestige of contributing knowledge to the international scientific frontier. So, while there were elements of an innovation system in place – firms seeking to service local market demands and research organisations with a remit to improve technologies for those firms – the 'system' was poorly articulated and the firms lacked sufficient absorptive capacity (see Sections 2.1 and 2.2 for a discussion on the importance of links and feedbacks, as well as knowledge and skills).

By contrast, the strategies used in the Asian countries proved to be more successful. These countries tended to use a sequencing approach in which firms were encouraged (and supported) to first develop their basic engineering and managerial competences. Complemented by other measures, such as huge investments over many years in training thousands of engineers (Freeman 2002), fostering links between firms and targeting a narrow range of strategic industrial sectors (Sauter and Watson 2008), the Asian countries encouraged their innovation systems to evolve from simpler imitative innovation to more complex creative innovation. Korea, for example, developed its steel industry to the point of becoming a world leader in the 1990s from having no capabilities in steel manufacturing in the 1960s. This included the use of protectionist measures to allow indigenous firms to strengthen their capabilities before having to face the full force of international competition, although the State itself applied significant pressure to ensure that indigenous firms did indeed achieve improvements in their capabilities (for more on these strategies and measures, see discussions in Chang 2002, Reinert 2007, Khan and Blankenburg 2009, Schmitz, Johnson and Altenburg 2013). China is one of the most iconic current examples of a successful catching-up country. Once again, as summarised in the case study on China further below, this success has been achieved to a large extent by concentrating on building technological capabilities in strategic industries and a functioning innovation system.

2.4 The socio-technical nature of innovation and technological change

Building on the innovation studies literature but broadening it with insights from anthropology, sociology and political science, the rapidly growing body of work on socio-technical transitions enables us to take our analyses beyond the focus of firms. More specifically, it facilitates a consideration of the technology user. It allows us to understand innovation and technological change as a process that occurs within the context of social practices and which shapes, and is shaped by, these practices and evolving local knowledge. Examples of such local knowledge include the cultural practices around cooking that define appropriate low-carbon energy alternatives, and expectations around personal mobility. Furthermore, as well as attending to existing institutions and market structures (e.g. supply chains for kerosene and subsidies intended to help the poor), a socio-technical perspective directs us to analyse how the dominant nature of such institutions creates a powerful inertia against alternatives (e.g. low-carbon energy technologies for lighting). Climate-compatible development – especially if it serves the needs of poor and marginalised people – is embedded with normative assumptions that do not necessarily align with the interests of such inertial forces. We cannot, therefore, take such normative commitments as given. Each can be contested, and the particular solutions to any commitment – even if not contested – are the subject of often fierce debate. These contestations and debates have material consequences for the choice of action undertaken and so it is important that we include attention to these politics in both our analysis of potential interventions and the way we conduct those interventions. Therefore, we begin our discussion of a socio-technical perspective by considering the notion of framing and its implications.

Societal services are realised dynamically out of the interplay of various co-evolving complex systems (social, technological, environmental). And any particular unfolding of these dynamics constitutes a specific development pathway amongst multiple possibilities (Leach, Scoones and Stirling 2007). Each of these complex systems themselves, and their combination, can be framed in different ways. And each framing informs – and is informed by – a narrative that interprets the world in a particular way, reflecting and reinforcing the perspective of whoever is promoting that narrative. As understood here, a narrative is used to "suggest and justify particular kinds of action, strategy and intervention" (Leach, Scoones and Stirling 2010b, 3) and so attempts to enrol actors and their resources into particular ways of achieving development goals. If this enrolment is successful then a particular direction of development is privileged over others.

Implicit in this description is the notion that multiple framings, narratives and pathways are possible. Different groups of actors interpret the world in different ways, each interpretation arising from different experiences, situations, understandings, values and interests. Favouring certain framings over others, actors will seek to promote narratives that would help to create their preferred development pathways. Some narratives will dominate, and are likely to become manifested in interventions. Other narratives remain marginalised, and are unlikely to become realised (Byrne *et al.* 2012c).

But this is not to argue that dominant narratives and pathways are immune to influences from the margins. As evidenced in the literature on socio-technical transitions, dominant socio-technical practices experience pressure from various sources, and experience internal tensions between the many dimensions (social, cultural, political, technical) that together constitute those practices (e.g. see Geels 2002, Raven 2005, Smith 2007). Climate change, for example, is creating increasing pressure on the dominant fossil-fuel based development pathway. And the climate change narrative has enrolled increasing numbers of actors and their resources; spawned the UNFCCC and instruments of climate governance such as the Kyoto Protocol; promoted certain strategies such as investment in renewable energy technologies; and argued for interventions such as carbon pricing. Of course, the fossil-fuel based development pathway remains dominant but it is clearly under mounting pressure and we could argue that its dominance is beginning to erode.

In trying to analyse how dominant practices come to be eroded, or how new practices come to be accepted, we can draw useful insights from the socio-technical transitions literature. Here we see that there are various ways in which marginal, experimental or sometimes radical socio-technical practices can come to influence mainstream practices and even thoroughly transform them over time (Geels and Schot 2007). Technology can play a central role in such transformations by affording opportunities for entirely new practices that create demands for widespread institutional change (Deuten 2003). And it is in regard to this transformative potential of technology and innovation that an understanding of knowledge creation and flows is especially important. As we will see in the case study of the Kenyan photovoltaic (PV) market below, the nurturing of knowledge creation on many fronts and the circulation of that knowledge, together with the capability building this facilitates, have been essential for the successful evolution of that market.

Fundamentally, a socio-technical perspective also provides us with the tools to understand how processes of climate technology uptake amongst firms and users might happen, how such actors participate in technology development and innovation, and how policy might pursue systemic interventions to nurture such change. This includes, for instance, understanding examples of climate technology experiments in developing countries as (protected) niches which have to compete with dominant regimes: e.g. unfamiliar low-carbon energy options (niches) competing with familiar fossil-fuel-based energy systems (regimes, with their attendant social norms and powerful vested interests as well as existing infrastructure and established technologies). This casts light on the way that a more systemic policy approach, focussed on nurturing innovation systems, can serve to connect and learn across climate technology experiments and niches (whether at firm, industry or user levels) through strategic interventions. Of particular relevance here is the burgeoning literature on strategic niche management ('SNM', or 'niche theory'), which we will now discuss briefly.

Having emerged from research within developed country contexts, the SNM approach has, in recent years, begun to be applied in the context of developing countries. For example, see the special edition of *Environmental Science & Policy* introduced by Berkhout *et al.* (2010) for the application of these ideas to developing Asia, and see Byrne (2011) and Byrne *et al.* (2014b) for their application in Kenya and Tanzania. Specifically, these papers focus on the use of niche theory to understand the dynamics of how novel technologies were tested in real-world settings, and whether or not they resulted in wider use and further development. A key feature of niche theory is that it directs our attention to the co-evolution of actors' expectations about a technology in the future; their learning as they experiment with that technology in real-world settings; the networks of other actors they develop; and the extent to which various socio-technical practices relevant to that particular technology become embedded in society. These co-evolutionary dynamics are assumed to happen in what amounts to a protective space – the niche – in which the normal pressures of market forces and technical performance are weakened, enabling essential learning to take place (Smith *et al.* 2014). Of course, these dynamics unfold within a broader context, which is conceived as consisting of various ‘regimes’ (mainstream, normal or dominant ways of doing things) and a wider ‘landscape’ (difficult-to-influence changes such as demographics, events such as wars, etc.) (Romijn, Raven and de Visser 2010). Eventually, some niches come to influence regimes over time, and can even replace them entirely.

Understanding the processes of how and where niches have been successful and unsuccessful in influencing regimes therefore raises the potential to understand where policy might deliberately intervene to nurture climate technology niches. A policy might aim, for example, to widen and deepen access to climate technologies to benefit poor and marginalised groups and do this by creating new – or nurturing existing – niches of climate technology applications amongst poor communities and households. Importantly, niche theory emphasises the role that key actors – ‘innovation system builders’ (Byrne *et al.* 2014b) – can play in developing a niche, raising potential for policy makers and other actors (e.g. NGOs or private companies) to emulate the actions of past successful innovation system builders to achieve wider impacts and broader uptake of climate technologies and innovations.

2.5 National systems of innovation as enabling environments for climate technology transfer, development and uptake

This sub-section draws together the insights from the preceding sub-sections to articulate how NSIs represent the overarching systems within which knowledge flows and the development of technological capabilities are nurtured, and how niches of climate technology adoption can be fostered to the point where they begin to compete with fossil-dominated, climate-incompatible regimes. As opposed to the limited definition given at the beginning of Section 2, we also provide a broad definition of what constitutes a national innovation system, connecting up relevant insights from the literatures discussed above.

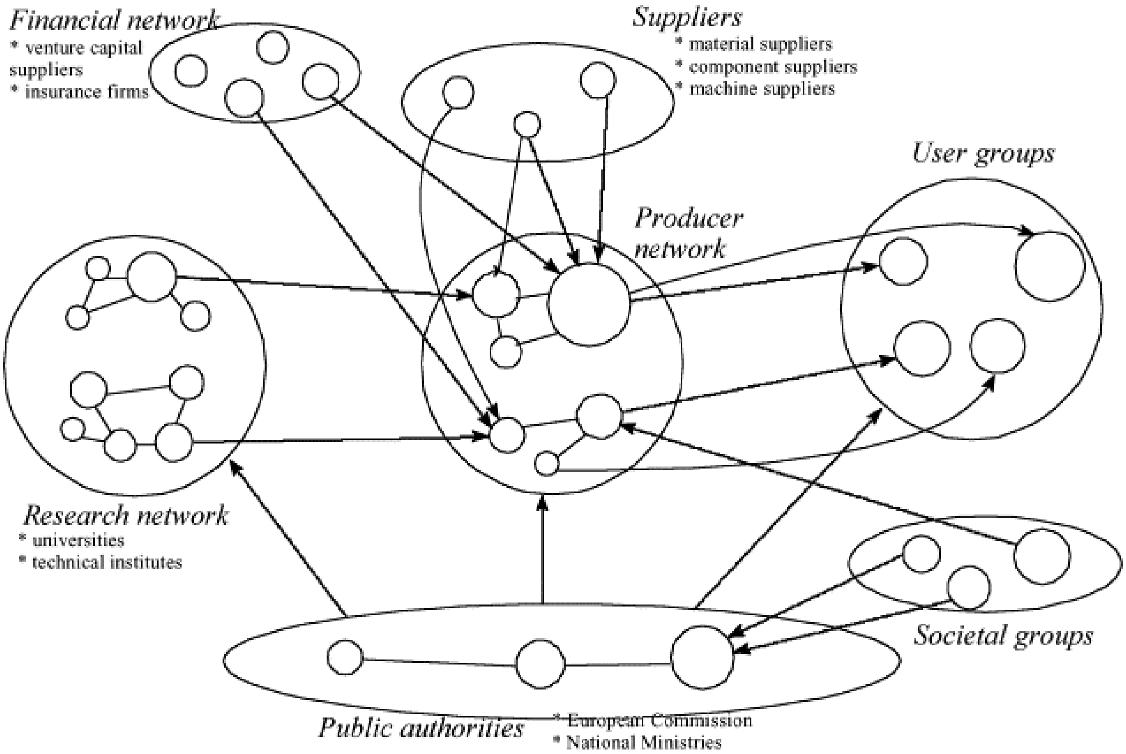
As we have seen in the discussion in Section 2.1, the majority of innovation in any context tends to be of an incremental form, where small efficiency gains are made little by little, or of an adaptive form, where existing technologies are adapted to work in new countries, industries, firms, farms or households. For example, incremental efficiency improvements characterised the Korean steel industry, which eventually moved to the international technology frontier (D’Costa 1998, Gallagher 2006), while adaptive innovation of the internal combustion engine was what facilitated Brazil’s international leading role in transport-related biofuels (Lehtonen 2011). This could equally apply, for example, in the context of a farmer in Sudan adopting water-efficient farming techniques and adapting them to their specific environmental conditions, or an entrepreneur in Kenya configuring small waste solar panel parts to create a business in supplying solar PV modules to charge mobile phones (as reported in Byrne 2011).

Of course, all countries aspire to possessing the capabilities for creating more radical innovations in the hope that these will bring higher value-added economic returns. And, certainly, there are countries that have achieved these goals in recent history, despite having begun their development pathways in extreme impoverishment. However, the pathways these countries built began with laying foundational capabilities first – incremental innovation capabilities in basic engineering and managerial competence. Alongside these foundational capabilities, they focussed on building and strengthening their innovation systems. As they did so, they were able to absorb more complex technologies and begin to further develop these indigenously. In time, this meant more attention to higher technology R&D, often in collaboration with international firms, and subsequent positions at the ‘frontiers’ of certain technologies. Those countries that attempted to develop their R&D capabilities before laying any foundations were generally unsuccessful, delaying their 'catching up'.

For most developing countries – and certainly for the least developed – only weak or highly fragmented innovation systems currently exist. Consequently, whilst they may be implementing some projects through the GEF, they find it difficult or impossible to attract the kinds of projects available through instruments such as the CDM. Even where some of them are now implementing small CDM projects, it is not clear that they are able to leverage any further development benefits. For example, Kenya has attracted some CDM projects to replace incandescent lamps with the more energy-efficient compact fluorescents but there appears to have been no attempt to move beyond the simple adoption of these to some kind of assembly activities that might enable the capture of higher value-added capabilities (Byrne 2013). This perhaps reflects weak policy-related capabilities as well as a lack of any appropriate existing industrial activities that might be exploited to move into such production. Whatever the case, it may represent a missed opportunity.

While the traditional innovation studies literature demonstrates the importance of innovation systems for achieving technology-related economic development goals, the socio-technical transitions literature shows us that we need to be cognisant of more than the skills of, and relationships between, industrial actors. This is particularly true when we are interested in creating entirely new technological or innovation trajectories that profoundly challenge the power of established technological systems (or socio-technical regimes). It is from this perspective that we can understand that cultures of practice are as much a part of the inertia of these established systems as the hard technologies and the actors who benefit from them. For example, attempts to address any of the problems associated with the use of cars for personal mobility, such as raising the price of fuel or city-centre parking fees, are met with fierce resistance from consumers as much as from producers. In other words, the interconnectedness and interdependencies that are needed for a well-functioning innovation system can also facilitate inertia in that system. Geels (2002, 1260) gives an indication of the interconnections that constitute such a system (in his case, a socio-technical regime – see Figure 2.3). But this diagram could just as easily represent certain aspects of a 'good' innovation system.

Figure 2.3. The multi-actor network involved in socio-technical regimes



Source: Geels (2002, 1260)

This points us to the need to develop innovation systems carefully so that they are more likely to be sustainable, particularly if we are interested in climate-compatible development, for which there are huge uncertainties. Niche theory offers particular hope here. Although niche analyses often concern themselves with radically new or highly novel innovations, niche activities consist primarily of incremental learning in real-world settings. As such, there is the chance that all the groups represented in Geels' (2002) socio-technical configuration, if brought together for 'problem-solving' in particular contexts, can develop workable 'solutions' – or innovations – in a co-evolutionary process that meets their differing needs. Niche theory identifies four sets of generic activities – or processes – that should be pursued in order to develop such workable solutions or innovations:

- Learning and creating knowledge
- Institutionalising learned socio-technical practices
- Growing and developing constituencies of support
- Consensus-building

In many ways, these activities fit well with what we know about innovation systems and what we so far understand about how to nurture their development. *Learning and creating knowledge* about particular innovations, most clearly, relates to the building of capabilities and is crucial for the continued evolution and development of an innovation system that is creative and adaptive. Such learning needs to be fostered on the many dimensions of an innovation (multiple 'socio-technical fronts'): not just the technical and economic, but also in terms of relevant user preferences and practices, government policies, and the infrastructure in which the innovation is to be used. *Institutionalising learned socio-technical practices* is the process by which the capabilities developed during learning are widely adopted. It also refers to the development and instigation of relevant policies, laws and regulations, as well as less formal 'rules' such as cultural norms. *Growing and developing constituencies of support* refers to actively encouraging the growth of networks of actors who invest various resources (financial, knowledge, political, etc.) to help realise the success of the innovation. These actor-networks can form the basis on which the linkages and feedbacks necessary for detailed understanding of societal and market needs can be built, as well as enhancing the more general flow of knowledge resulting from learning. They also help in *consensus-building* by providing the channels through which expectations about the innovation and its role in 'solving' particular societal needs can be discussed, negotiated, contested, and so on. And consensus-building can justify certain kinds of practice over others, providing – through institutionalisation processes – the cultural norms to which firms can respond when developing specific innovations. Consensus-building can also perform more overtly political work, pressuring policymakers into designing institutional frameworks that support specific innovations. Of course, there are no guarantees of a smooth ride in these processes – and some innovations will inevitably fail – but their incremental nature does at least leave space for adaptation to changing circumstances (whether these are social, technical or environmental). Specific policy recommendations are discussed in Section 4, which translate the conceptual processes identified here into suggested practical interventions.

To summarise, we can define in broad terms what a well-functioning NSI means. Based on the literatures discussed in this report, an NSI is made up of "…interconnected firms, (research) organisations and users all operating within [a national] institutional environment that supports the building and strengthening of skills, knowledge and experience, and further enhances the interconnectedness of such players" (Byrne et al. 2012a, 1). We can add to this the international dimension. That is, any well-functioning national innovation system will also be connected internationally through market, social and political relationships and, indeed, these are essential for the continued flow and development of knowledge, skills and innovations.

2.6 Relative differences in NSIs across developing countries

The decades of the post-World War era have seen a divergence in the fortunes of the developing countries. Some have achieved impressive industrialisation and economic growth, while others have stagnated. Of course, there are many reasons to explain this divergence – including war versus peace, environmental crises versus relative stability, disastrous political leadership versus more benign states, different colonial legacies, rich versus poor resource endowments – but their success or otherwise in building functioning innovation systems is also an important factor (Bell and Pavitt 1993, Fagerberg and Godinho 2005). Whatever the reasons for this highly uneven innovation system building across developing countries, it is clear that no one set of technology-specific policies is likely to work in every context (Chaminade *et al.* 2009). Not only do developing countries have different histories, legacies, endowments, environments, cultures and politics, but they also face a wide variety of context-specific development challenges and priorities. For example, the many sparsely populated countries of sub-Saharan Africa have huge challenges in reaching rural communities with roads and electricity grid extensions compared with more densely populated regions in the world. The livelihoods available to those living in mountainous areas are different to those on the dry savannah, with consequent differences in opportunities to innovate. Countries with particularly high populations of poor people do not provide attractive investment opportunities for business in consumer goods and so it is difficult to create spaces in which to enhance innovation capabilities. See Section 3.2 for an extended discussion of context-specificities in relation to innovation system building.

In terms of technologies and innovations relevant to climate-compatible development, there are perhaps even fewer success stories. Clearly, China, India and Brazil stand out for some specific kinds of climate technology – wind power and solar PV (China and India, and to some extent PV in Indonesia), and biofuels (Brazil) – but these countries are also now, or likely to be in the case of Brazil, heavily reliant on fossil fuels. Nevertheless, there are serious policy efforts to move away from this reliance and there have been impressive gains (e.g. see Watson *et al.* 2014 on China). Most other developing countries, however, have not yet achieved much in terms of building appropriate innovation systems by harnessing opportunities in specific climate or other technologies. Still, in some ways, this could be an opportunity in itself. That is, to the extent that innovation systems are weak in these countries, and that they have not yet locked in to high-carbon lifestyles, they have the chance to begin building climate-compatible development pathways now and perhaps avoid some of the worst excesses of fossil-fuel based vested interests (Byrne *et al.* 2014a) whilst simultaneously, from an adaptation perspective, working to ensure that innovation systems focus on technologies which are able to boost adaptive capacities and resilience.

Once again, bearing the discussions in mind concerning innovation system building, especially in regard to the insights from the socio-technical transitions literature, if developing countries are to realise climate-compatible development then policy interventions will need to be sensitive to the enormous variety of contexts between (and within) those countries. Moreover, as climate change begins to reshape local environments, policy interventions will need to adapt alongside adaptations arising in technologies and innovations that (hopefully) will be forthcoming from their maturing NSIs. To achieve these adaptive policy capabilities at the national level, it may be better for international policy interventions to focus on promoting particular kinds of processes – as outlined in regard to niche theory above – than to be overly concerned with specific instruments that are intended to work in all contexts.

With this in mind, we conclude Section 2 of this report with two case studies. Firstly, we present a summary of empirical analysis on China and the way in which a focus on building innovation systems in order to develop technological capabilities around different climate technologies has been central to China's success. This is then followed by an example of an innovation system building account of the success of the solar PV market in Kenya, which also illustrates the innovation system building processes outlined within niche theory.

2.7 Case Study: China – a national innovation system building master class

The astounding success of China in various climate technologies (e.g. wind and solar) is well known and often cited. China is, however, often dismissed as a special case – a country way ahead of most other developing countries in terms of its levels and rate of economic growth and the technological capabilities it possesses and therefore too different from other countries to draw comparable lessons (although in reality, whilst rapidly increasing, China's current capabilities across many technologies are often more patchy and not quite as advanced as is often assumed – see Breznitz and Murphree 2011, Watson *et al.* 2014). A closer look at the history of how China has developed capabilities across different climate technologies, however, reveals a story that is of significant relevance to other developing countries in considering strategies for galvanising more rapid rates of climate technology development, transfer and diffusion (together with the opportunities for economic growth that this can bring). The story is one of strategic, systemic and largely incremental development of indigenous technological capabilities via a carefully conceived approach to nurturing China's innovation system. As Stua (2013) demonstrates, even in its engagement with international policy mechanisms like the CDM, China has pursued a careful and deliberate strategy of using these mechanisms to bolster domestic efforts to build technological capabilities and strengthen its NSI.

Watson *et al.* (2014) provide an insight into China's climate innovation system building via empirical analysis across three sectors: energy efficiency in the cement industry, electric vehicles and efficient coal-fired power generation. In each of these sectors, similar patterns are observed, yielding four key insights for designing policy that aims to boost climate technology transfer, development and diffusion in other developing-country contexts (Watson et al. 2014, 13):

1. Rather than technological capability building being driven 'downwards' by efforts around more complex, R&D-led interventions, it tended, in the cases examined, to have been driven 'upwards' from technological learning at the simpler, market-oriented level. In cases where policy focused on R&D driven interventions to build capabilities (e.g. in electric and hybrid electric vehicles), there had been less success in the development of Chinese firms' technological capabilities. This supports Bell's (1997, 75) assertion that "… dynamic technological capabilities are cumulatively built 'upwards' from simpler to more complex design, engineering and managerial competences, not 'downwards' from R&D."

2. Where Chinese firms were observed to have made advances, this had mostly been achieved via relationships with foreign firms to facilitate knowledge flows and learning. In several cases this was achieved by relationships with second-tier companies rather than those at the technological frontier. Initial advances typically developed production capabilities in Chinese firms. These led to learning and incremental change, and the later development of more advanced innovation capabilities.

3. Importantly, Chinese domestic policy played a key role in incentivising firms' engagement with climate technologies. A combination of market support, regulations and R&D support was crucial, creating a more systemic approach to climate technology transfer, development and diffusion, and the development of increasingly advanced technological capabilities.

4. The Chinese government took a strategic and systemic approach to leveraging opportunities for funding and capability building via international climate change policy, using the CDM in particular as a means to bolster domestic policy efforts to strengthen China's NSI in relation to the sectors analysed. This innovation system building approach was clearly more effective in building indigenous capabilities in China than an international policy mechanism which supports hardware transfer on a project by project basis.

These insights are significant. They demonstrate how a strategic, policy-driven approach, which focuses at a systemic level, building NSIs via bottom-up and often incremental processes of technological capability building, can lead to much more rapid and sustained processes of climate technology transfer, development and diffusion – with a myriad of accompanying economic benefits. In many ways, the case of China can be seen as a master class in climate innovation system building.

2.8 Case study: Off-grid solar PV in Kenya

There are estimated to be in excess of 300,000 solar home systems (SHSs) in Kenya (Ondraczek 2013), sold through a vibrant private market that is considered one of the most dynamic per capita off-grid solar markets historically (Jacobson 2007). Recent years have also seen the growth of a market for pico-solar products – essentially, solar lanterns that in some products also have provision for charging a mobile phone and powering a radio.

For many years, the rhetoric used to describe the SHS market's evolution has sustained the notion that it has been private sector led, and the rise of the pico-solar market is similarly described but uses bottom-of-the-pyramid (BOP) rhetoric. However, closer inspection of the evolution of these markets reveals that neither has been simply private sector led and that neither success is simply down to an enabling environment. Instead, important innovations have been driven or facilitated by donor involvement throughout the local supply chain, along with detailed understanding of user needs and desires. Moreover, the Kenyan policy environment has at times been hostile to the promotion of solar PV and policy support remains somewhat ambivalent. There is also some evidence that innovation in the Kenyan market is moving beyond the selling of imported technologies towards the development of an innovation system around PV. Several donors are supporting the implementation of a Climate Innovation Centre, and a PV module assembly plant – also involving donor support – began operations in Naivasha in August 2011 (Oirere 2012). Analysis of the evolution of this market reveals that the assembly plant is actually just one example in a decades-long line of incremental innovations, often driven through interventions supported by donors that, taken together, have had the effect of a systemic intervention. Based on Byrne *et al.* (2014b), we will give an account of this history, beginning with the entry of PV into Kenya around the late 1970s.

2.8.1 Early innovation system builders

PV was already in use to some degree in Kenya in the late 1970s and early 1980s, where it was used to power commercial and community applications such as telecommunications facilities and health centres. The first recorded experience with SHSs was in the mid-1980s, where an ex-Peace Corps volunteer, Harold Burris, used PV for his home. Burris had worked in the nascent US solar industry before coming to Kenya. In 1985, he teamed up with another Peace Corps volunteer, Mark Hankins, to install PV lighting in a rural Kenyan school. Following this installation, the headmaster and teachers wanted PV for their homes. From this point, Burris began to market these 'solar home systems' in the area around the school; a relatively rich part of Kenya due to the production of cash crops. Within a few years, Burris and his technicians were busy installing SHSs and the PV suppliers in Nairobi soon entered the market once they began to hear about its growing success.

Later, Hankins, following field research investigating this nascent SHS market for his MSc, began to get involved in solar training when in 1992 he started his own company, Energy Alternatives Africa (EAA), through which he started to win project funding to help experiment with ideas for further developing the market. Over the next decade or so, EAA became an important player in the Kenyan SHS market by implementing dozens of donor-funded projects. These covered a wide range of interventions and research. For example, there were PV system installation projects in community buildings, such as schools and hospitals, alongside training of local technicians; whilst some involved developing and testing various products or balance-of-system components, such as solar lanterns or charge regulators. Some projects were implemented to help build local manufacturing capability for solar batteries.

And some projects tested different financing mechanisms, such as micro-credit through local Savings and Credit Cooperatives. Still others involved conducting detailed surveys of SHSs, their uses (and abuses) and the preferences of SHS buyers.

Over the course of the decades that followed, EAA became an important innovation system builder in the Kenyan SHS niche by working with a wide variety of private and public sector actors in the kinds of projects just noted. By doing so, EAA helped in significant ways to connect actors together, to gather highly detailed information about user demands and preferences, to share information widely, to create codified and tacit knowledge from their projects (where the tacit knowledge was embodied in the project participants who could carry this to their next interventions), and to work on numerous 'socio-technical fronts' – some technical, some financial, and some managerial. While doing so, Hankins wrote extensively about the various experiences, sometimes as a reporting requirement of the donors, and sometimes for his own publication record. The effect was to help build the actor-networks that niche theory identifies as important; create many opportunities for learning in real-world settings, and share this learning widely; build detailed market information, especially in articulating consumer preferences; and help to embed new socio-technical practices, not least through the solar training courses. Furthermore, Hankins, in particular, became an opinion leader in the solar field in Kenya (and beyond), persistently promoting the technology locally and internationally and thereby helped to build some degree of consensus – amongst some groups (senior energy policymakers were unconvinced) – in the Kenyan niche.

2.8.2 The pico-solar market: Lighting Africa

In September 2007, the International Finance Corporation (IFC) launched Lighting Africa with a global call for project proposals aimed at developing new lighting products and delivery models for Africa's large un-electrified rural off-grid lighting market. The hope was that recent advances in performance of key technologies – especially light-emitting diodes (LEDs) – could be harnessed to provide cheaper and better lighting for the BOP. Grants of up to USD 200,000 were available for each successful proposal, and 16 were selected from the more than 400 proposals received, four of them to be implemented in Kenya (LA 2008, 6-7). Since then, Lighting Africa conferences were held in 2010 (Nairobi) and 2012 (Dakar) during which awards were given for a selection of 'outstanding' lighting products on the market.

The Lighting Africa programme also began implementing a wider range of activities soon after its launch in 2007. By the time of its second-year progress report, these included: market research in several countries; product testing and the development of quality assurance methodologies; identification of financing needs throughout the value chain; knowledge-sharing and self-evaluation; and moves to identify policy constraints by researching the policy environments in several countries (LA 2009). For Kenya, by the end of 2008, there were already highly detailed qualitative and quantitative market assessments (IFC 2008a, 2008b). And much more research followed including on products available in Kenya, product testing, and a review of the policy environment and policy actors (see the Lighting Africa website[5] for these reports).

In 2009, Lighting Africa became much more active in Kenya in terms of interventions. With a budget of about USD 6 million, over the next few years – up to the official completion of its

[5] http://www.lightingafrica.org/

pilot phase in mid-2013 – the programme engaged in an aggressive and roaming awareness-raising campaign, quality-assurance labelling of products, setting up a product-quality testing facility, training technicians, capacity-building for business development and for finance institutions, lobbying policy makers on regulations, and building networks of actors to encourage the flow of information. Whilst it is difficult to determine the extent to which outcomes can be attributed directly to these efforts, the programme does make a series of claims (see Table 2.1). And a recent updated survey in three towns in Kenya tends to support the notion that the market for small off-grid lighting products has expanded rapidly in the past four years (Harper, Alstone and Jacobson 2013).

Table 2.1. Lighting Africa claimed impacts and outcomes up to end of December 2012

Quantity	Claimed impact
2	Test methods for off-grid lighting products, used in four laboratories including one in Kenya
2	Eco-design briefing notes focussing on health and safety issues for consumers, distributors and manufacturers
7	Micro-finance institutions providing micro-loans for consumers to purchase quality-assured modern off-grid lighting products
8	Country studies identifying key policy barriers to the adoption of modern lighting products (Kenya is one of the countries covered)
12	Technical briefing notes published, providing manufacturers with information to help them design and improve their lighting products
15	Manufacturers/distributors receiving advisory services from Lighting Africa
30	Manufacturers whose products have passed the minimum quality standards
49	Products passed the minimum quality standard
150+	Lighting products tested
1500+	Village forums in Kenya and Ghana organised to educate rural families about the benefits of solar lighting over kerosene
1,386,000	Off-grid lighting products that passed Lighting Global quality standards sold in Africa

Source: Based on http://www.lightingafrica.org/resources/annual-reports.html (accessed 16 October 2013)

Reflecting on the activities of EAA from 1992 and over the next few decades, we would suggest that the interventions in which it participated (usually funded by donors) had a cumulative systemic effect. That is, EAA operated on numerous 'socio-technical fronts' (or dimensions of the complex of socio-technical practices in the Kenyan PV niche), helping to build capabilities and generate knowledge relevant to incremental innovations and the growth of the market. However, none of the projects in which EAA were involved had large sums of money and so the individual projects tended to be somewhat piecemeal. Contrasted with the later Lighting Africa programme we see that a similarly systemic intervention – but this time backed by quite large sums of money – was able to achieve a huge impact in a short period. Of course, Lighting Africa did not occur in a vacuum. It could build on the long years of work already done in the Kenyan PV niche. Nevertheless, it introduced a completely new set of products into a market in which the customers were generally very poor. This would have been highly risky for any private sector actor to attempt, and possibly explains why none had tried before the Lighting Africa programme started. However, there are now many private firms working in the pico-solar market in Kenya (and elsewhere in Africa). And, it appears as though Lighting Africa became an important innovation system builder around pico-solar products in Kenya.

Building on the insights discussed and illustrated in section 2, we now turn to the implications for the issues that need to be addressed by policy interventions. Then, in section 4, we outline some concrete policy recommendations.

3. Issues policy must address to nurture NSIs

Having outlined the relevance and key building blocks of NSIs, in this section we deal with two key issues that must be considered when designing policy mechanisms geared towards developing and learning across NSIs. We first deal with the need to understand the nature of knowledge, in particular the difference between tacit and codified knowledge and the greater relevance of the former to developing technological capabilities. This includes attention to the contentious (and often over emphasised) issue of Intellectual Property Rights (IPRs). We then deal with the need to understand the multitude of context specificities that are essential to respond to when designing successful policy interventions. This helps to suggest what kinds of generic policies enable attention to be paid to context specificities and, as a result, are more likely to enable sustained and widespread development, transfer and uptake of climate technologies.

3.1 Tacit vs. codified knowledge

As emphasised in Section 1 above, knowledge flows are a core component of technology transfer and are essential to building technological capabilities. A core function of NSIs is therefore to create the enabling conditions for nurturing such flows, between firms and other key actors within a country and with relevant actors internationally. However, understanding the nature of these flows, and the relevance of different types of knowledge flows, is critical to avoiding fixating on particular policy foci which are unlikely to yield significant benefits in terms of building technological capabilities within developing countries. In particular, differentiating between tacit and codified knowledge, and the greater significance of the former to building technological capabilities, is essential.

Codified knowledge, as the name suggests, relates to knowledge that is articulated in some way. This can include IPRs (legal rights over ideas, including copyrights, trademarks and patents), but it also often includes a range of other proprietary knowledge such as trade secrets that have not necessarily been formally or legally protected. The latter overlaps with the second type of knowledge – namely, *tacit knowledge*. Tacit knowledge refers to human-embodied knowledge acquired through experience of doing things, and would extend to more institutionally embodied knowledge where firms and other organisations develop capabilities around, for example, management systems and approaches which are passed on through generations of employees. So, codified knowledge might relate to engineering and manufacturing processes (e.g. for manufacturing advanced wind turbine blades or drought tolerant crops) whereas tacit knowledge would relate to the applied engineering, systems integration or plant breeding and modification *skills* necessary to effectively work with a new engineering, manufacturing or biotech process.

Even when providing a simple definition of tacit and codified knowledge it is very quickly obvious that relevant tacit knowledge is a prerequisite for codified knowledge to have any use or relevance to a firm or industry. Think, for example, of giving a standard, local car mechanic access to the patents for core components of a new design of Formula 1 racing car engine – 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 1 development and manufacturing teams (the latter being tacit and neither codified nor legally protected in any way). It is often these processes of more tacit knowledge-acquisition that more accurately characterise learning by firms and other actors as NSIs increase in levels of sophistication and scale and lead towards processes of innovation and change. Foster and Heeks (2013) characterise these tacit learning processes under three categories: learning by doing (e.g. by engaging in production processes); learning by using (e.g. making adjustments to get new technolgies to fit specific tasks); and learning by interaction as actors interact and work with other actors across innovation systems. None of these categories of learning and capability development rely explicitly on access to codified knowledge; rather, they represent far more fundamental processes of tacit knowledge sharing and deeper learning.

However, the centrality of tacit knowledge, or experience with working with the technology and processes in question (or related technologies), has tended to be overlooked within international discussions around climate technology development and transfer in favour of a fixation on codified knowledge, and IPRs in particular. As a result, IPRs have become a politically contentious issue within negotiations under the UNFCCC. The debate tends to be framed around two opposing perspectives. On the one hand, some (often developing country) parties and observers claim that developing countries must have free access to IPRs for climate technologies. On the other hand, other (often developed country) parties and observers claim that the key barrier to climate technology transfer to developing countries is the weak IPR protection regimes in many developing countries which, they argue, provides a disincentive to international, technology leading companies to deploy new climate technologies in those countries.

In a detailed analysis of the background to these two conflicting perspectives on IPRs in relation to climate technologies, based on a comprehensive review of available empirical evidence (which covered a suite of clean energy and energy efficient end-use technologies based on a range of studies by different organisations), Ockwell *et al.* (2010a) demonstrate three key things. Firstly, the two perspectives can best be understood as having emerged from alternative motivations for developed and developing countries to become party to the UNFCCC. For developed countries, the key driver was a desire to avoid future economic costs of climate change. This had to include climate (particularly low carbon) technology transfer to developing countries to mitigate future emissions from economic development in these countries (simultaneously providing opportunities for offsets against developed countries' own emissions). For developing countries, a core incentive was the promise of access to new technologies – technology ownership being directly correlated with economic wealth and still largely weighted towards the global north. Without understanding these background motivations, it is difficult to move beyond the political impasse concerning IPRs.

The second insight is that there is empirical evidence to support both sides of the IPR debate. On the one hand, in none of the cases analysed did developing country firms lack access to the technologies in question, and none reported IPRs as having constituted a barrier to technology access to date. Anecdotal evidence tended to reinforce the centrality of tacit knowledge (as opposed to IPRs) as the key barrier: e.g. with Indian LED manufacturers at the time reporting tacit experience of white spectrum LED manufacturing processes being the key barrier to them entering this new market (not access to patents). On the other hand, several of the firms reported that were they to attempt to reach the technological frontier in their sectors (e.g. thin film solar PV as opposed to conventional PV panels) then IPRs would become a more significant consideration. The idea that empirical evidence supports both sides of the IPR debate is further supported by more recent analysis by Abdel Latif (2012). Based on a collaborative project by the United Nations Environment Programme (UNEP), the European Patent Office (EPO) and the International Centre for Trade and Sustainable Development (ICTSD), which included detailed analysis of patent databases and an extensive survey of developing and developed country firms involved in clean energy technologies, Abdel Latif (2012) reports that IPR protection was not found to be a significant barrier to technology transfer. Firms interested in licensing to developing countries were seen to be more concerned about other attributes – including favourable markets, the investment climate, human capital and scientific infrastructure – and many firms were willing to offer flexible terms to developing countries with constrained capacities.

This links directly to the final insight from Ockwell *et al.*'s (2010a) analysis, and the key point in the context of understanding the role and importance of a focus on building NSIs. Focussing on building technological capabilities, which necessitates a focus on innovation system building, is the best way to achieve more sustained development and transfer of climate technologies to developing countries. This would deliver against the background motivations of *both* developed *and* developing countries. In other words, it would promote climate technology access and economic development, mitigating future emissions whilst simultaneously underpinning broader, long term, climate-compatible development.

This brings us to the crux of the matter in relation to the focus of this report. Nurturing climate innovation systems in developing countries is the key to achieving more sustained processes of self-defined, context-sensitive climate technology development, transfer and uptake in developing countries. These innovation systems are necessary in order to build the technological capabilities of various actors within the developing country, taking into account the different context-specific and climate technology needs of local firms and communities. Knowledge flows are critical to building these capabilities. However, the qualitative type of knowledge that is relevant and likely to have most impact on host country capabilities will vary according to the wide range of context-specific considerations discussed below.

In some cases knowledge will be codified, and in some cases this codified knowledge will be in the form of IPRs (as opposed, for example, to trade secrets). But IPRs are only a small part of a much bigger picture. Access to IPRs does not ensure developing country access to climate technologies. Access to other knowledge, particularly tacit knowledge, is often a more important barrier. In many cases (and indeed all the case studies considered in this report – e.g. the Kenyan PV sector and the Korean steel industry) tacit knowledge and knowledge acquired through working with technologies, most often under license and protected by patents, has played a far more significant role than access to IPRs *per se*. IPRs are only likely to be prohibitive once developing country firms reach the technological frontier. IPRs should thus be considered as sometimes necessary, but never sufficient, as a focus of policy mechanisms that aim to build NSIs. Instead, policy mechanisms focussed on nurturing innovation systems should be prioritised. Ways in which this might be achieved are explored in detail in Section 4 below.

3.2 Context-specificities in technology needs and appropriate knowledge flows

A final key consideration that policy interventions must negotiate is the importance of focussing on a needs-based approach to policy which properly responds to the context-specificities that define the appropriateness of climate technology options and related knowledge flows in any given situation (Ockwell and Mallett 2012). Hulme (2008, 2009) alludes to the importance of context specificities through his emphasis on how the idea of 'climate change' has been dominated by certain constructions of the issue which ignore the multiple spatially and culturally contingent understandings and meanings of 'climate', and hence (by implication) potentially undermine constructive ways forward for society to both interpret and decide how to respond to a changing climate. This has fundamental implications when considering knowledge transfer between different contexts (between different NSIs and the myriad of actors therein – firms, communities, policy actors, industry associations and so on) insofar as it implies contingencies both in terms of what kind of knowledge and related technology might be appropriate across different contexts, and in terms of the type of policy intervention that will be effective in brokering knowledge transfer and technological capability building. These issues are unpacked below.

The extent to which different types of knowledge and technology are likely to be appropriate depends on a range of context-specificities, such as their applicability within different socio-technical circumstances and their applicability within different physical, cultural and economic contexts. For example, the technological needs of communities with different wealth levels need to be understood – poorer communities, for example, might perhaps have a greater need for technologies related to subsistence needs; wealthier communities might have priorities around transport, or processing goods to add value. Questions need to be asked as to what extent climate technologies facilitated under existing international policy mechanisms are pro-poor (for a useful point of departure, see Urban and Sumner 2009, and Byrne *et al.* 2014b). In poor rural areas, for example, it might be more viable to explore adaptive innovation around low maintenance configurations of solar PV and LED technologies, as opposed to clean options for centralised energy generation which might better suit urban industrial interests. And in adapting to climate change, technologies such as drought-resistant strains of crops, or knowledge regarding new farming methods in increasingly flood-prone areas, might be of more relevance to poor people than advanced engineering solutions for strengthening coastal flood defences.

This interest with the extent to which the needs of poor people are being met through policy interventions around climate technologies speaks to an emerging concern amongst development practitioners and researchers with the idea of "inclusive innovation" (see, for example, IDRC 2011). In essence, this is a concern with the extent to which technology innovation and diffusion serves the needs of poor and marginalised people. As Foster and Heeks (2013) demonstrate, whilst an innovation systems perspective is well suited to better understanding innovation in a pro-poor context, this emphasis on inclusivity and pro-poor innovation and diffusion of technologies requires attention to a number of specific considerations which are underplayed in traditional innovation systems-based approaches to analysing policy and practice. These include a need to attend more to the role of processes of technology diffusion, informal demand-side actors and intermediaries, and the role of localised and informal institutions.

A range of different physical and environmental considerations are also likely to come into play in determining the context-specific considerations that policy and practice must attend to if appropriate knowledge flows and capacity building are to be brokered. For example, different wind technology solutions are viable under different ambient conditions, and in other conditions are not viable at all. Carbon capture and storage (CCS) technologies will need to be adapted to suit both local fuel sources and geological storage options (Tomlinson, Zorlu and Langley 2008). And these physical spatial variations are also likely to play out simultaneously in the form of socio-cultural considerations – for example, energy efficiency or clean, decentralised energy options need to work within the context of existing cultural (behavioural) practices and existing infrastructure; and so on. So a range of different spatial and socio-cultural considerations come into play when considering what types of knowledge flows and technologies are likely to work or be appropriate within different developing country contexts.

There are also critical context-specific considerations regarding the ways in which knowledge flows are likely to be most effectively brokered in order to build technological capabilities within different developing country contexts. As emphasised in Section 2, the needs of rapidly emerging economies are likely to differ significantly from the needs of other developing countries, and particularly least developed countries, in this respect. However, it is important to note that even across such contexts, appropriate levels of knowledge flows are likely to vary according to the specific climate technology in question and the availability of existing (or related) technological capabilities in different country contexts. A distinct need exists to understand and chart the distribution, nature and level (productive through to innovative) of different technological capabilities for working with different climate technologies across and within different country contexts. For example, to what extent do different developing countries, regions, firms, or communities therein, have the capabilities to work with technologies at different stages of commercial development (e.g. dealing with higher investor risk at earlier stages of technology development), or to work with the hardware and software components involved? One example of this would be a technology like CCS which involves more complex systems management capabilities than small scale solar PV (Ockwell *et al.* 2010b).

Importantly, consideration of the existing levels of relevant technological capabilities has material implications for which part of the innovation chain would benefit from targeted interventions. In Kenya, for example, where solar PV assembly has only recently begun, interventions focussed at the demonstration of process manufacturing techniques might be most appropriate. In the wind industry in China, on the other hand, were it not already considered sufficiently advanced, knowledge flows might be more effectively targeted via international collaborative efforts at the early R&D stage (see Ockwell, Sagar and Coninck 2014 for a discussion of collaborative R&D and climate technology transfer). Such nuanced understandings of relative technological capabilities inter- and intra-nationally have a key contribution to make to better orienting international policy efforts in ways that can be effectively targeted towards nurturing innovation systems and developing technological capabilities.

In their discussion of collaborative R&D and climate technology transfer, Ockwell *et al.* (2014) also draw on Sagar's (2009) typology of the different climate technology needs against which collaborative R&D efforts might be targeted via national or multilateral actions under the UNFCCC. This typology broadly classifies climate technologies into three categories: first, those that already exist and might meet developing country needs; second, those that do not yet exist, but which might be developed to meet nascent needs via targeted policy incentives; and, third, technologies that might be needed to meet future needs. The discussion above highlights the important need to extend Ockwell *et al.'*s (2014) analysis in order to further consider the appropriateness of such a framework at different stages along the innovation chain – moving away from a fixation on R&D and recognising the potential value (depending on context) of interventions at other stages of the innovation chain. As the discussion in Section 2 emphasised, authors like Bell (see especially 1997) have elucidated how technological capabilities are often developed incrementally in developing country firms via international knowledge flows that facilitate gradual increases in levels of sophistication. This implies in many countries (and particularly in many least developed countries where levels of capabilities are low in many areas) that international knowledge flows might be much better targeted at climate technologies which are already widely commercially available and building upwards from there (as in the example of Lighting Africa in Section 2 above). The impact in terms of building sustainable innovation systems in the long term is likely to be no less profound. Note that this also speaks to the importance of policy interventions that attend to the existing levels of capabilities within specific country and technology contexts.

To some extent this focus on context-specificities might be interpreted as confounding policy efforts, especially those at the national and multilateral levels that characterise actions under the UNFCCC. Some observers might push instead for the identification of non-context-specific issues so that more generic policy approaches might be developed and applied. Indeed, there has been, and still is, a tendency for international climate policy to focus at this level. For example, the generic failure of markets to capture the positive externalities of lower carbon technologies was a key rationale behind the kind of ‘hardware financing’ approach that has characterised policy in this field to date. Other generic issues might include socio-technical lock-in to existing, high carbon technologies or agricultural technologies that are over reliant on high levels of water or fertilizer inputs. However, notwithstanding country-driven activities through institutions such as the GEF, the tendency to focus on policy options that are not sensitive to context-specificities is, as argued above and below, a key reason why climate technology transfer efforts under the Convention are likely to have met with limited success to date. In fact, a policy focus on nurturing innovation systems is the key way in which these past policy shortcomings can be overcome. Interventions that aim to play an ‘innovation system builder’ role in developing countries provide the basis for designing policy approaches characterised by non-context-specific (generic) processes/interventions. Following the ideas provided by SNM, and discussed in Section 2.5, such processes and interventions include network building, fostering learning, consensus building and experimentation. They are generic change processes but they respond to context-specificities and so can be used to develop and strengthen inclusive innovation systems in particular places. In the final section of this report below we explore some of the concrete ways in which these climate policy interventions can play this nurturing, innovation system builder role.

4. Policy recommendations

Sections 2 and 3 have clearly demonstrated how a policy approach focussed on nurturing innovation systems has the potential to facilitate more widespread and sustained transfer, development and diffusion of climate technologies in developing countries. Such an approach also makes significant contributions to countries' potential for economic growth. In this final section we therefore focus on practical policy recommendations for nurturing NSIs which can be pursued at national and multilateral levels. The core aim is to support interventions which enable actors and institutions to act as *Climate Relevant Innovation-system Builders (CRIBs).* The key is to do so via nationally nested, demand-driven interventions that are internationally networked and based on learning across different contexts in order to build indigenous technological capabilities and well-functioning, context-sensitive innovation systems.

We begin by articulating the overarching goals which the analysis in Sections 2 and 3 implies policy needs to achieve. We then briefly review the existing international climate policy landscape to highlight key policies which an innovation system building approach can (and should) work with and build upon. We conclude with key policy recommendations and options for the institutional architecture through which these could be delivered.

4.1 Overarching policy goals and related policy interventions

The overall goal of policy must be to build functioning innovation systems which augment the transfer, development and diffusion of climate technologies and practices in developing countries, enhancing technological capabilities through a range of targeted interventions. These must be inclusive in their approach – attending to the self-defined needs of those countries and different groups within – if climate technology uptake is to be widespread and underpin future climate-compatible development pathways. Material presented in this report provides some clues as to what such an inclusive approach might be. The various interventions reported here, that have achieved some measure of success, were designed and implemented on the basis of careful and context-specific understanding of the needs in the market and of users. Notable in this regard is Lighting Africa, which conducted highly detailed studies of the lighting practices and needs of poorer users in Kenya (and elsewhere). This suggests that further gains might be achieved by including users more actively in the design of promising solutions to their needs, rather than merely observing these needs and eliciting users' feedback on products already in the market. The overall desired result is to provide protective spaces in which climate-compatible technologies and practices can be fostered; thus promoting their adoption, adaptation and further innovation.

In order to achieve this, we suggest the following overarching policy goals should orient interventions. However, it is important to note that interventions to build innovation systems are deeply interdependent. They are therefore best implemented together in systemic fashion rather than separately. We conclude this sub-section with a table (Table 4.1) which articulates a range of specific policy interventions which should be pursued in order to fulfil each goal. In subsequent subsections we go into detail on how efforts under the Convention and parallel climate technology initiatives could deliver such interventions.

4.1.1 Goal 1: Build networks of diverse stakeholders

Efforts are required to link diverse arrays of stakeholders, from technology importers and suppliers, through to policy makers and technology users. Such networks enable the flow of knowledge amongst stakeholders, each of whom can bring different resources, experiences and perspectives to bear on problem-framing and problem-solving activities. They can also become a fundamental element of innovation systems by establishing the linkage component of capabilities. But these linkages must be strong and meaningful. In order to achieve this, stakeholders need to work proactively together in projects, programmes and other interventions. In doing so, they are more likely to build mutual trust and understanding, as well as identify strengths and weaknesses in local technological capabilities. Simultaneously, by pursuing such activities, new technological capabilities can be built, including the development of relevant knowledge and skills.

4.1.2 Goal 2: Foster and share learning

Learning is critical to the development of technological capabilities and functioning innovation systems, and the resulting successful markets for climate technologies that these can support. A key role for policy lies in commissioning research – whether market research, academic analysis, monitoring and evaluation, baseline studies, R&D and so on – and making sure the results are publicly available. Because contexts evolve in unpredictable ways, incremental innovation supported by reflexive analysis offers a practical strategy to shape climate-compatible development pathways. Research at all levels from local to international, and from different perspectives, can provide crucial information to help realise such reflexive change. The public availability of such information can play a fundamental role in reducing perceived risks amongst both potential investors and technology users, as well as enhance the transparency of policy processes. This facilitates clear and evolving understandings of things like: user needs and preferences, appropriate hardware components, relative performance of different technology brands, approaches that have met with success, factors that contributed to difficulties or failures and how to overcome these, training and education needs, and so on. The learning and experience that results can feed into future projects and programmes, whether publicly or privately funded.

4.1.3 Goal 3: Promote the development of shared visions

Linked to the need to build meaningful networks and foster learning, there is the need to create shared visions of what climate-compatible development looks like in particular contexts, and what roles climate technologies play in those contexts. This is not simply a top-down effort in which climate technology solutions are chosen and then stakeholders are persuaded of their merit through dissemination and awareness-raising activities. As everyone is affected by both climate change and efforts to address it, consensus-building around climate-compatible development is critical. Learning from research and experience provides an essential component for constructive debate and is itself enhanced by the flow of knowledge through diverse stakeholder-networks. By fostering understandings of what climate technologies can and cannot provide, how they work and the ways others have benefited from them, visions can develop around informed understandings of different technological options. It also affords opportunities for users to provide feedback on both their self-defined needs and their experiences (good and bad) with different technologies. As a result, shared visions develop amongst technology users, suppliers and other stakeholders relating to what and how climate technologies can underpin different development pathways. This simultaneously provides vital user-feedback into both technology design and the configurations and brands that vendors and suppliers provide, with attendant implications for potential market size and profitability.

4.1.4 Goal 4: Support diverse experimentation

Again linked to learning, funding is needed to provide protected spaces for experimentation with promising climate technologies, practices and policies. Stakeholders throughout the supply chain need to gain experience of climate technologies and learn what works and what does not within specific contexts (across different countries, regions, villages, technologies, etc.). Experimentation can target a range of different aspects. It might, for example, include supporting new multi-stakeholder projects that test and develop ideas. These could relate to new technical configurations, new hardware, new practices around existing technologies, new consumption and production practices that could improve the benefits accrued by users, and so on. Experiments might also focus on mutually supportive interventions that link different stakeholders across markets, thereby building supply chains and fostering new market opportunities where potential market players lack awareness of each other and/or potential market opportunities they might target. Interventions could also experiment with working 'upwards' through value chains, building on existing markets to develop progressively higher-value segments, adding value to existing sectors and fostering increasing economic returns from climate technology initiatives across developing countries.

4.1.5 Specific policies and interventions for delivering against these overarching goals

Table 4.1 below details a (non-exhaustive) list of specific policies and interventions which would deliver against these overarching goals and contribute to climate innovation system building.

Table 4.1. Specific policies for delivering against the overarching goals for developing climate innovation systems in developing countries

Goal 1. Network building
Linking diverse stakeholders nationally
" " " internationally
" " " locally
" " " across markets
" " " across sectors (private/public/NGO/research etc.)
Linking 'supply-side' actors (e.g. supply chain, policy, NGO, etc., actors) with technology users
Linking national government with technical experts
Linking national firms with international firms
Goal 2. Learning
Commission market research
Commission research into technology user needs and preferences
" " " technology performance
" " " education and training needs
Monitoring and evaluation of projects/programmes
Conduct baseline studies
Conduct comparative research across local/national/international scales that addresses the various research foci above
Make results of research and monitoring and evaluation publicly available
Create spaces for stakeholders to reflect on research and experiences
Provide training for firms
Provide training for suppliers and installers
Provide training for technology users/villages/households
Advise/develop technology certification schemes
Advise on education and training needs (up to and including postgraduate training)
Goal 3. Foster shared visions
Convene consensus-building events with different national stakeholder groups
Convene scenario-building events to discuss alternative development pathways that different climate technologies might contribute to/constrain
Facilitate opportunities for different stakeholders to feedback into the technology design and configuration process
Goal 4. Provide protected spaces for experimentation
Encourage/incentivise treatment of "failures" as valuable points for learning
Commission projects as experiments (examples of potential foci for experimentation are provided below)
Experiment with technological hardware
" " policies
" " social practices in relation to climate technologies
" " new stakeholder configurations
" " production processes
" " linking stakeholders across markets to create new market opportunities and market awareness
" " value adding experiments working upwards through supply chains

4.2 Existing international policy mechanisms

Whilst working towards the overarching goals above, it is essential that policies designed to nurture NSIs are implemented in a way that recognizes and builds on existing relevant policy mechanisms and institutions. Designing effective policy also requires an understanding of what these existing initiatives are doing that is of relevance to nurturing NSIs and where there are gaps which need to be filled. Here we review three core areas of relevant policy efforts: the CTCN; the World Bank's Climate Innovation Centres (CICs); and four parallel climate technology centre and network initiatives currently being funded by the GEF.

It should be noted that a range of other institutions (e.g. IRENA – the International Renewable Energy Agency), policies, mechanisms (e.g. the CDM) and centre-based models (e.g. Innovación Chile, CGIAR – the Collaborative Group for International Agricultural Research) also exist and deserve explicit consideration when implementing the recommendations within this report. It is, however, beyond the scope and space available here to provide a full review of all relevant initiatives. Some points of reference which do provide a level of review and analysis of other initiatives include Sagar (2010) and (Ockwell et al. 2014).

4.2.1 Climate Technology Centre and Network (CTCN)

In the context of actions under the Convention, one of the most relevant institutions is the CTCN[6], the operational arm of the UNFCCC's Technology Mechanism under the strategic guidance of its own advisory board (see Figure 4.1). As its name suggests, the CTCN is structured around a core climate technology centre that coordinates a broader network. The *Centre* is hosted and managed by UNEP in collaboration with the United Nations Industrial Development Organisation (UNIDO) and support from 11 centres of excellence located in developing and developed countries.

[6] See http://www.unep.org/climatechange/ctcn/Home/tabid/131937/Default.aspx

Figure 4.1. CTCN Structure and relationship to UNFCCC

Source: http://www.unep.org/climatechange/ctcn/AboutUs/tabid/155769/Default.aspx

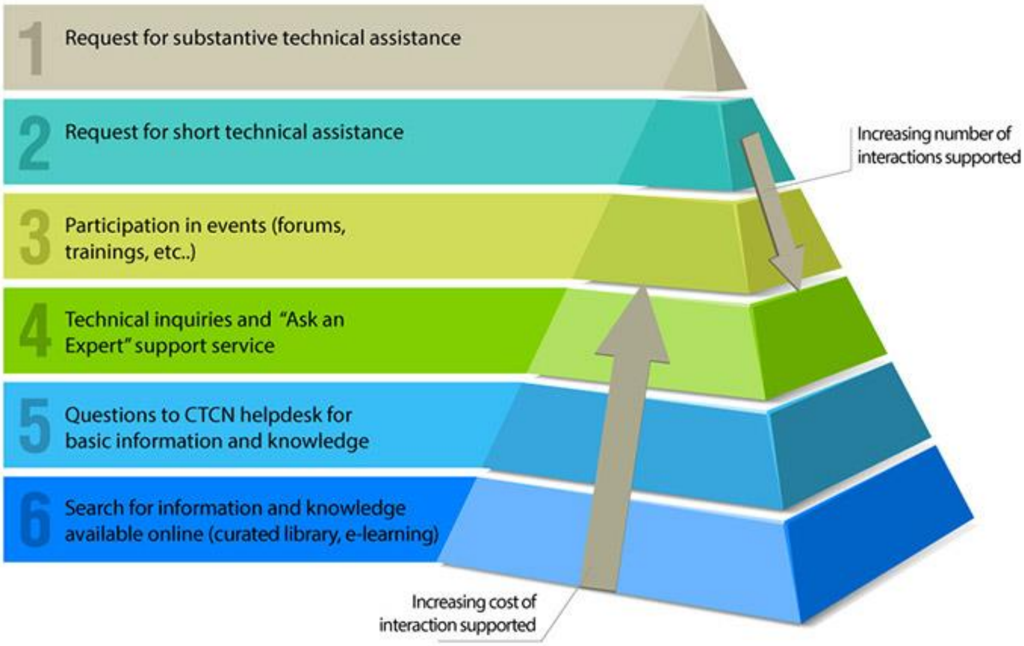
The CTCN's *Network* refers to a range of technical experts and centres of excellence that have expertise that might be matched against requests for technical assistance from countries. Requests from countries come from national designated entities (NDEs). NDEs (usually government ministries or agencies[7]) are granted responsibility by Parties to the Convention to manage national technology related requests to the CTCN. These requests are coordinated by the Centre, which responds itself to some while others are farmed out to relevant experts in the Network. This NDE instigated approach attempts to facilitate a process that is demand-driven by Parties. There are three core services offered by the CTCN (see CTCN 2014 for a detailed description of these services):

1. Provide technical assistance to developing countries to enhance transfer of climate technologies
2. Provide and share information and knowledge on climate technologies
3. Foster collaboration and networking of various stakeholders on climate technologies

The first core service follows requests from NDEs whilst the other two services can be initiated by the CTCN or other stakeholders, as and when common needs are identified. Figure 4.2 illustrates how these services are interrelated.

[7] For a full list, see http://unfccc.int/ttclear/templates/render_cms_page?s=TEM_ndes

Figure 4.2. Hierarchy of CTCN services



Source: CTCN website available at: http://www.unep.org/climatechange/ctcn/Services/Introduction/tabid/771787/language/en-US/Default.aspx (accessed 19/08/14)

From the perspective of building NSIs, there are several key points to note with regard to the CTCN:

1. The Network is not an in-country network of actors of relevance to different (existing or emerging) climate technologies as prescribed in the overarching goals in Section 4.1.
2. There is nothing, in theory, stopping Parties requesting, via NDEs, support from the CTCN in advising on and instigating the kind of climate innovation system building policies detailed in Table 4.1.
3. NDEs are usually government institutions – not locally nested, climate technology specific institutions.
4. At present the CTCN's activities do not explicitly recognize the need to nurture NSIs as a key part of the technology transfer, development and diffusion process – although elements of innovation system building are implicit within two of the CTCN's core services: those focussed on information and knowledge sharing and fostering collaboration and networking between stakeholders.
5. The recognition of knowledge sharing, networking and the emphasis on capacity building elaborated in the operating manual for NDEs suggests significant potential for the CTCN to coordinate its efforts to achieve a more explicit focus on innovation system building. However, this would require more explicit attention to, and understanding of, NSIs and processes for strengthening them to be integrated into the CTCN's approach. In Section 4.3 we provide details of two concrete proposals for achieving these NSI-building and strengthening processes in the CTCN's activities.

4.2.2 Climate Innovation Centres (CICs)

Beyond the CTCN, there are other initiatives and organizational actions that need consideration, with which efforts targeted towards nurturing NSIs for climate technologies need to coordinate. The World Bank (via infoDev), in collaboration with DFID and Danida, are in the process of implementing a number of Climate Innovation Centres (CICs)[8]. CICs have been launched (or have business plans and are in the process of being launched), in seven locations: Kenya, India, Ethiopia, South Africa, Morocco, Vietnam and the Caribbean. The CICs' focus is very much on financing local entrepreneurship around climate technologies via "… a tailored suite of financing and services that support domestic SMEs [Small and Medium-sized Enterprises]"[9]. As such, and given their networked, international reach, the CICs represent an important initiative to engage with in any attempt to foster NSIs. However, their explicit finance/innovation/entrepreneurship focus limits them to only one small (but nevertheless important) part of any more systemic approach to nurturing NSIs. This is not to say, however, that climate innovation system building could not be integrated as part of the CICs' broader activities under an extended remit. This may be something that infoDev/DFID/Danida and/or national governments and local partners in the CICs might wish to consider in future. CICs are, after all, likely to represent important networks of climate technology relevant individuals and organizations across the public, private and NGO sectors and provide excellent potential routes for identifying and engaging with key actors.

4.2.3 GEF funded initiatives

The other key initiatives of note here are those being implemented by the GEF under its Long-Term Program on Technology Transfer. These include[10]:

1. The project "Pilot Asia-Pacific Climate Technology Network and Finance Center", which is being implemented with the Asian Development Bank (ADB) and UNEP.
2. The project "Finance and Technology Transfer Centre for Climate Change" by the European Bank for Reconstruction and Development (EBRD).
3. The project "Pilot African Climate Technology Finance Center and Network" by the African Development Bank (AfDB) (which includes regional partners that are part of the CTCN consortium).
4. The regional project "Climate Technology Transfer Mechanisms and Networks in Latin America and the Caribbean (LAC)" by the Inter-American Development Bank (IADB) which is currently in preparation, again with regional partners that are part of the CTCN consortium.

As with the CICs, the emphasis of the second of these various initiatives (the EBRD one) is mostly focussed on finance. However, the other three all have elements which pertain to a more networked, capacity building focus and hence have potential to act as innovation system builders via a more explicit system building focus. For example, the ADB led Asia-Pacific

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[8] See http://www.infodev.org/articles/cicbusinessplans

[9] http://www.infodev.org/articles/climate-technology-read-more-about

[10] See http://unfccc.int/resource/docs/2013/sbi/eng/05.pdf and http://unfccc.int/resource/docs/2014/sbi/eng/inf03.pdf (Appendix 1)

initiative (number 1 above) includes aims of[11]: facilitating a network of national and regional technology centres, organizations, and initiatives; building and strengthening national and regional climate technology centres and centres of excellence; designing, developing, and implementing country-driven climate technology transfer policies, programs, demonstration projects, and scale-up strategies. These activities are pursued in parallel to another part of the initiative which focusses explicitly on finance.

Whilst detailed information is difficult to obtain on number 3 (the AfDB led African initiative), it seems that, as well as a core finance component, more network and capacity building activities will be included, with publicity materials released by AfDB suggesting that "enhancing networking and knowledge dissemination" is seen as the key way the project will "scale-up deployment of [climate technologies]"[12]. The final, IABD, one (number 4) is not yet operational. However, it is very much focussed on network and capacity building. As well as providing finance, it seeks to "… strengthen existing activities on [environmentally sound technologies] in LAC and aim at the consolidation of long-term collaborative initiatives that are aligned with the objectives and modalities of the Technology Mechanism under UNFCCC"[13]. Planning, assessments and networks are at the foreground of the activities proposed under this initiative.

As with the CTCN, however, the extent to which these GEF-funded initiatives support the development of NSIs strongly depends on the extent to which an explicit focus on innovation system building can be mainstreamed across the various activities. The language used is certainly open to a systemic focus, but achieving real differences to NSIs will depend on more deliberate integration of climate innovation system building activities across the board.

4.2.4 Gap analysis of existing policy

In order to get an overview of the extent to which the initiatives reviewed above are delivering the kind of policy interventions that would be likely to achieve climate innovation system building, delivering against the overarching goals articulated in Section 4.1 above (via activities akin to those detailed in Table 4.1 above), the following table (Table 4.2) provides a colour coded, graphical overview of the current and potential coverage of each initiative. Table 4.2 also provides a useful overview of the aggregate pattern of coverage across the initiatives. Each initiative is assessed, based on available public documentation, on the extent to which it: a) explicitly includes activities akin to the policy options under each goal within its existing remit and structure (the green Ys for "yes" in the table); b) has potential to deliver against a policy option within (or with incremental adjustments to) its existing remit and institutional structure were this to be considered desirable (the yellow Ps for "possible" in the table); and c) whether delivering against a goal is outside the scope of the initiative without significant revisions to remit and institutional structure (the red Ns for "no").

[11] http://www.adb.org/sites/default/files/pub/2012/pilot-asia-pacific-climate-technology-flyer.pdf

[12] http://www.afdb.org/en/news-and-events/article/afdb-creates-african-pilot-climate-technology-and-finance-centre-with-gef-support-13344/

[13] http://www.iadb.org/en/projects/project-description-title,1303.html?id=RG-T2384

Several key observations can be made from Table 4.2:

1. Most initiatives have potential within, or via incremental adjustments to, their existing remit and structure to extend their activities to include explicit climate innovation system building activities.
2. At present, however, there is very limited explicit focus on activities which would nurture climate innovation systems in developing countries.
3. The most coverage exists in the area of network building. However, even this coverage is patchy, with most initiatives focussing on high-level national or, more commonly, international networking activities, or linking national entities with international technical experts. Many of the essential networking activities that are necessary to build innovation systems in ways that will result in sustained, climate compatible technological change are generally not addressed (e.g. linking with technology users or fostering local networks along supply chains).
4. Learning receives a small amount of very patchy coverage across the initiatives.
5. Fostering shared visions and providing protective spaces for experimentation are not covered at all at present.

Table 4.2. Gap analysis of international policy mechanisms against climate innovation system building goals

Notes: This table illustrates the extent to which policy options that might deliver against the overarching climate innovation system building goals articulated in Section 4.1 above are: a) explicitly addressed under the existing remit and structure of the various international initiatives discussed in Section 4.2 (the green Ys for "yes" in the table); b) could potentially be addressed within, or with incremental adjustments to, their existing remit and institutional structure were this to be considered desirable (the yellow Ps for "possible" in the table); and c) the option is outside of the scope of an initiative without significant revisions to remit and institutional structure (the red Ns for "no"). The initial row also indicates whether innovation system building is an explicit goal of each initiative.

Key:

CTCN = Climate Technology Centre and Network

CIC = Climate Innovation Centre (World Bank/DFID/Danida initiative)

ADB = Pilot Asia-Pacific Climate Technology Network and Finance Center – Asian Development Bank (ADB) and UNEP

EBRD = Finance and Technology Transfer Centre for Climate Change – European Bank for Reconstruction and Development (EBRD)

AfDB = Pilot African Climate Technology Finance Center and Network – African Development Bank (AfDB)

IADB = Climate Technology Transfer Mechanisms and Networks in Latin America and the Caribbean (LAC) – Inter-American Development Bank (IADB)

Y	= Yes – Explicit aim of initiative
P	= Possible – Potential to deliver within, or with incremental changes to, existing remit and institutional structure
N	= No – Outside scope of initiative (without significant revisions to remit and institutional structure)

Climate innovation system building goals	**CTCN**	**CIC**	**ADB**	**EBRD**	**AfDB**	**IADB**
Explicit focus on climate innovation system building?	N	N	N	N	N	N
1. Network building						
Linking diverse stakeholders nationally	P	Y	Y	N	P	Y
" " " internationally	Y	Y	Y	N	Y	Y
" " " locally	P	P	P	N	P	P
" " " across markets	P	P	Y	N	P	P
" " " across sectors (private/public/NGO/research etc.)	Y	P	Y	N	Y	P
Linking 'supply-side' actors (e.g. supply chain, policy, NGO, etc., actors) with technology users	P	P	P	N	P	P
Linking national government with technical experts	Y	P	Y	Y	Y	Y
Linking national firms with international firms	Y	P	Y	N	Y	P
2. Learning						
Commission market research	P	N	P	N	P	P
Commission research into technology user needs and preferences	P	N	P	N	P	P
Commission research into technology performance	P	N	P	N	P	Y
Commission research into education and training needs	P	N	P	N	P	P
Monitoring and evaluation of projects/programmes	P	N	Y	N	P	P
Conduct baseline studies	P	N	P	Y	P	P
Conduct comparative research across local/national/international scales that addresses the various research foci above	P	N	P	N	P	P
Make results of research and monitoring and evaluation publicly available	P	N	P	P	P	P
Create spaces for stakeholders to reflect on research and experiences	P	N	P	N	P	Y
Provide training for firms	P	N	P	P	P	P
Provide training for suppliers and installers	P	N	P	P	P	P

Climate innovation system building goals	**CTCN**	**CIC**	**ADB**	**EBRD**	**AfDB**	**IADB**
Provide training for technology users/villages/households	P	N	P	N	P	P
Advise/develop technology certification schemes	P	N	Y	P	P	Y
Advise on education and training needs (up to and including postgraduate training)	P	N	P	P	P	P
3. Foster shared visions						
Convene consensus building events with different national stakeholder groups	P	N	P	N	P	P
Convene scenario building events to discuss alternative development pathways that different climate technologies might contribute to/constrain	P	N	P	N	P	P
Facilitate opportunities for different stakeholders to feedback into the technology design and configuration process	P	N	P	N	P	P
4. Provide protected spaces for experimentation						
Encourage/incentivise treatment of ‘failures’ as valuable points for learning	P	N	P	P	P	P
Commission projects as experiments (examples of potential foci for experimentation are provided below)	P	N	P	P	P	P
Experiment with technological hardware	P	N	P	P	P	P
Experiment with policies	P	N	P	N	P	P
Experiment with social practices in relation to climate technologies	P	N	P	N	P	P
Experiment with new stakeholder configurations	P	N	P	N	P	P
Experiment with production processes	P	N	P	P	P	P
Experiment with linking stakeholders across markets to create new market opportunities and market awareness	P	N	P	P	P	P
Experiment with value adding experiments working upwards through supply chains	P	N	P	P	P	P

4.3 Climate Relevant Innovation-system Building under the UNFCCC

Table 4.1 lists a host of activities that policy can support to nurture climate innovation system building. In this final section we deal with how this could best be facilitated under the UNFCCC. The section is divided into two parts which pertain to two linked options for achieving climate innovation system building under the UNFCCC. Ideally both options would be implemented. The first option is more ambitious and needs to be demand-led by Parties. The second option, however, can be implemented directly by the CTCN/TEC and integrated into the CTCN's explicit remit and guide future activities that respond to demand from NDEs. This second option can also be integrated into the practices of other multilateral initiatives, including the GEF funded initiatives discussed in Section 4.2 above. There is also no reason why the CICs could not extend their remit in order to engage in these broader, climate innovation system building activities (their emerging networks of actors within the countries they are operating in certainly make them well placed to do so).

In summary, the two proposals below involve the following:

1. **Proposal 1:** Strengthen the capacity of NDEs by funding and supporting the establishment of national level Climate Relevant Innovation-system Builders (CRIBs). CRIBs would play a strategic, facilitating role, linking up relevant national actors, targeting and coordinating project and programme level interventions to maximize benefits to NSIs. CRIBs (through NDEs) would coordinate with the CTCN to communicate national priorities (with due knowledge of national policy priorities and local realities). The CTCN (as per its existing remit) would then act to network CRIBs internationally, facilitating knowledge flows and access to international technological capabilities based on a more detailed understanding of national/local capabilities and needs.
2. **Proposal 2:** Use climate technology projects and programmes explicitly to build climate innovation systems. If pursued jointly with Proposal 1, this role can be facilitated by CRIBs, in coordination with the CTCN. If pursued in isolation, this can be achieved by revising the remit and approach of the CTCN to integrate a climate innovation system building approach into projects, programmes and related interventions, and to provide advice, via NDEs, on how Parties can bolster their own NSIs.

The proposals are presented in more detail below. It is important to emphasise that the success (practically and politically) of these proposals relies on them remaining very much country-driven and demand-led. The intention is to devolve as much agency as possible to individual countries, whilst providing international support in the form of funding and expertise. This conforms both to the spirit of the Convention and to specific commitments to supporting climate technology transfer, development and diffusion.

4.3.1 <u>Proposal 1: Strengthening capacities of NDEs via establishment of Climate Relevant Innovation-system Builders (CRIBs) within individual countries</u>

- It is clear from empirical research that effective innovation systems emerge around specific climate technologies via targeted, long term efforts by specific actors or 'champions' (acting as innovation system builders).
- Where this has been driven via strategic interventions (e.g. CGIAR, Innovación Chile, the Carbon Trust) it has required nationally situated, long term institutional presences that pursue approaches that engage with, and are sensitive to, the needs and contexts of the people and organisations they engage with.

- In the context of the Convention this can be achieved by strengthening the capacities of NDEs by supporting the establishment of dedicated Climate Relevant Innovation-system Builders (CRIBs).
- CRIBs would play a strategic facilitating role within countries, acting as the focal/convening point for a national network of actors across the spectrum of those involved in innovation systems (from users, through supply chains, to NGOs and policy makers) and championing the development of climate innovation systems around different technologies. Their core remit would be to link together national actors around a strategic, long term, nationally defined vision (cognisant of national policy goals and local realities). They would develop detailed knowledge of national capabilities, key areas where opportunities exist for rapid development and growth, and identify areas where international expertise and knowledge sharing is required.
- In this way, CRIBs would support NDEs in liaising with the CTCN to facilitate targeted, nationally driven access to international expertise.
- CRIBs would have a remit that focused explicitly on sustainable development via enhanced activities around climate technologies (at both commercial and household levels, thus delivering against both human development and economic growth agendas).
- CRIBs would provide strategic oversight, advising on how to target climate technology programmes and projects in a coordinated way that responds to identified priority areas for both rapid growth and long term capacity building.
- CRIBs would also lead on the implementation of Proposal 2 below, ensuring that all climate technology projects and programmes nationally are explicitly designed to contribute to building the country's climate innovation system.
- CRIBs could be based within government departments, or within existing centres of expertise within countries, or established as independent entities linked to NDEs. From the perspective of building and sustaining capacities in the long run, the latter two approaches would be preferable.
- The creation of CRIBs will assist in overcoming an important concern regarding the potential for the CTCN's network to become too large and unwieldy. CRIBs would significantly bolster the capacities of NDEs, ensuring that the demand-led vision of the CTCN is meaningfully realised and that technical assistance sought via the CTCN is targeted at nationally defined priorities based on in-depth knowledge of national capabilities and needs (something which is realistically beyond the capacity of NDEs, which, at present, generally consist of a small percentage of a civil servant's time).
- Funding is envisaged via a portfolio of sources, including the Green Climate Fund (which might fund core centre costs), the GEF, national governments, donors, NGOs, other multilateral organisations, and the range of other international actors with an interest in funding sustainable development and climate change mitigation/adaptation oriented projects and programmes.
- As with the CTCN, careful attention is needed up front to ensure that activities conform to the funding criteria of the GEF, the Green Climate Fund and other potential funders (e.g. donors and the development banks). This may require specific tailoring and packaging of different initiatives accordingly.
- The key added value of such funding being channelled through, or at least engaging with, CRIBs is the opportunity to increase coordination and ensure every dollar spent leverages further benefits in building climate relevant aspects of NSIs via a grounded understanding of the context-specific needs of individual countries and technologies.
- This would provide the most powerful and effective means of mainstreaming climate innovation system building activities within individual countries, with a myriad of

benefits in terms of driving sustainable, long term, climate technology development, transfer and diffusion.

4.3.2 <u>Proposal 2: Extending the remit of the CTCN to ensure climate technology projects and programmes contribute to 'innovation system building'</u>

- Ideally Proposal 2 would be pursued in tandem with Proposal 1, with CRIBs, in their supporting role to NDEs, leading the national implementation of Proposal 2 in liaison with the CTCN.
- Should Proposal 1 above be considered too ambitious or meet with resistance, Proposal 2 can still be implemented via an extension to the CTCN's remit and explicit recognition of climate innovation system building as a core aim of the CTCN.
- In reality it is likely some Parties will pursue Proposal 1 whilst others will not. Proposal 2 is therefore designed to work effectively within such a context.
- Proposal 2 essentially involves mainstreaming climate innovation system building across all climate technology projects and programmes, ensuring every opportunity is taken to use projects and programmes to achieve climate innovation system building impacts. More detail on the specifics of how projects and programmes can be used as opportunities for climate innovation system building, in line with the overarching goals outlined in Section 4.1, is provided in Section 4.4 below.
- A monitoring and evaluation system would be developed (either at a national level by CRIBs, or at an international level by the CTCN, with potential to advise NDEs on its national application) to enable any projects or programmes to be assessed on the basis of their potential to contribute to climate innovation system building within (and beyond) the country in question. Recommendations would then be made as to how the climate innovation system building potential of projects and programmes might be increased, to the long term benefit of sustainable development goals within each country.
- A broader monitoring and evaluation system should also be implemented by the CTCN to ensure the ongoing assessment and development of how climate innovation system building is progressing across different countries and regions and make recommendations on priority areas for further work.
- This will likely require some additional resources to enable the CTCN to integrate climate innovation system building analyses into its approach and to secure any additional expertise that might be appropriate to ensure an understanding of climate innovation system building is represented within its core staff and network of experts.
- This expertise should also be explicitly made available, via the CTCN's network, to NDEs (and CRIBs if implemented) in support of any relevant climate technology activities in-country.
- A similar approach to mainstreaming climate innovation system building across projects and programmes could also be integrated in a similar way under the existing parallel initiatives funded under the GEF (see Section 4.2).

4.4 *Realising Proposal 2: How to mainstream climate innovation system building across projects and programmes*

Whilst it is possible to pursue explicit climate innovation system building activities of the nature detailed in Tables 4.1 and 4.2 above, it is also possible to use any climate technology project or programme as a powerful climate innovation system building tool. This requires mainstreaming a focus on building innovation systems across all projects and programmes and designing and implementing them as real-world experiments so as to better foster learning, capability and system building.

From the evidence and analysis presented in this report, it is clear that there is a role for donors (and other funders, including inter-governmental organisations and NGOs) in such projects to provide adequate protection against the full force of market selection pressures. It is under these conditions that stakeholders can experiment to generate the learning needed for the sustained development, transfer and diffusion of climate technologies and practices, and nurture the development of climate innovation systems.

But there are other aspects to the design of projects and programmes that appear to be important. First, we should be clear about what a project or programme is meant to achieve: is it the demonstration of a ready-made solution for others to imitate or is it experimentation to contribute understanding of what solutions could work? Second, the motivation of project participants needs to be considered as does, third, the scope of projects. And, finally, the way in which projects relate to each other can have powerful impacts, which also generates implications for the role of institutions at national and international levels. Each of the aspects related to projects, donors and other public funding bodies, as well as national and international institutions, is elaborated below. Included in these elaborations are non-exhaustive suggestions of how each aspect of projects might relate to the four goals recommended above: (1) build networks of diverse stakeholders; (2) foster and share learning; (3) promote the development of shared visions; (4) support diverse experimentation.

4.4.1 <u>Projects as experiments</u>

Projects and programmes should be seen and used as experiments that are implemented in order primarily to learn rather than aiming solely to achieve or demonstrate particular solutions. In other words, they could be recast as experiments to make this learning function clearer, in a similar sense to the way R&D activities are often characterised. As such, the measures of success of a project (or programme, experiment) need to be considered carefully. For example, quantitative indicators can be useful but they can become the sole focus of evaluation. A range of qualitative 'indicators' could help to identify more subtle but important impacts, such as the kinds of knowledge created from experimentation or the nature of relationships fostered in network-building. This could also help to reduce the tendency to assess projects and programmes in 'failure' versus 'success' terms, thereby encouraging the sharing of outcomes. In essence, this is about the need to redefine success as the generation of important lessons rather than ready-made solutions.

In terms of the four goals recommended above, this aspect of projects most clearly relates to supporting diverse experimentation (goal 4). But the purpose of experimentation, as has been argued, is to create opportunities for learning and so there is a direct link to the goal of fostering and sharing learning (goal 2). That is, the experiments themselves are the spaces in which learning is fostered. However, learning is only useful to broader innovation system building if it is shared. These lessons will, of course, be immediately available to project participants who, by working together, will form a network (at least for the duration of the project) and thereby contribute to network-building (goal 1). But, for wider and longer-term network and innovation system building, lessons need to be shared publicly. This will not only help to build networks of diverse stakeholders (by providing lessons of potential interest to actors external to projects themselves) but can also promote the development of shared visions by grounding possible visions in real-word experience (goal 3).

4.4.2 Motivation of project participants

In order for projects and programmes to generate useful learning, the participants must be motivated to solve real problems. That is, the problems the project or experiment explores need to be relevant to those involved and so should be defined by them. The motivation will be further enhanced if the participants have material interests in the outcomes; if the learning will have value for them. There is a clear link here with the issue of risk. Whilst mitigating risk is important, particularly for private sector actors, the elimination of risk could be de-motivating. So, participants should be expected to invest some material resources in experiments, partly to demonstrate to others their commitment but also to ensure that they have a stake in the outcomes.

This aspect of projects highlights the need for them to be attractive to potential participants and so, considering the goal of building diverse stakeholder networks (goal 1), reinforces the point above that problems should be defined by potential participants. Moreover, this self-definition of problems will raise the chances that projects will be both relevant to diverse stakeholders and create opportunities for learning from a diversity of individual perspectives and particular contexts. Clearly, there are links to fostering and sharing learning (goal 2). But responding to participant motivations for project involvement is also more likely to mean deeper commitment to projects and efforts to develop shared visions (goal 3). And, if attempts to attract a wide variety of participants are successful then there will be more opportunities to conduct a diversity of experiments, thereby linking with goal 4.

4.4.3 The scope of projects

It is clear that learning is facilitated by deep interactions amongst a broad range of actors who can bring their problem-solving efforts to bear on the many dimensions of development pathways as they unfold in different contexts. This suggests that there needs to be experimentation on many of these dimensions simultaneously. However, it would be extremely difficult for a small number of actors to achieve this. To overcome this difficulty, either complex projects involving a wide range of stakeholders could be implemented or many simpler projects could be implemented programmatically, each one operating on a selection of the dimensions of a development pathway. Each approach will have its advantages and disadvantages. The point is to generate learning across the multiple dimensions of a pathway so that climate technologies and practices can emerge in a co-evolutionary process. The assumption here is that co-evolutionary learning will tend to produce mutually reinforcing technologies and practices that operate in sympathy with their context, thereby increasing the chances of widespread adoption of those technologies and practices, and their sustainability.

Another important point here relates to continuity of efforts. Here, programmes may have the potential to deliver innovation system building in ways that individual projects may not. Funders often want to see results within a few years. Although funders should monitor progress and stop activities when they are clearly not functioning, really making headway on an innovation system might take much more than a project period – although the potential contribution of individual projects should not be underestimated. Nevertheless, unless within a programmatic context with a timespan of say ten to fifteen years, or within the context of a more coordinated national approach to commissioning projects (as would be achieved via the creation of the CRIBs advocated in Proposal 1 above), projects run the risk of being one-off efforts with very limited structural contributions. A related point is a trusting relationship between different actors. In societies where contracts do not play a huge role, but relations make the difference, having the same person run the same programme (or CRIB) for longer can be a key success factor.

In terms of the recommended goals, projects (or programmes) with a wide scope – as indicated by the range of development dimensions along which a project or programme is operating – are more likely to result in a diversity of learning opportunities and lessons generated. Most clearly, this links with the goal of fostering and sharing learning (goal 2). And, of course, this links clearly with the recommendation to support diverse experimentation (goal 4). But projects with wide scope are also likely to need to engage with a wide range of actors and so they increase the opportunities to build networks of diverse stakeholders (goal 1). If there is support for projects and programmes over the longer term – as per the point above about continuity of efforts – then there is also more chance that such networks will develop strong relationships (also contributing to goal 1). The combination of learning from diverse experimentation and the continuity of network building should also help actors to develop shared – and grounded – visions (goal 3).

4.4.4 Interactions with other projects

Following on from the previous recommendation, even complex projects or programmes of projects could be constrained in their learning, particularly if the funding is from a narrow range of sources. Moreover, if they are under the same management they will be dependent on the particular abilities of that management. As the case studies explored in this report demonstrate, projects or programmes implemented from *different* perspectives, if encouraged to interact meaningfully over the long term, can generate learning that helps to achieve dramatic results. This requires some degree of coordination, of course, but not necessarily management. That is, the individual projects and programmes need to be able to communicate directly with each other as well as via a central actor. It is here that value could be added via the involvement of, and coordination through, the CTCN – this value added would be significantly enhanced via the creation of CRIBs as per Proposal 1 above.

Encouraging interaction across projects clearly links with the recommendation to foster and share learning (goal 2) but there are also links to the other goals. Interactions will help to further build networks of diverse stakeholders (goal 1) by creating opportunities for various stakeholders to meet and share their knowledge. But interactions of this kind can also create spaces in which stakeholders discuss, debate and develop shared visions (goal 3). And, awareness and understanding of other projects means the possibility to ensure that any new projects or programmes do not replicate unnecessarily experiments already conducted, thereby contributing to the goal of supporting diverse experimentation (goal 4).

4.4.5 Role of donors and other public funding

Many private sector actors, particularly small players in developing countries, cannot risk much of their capital to undertake experiments. However, there might be significant benefits if they were able to do this, for themselves and for wider society. Therefore, a substantial share of the risk inherent in experimentation could be borne by donors, who can justify their financial support in terms of these potential social benefits. Other sources of public funding, including via the Green Climate Fund and the regional development banks, could serve a similar purpose – although it is important to ensure that funding sources are also accessible to smaller actors who might not have the capacities to engage with large, multilateral funding streams (suggesting a role for donors and NGOs in bridging or plugging this gap). The involvement of public funding also has the additional significant benefit of making learning from projects publicly available, thus contributing to wider learning and long term capacity building.

Another aspect of the risk issue is the stability and long term provision of support, as noted above in regard to the continuity of efforts. If the support is unstable, intermittent or short term then it is more likely to increase risk than mitigate it. This is not to argue that support should be unconditional. There needs to be a way to maintain motivation in individual projects but the thematic, or overarching, support can be maintained so that there is confidence amongst stakeholders that it is worth them investing effort in particular experiments.

Linking with the recommended goals, we can see that the risk-bearing nature of public funding will more likely foster learning (goal 2), because of the space it creates in which to experiment (goal 4). And public funding means a greater likelihood to share learning, because of the demand to make available publicly-funded research (goal 2). But the public availability of lessons can also help in building wider networks of stakeholders (goal 1). And wider availability of learning can help in public discussions and debates about shared development visions (goal 3).

4.4.6 Role of institutions

In order to achieve all of the above, appropriate institutional structures are necessary. Under the current CTCN structure, this would fall to NDEs to implement. However, it is highly unlikely that NDEs, amongst all their other competing priorities, will have the capacity to meaningfully pursue such priority system-building concerns. It is this that drives the rationale for the creation of CRIBs under Proposal 1 above. In the absence of CRIBs, the CTCN would, as per Proposal 2, need to look towards mainstreaming climate innovation system building through its own approach to developing, supporting, monitoring and evaluating projects and programmes.

Finally, with regard to the recommended goals, institutions of the kind discussed can provide formal channels and mechanisms for coordination and linking. So, institutions can link to other institutions in formal arrangements, whether they are sub-national, national or international. This directly helps to achieve network building (goal 1). It also helps to coordinate sharing of lessons from projects (goal 2) and, indeed, can be useful for coordination of projects and programmes themselves such that there is a continuing diversity of experimentation (goal 4). And, exploiting formal links and stakeholder networks, institutions can organise more structured forums in which to develop shared visions (goal 3).

4.5 Suggestions for the TEC

Based on the analysis and discussion of policy options in this report, it is suggested that the TEC consider the following actions. These are divided between: 1. Possible recommendations to be made to the COP for supporting the establishment of Climate Relevant Innovation-system Builders (CRIBs) and extending the remit of the CTCN; 2. Possible recommendations to the COP on nationally appropriate actions for developed and developing country Parties; and, 3. Possible follow up work for the TEC.

4.5.1 <u>Possible recommendations to the COP on funding the establishment of Climate Relevant Innovation-system Builders (CRIBs) and extending the remit of the CTCN</u>

A comprehensive approach to mainstreaming the development of NSIs to support more widespread and sustained development, transfer and uptake of climate technologies in developing countries requires funding and support to implement either or both of Proposals 1 and 2 in Section 4.3 above. This responds directly to the gap analysis of existing funding and policy approaches in Section 4.2.4 and Table 4.2 above.

These recommendations are firmly rooted in the TEC's remit [14]. The TEC's priority recommendation to the COP should therefore be to table consideration by Parties of these two proposals, which can be summarised as (see Section 4.3 above for further detail on each proposal):

1. Proposal 1: Strengthen the capacity of NDEs under the CTCN by funding and supporting the establishment of national level Climate Relevant Innovation-system Builders (CRIBs) within developing countries.
    a. CRIBs would play a strategic, facilitating role, linking up relevant national actors, targeting and coordinating project and programme level interventions to maximize benefits to NSIs.
    b. CRIBs (through NDEs) would coordinate with the CTCN to communicate national priorities (with due knowledge of national policy priorities and local realities).
    c. The CTCN (as per its existing remit) would then act to network CRIBs internationally, facilitating knowledge flows and access to international technological capabilities based on a more detailed understanding of national/local capabilities and needs.

2. Proposal 2: Use climate technology projects and programmes explicitly to build climate innovation systems.
    a. If pursued jointly with Proposal 1, this role can be facilitated by CRIBs, in coordination with the CTCN.
    b. If pursued in isolation, this can be achieved by revising the remit and approach of the CTCN to integrate a climate innovation system building approach into projects, programmes and related interventions, and to provide advice, via NDEs, on how Parties can bolster their own NSIs.

Proposal 1 should be highlighted as the preferred option with most potential to foster the development of NSIs around climate technologies in developing countries. Proposal 2 would be best used to augment the remit of the CTCN, mainstreaming a focus on NSIs. Proposal 2, could, however be pursued on its own if Proposal 1 were seen as too ambitious.

It should be emphasised to the COP that both proposals (particularly Proposal 1) would support nationally driven and nationally appropriate actions and increase Parties' agency to

[14] See the Conference of the Parties decision 1/CP.16, paragraph 121.

foster climate technology development and transfer in ways that respond to their own, nationally determined needs and priorities.

As part of the TEC's remit to give special consideration to least developed country Parties (decision 1/CP.16, para. 121(c)), it should be emphasised that in least developed countries where NSIs tend to be weakest, the establishment of CRIBs under Proposal 1 has even more potential to contribute to both the development, transfer and uptake of climate technologies and broader processes of economic development and creation of new markets, added value and new industrial activity.

4.5.2 Possible recommendations to the COP on nationally appropriate actions for strengthening NSIs

The TEC should recommend the following actions to Parties as policy and programme priorities that will augment climate technology development and transfer by building and strengthening NSIs. As with the recommendations above, these actions are firmly rooted in the TEC's remit as noted above.

The following actions, policies and programmes, drawn from Table 3.1 and designed to address the overarching policy goals outlined in Section 4.1 above, could be recommended to Parties:

4.5.2.1 Goal 1: Network building

1. Foster networks that link diverse stakeholders of relevance to technological capabilities around climate technologies nationally, internationally, locally, and across markets and sectors (private, public, NGO, research, etc.)
2. Work to link these networks to technology users
3. Establish links between national, regional and local government and national and international technical experts
4. Link national firms with international firms (at any level – not necessarily firms at the technological leading edge – all international knowledge exchange is important)

4.5.2.2 Goal 2: Learning

1. Commission market research to understand the nature and extent of existing national markets for climate technologies
2. Commission research into technology user needs and preferences to understand the nature of national markets and opportunities to adapt climate technologies to fit with national user needs and preferences, leading to new national market creation
3. Commission research into technology performance to inform actions to improve reliability of climate technologies and the introduction of national standards
4. Commission research into education and training needs around climate technology installation, use and vending
5. Implement monitoring and evaluation of climate technology projects and programmes, aiming to support systemic learning from and responding to failures as well as successes
6. Conduct baseline studies of climate technology use, sales of specific technologies, availability of specific technologies, existing and potential markets, etc.

7. Conduct comparative research across local/national/international scales that addresses the various research foci above, paying close attention to scale-specific considerations that emerge
8. Make results of research and monitoring and evaluation publicly available so that potential market entrants can learn from and respond to empirical evidence on the size, nature and potential of national markets
9. Create spaces for stakeholders to reflect on research and experiences, such as via workshops, conferences, trade shows, etc. (and use the reach of the networks advocated above to engage relevant stakeholders in such learning events)
10. Provide training for firms via formal, accredited courses
11. Provide training for suppliers and installers via formal, accredited courses
12. Provide training for technology users, villages, households – this can be formal or informal but should be led by accredited providers
13. Provide advice to firms on, and support development of, technology certification schemes
14. Provide advice on education and training needs (up to and including postgraduate training) for working with climate technologies

4.5.2.3 Goal 3: Foster shared visions

1. Convene consensus-building events with different national stakeholder groups
2. Convene scenario-building events to discuss alternative development pathways that different climate technologies might contribute to or constrain
3. Facilitate opportunities for different stakeholders to feedback into the technology design and configuration process

4.5.2.4 Goal 4: Provide protected spaces for experimentation

1. Encourage or incentivise treatment of 'failures' as valuable points for learning – this can be operationalised via the research and monitoring and evaluation efforts advocated above
2. Commission projects explicitly as experiments (as opposed to 'solutions'), experimenting with a range of factors, including:
    - technological hardware
    - policies
    - social practices in relation to climate technologies
    - new stakeholder configurations
    - production processes
    - linking stakeholders across markets to create new market opportunities and market awareness
    - value-adding experiments working upwards through supply chains

4.5.3 Follow up work for the TEC

The TEC's workshop on NSIs provided an important starting point for its contribution in the area of NSIs. Looking forward to the TEC's 2015-16 rolling work plan, together with fulfilling Activity 4.3 of the TEC's 2014-15 rolling work plan ("Further work on enablers and barriers, taking into account the outcomes of the workshop on NSIs"), there are several follow-on activities which would make valuable contributions to Parties and other actors seeking to develop and strengthen NSIs around climate technologies.

The key issue that the actions below are designed to address is the absence to date of an attempt to integrate consideration of NSIs into activities under the Convention. There is therefore significant value in commissioning desk-based analysis and supporting deeper empirical research which builds on the insights in this current report on the value of an NSI-based approach to climate technology development and transfer and aims to learn lessons from NSI-focussed analysis of existing international and national initiatives. Such research would provide valuable, empirically grounded support to the nationally appropriate actions recommended above.

Action	Deliverables	Expected outcomes	Technology Executive Committee function / Conference of the Parties mandate
1. Provide support to Parties for articulating in-depth analyses of NSIs, including existing capabilities, relevant institutions, etc. 2. Commission work to identify examples of successful NSI building around specific climate technologies and participatory historical analysis of the factors that contributed to successful NSI building in these cases and how these might be replicated across different contexts (see, for example, the work of Byrne et al 2014 on solar PV in Kenya) 3. Commission a desk-based gap analysis, augmented with expert interviews, on the strengths and weaknesses of existing international initiatives in building	a. National reports on NSI building b. TEC briefs c. Key messages to COP	Enhanced, empirically grounded understanding among Parties and stakeholders of how to operationalise and institutionalise an NSI-based approach to addressing barriers and creating enabling environments for climate technology development and transfer Enhanced understanding on barriers and enablers	Analyse policy and technical issues related to the development and transfer of technologies (decision 1/CP.16, para. 121(a)) Recommend actions to promote the development and transfer of technology (decision 1/CP.16, para. 121(b)) Recommend guidance on policies and programmes (decision 1/CP.16, para. 121(c)) Promote and facilitate collaboration on the development and transfer of technologies (decision 1/CP.16, para. 121(d)) Recommend actions to address barriers

NSIs for climate technologies. This should build on the initial sketch provided in Section 4.2.4 and Table 4.2 of the current report. 4. Commission further desk-based research, including expert interviews, to understand the extent to which NSI building was an aim of the Lighting Africa initiative, and ways in which the initiative provides explicit lessons for operationalising the lessons in this report 5. Similar to the report commissioned by infoDev on CICs (Sagar 2010), commission a desk-based study looking at detailed case studies of existing Centre based initiatives and the lessons that could be learned for building NSIs (potential case studies include CGIAR, Innovación Chile and the Carbon Trust)			(decision 1/CP.16, para. 121(e)) Seek cooperation with relevant international technology initiatives, stakeholders and organizations (decision 1/CP.16, para. 121(f)) Initiation of the exploration of issues relating to enabling environments and barriers, including those issues referred to in document FCCC/SB/2012/2, paragraph 35 (decision 1/CP.18, para. 60)

4.6 Conclusion

Building on insights from the Innovation Studies and Socio-Technical Transitions literatures, this report has demonstrated how policy focussed on developing and strengthening NSIs could significantly increase and sustain the development and transfer of climate technologies to developing countries. Nurturing NSIs provides a focus for generic policy interventions at national and international levels that are able to respond to the context-specific needs of different countries, technologies and social practices therein. By focussing on the overarching goals of *building networks, fostering shared learning and shared visions, and supporting* *experimentation through projects and programmes*, international climate policy focussed on nurturing NSIs could have a profound impact on climate technology development and transfer, achieved via the more detailed policy interventions outlined in this report (see Section 4.5).

It is time for international climate policy to make the shift towards using policy interventions as Climate Relevant Innovation-system Builders (CRIBs). This would best be achieved via adoption by the COP of the two Proposals outlined in this report (see Sections 4.3. and 4.5). Both proposals (particularly Proposal 1) would support *nationally driven and nationally appropriate actions* and increase Parties' agency to foster climate technology development and transfer in ways that respond to their own, *nationally determined needs and priorities*. The aim should be to build indigenous technological capabilities and well-functioning, context-sensitive NSIs via nationally nested, demand-driven, internationally networked activities with learning shared across different contexts. It is these NSIs (understood from a broader, socio-technical perspective) that will provide the bedrock of technological change and sustainable, climate-compatible development well into the future.

Within the broader perspective introduced at the beginning of this report of fostering pathways of climate technology transfer and development which deliver against the self-defined needs of poor countries and poor people therein, it is clear that a CRIBs based approach has strong potential to deliver. By focussing on nurturing NSIs, CRIBs can go beyond the limits of existing 'hardware financing' policy approaches to extend the promising advances made by the CTCN and related international initiatives in ways that better support sustained climate-compatible development in individual countries along self-defined pathways.

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