Innovation, Sustainability, Development: A New

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Low Carbon Development: The Role of Local Innovative Capabilities

David Ockwell, Adrian Ely, Alexandra Mallett,
Oliver Johnson and Jim Watson

Energy

About the paper

The term "development" is synonymous with economic growth. Theory and empirical evidence suggests decoupling energy use from economic growth is unlikely, implying an urgent need to decarbonise energy use and supply if developing nations are to be protected from the impacts of climate change. The political discourse on facilitating low carbon growth in developing countries has focused on technology transfer. This paper argues that this will only underpin long term, low carbon growth if pursued in such a way as to facilitate the development of innovative capabilities within developing countries. This can best happen via international collaborations at the appropriate point along the research, development, demonstration and deployment spectrum, defined by existing levels of innovative capabilities within a country and its specific technological needs, which may vary regionally. Policy processes need to engage more actors in democratically inclusive and accountable fora to map out pathways to locally-relevant low carbon futures. These should not be merely technocratic (and technology-focussed), but should also include government, firms, civil society and users themselves.

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About the Manifesto project

In 1970 a radical document called The Sussex Manifesto helped shape modern thinking on science and technology for development. Forty years on, we live in a highly globalised, interconnected and yet privatised world. We have witnessed unprecedented advances in science and technology, the rise of Asia and ever-shifting patterns of inequality. What kind of science and technology for development Manifesto is needed for today's world? The STEPS Centre is creating a new manifesto with one of the authors of the original, Professor Geoff Oldham. Seeking to bring cutting-edge ideas and some Southern perspectives to current policy, the New Manifesto will recommend new ways of linking science and innovation to development for a more sustainable, equitable and resilient future.

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INTRODUCTION

Concerns about the impacts of growing global demand for energy were already identified at the time of the original Sussex Manifesto (Singer et al 1970), especially regarding the prudent use of finite fossil fuel resources. The *Limits to Growth* (Meadows et al 1972) and other writings around the same time (see for example Buckminster-Fuller 1969) pointed with urgency towards the risk of exhausting fossil fuel resources. Whilst many of the predictions of exhaustion within *Limits to Growth* were clearly wrong, concerns about resource scarcity have not gone away. Energy policy debates have recently returned to this issue, and increasingly mirror those of the early 1970s. The possibility of an impending peak in global oil production is frequently highlighted, though its immediacy and impacts remain subject to extensive uncertainty and controversy (e.g. Bentley et al 2007; Watkins 2006)[1].

Limits to Growth also mentioned the other important global energy policy challenge: climate change. Although it highlighted increases in CO_2 emissions as a result of human fossil fuel combustion, it primarily focused on the potential role of 'thermal pollution' (direct heating of the atmosphere by fossil fuel combustion) rather than an enhanced albedo effect (Meadows et al 1972: 72-74). The SPRU response to *Limits to Growth* focused on the problem of declining supplies of fossil fuels and uranium, and cited work that dismissed thermal pollution and CO_2 generation as a 'bogey' that should not distract us from the real problem of resource scarcity (Cole et al 1973: 90,106). Clearly the science has moved on since then. We now know that anthropogenic emissions of CO_2 are causing climate change. Furthermore, without radical reductions in emissions the impacts on humanity and the earth are likely to be extremely serious (IPCC 2007).

This paper is based on empirical work conducted within the Sussex Energy Group at SPRU in recent years on energy, climate change and development. It sets out our views on the role of low carbon innovation in future sustainable development pathways for developing countries.

THE CENTRAL IMPORTANCE OF ENERGY FOR GROWTH

Despite the wave of scholarship in the late 1960s and early 1970s that broadened the notion of 'development' (see Ely and Bell 2009), the term is still often used as synonymous with 'economic growth'. More often than not, growth in Gross Domestic Product (GDP) acts as an implicit development objective, and despite its weaknesses, GDP *per capita* remains the primary metric used to differentiate between countries' levels of development. More recently, some metrics have added life expectancy and education components to this, for example, in the UNDP Human Development Index.

The shortfalls of equating development with economic growth are now beginning to influence more mainstream debate (see for example Jackson 2009). For now, however, let us accept that sustained economic growth is an imperative for the vast majority of governments across the world, and this growth is measured using GDP.

Today, worries about diminishing supplies of fossil fuels, especially illustrated by the 'peak oil' debate and associated concerns over energy security, are resurfacing. Furthermore, transforming energy systems to avoid further anthropogenic climate change is seen as an urgent challenge facing mankind (Scrase and MacKerron 2009). Recent research suggests that the halving of global greenhouse gas emissions by 2050 envisaged by recent G8 Communiqués still have a 12–45%

[1] Through the UK Energy Research Centre, the Sussex Energy Group is currently investigating the proposition that global demand for conventional oil will be constrained by resource availability before 2020.

probability of exceeding 2 °C, the level widely thought of as leading to 'dangerous' climate change (Meinshausen et al 2009). The economist Nicholas Stern argues that in order to limit atmospheric carbon dioxide to 500 parts per million 'we will need a revolution that surpasses the scale and impact of previous world-changing technologies such as railways and personal computers' (Brahic 2009). The transition to low-carbon energy systems (that might also achieve radical reductions in energy intensity) is perhaps central to the global innovation challenge for the New Manifesto. This transition also clearly illustrates the importance not merely of the rate or scale of innovation, but of the ***direction*** in which innovation (and the systems within which it occurs) must develop.

In comparison to other sectors, energy has been shown to be of fundamental importance to economic activity. Increases in GDP have historically been, and seem set to continue to be, coupled to corresponding increases in energy use. This is borne out both by empirical evidence and the strands of economic theory that account for the laws of thermodynamics, which govern the use of energy and its physical by-products (Ockwell 2008). As the use of energy, principally from fossil fuels, accounts for over 60% of global greenhouse gas emissions, this implies an urgent imperative to decarbonise energy systems.

In addition to this, there may be a need to change the direction and/or composition of economic growth. As noted earlier, fundamental questions about the sustainability of conventional economic growth are increasingly being raised in mainstream debates. A recent example is a report from the Sustainable Development Commission, an official advisory body for the UK government (Jackson 2009). The Sustainable Development Commission report argues that the stabilisation or reduction of the level of economic activity would not necessarily mean a similar curtailing of broader processes of development and progress by societies. However, it also acknowledges that redefining notions of progress and development so that they are not reliant on conventional economic growth is extremely challenging.[2]

Given the practical unlikelihood of any shift away from the political imperative for sustained economic growth – at least in the near future – the transition to low carbon societies requires a particular emphasis on decarbonising energy supplies (Japan-UK Working Group 2008; G8 2009; DECC 2009). This demands the rapid diffusion of low carbon energy technologies – be they energy generation, transmission or efficient end use technologies – and thus change at a systemic level. Efficient end-use technologies, for example, whilst unlikely to be sufficient on their own to decouple growth from energy use, are likely to play an integral role in the transition to low carbon societies.

Making the transition to a low carbon economy requires leadership from, and presents a significant challenge to, the developed world, which is currently locked in to high carbon technological, economic and social systems (Unruh and Carillo-Hermosilla 2006). But the challenge is not limited to the developed world, which will most likely suffer less severe impacts from the climatic changes driven by carbon emissions from economic activity. It also implies an urgent need for developing countries to follow low carbon growth pathways, which avoid the energy/carbon intensive systems configurations that have characterised, and continue to characterise developed nations. This is particularly important for the middle income emerging economies: China, India, Brazil, Mexico and South Africa which have large current and projected increases in fossil fuel use.

This kind of low carbon global transition by middle income countries could also set a trend for less developed nations to follow at later stages of their development. Rather than following the previous trajectories of industrialisation the opportunity exists for the emerging economies to drive new innovation trajectories that bypass and avoid lock-in to those regimes and systems most responsible for global climate change (Sauter and Watson 2008; Ely and Scoones 2009).

[2] See Stirling, A. (2009) *Direction, Distribution, Diversity! Pluralising Progress in Innovation, Sustainability and Development*, STEPS Working Paper 32, Brighton: STEPS Centre, for further discussion of 'notions of progress'.

INNOVATIVE CAPABILITIES FOR LOW CARBON DEVELOPMENT

It is often argued that a pre-requisite for low carbon development in emerging/developing economies is the transfer of low carbon technologies from where they are predominantly owned in the North, to where they can be put to good use in the South to avoid emissions from future economic growth. 'Low carbon technology transfer' is a phrase that dominates the more controversial negotiations under the UN Framework Convention on Climate Change (UNFCCC), and forms one of four central objectives under the Bali Action Plan (UNFCCC 2007). In Bali countries agreed to support actions aimed at increasing the transfer and diffusion of affordable low carbon energy technologies, increasing research and development (R&D) cooperation, promoting financial mechanisms to support this work, and assessing the effectiveness of mechanisms and tools for technology cooperation in certain sectors.

What the political discourse generally fails to account for, however, is the fact that in order for a process of technology transfer to underpin long term, low carbon economic growth, it is not sufficient to merely sell/give a country, firm or organization pieces of 'hardware', or physical, tangible objects. It is also imperative that the technological know-how that underpins the processes of innovation in low carbon technologies, sometimes referred to as 'software' (e.g. knowledge, processes), is also developed within – or transferred to – developing countries. In this way developing nations can build the expertise necessary to become low carbon producers and innovators in their own right, as opposed to just being consumers of new technology, in many ways dependent on continued imports. Furthermore, technology transfer is not just a process that can be carried out between developed and developing country governments. Firms and other actors such as research institutes – many of them privately owned – are key to this process since it is they (not governments) who develop low carbon technologies, and buy and sell them in markets.

The process of acquiring new innovative capabilities within firms and other organisations in developing countries, elsewhere referred to as technological learning or developing new 'technological capacity' (Ockwell et al 2008; Bell 2009), has been studied for more than two decades by scholars in Latin America (e.g. Katz 1987), India (e.g. Lall 1987), South Korea (e.g. Kim 1987) and elsewhere. It is further analysed with respect to *directions* of development within other papers in this series. In one of these papers (Bell 2009), Martin Bell makes the important point that technology imports into developing countries and localised innovation within those countries are not alternatives – but are complementary processes that are often both necessary to develop innovative capabilities. For example, South Korea's automotive manufacturers were able to catch up with international market leaders through a combination of indigenous technology development and international technology acquisition (Sauter and Watson 2008). Therefore, the potential for realising sustained low carbon growth trajectories in emerging economies rests on the development of these new low carbon innovation capabilities – and a careful balance between international and domestic sources of these capabilities.

Recent research by the Sussex Energy Group and the Tyndall Centre has explored four possible low carbon development pathways for China (Wang and Watson 2008). These pathways combine continued economic development with limits on cumulative carbon emissions over the period to 2050. Within each pathway, the role of low carbon innovation is explicitly analysed. A key issue is the relationship between this innovation and the speed at which Chinese carbon emissions growth could slow down – and eventually be reversed. Within some of the scenarios analysed, China's emissions could peak as early as 2020 as a result of rapid changes in industrial structure (e.g. in favour of high value added industries and services) and quick progress with the development and deployment of low carbon technologies. International technology transfer would play a key role in this technological development process since the gap between the capabilities of Chinese firms and those of internationally leading firms remains large in many sectors.

International technology transfer arrangements and the policy incentives put in place to encourage technology transfer therefore need to focus on how they can contribute constructively to this process of innovation capability-building over time. Our research with colleagues in India on barriers to the transfer of low carbon energy technologies has flagged up several key considerations for guiding policy geared towards developing new innovation capabilities (Ockwell et al 2008; Ockwell et al forthcoming). These include:

Low carbon technologies are at different stages of development. This means that low carbon technology transfer involves both vertical transfer (the transfer of technologies from the R&D stage through to commercialisation) and horizontal transfer (the transfer from one geographical location to another) transfer. Barriers to transfer and appropriate policy responses often vary according to the stage of technology development as well as the specific source and recipient country contexts. This issue of context specificity is addressed further below.

Less integrated technology transfer arrangements involving, for example, acquisition of different components of an energy technology from a range of host country equipment manufacturers, are more likely to involve knowledge exchange and diffusion through recipient country economies than more integrated arrangements, such as turnkey plants or projects, i.e. those which are ready (at the turn of a key) for the 'customer' to use or operate.

Recipient firms that strategically aim to obtain technological know-how and knowledge necessary for innovation as part of the transfer process (building *absorptive capacity*) are more likely to be able to develop their capabilities as a result. For example, Kim (1998) demonstrates how managers within Hyundai took a strategic approach to acquiring migratory knowledge (knowledge that can be accessed relatively easily) during the acquisition of foreign technology in order to expand the firm's existing knowledge base. This factor is seen as having been instrumental in intensifying Hyundai's organisational learning and shifting the company's learning orientation from imitation to innovation.

Other considerations include the role of Intellectual Property (IP), domestic policy drivers and collaborative research, development, demonstration and deployment arrangements. These issues are dealt with in more detail below.

INTELLECTUAL PROPERTY

Much debate has tended to focus on the role that IP (by which most commentators in the low carbon energy context tend to mean patents) might play in facilitating technology transfer. The G77/China under the UNFCCC negotiations, for example, have proposed the creation of a multilateral fund to buy up IP in relation to low carbon technologies, somewhat akin to the 'technology transfer bank' proposed in the original Sussex Manifesto[3]. Annex I nations tend to be resistant to this proposal, arguing that developing countries having access to IP will not necessarily equate with technology development (See for example DECC 2009; UNCTAD-ICTSD 2003) as discussed further below. Empirical evidence to date on the role of IP is mixed. Various studies (Barton 2007; Lewis 2007), including our own as yet unpublished work in India[4], have shown that the picture is more complicated than the political debate implies (for a detailed discussion see Ockwell et al forthcoming). Whilst with all the technologies studied, firms in emerging economies (India and China being the two countries most studied) are active at some point along the research, development, demonstration and deployment (RDD&D) spectrum, at the time of study none were producing at the cutting edge. We have found in our research that lack of access to IP did seem to have the potential

[3] This was proposed as 'a valuable if partial solution' to 'the problem of access to technology' (see Singer et al 1970: paragraph 8).

[4] Phase II of the UK-India collaborative study on low carbon technology transfer is awaiting release pending Government of India sign off – see http://www.sussex.ac.uk/sussexenergygroup/1-2-9.html for updates.

to slow the rate at which firms in developing economies could begin to reach the cutting edge. For example, successful Indian photovoltaic technology firms predicted difficulties in moving to produce thin film grade silicon, and Indian automotive firms and related public sector organisations were, despite a successful public-private Indian collaborative partnership, taking time to negotiate the IP that exists in relation to hybrid vehicles. This suggests that in some instances access to IP might indeed need to be facilitated via international policy mechanisms.

But simple access to IP is only part of the picture. Many low carbon technologies have a vast array of associated patents. Even in cases where access to these patents is possible, this is often not enough for firms to begin producing these technologies. A huge amount of knowledge is often protected by companies in the form of trade secrets and tacit knowledge relating to, for example, the management and manufacturing systems that underpin the ability to apply these patents within the production process. For example, in 2006 when we spoke to Indian Light Emitting Diode (LED) manufacturers they emphasised that access to IP relating to white LEDs would not enable them to start manufacturing this technology. Instead, what they wanted most was access to existing manufacturers' knowledge about the manufacturing processes involved. Moreover, IP does not necessarily provide knowledge of the processes of innovation that lay behind the development of new low carbon technologies to which the IP relates. It is access to this 'know-why' knowledge (knowledge of the processes that lead to new innovations and why they work), and hence not IP in isolation, that underpins the development of new low carbon innovative capabilities.

It is also not clear how much a fund that bought up IP would address the problem of additional costs associated with low carbon technologies. A key reason why conventional, high carbon technologies are often more attractive than advanced, low carbon technologies is that conventional technologies tend to be cheaper. It is unclear how much of the additional cost of low carbon technologies is related to IP, but in many instances this cost is unlikely to be significant enough to make low carbon technologies financially competitive if met by an international IP fund. An IGCC plant, for example, might be 25-30% more expensive than a supercritical conventional coal fired power plant, but only a small proportion of that additional cost is likely to be associated with IP. In addition to licensing fees, these higher costs relate to the capital intensity and complexity of IGCC technology. It is not yet a fully commercial technology (at least in coal fired applications). Therefore its costs include many 'first of a kind' elements generally associated with newer technologies. Our research in India suggests that a far more important barrier than IP for Indian companies wishing to work with IGCC has been difficulties related to accessing knowledge on the practical experiences of global leaders in this technology, compounded by the fact that there are few suppliers and only semi-commercial plants in operation worldwide – thus again emphasising the importance of tacit knowledge.

The higher costs of many low carbon technologies suggest that substantial international funding needs to be part of the policy tool box available to help develop low carbon innovation capabilities in developing countries. But domestic policy will also play an essential role, just as it will in developed countries. Without regulations to limit or price carbon emissions in key economic sectors (e.g. transport or power generation), there will be a lack of demand for more expensive low carbon technologies. Increased demand is essential for driving economies of scale and reducing production costs, thus driving down prices and further stimulating demand. The high cost of batteries for hybrid vehicles, for example, is unlikely to decrease without more large scale production, which needs to be driven by increases in demand for hybrid and/or electric vehicles.

INTERNATIONAL COLLABORATIVE RDD&D

But how, in practice, can the development of new, low carbon innovation capabilities be facilitated? Certainly the production of 'Technology Needs Assessments' (TNAs) under the UNFCCC,[5] which read more like technology wish lists than detailed assessments of technological needs and existing capabilities, is unlikely to achieve this. This has led to a number of proposals for institutional and policy innovations designed to develop these capabilities. For example, think tanks E3G and Chatham House have advocated the establishment of low carbon zones in China (Findlay and Preston 2008). These mirror the Special Economic Zones that were at the forefront of China's opening up policies of the 1980s. They are conceived as specific geographical areas in which institutions and incentives are designed to foster and accelerate low carbon innovation and development. International assistance in the form of financial and other support is envisaged to help establish these zones. Similarly, the UK's Carbon Trust has developed a concept for a network of low carbon innovation centres in developing countries (Carbon Trust 2008). This concept is now being taken forward as a pilot project by DFID and the World Bank (see below).

Our own research has focused on the possible role of collaborations between international technology leaders and firms and/or organizations in developing countries. These could focus at any point along the RDD&D spectrum, depending on where developing country firms' existing capabilities imply they might benefit most. For example, Indian companies working to develop hybrid vehicles are making inroads into demonstration initiatives, and thus might benefit most from engagement with technology leaders at this level, or in learning from others' experiences of how to move from demonstration to commercial deployment. Indian wind companies looking to develop cutting edge wind turbine blades that achieve high efficiencies at lower wind speeds might benefit most from collaborations at earlier research and development stages. In general, firms in developing nations would benefit from more direct access to the tacit knowledge and experience of leading firms. This is the rationale behind the Carbon Trust's proposal for low carbon innovation centres, and has now led to a joint initiative between infoDev, which is a global financing programme among development agencies, administered by a Secretariat at the World Bank, and the UK's Department for International Development (DFID). Launched in London in July 2009, the project aims to examine opportunities and barriers to low carbon innovation in selected pilot countries (Phase I). A potential Phase II would provide seed money from the World Bank to follow on the results of the initial findings, possibly leading to the creation of low carbon innovation centres in these countries, in partnership with local private and public partners.[6]

International collaborations at earlier stages of technology development also have the potential to overcome IP issues if resulting IP were jointly owned by the collaborating entities, although this would require careful negotiation at the outset. Consideration might also need to be given as to whether it was desirable for collaborations that benefit from public funding to make resulting IP publicly available after a given time period. For instance, our recent research has focused on the hybrid vehicles in India. The Indian government has provided 70% of the US$140 million required to kick-start the National Hybrid Propulsion Program (NHPP), which encourages indigenous innovation in the area of hybrid vehicles. Here, companies and organizations involved in the initiative have agreed to keep the IP on technologies they have developed individually, but to share the IP on any new advances established jointly. There is also an understanding that the jointly developed IP will be publicly released several years after development.

But any policy aiming to achieve international collaborative RDD&D will have to overcome a difficult problem, namely the concern of private firms and national governments with sustaining any technological advantage they may have. Careful thought therefore needs to be given to how

[5] See http://unfccc.int/ttclear/jsp/CountryReports.jsp (accessed 16th August 2009) for further information.
[6] See http://www.infodev.org/en/Article.392.html (accessed 16th August 2009) for further information.

international collaborations might be facilitated in such a way as to provide sufficient incentives to engage international technology leaders, or even second tier companies. This might be achieved by highlighting new market opportunities that might exist in developing nations, particularly if this were underpinned by policy commitments at a domestic level that favoured low carbon technologies. Another incentive that might be better researched and communicated to international firms is the extent to which adapting technologies to local contexts in developing countries can open up new markets – an insight observed by The Energy and Resources Institute (TERI)'s work on energy efficiency improvements amongst Small and Medium-sized Enterprises (SMEs) in the glass and foundry sectors in India (see Pal 2006, for example).

WHERE DOES POVERTY COME INTO ALL OF THIS?

Readers will have noted the emphasis thus far on emerging economies – in particular India and China. From a climate change mitigation perspective, this emphasis is understandable. Rapidly developing middle income countries already contribute significantly to global emissions (though their per capita emissions remain well below those of OECD countries). It is also important to remember that such middle income countries continue to face the challenge of lifting large numbers of their citizens out of poverty. However, any successful policy response needs to be context specific – and to take into account other, less developed countries as well. Many less developed countries are on the front line of climate change and are already starting to experience its effects. Their capacity to adapt to climate change is often comparatively weak. Furthermore, many of their citizens lack access to modern energy systems and the services these offer.

The appropriateness of different policy responses relies on a range of context-sensitive factors, such as: the nature of different technologies; their appropriateness within different country contexts; the institutional architecture and related barriers and incentives that exist within different countries and in different regions within those countries; and the different needs of different parts of society within and across countries. For example, what is appropriate for a rapidly emerging economy like China is unlikely to be right for many countries in South-East Asia or Sub-Saharan Africa. This might be related to existing levels of (economic) development, or it might be due to existing technological or institutional characteristics. It could also be influenced by climatic or ecological considerations – the appropriateness of wind, solar, hydro or biofuel solutions, for example, is hugely variable across different countries. Middle income countries such as China already have significant energy infrastructures that require radical change to make them more sustainable as well as further development. Low income countries such as Kenya have comparatively weak energy infrastructures which contribute little to global problems such as climate change. For the latter group, a key priority is to extend these infrastructures – and to do so in a sustainable way.

A point that is also often ignored within the international debate, particularly on technology transfer, is the point mentioned above relating to the variation in needs within a country. To what extent, for example, is technology transfer likely to meet the needs of the rural poor? Across much of the developing world, the majority of people without electricity are living in rural areas (Modi et al 2005: 116; Vedavilli 2007). Politicians might be attracted to large infrastructure projects in order to secure reliable power for key economic centres. But poor people in rural areas might benefit far more significantly from simple to operate and repair, distributed energy technologies, such as solar cells with LED lighting that could facilitate a shift away from a reliance on kerosene. Furthermore, such distributed solutions could be more cost effective in some circumstances.

Important lessons can be drawn from the attempted implementation of a 'one-policy-fits-all' model (Xu 2006) of electricity sector reform around the world since the 1990s. Liberalisation and privatisation has often been advocated as a way to ensure the necessary investment in energy infrastructure. Among other things, this model failed to address the different starting points and institutions existing within different countries (Besant-Jones 2006). Whilst the goal of reform - an efficient, sustainable and affordable electricity supply – was undisputed, how to get there was not. Adaptability of the model was limited by low indigenous capabilities, dependence on foreign consultants and donor conditionality. The resultant lock-in led to significant underinvestment as traditional lenders withdrew to make way for private investors who never arrived and in many cases culminated in the rejection of reform altogether. What can be seen today is the growth of hybrid electricity sector models (Gratwick and Eberhard 2008) based on what is locally appropriate and feasible. Applying this lesson to the debate on technology transfer and developing indigenous capabilities, it is imperative that local conditions are taken into account and an array of pathways kept open.

The development of low-carbon energy systems in low-income countries through technology transfer and development of indigenous capabilities is certainly blighted by huge capacity constraints. However, another central challenge when considering the diversity of socio-economic contexts is weighing decarbonisation against the priority of expanding access to help reduce poverty. Compare, for instance, electricity grid coverage in various countries - 98.6% in China, 43% in India in 2004 (Urmee et al 2009: 355), as compared to 45% in Ghana, 7.9% in Kenya or less than 0.1% in Niger at approximately the same time (Modi et al 2005: 43). The drive for commercialisation as part of electricity reform meant that it was unviable to expand access to outside urban and industrial areas, leading to concern over how to achieve expansion of access in rural areas. As a result, since around 2000 access to electricity has become a more urgent priority for governments and donors alike when discussing energy sector needs relating to poverty reduction in low-income countries[7]. The figures, although unreliable, are stark. Out of 29 countries in Sub-Saharan Africa, the 2009 African Development Indicators identify only 10 with rural access rates above 10% (World Bank 2009a). Recent estimates state that of the 21 Sub-Saharan African countries, over half (12) have levels of access to electricity of less than 20%, one third (7) between 20-50%, and only Nigeria and South Africa have access levels above 50% (Eberhard 2008: 35). In many cases, suppressed demand due to power shortages and inability to finance new connections is allowing population growth to outpace the electrification rate, leading to declining levels of access (Eberhard 2008: v).

Earlier figures demonstrating the differences in electrification rates across various Sub-Saharan African states (and the urban-rural differences within them) are shown in Table 1.

Table 1. Urban and rural dimensions of energy use in selected Sub-Saharan countries

Country	National Population in Millions (1999)	National Electrification Rate (%) (2000, 2004)	Urban Electrification Rate (%) (2004, 2002)	Rural Electrification Rate (%) (2004, 2002)
Ethiopia	61.7	4.7	13.0	0.7
Ghana	19.7	45.0	82.5	20.9
Tanzania	32.8	10.5	39.0	1.0
Kenya	29.5	7.9	20.0	1.7
Niger	10.4	< 1.0	36.6	0.2
Senegal	9.3	30.1	68.9	6.1
Chad	7.5	-	9.4	0.1

Source: Adapted from Modi, V., McDade, S. Lallement, D. and Saghir, J. (2005) *Energy Services for the Millennium Development Goals*, Washington, DC and NY: the World Bank and UNDP, p. 43

[7] For example, the *Report of the World Summit on Sustainable Development* (2002), 'The Johannesburg Plan of Action 2002', UNESA; and World Bank (2001) *The World Bank Group's Energy Program: Poverty Reduction, Sustainability and Selectivity*, Washington DC: World Bank.

African governments and development partners, their traditional financiers in the power sector, both see access as a top priority. Measures to create rural electrification or energy agencies (REAs) to facilitate this are ongoing and ambitious grid expansion projects are being written into Power Sector Master Plans (PSMPs).

The PSMPs tend to emphasise utilisation of large-scale generation projects to exploit hydro and thermal potential and regional integration of grid networks. The need for system rehabilitation, let alone access expansion, coupled with limited Government financial and human capacity means that *low-carbon* growth is often of low national priority. It is therefore unlikely that mechanisms to help emerging economies develop indigenous capabilities for low-carbon growth will be seen as relevant. This is in sharp contrast to international discourse, which frequently accepts that access expansion and economic growth in low-income countries can be achieved through low-carbon pathways. It is necessary to link up the separate debates over access and low-carbon technology transfer to address local contexts and priorities and openly acknowledge the challenges they present.

As noted earlier, those most likely to suffer from the consequences of dangerous climate change will be located in the least developed countries where access to electricity is currently lowest. This raises a fundamental ethical debate over whether the same low-carbon growth pursued by developed and emerging economies should be pursued by, or imposed upon the lowest-income countries. A number of problematic issues currently exist in relation to current approaches being pursued in low-income countries. First, most planned expansion in Africa is hydro-electric, and thus low-carbon (World Bank 2009b; World Energy Council 2007), although the sustainability of some large examples may be questionable. With myriad power crises due to water shortages in times of drought, security of supply (using diverse indigenous resources – be they fossil fuels or renewable supplies) and regional integration is arguably more important to the national economy and access expansion than low-carbon growth. Second, governments of low-consuming countries might argue that even if expansion plans were achieved with carbon intensive generation plants the carbon emissions would still be minimal. Taking Tanzania's PSMP as an example, the maximum estimate for national energy requirements by 2031 is 28,000GWh. In comparison, in 2004, South Africa produced 206,960GWh, India produced 587,870GWh and China produced 1,926,970GWh (Energy Information Administration 2004). With financial constraints already a problem, unless some international financial incentives are put in place, how can these nations be expected to forego large expansion using carbon intensive, but larger scale, power plants in favour of smaller scale expansion using low-carbon technologies?

DIVERSE CONTEXTS AND THE IMPORTANCE OF LOCAL INNOVATION CAPABILITIES

It is difficult to see how generalised international policy initiatives can be flexible enough to cater for national and sub-national perspectives and priorities. However, whilst access and decarbonisation might in some cases be viewed as conflicting objectives, there is much potential for designing energy systems that can serve both these and other purposes.

There are a number of features of low-carbon generation technologies that might be relevant to improving access, especially if development is seen as an underlying policy goal – and not only economic growth centred around industrial centres close to the grid. Many low-carbon technologies are decentralised. For example, distributed micro-generation technologies could in principle be combined where possible with intelligent grids and energy efficient end use technologies to provide more robust and resilient supplies. Such distributed energy systems that operate independently of the main power grid could be particularly appropriate in countries such as Tanzania, with a geographical area of almost one million square kilometres and where over 80% of the population live in rural areas, only 2% of which have access to electricity.

There is another, somewhat more subtle characteristic of such distributed generation approaches, especially with regard to the need specified earlier to innovate at the level of low carbon *systems* rather than merely in individual technologies. In many sub-Saharan African countries the building of grid transmission lines and sub-stations, let alone hydro and thermal power stations, often is outsourced to foreign firms. Partly because policies pay insufficient attention to building local capabilities, indigenous innovation is rare in these contexts of power supply. However, indigenous innovation throughout the whole supply chain could be easier to achieve – and indeed is already occurring – in smaller, decentralised energy systems such as solar PV, mini-hydro and wind. In distributed locales, technologies and behaviours are emerging that complement such low-carbon (and in many cases low-energy) systems (ESMAP 1999; Kammen 2002; World Bank 2008). Alongside distributed generation, therefore, there is an opportunity for distributed innovation – the promotion of local innovation capabilities to incrementally tinker with and adapt external technologies in order to address local needs and environments. The result, if implemented properly, will be the emergence of a more diverse assortment of socio-technical systems, catering for diverse and in many cases irreconcilable notions of development and sustainability. However, it is important not to assume that such low carbon energy systems are automatically amenable to distributed innovation. Technological innovations such as smart grids can be complex (at least as envisaged in developed country contexts), and could demand high levels of innovative capacity to install, operate and maintain.

Rather than the best low-carbon technologies diffusing from a unitary technological frontier, locally-adapted innovations could therefore increasingly play an important role in low carbon development. In some (but not all) cases they will find application in other locations or markets. Rather than established multinational companies seeking bottom-of-the-pyramid fortunes, these innovations may instead emerge from innovation actors in emerging economies that already serve informal, unregulated markets seeking radically low costs. Such 'below the radar' innovation as it has been characterised by one group of scholars (Clark et al 2009) needs to be better understood so that it can more easily be identified and, where appropriate, supported by government or other actors. At a more micro-level, mechanisms for sharing knowledge between individual innovators in different locales in appropriate and accessible ways (in a similar way to that envisaged by AfricaAdapt's recently launched knowledge-sharing innovation fund) will also provide the opportunity for cross-fertilization and flourishing of otherwise isolated innovations.

COMMON BUT DIFFERENTIATED RESPONSIBILITIES AND GLOBAL ENERGY TRANSITIONS

The need for low carbon growth has been much discussed in policy circles in recent years. For both developed and developing countries, this particular direction for growth offers the possibility of allowing continued economic development whilst taking into account the global need for climate change mitigation. This paper has discussed the prospects for low carbon growth in developing countries with a particular focus on the role of low carbon innovation.

As discussed at the outset, the characterisation of the transition to low carbon societies as one of 'low carbon growth' is not without its problems. Over the past several decades, there have been repeated calls for a more critical approach to the policy focus on growth (or at least conventional economic growth) because of potential incompatibility with sustainable development. Seen in this light, it is perhaps better to talk in terms of *low carbon development*, and to debate what such development should look like. As with the general debate about development, there are many complex perspectives and factors that are important.

From the perspective of low carbon development, an important issue is the extent to which this process should be tied to economic growth, expressed by a steadily increasing level of GDP per capita. This paper has referred to the evidence of a strong association between energy consumption and GDP. If this strong association continues, low carbon development means either a radical shift to a lower carbon energy system or a shift towards a mode of development that is less reliant on economic growth - or perhaps a combination of both these strategies. But given the controversial nature of any move away from economic growth, the 'decarbonisation' of energy systems is particularly vital.

In a developing country context, this distinction between low carbon growth and low carbon development seems rather semantic. In developed countries, there is evidence that increasing economic activity does not necessarily lead to greater levels of well being (e.g. Jackson 2009). However, within developing countries there is a pressing need to alleviate widespread poverty and raise incomes – often from very low levels. Here, increasing levels of GDP – both in general and per capita across all segments of the population – is still an essential part of the development process.

However this debate may eventually be resolved, this paper has illustrated three principles for the inclusion of developing countries within global efforts to tackle climate change and improve access within developing countries to modern energy services. First, such efforts need to recognise that many developing countries are already low carbon societies, but these societies are failing to deliver the energy services people need. Hence advancing low carbon development as a policy goal can easily be misunderstood as being 'anti development'. Second, there is a need for a differentiated approach to developing countries within any global agreement. Policies need to be context specific in terms of the country, region (rural/urban, richer/poorer), and the appropriateness of different low carbon technologies for each context. In other words, policies need to put into practice the principle within the Kyoto Protocol of 'common but differentiated responsibilities'.[8] Third, there is a key role for innovation in low carbon development pathways. More specifically, innovation capabilities need to be fostered by a combination of localised innovation and international technology transfer.

This paper has focused in particular on the third of these principles –the role of international collaborations in developing innovative capabilities. Experience shows that successful technology transfer should not only focus on the sale of low carbon technology hardware from one firm to another. Technology transfer should also contribute to innovative capabilities by strengthening the underlying knowledge associated with these technologies within developing countries. Such international collaborations should focus on the appropriate point along the research, development, demonstration and deployment spectrum, as defined by existing levels of innovative capabilities within a country or location. A 'one size fits all' approach will not work: policies to support such collaborations need to take into account each country or locality's specific technological needs and capabilities.

This need for a more differentiated approach to innovation should go beyond the Technology Needs Assessments that are currently being implemented under the UNFCCC. It means that the international policy process should support more comprehensive but locally-relevant low carbon development pathways. These pathways must include a combination of national developing country actions and support from OECD countries and in some cases the emerging economies. Such OECD support needs to be substantial. Many developing countries feel that for too long, the industrialised world has made and broken promises to assist them with more sustainable technologies and the costly impacts of global environmental problems. The international policy process must make good on these promises in a way that improves the capacity of developing countries to develop in a low carbon way. Supporting innovative capabilities is an indispensable part of this process.

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[8] See Article 10 of the Kyoto Protocol:
http://unfccc.int/essential_background/kyoto_protocol/items/1678.php, accessed 10 September 2009

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