Low carbon development, poverty reduction and innovation system building

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Introduction

Access to modern energy services is a critical human development priority and can be transformative to the livelihoods of poor people and their economic potential. A tension is sometimes perceived between increasing energy access and pursuing low carbon development. High carbon, conventional energy options are often viewed as cheaper and hence easier for poor countries to pursue. However, multiple synergies potentially exist between human and economic development priorities and access to low carbon energy technologies. Renewable energy can facilitate access in areas where grid based provision is prohibitively expensive and unreliable, energy efficient technologies can improve availability of energy services, such as lighting and heat, and a combination of the two can increase local and national energy security and economic resilience by reducing exposure to the price fluctuations and political constraints of fossil fuel imports. Access to low carbon energy technologies is therefore potentially critical to meeting the Millennium Development Goals – MDGs (Modi et al 2006).

At a national level, it has long been argued by many that economic development can be best achieved through industrialisation; exploiting technology and innovation to appropriate increasing returns rather than relying on static comparative advantages from which there are likely only diminishing returns (e.g. see Reinert 2007; Cimoli et al 2009). But exploiting technology and innovation requires appropriate capabilities and enabling systems of interconnectedness between those with such capabilities: i.e. innovation systems – whether conceived as, for example, regional, national, sectoral or technological innovation systems. We take such systems to include the "network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies" (Freeman 1987). And we assume capabilities to be "the resources needed to generate and manage technical change, including skills, knowledge and experience, and institutional structures and linkages" (Bell and Pavitt 1993). For many poor developing countries, such innovation systems and capabilities are weak or practically non-existent. Therefore, if poor countries are going to benefit from the increasing returns possible through innovation then such systems and capabilities need building.

Combining the two perspectives – low carbon development and innovation systems – we can begin to see an approach that may help poor developing countries work towards achieving poverty reduction while supporting sustainability goals. Drawing on several literatures, this paper argues that the building of pro-poor low carbon innovation systems requires attention to more than the deployment of low carbon technological hardware through market mechanisms (Byrne, Smith et al 2012). It will involve strategic policy interventions, public and private money, the active participation of the poor in innovation activities, political work against fossil fuel interests and in favour of low carbon constituencies, and co-evolutionary learning across the many social and technical dimensions of how societal services are realised. Moreover, these efforts will take time to bear fruit and are inherently uncertain (Byrne, Schoots et al 2012).

The paper is organised as follows. The next section provides a brief critique of existing low carbon development policy. That is followed by a conceptual discussion covering development pathways, technology and innovation systems, and the building of low carbon innovation systems. We then provide a short history of the evolution of the Kenyan solar home system market in order to illustrate some of the ideas presented in the conceptual discussion. The paper ends with conclusions that arise from both the conceptual and empirical discussions.

International low carbon development policy

Existing international policy mechanisms for low carbon development have had mixed results, with little impact on poor developing countries, particularly Least Developed Countries (LDCs). For example, only 0.2% of certified emissions reductions under the Clean Development Mechanism (CDM) are expected to come from LDCs (De Lopez et al 2009). We have argued elsewhere that this problem is in part due to a tendency to frame low carbon energy access in developing countries around the notion of low carbon 'technology transfer', where technology is understood narrowly as simply consisting of hardware (Byrne, Smith et al 2012). This narrow understanding steers policy towards financing incremental costs of low carbon hardware, such as via credits for investing in low carbon projects under the CDM. Whilst hardware is clearly important, these financing mechanisms have led to an uneven distribution of investment, both technologically and geographically, with the poorest nations benefiting least, if at all. The majority of support is concentrated towards rapidly emerging economies, where financing and deployment environments are already attractive. The technologies funded tend to be low risk or mature, and mostly relate to large project based initiatives that are less likely to attend to the needs of poorer groups.

Furthermore, as the CDM in particular is based on private sector investment in individual projects, it is concerned primarily with generating profit from emissions reductions, not with building local innovation systems and the capabilities within them to foster innovative development of technologies. Indeed, we could argue that the incentive is to reduce the potential for building local innovative capabilities so that project developers maintain control over technologies (e.g. see Douthwaite 2002 for a discussion on the protection of knowledge hindering innovative activity). Where the CDM has been used to build innovation systems it has been done through the strategic intervention of the state, as is the case in China (Watson et al 2011). For poor developing countries, where capabilities for policy implementation are generally weak and the potential to generate emissions reductions now is low, the CDM or similar policy instruments are unlikely to be of any benefit in regard to low carbon innovation system building.

If we accept this analysis then it is clear that a different approach is necessary in LDCs and other poor developing countries. In the next section, we sketch a promising approach that arises from the literature on socio-technical transitions, but develop this on the basis of insights from innovation studies. We then illustrate the approach briefly with an example of the evolution of the solar home system (SHS) market in Kenya.

Low carbon development pathways

This paper is concerned with the role of policy in fostering low carbon technology uptake as part of development pathways that serve the needs of poor and marginalised people. As such it makes inherent normative assumptions, viewing poverty reduction and climate change mitigation as priority development commitments that might be simultaneously achieved. Such normative commitments cannot be taken as given. Each can be contested, and the particular solutions to any commitment – even if not contested – are the subject of sometimes 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 low carbon development pathways by considering the notion of framing and its implications.

Societal services or functions (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 co-evolving complex systems (social, technological, environmental) and any particular unfolding of these dynamics constitutes a specific development pathway amongst multiple possible pathways (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 et al 2010: 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, Smith et al 2012).

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 come under pressure from external dynamics, and experience internal tensions between the many dimensions (social, cultural, political, technical) that 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 United Nations Framework Convention on Climate Change (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 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). But if we are to make use of these transformational possibilities to realise normative goals, such as pro-poor low carbon development, then we need to be careful how we understand technology itself (Watson et al 2011). Our argument here is that an inadequate conception of technology will likely produce – at best – inadequate technology policy, such as with many 'technology transfer' efforts and instruments such as the CDM. Worse, such policy could be ineffective or even counterproductive (Byrne et al 2011). For instance, inadequately conceived low carbon technology transfer to developing countries could see the failure of those technologies, resulting in pressure to turn to carbon-intensive options instead, locking development pathways into high carbon directions. For insights on the nature of technology, and its role in helping to realise pro-poor, self-determined, development pathways we can turn to the innovation studies literature.

Technology and innovation systems

An important insight in the 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 2010). Extending this idea, some authors demonstrate that hardware is also embedded with social or cultural assumptions (Agarwal 1986; Pacey 1983; Wynne 1995). An essential characteristic of this 'software' is tacit knowledge – a fundamental aspect of knowledge and skills that is difficult or impossible to articulate but can be cultivated through practice (Polanyi 1966). Combining these ideas, we begin to form the notion of socio-technology, echoing the language of socio-technical transitions thinking discussed above. Flowing from these ideas, and demonstrated in the literature, we see that technologies are created, adopted and adapted within a systemic environment. This idea has long been studied in regard to innovation systems, with particular attention to the linkages between firms and other actors, and the institutional setting of policies, laws, regulations and norms (e.g. see Bell 1990, 1997, 2009; Bell and Pavitt 1993; Freeman 1992; Hobday 1995a, 1995b; Katz 1987; Kim et al 1989; Lundvall 1992; Ockwell et al 2008; Radošević 1999; Watson et al 2011).

One way to understand the significance of some of these ideas is depicted in Figure 1, 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 possible technology flow (A, B and C) during transfer projects into a local innovation system. 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 "peopleembodied knowledge and expertise". Both flows 'A' and 'B' add to or improve the production capacity of a firm or economy, but do little or nothing for developing the skills needed for generating new technology. 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).

Within the context of a concern with low carbon 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 lower carbon social and economic practices. The existing technological capabilities in the local context are sometimes referred to as absorptive capacity, defined originally by Cohen and Levinthal (1990: 128) as the ability of a firm to "recognize the value of new information, assimilate it, and apply it to commercial ends". However, it has also been used to demonstrate the impact of individual firms' absorptive capacity on the ability of clusters of firms to adopt and adapt new technologies (Giuliani and Bell 2005), and – within the low carbon context and of particular relevance to us here – to explain the ability of countries to achieve technological learning through the CDM (Doranova 2009).

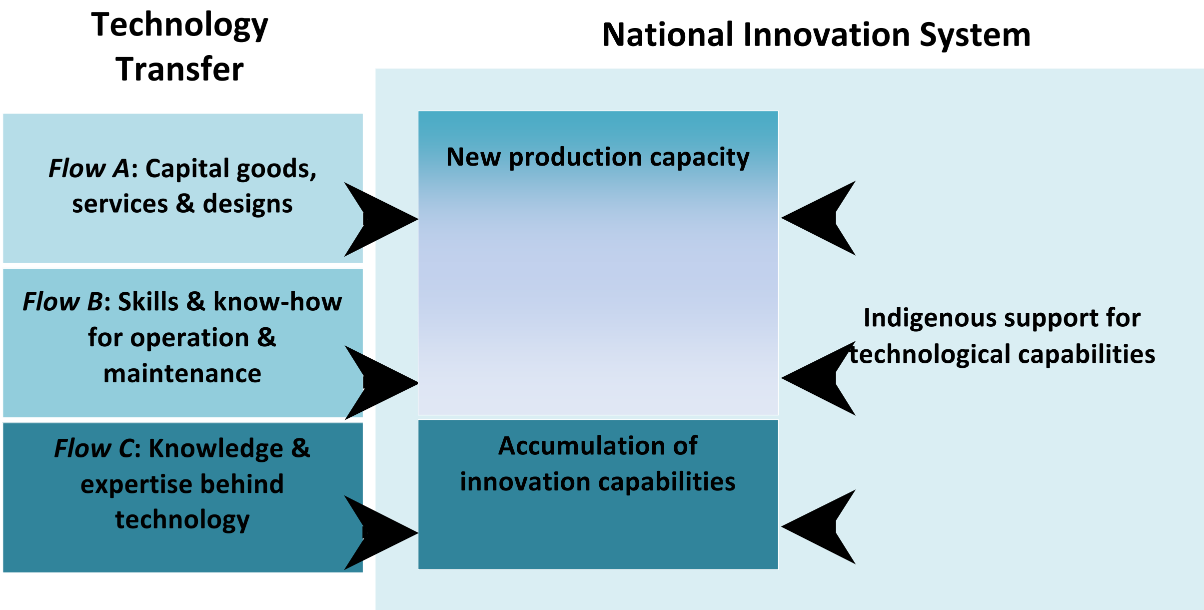

Figure 1: Technology transfer and indigenous innovation

Source: Adapted from Watson et al (2011: 16) based on Bell (1990)

The diagram in Figure 1 does not show explicitly the importance of the institutional environment, although the innovation literature does so, especially with regard to formal national and international policies. These can help to enhance existing industrial activity – to raise the level of capabilities to increase competitiveness, for example – but are also important for fostering new industrial activity that would otherwise not be pursued (e.g. see Cimoli et al 2009). In the case of low carbon technologies – and a concern with broader processes of low carbon technological change – this latter point is particularly relevant (Ockwell et al 2010). Many existing low carbon alternatives are not yet competitive with carbon-intensive technology options and so market demand for many low carbon technologies tends to be weak or marginal. But it is likely that we will need a range of low carbon technologies, and the need is becoming increasingly urgent. In principle, appropriate policies could foster the improvement of low carbon technologies, and the local capabilities and innovation systems that can sustain and develop them. The result could be a multiplicity of co-existing pathways, each appropriate to its context, promoting more equitable human development (Stirling 2009).

Building low carbon innovation systems

More recently, the broader dimensions of the systemic environment in which innovation and development takes place (social, cultural, political together with the economic, institutional and technical) have received attention in the socio-technical transitions literature (e.g. see Berkhout et al 2004; Byrne 2011; Geels 2002; Geels and Schot 2007; Raven 2005; Rip and Kemp 1998; Smith 2007; Smith et al 2010). And, this socio-technical approach has 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) for their application in Kenya and Tanzania. Specifically, these papers focus on the use of strategic niche management (SNM, or '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. In the case of Byrne (2011), the evolution of solar home system (SHS) markets in Kenya and Tanzania is traced over several decades from their beginning (in Kenya) in the mid 1980s. We will summarise some of the findings in the next section.

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 societal embedding of various socio-technical practices relevant to that particular technology. These co-evolutionary dynamics are assumed to happen in what amounts to a protective space – or niche – in which the normal pressures of market forces and technical performance are weakened, enabling essential learning to take place (Smith et al in press). 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 et al 2010). 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 low carbon niches. A policy aim might be, for example, to widen and deepen access to low carbon energy technologies to benefit poor and marginalised groups and do this by creating new – or nurturing existing – niches of low carbon energy technology applications amongst poor communities and households. Importantly, niche theory emphasises the role that key actors, known as "cosmopolitan actors" (Deuten 2003) or "innovation system builders", 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 low carbon energy technologies. It is here that a brief account of the evolution of the Kenyan SHS niche can illustrate these ideas.

Evolution of the Kenyan SHS niche

The brief account that follows draws on Byrne (2011), in which a fuller analysis of the Kenyan SHS niche can be found (as can an account of the Tanzanian niche). Photovoltaic (PV) technology 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, Burris 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 began to hear about this growing market. They soon entered the market themselves.

Hankins, who had gone to the UK in the late 1980s for a masters degree at Reading University, discovered this thriving market when he returned to Kenya to do research for his dissertation. After gaining his masters, he returned to Kenya and began to get involved in solar training, and 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 SHS market. Over the next decade or so, EAA became an important player in the Kenyan SHS market by implementing many projects with funding from various donors. Some of the projects were to install PV systems in community buildings, such as schools and hospitals, alongside training of local technicians. Others 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 capacity for solar batteries. And some projects were to test different financing mechanisms, such as micro-credit through local Savings and Credit Cooperatives.

Building on the ideas above, an SHS niche can be understood to have developed in Kenya, together with key aspects of a relevant innovation system, facilitated in large part by the strategic activities of certain key actors, particularly EAA. Over time, EAA worked with a wide variety of actors in the SHS niche in Kenya, and on a range of dimensions of the niche – 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 noted as important by niche theory; 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. In short, EAA can be seen as a cosmopolitan actor – or innovation system builder – in the Kenyan SHS niche.

The SHS market in Kenya is now worth about USD 6 million annually and there are more than 300,000 SHSs installed in homes across the country (Ondraczek 2012). This is still a relatively small fraction of the population with access to small quantities of electricity from PV, and so it would be premature to say that the niche has replaced the dominant view that electricity should be provided through the grid. Nevertheless, significant advances have subsequently been observed in relation to SHSs in Kenya. For example, the Kenyan government – for many years hostile to PV (and other renewable energy technologies) – recently implemented a large project to install PV systems in schools; a project worth about a third of the annual SHS market. And Kenya now has a feed-in tariff for PV (MOE 2012). Furthermore, there have been recent developments to begin manufacturing solar modules in Kenya through a Dutch-Kenyan joint venture (see http://www.ubbink.co.ke/). Before this, there had been interest from a Chinese company to manufacture modules in Kenya (Disenyana 2009) but the deal fell apart following the post-election violence in 2008.

It is also worth noting the observation that the Kenyan SHS market – one of the largest globally (Ondraczek 2012) – was not led by the private sector, contrary to the usual characterisation of it. Instead, it relied in important ways on donor interventions to create space for experimentation and learning. These interventions often involved private sector actors who then used the learning to further develop their activities in the market. So a more accurate characterisation would be that it was a public-private cooperative development (Byrne 2011).

Conclusions

The evolution of the Kenyan SHS niche demonstrates that it is possible for policy to intervene in low income countries to foster the building of low carbon innovation systems. Such interventions can make use of the notion of innovation system builders, and the Kenyan SHS niche story suggests there are roles for both public and private actors in this building effort. These roles are likely to be complementary, where the public sector can mitigate the risks of learning from which the private sector can benefit while supporting wider social gains (in this case, the increasing adoption of SHSs providing environmentally friendly electricity to rural households and the job opportunities associated with this growing market).

Furthermore, the recent development of module manufacturing suggests that the Kenyan SHS ‘innovation system’ could be at the beginning of a path followed by other countries that built their innovative capabilities over time: i.e. starting with the local manufacture of modules, there may be an evolution towards more complex capabilities around PV in Kenya. This raises the question of whether there is a pattern here that could be replicated in other countries and in other low carbon technologies. That is, should countries first develop local markets for low carbon technologies in order to attract investment in manufacturing those technologies locally? Alongside this process, the beginnings of an innovation system relevant to such technologies could be encouraged, where the innovations are mainly concerned with the delivery of services (such as rural electrification). As investments in manufacturing capacity then materialise, more complex innovative capabilities could be fostered.

Related to this building of local capabilities, there may be opportunities to address poverty reduction more directly. At present, the goal of direct poverty reduction is not really being achieved in the Kenyan SHS niche but it might be possible to put greater effort into this as the capabilities around PV evolve. That is, local innovation effort might be directed to finding ways to increase electricity access for the poor through new solar technologies and associated socio-technical practices.

Finally, it is worth reiterating our point that it is important to conceive of technology as more than just hardware. Recognising that knowledge is an essential component of technology has implications for what technologies are adopted but also for how they might be adapted and created over time. This, in turn, highlights the importance of building local innovation systems and capabilities. And wrapped up in all this is the politics of development pathways. Hankins, for example, created a narrative of private sector led development of the Kenyan SHS market that he deployed successfully to attract resources from – paradoxically – donors to help build that market. It took many years for the Kenyan government to adopt a positive view of renewable energy technologies but we might speculate that the work of actors like Hankins, together with the evidence from real experience on the ground, will have played some part in this change of heart. In other words, innovation system builders may be important for creating persuasive narratives as much as for building the more technical aspects of innovation systems. But these are tentative ideas that suggest themselves from the research and analysis reported here. There is much work to be done to integrate the theoretical insights from socio-technical transitions and innovation systems approaches. Watch this (contested?) space.

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