Low-carbon innovation for industrial sectors in developing countries

Policy brief
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Abstract

Low-carbon innovation in industrial sectors in developing countries presents economic opportunities that can help realise sustainable development pathways. Under business-as-usual, industries being established in developing countries are likely to move along carbon-intensive or inefficient pathways, increasing greenhouse gas emissions in the short term and the likelihood of establishing high-carbon lock-in over the longer term. However, there is a wealth of evidence from industrialisation experiences around the world demonstrating the kinds of strategies that make it possible to take advantage of low-carbon opportunities to instead create climate-compatible development pathways.

This policy brief aims to illuminate potential pathways and policy actions for low-carbon innovation in emerging industry sectors in developing countries. It focusses, firstly, on the low-carbon and energy efficiency gains that are possible in energy-intensive manufacturing. Secondly, the brief explores opportunities for developing countries to insert themselves into global low-carbon value chains by developing manufacturing capacity in energy-supply technologies.

The brief ends with policy recommendations that could be enacted at both the national and international levels, making use of existing institutions as well as learning from the literature on past industrialisation experiences.

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Introduction

Low-carbon innovation in industrial sectors in developing countries presents economic opportunities that can help realise sustainable development pathways. Under business-as-usual (BAU), industries being established in developing countries are likely to move along carbon-intensive or inefficient pathways – in a manner similar to those in many industrialised countries – increasing greenhouse gas (GHG) emissions in the short term and the likelihood of establishing high carbon lock-in over the longer term. This would lead to levels of CO_2 emissions that escalate further. For example, Figure 1 shows global industrial CO_2 emissions based on modelling undertaken through the LIMITS[1] project, in which it is clear that non-OECD countries will account for the bulk of industry-related GHG rises under BAU up to 2100. Fortunately, however, there is a wealth of evidence from industrialisation experiences around the world demonstrating the kinds of strategies that make it possible to take advantage of low-carbon opportunities to create, instead, climate-compatible development pathways.

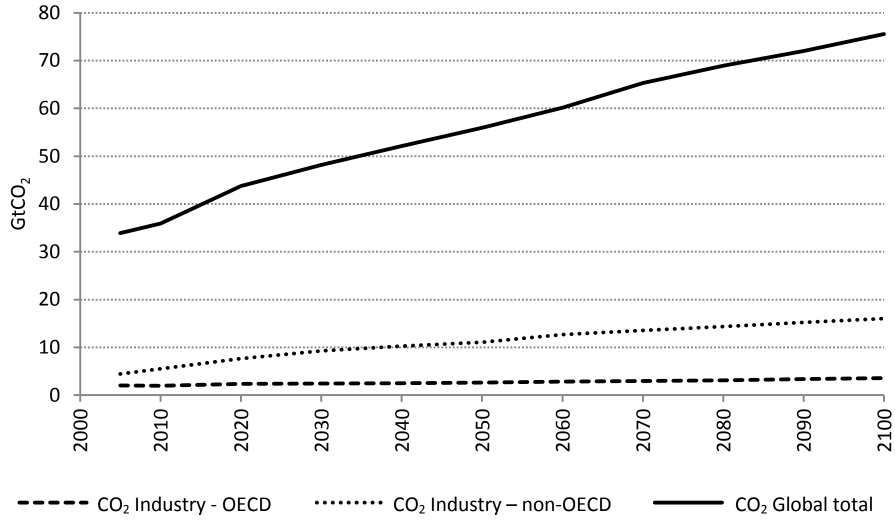

Figure 1: Historical and projected baseline industrial and total CO_2 emissions 2005 – 2100 in OECD and non-OECD[2] countries (source: based on ECN, forthcoming)

This policy brief aims to illuminate potential pathways and policy actions for low-carbon innovation in emerging industry sectors in developing countries. It focusses, firstly, on the low-carbon and energy efficiency (EE) gains that are possible in energy-intensive manufacturing, with illustrations from the cement sector in sub-Saharan Africa (SSA). Secondly, using the examples of photovoltaics (PV) in China and wind

[1] LIMITS: Low climate IMpact scenarios and the Implications of required Tight emission control Strategies (see http://www.feem-project.net/limits/index.html)
[2] Non-OECD includes Turkey, Czech Republic, Slovak Republic, Hungary, Poland, Estonia, Slovenia and Israel

power in India, the brief explores opportunities for developing countries to insert themselves into global low-carbon value chains by developing manufacturing capacity in energy-supply technologies.

Low-carbon industries in developing countries: needs, opportunities and strategies

Expanding industrial activity is, by itself, a significant challenge for many developing economies. This is now compounded by the need to move away from BAU and follow low-carbon development pathways to help address the climate challenge. Nations that are in the process of industrialisation – especially those with less developed infrastructures – are in a sense defining their industrial development trajectories. It is therefore an opportune moment to start creating pathways that position them for a climate-compatible future, thereby avoiding carbon lock-in that would later present them with the same challenges currently faced by industrialised countries.

Moreover, there are important development benefits to be gained from pursuing low-carbon development pathways. These relate to the accumulation of technological and innovative capabilities[3] that can support national efforts to achieve self-directed sustainable development goals, as well as longer-term energy security and access to markets that have environmentally stringent regulations.

There is plentiful evidence from studies of economic development that provides useful insights for creating low-carbon industrial pathways. For example, Chang (2002), Reinert (2007) and Cimoli et al. (2009) provide evidence of 'catching-up' strategies and experiences of successful countries around the world since before the British industrial revolution. These studies show that it has been an abiding feature of industrialisation in many countries to create and manage markets and to protect local firms from international competition (e.g. see Reinert 2007). Many of the policy tools used for these actions – where they generate technological learning and the accumulation of capabilities – could be relevant to fostering low-carbon industrialisation. Creating markets, for example, can be achieved by incentivising firms to invest in particular technologies – i.e. creating above-average profits or *rents* (e.g. see Schmitz et al. 2013) – whilst subsidising their consumption.

Of course, we should be careful about the use of such policy tools. There are inherent uncertainties in creating markets and using protectionism. For example, instead of firms investing in new technologies, and building the capabilities associated with them, they might simply engage in rent-seeking – extracting above-average profits from these rents without achieving any improvement in their capabilities (Cosbey 2013; Altenburg 2011). Furthermore, it is not yet clear how to mitigate these uncertainties in our interventions and incorporate their effects in our analyses (Altenburg and Pegels 2012; Schmitz et al. 2013).

[3] We use 'capabilities' to refer to skills, knowledge and connections between actors throughout a society and/or economy.

But, assuming that we can make headway using these strategies, we should recognise that capabilities also need cultivating in other parts of national innovation systems, not just within firms (Byrne et al. 2012). These include the capabilities of research institutes, policy makers, civil society and communities. Each type of actor will require particular kinds of capabilities, including technology appraisal, selection, operation and maintenance, as well as further innovation; identifying needs, and selecting and implementing appropriate policies; and participatory civil society and user engagement.[4]

Energy-intensive and manufacturing industries

Globally, industry accounted for about one-third of final energy consumption in 2010 (IEA 2013, p. 65). The global average for industrial EE is only about 30% and so enormous opportunities exist for reductions in energy demand and associated GHG emissions (GEA 2012, p. 48). EE is often seen as an easy win for reducing energy demand and GHG emissions, but there are also potential rebound effects[5] that can undermine expected benefits and these need to be understood and addressed (e.g. see Chitnis et al. 2013).

Much of the growth in energy-intensive industrial sectors is now taking place in developing countries, so it is helpful to examine what low-carbon innovation opportunities exist for improving[6] their performance. Some basic information on the cement industry in sub-Saharan Africa (SSA) is presented in Box 1, while implications for policy are described in the text below.

[4] This point was already recognised in the earlier policy briefs on the bottom of the pyramid and the rising middle class (Sagar 2013; de Coninck and Byrne 2013).
[5] According to Chitnis et al. (2013, p. 235), "Rebound effect" is an umbrella term for a variety of behavioural responses to improved energy efficiency of which the effect is a net increase in energy consumption and carbon/GHG emissions relative to a counterfactual baseline.
[6] There are several international efforts to improve efficiency in industrial production, the most long-standing of which is the joint UNIDO-UNEP Resource Efficient and Cleaner Production (RECP) Programme (see http://www.unep.fr/scp/cp/).

Box 1: Case study cement manufacturing in sub-Saharan Africa

The cement industry in sub-Saharan Africa is oligopolistic, with just a few firms competing in some countries. Many of the large companies are multinationals headquartered in Europe or North America, but there is also a Nigerian international cement producer (Dangote). The structure of the industry, together with a legacy of former widespread state-ownership of cement production, means that innovations that could have reduced costs have been avoided through lobbying against imports of cement so as to maximise returns on existing production facilities.

However, import-bans have been lifted in some countries in order to try to meet high demand. The outcomes have been mixed. In Kenya, for example, there have been investments in new plant and innovations towards lower costs. In Tanzania, this has not been the case so much as demand was still not met.

Whilst some of the innovations that occurred as a result of market price pressure have reduced carbon intensity – such as using less clinker in the production process – others have increased carbon intensity by switching to coal to power the production process.

Sources: Ionita (2012); Ionita et al. (2013)

Low-carbon innovation in the production of cement in SSA is coming from a mix of indigenous innovation, market pressure, foreign expertise and interventions by finance organisations (in particular, multilateral development banks) (Ionita 2012; Ionita et al. 2013).

African-owned multinational cement companies seem to be as efficient in their production operations as multinationals from Annex-I countries. However, locally-owned companies producing mainly for their local markets are less efficient (in particular in countries with high import barriers for cement), have poorer access to knowledge on low-carbon technologies, and have weaker incentives to innovate. The weak price pressure as a result of an absence of competition helps to explain some of the disparity between locally-owned and multinational performance.

Protection of local firms

An additional explanation for this performance-disparity could be a lack of innovation capabilities among local firms. Protectionism can be used to help local firms build such capabilities, but can also be ineffective – or worse – for achieving low-carbon and efficiency goals if it results in rent-extraction from a captive market. The key here is to use – and withdraw – protectionism strategically (e.g. see Khan and Blankenburg 2009; and the cases on PV and wind power discussed below).

Some evidence suggests that rent-extraction is the more likely explanation for protection in the case of SSA cement production. The company Dangote, for example, has successfully lobbied the Nigerian government to ban imports since the beginning of 2012, thereby denying the local market access to cheaper cement.

However, even when imports are available, some evidence suggests that local firms do not necessarily innovate. The local Tanzanian cement manufacturers, for example, are said to have no plans to expand production despite high demand and competition from cheaper imports (Ionita 2012). One possible explanation for this is that the local firms are unwilling or unable to risk investments in new plant, preferring instead to extract rents from existing operations. Increased competition from even more imports might create the necessary pressure to encourage local firms to invest in new plant but, for now, it appears that they can sell all their cement despite its higher price.

The lessons here are that market protection policies to encourage innovation need to avoid fostering rent-extraction behaviour (Schwarzer 2013), be in line with market demand and have removal of the policies built in when support is no longer needed.

Innovation in equipment manufacturing

Policy interventions for low-carbon innovation in the cement sector in SSA are just beginning to develop. There are innovation efforts around manufacture of equipment (type of kiln) and in basic R&D in this field. Research institutes are opening in many SSA countries and knowledge-sharing networks are being supported between European and African countries (Nassingwa and Nangoku 2012; Msinjili and Schmidt 2012; SPIN 2011; Gluth et al. 2011). Still, poor communication between research institutes and industry is somewhat hindering these innovation efforts (Nassingwa and Nangoku 2012). If they are to be successful then there is a need to enhance such communications.

Energy efficiency, energy sources and GHG emissions

In response to increasing demand on the continent, investments in new plants are being made and tend to be based on best available technology (BAT), which generally means the use of dry-process[7] production equipment (Ionita et al. 2013). Multilateral development bank lending has played a role in some of these low-carbon investments, with loans conditionally tied to choice of technology.

However, in order to cut production costs, there is also a move towards using coal as the main energy source, while the use of coal for heating is already high in SSA compared to other regions (Ionita 2012). So, while EE is being improved, the GHG benefits can be undermined by the turn to higher-carbon energy sources.

Agreements and industry initiatives

Some of the main players in the SSA market are members of the World Business Council for Sustainable Development (WBCSD) Cement Sustainability Initiative (CSI), which included a commitment to a 20% reduction in CO_2 emissions from cement production by 2012 (WBCSD 2012; Ionita et al. 2013). It is not clear whether this was achieved. However, it is clear that CSI members have access to the latest technologies, the best capabilities, and to finance that could further low-carbon options in the cement sector in SSA (Ionita et al. 2013). As they have largely exhausted current EE opportunities in their plants in other parts of the world, they are more likely to drive low-carbon innovation in the SSA market next (Ionita 2012).

[7] Dry-process cement production is considerably more energy-efficient than the older wet-process method (Müller and Harnisch 2008).

Policy for low-carbon innovation in energy-intensive industries

Whilst there are clearly market forces at play to encourage investments in low-carbon innovation, there are also factors hindering these investments. As such, there is still much that government policy can do to foster low-carbon innovation in EE in the SSA cement industry, and much that is likely needed in other energy-intensive industries. Relevant policy interventions include: regulation to ensure the use of BATs; enhancing knowledge-sharing networks; strategic use of foreign investments to build local capabilities (such as through joint ventures between foreign and local firms); and policies that favour the use of low-carbon energy sources over fossil fuels.

Energy supply technology manufacturing

Favouring low-carbon energy over fossil fuels will require huge scaling-up of investment and capability-building throughout the low-carbon energy supply system, as well as complementary measures against fossil fuels. Investment needs in renewable energy systems, for example, are estimated to be in the range of USD 260-1,010 billion annually up to 2050 (GEA 2012, p. 29). As with energy-intensive industries, this challenge offers economic opportunities for developing countries. Some of these opportunities lie in the increased use of low-carbon energy technologies to service growing energy demand at all levels from the household to industrial activity. Other opportunities lie in the manufacture of low-carbon energy technologies for the local energy system and for export. Driven by local and foreign demand, therefore, both large-scale and modular energy supply industries can be fostered in developing countries that are looking to industrialise.

Box 2: India's wind energy industry

India has long supported the development of a domestic wind power industry, beginning in the 1990s (Sharma et al 2012). However, policy support has not always been stable, reflected in uneven growth of the industry (Lewis 2007). Still, support has included aggressive market-creation policies (e.g. Feed-in Tariffs, FITs), protectionism through the use of import tariffs on complete turbines (to encourage local assembly and, perhaps, reverse-engineering of components), state-level targets for wind-powered generation, tax breaks, and many others.

The domestic firm Suzlon has evolved as a major presence, alongside international wind turbine manufacturers. Suzlon has taken advantage of increasing global specialization of knowledge and manufacturing – seen in the emergence of global value chains – to establish itself within a relatively short time frame. Following its successful rapid growth, Suzlon has also bought specialist firms in other countries, diversifying its capabilities and building its own international networks (Lewis 2007).

Box 2 outlines the experience of India's wind energy industry. In terms of the strategies used to create this experience, research shows that Indian firms have built their technological capabilities through a sequence of licensing the production of foreign technologies, joint ventures with technology leaders and collaborative R&D (Lewis 2007; Lema and Lema 2013). It also seems that the building of such capabilities in wind power in India helps to explain some of the success it has enjoyed in attracting Clean Development Mechanism (CDM) projects in the sector (Lema and Lema 2013).

In China, there have been several strategies used by Chinese firms to rapidly develop their manufacturing capabilities and become increasingly competitive (see Box 3 for a sketch of the Chinese PV experience). Initially, production capabilities were developed by buying production equipment from foreign suppliers, mainly in Germany and the US. But more complex knowledge has been developed through the recruitment of expertise and talent from abroad, as well as benefits gained from foreign-educated and trained Chinese engineers who returned to China to start or join new companies. Some of these engineers developed relationships with foreign companies and universities and these led to cooperative R&D agreements that continue to evolve (see Gallagher and Zhang 2013).

However, increasing competition in the manufacturing market led to reduced profits, and unstable supplies of increasingly costly silicon ingots. Chinese firms responded by vertically integrating upstream segments of the PV value chain – polysilicon, ingot and wafer manufacture. More recently, the firms have vertically integrated downstream segments such as the manufacture of balance-of-system components, system integration, installation and others. By capturing more of the value chain within the operations of single firms, Chinese PV companies have been able to reduce their costs, and therefore increase their profits while maintaining or improving their global competitiveness.

An unexpected benefit of vertical integration in China has been the evolution of PV industrial clusters. These have led to better communication between engineers, even in different plants, and some cutting-edge process innovations as a result. For example, it is claimed that some Chinese firms are able to cut PV wafers thinner than their foreign competitors, reducing waste and thereby cutting costs. Still, some firms are getting access to 'frontier' knowledge by acquiring or investing in foreign firms, in much the same way that other Chinese industries have enhanced their capabilities, which also gives them better access to foreign markets. The same goes for India's wind power industry (Lema and Lema 2013).

Box 3: Case study PV manufacturing in China

Although China only entered the global PV industry in 2001, its experience with the technology is long-standing. It first fabricated a silicon solar cell in 1958, soon after the United States, and subsequently used the technology in space applications. By the mid-1970s, China was using PV in rural areas and established small-scale manufacturing in the 1980s. Starting in 1985, it began importing production lines from the US, Canada and others, increasing its production capacity to 4.5 MW per year. China could be seen, therefore, as building some PV manufacturing capabilities by servicing this local demand. Later, growing demand in Japan and Germany – driven by their market-creation policies – spurred the company Suntech to establish a 10 MW production line in 2002. Many Chinese firms subsequently entered the module-manufacturing market and China became the world's leading producer of PV modules in 2007, reaching 20 GW annual capacity in 2010. But the global financial crisis has resulted in scaled-back market-creation policies in many of the countries to which China was exporting and so China has compensated by introducing domestic market-creation policies instead. Furthermore, it is hoping that PV can play a role in mitigating climate change and enhancing energy security. Its 12th five-year plan has domestic targets of 35 GW installed PV by 2015, and 100 GW by 2020.

Source: Gallagher and Zhang (2013)

Building local capabilities for manufacturing energy technology

These cases from the Chinese PV industry and wind power in India illustrate more general findings in studies of industrialisation (e.g. Chang 2002; Reinert 2007; Cimoli et al. 2009). We could, therefore, suggest that countries with weak technological capabilities – in general, the less-developed countries – might prefer to pursue industrialisation by helping local firms build their technological capabilities to service local protected markets and gradually transition to opening up those markets to increasing international competition. Local firms would then be able to build their absorptive capacity before they can begin to benefit from knowledge 'at the frontier' and face increased exposure to international competition.

Policy recommendations for low-carbon pathways in industry

Case-based reviews of two areas of industrial activity – energy-intensive and energy-supply technology manufacturing – have revealed potential interventions that could have significant impacts on GHG mitigation while leveraging important development benefits for industrialising developing countries. This provides a basis on which to deduce policy recommendations but, first, we must observe that each developing country will have its own 'starting point' when embarking on a low-carbon development pathway. Therefore, it is important that low-carbon development policies are aligned with national priorities. Once those priorities are clear, international support can be requested – wherever this is appropriate – to assist in reaching widely-accepted policy aims.

National policy: Low-carbon innovation capabilities

An important aspect of low-carbon innovation is the building of appropriate local technological and innovation capabilities. Building these capabilities takes time, resources, directed effort and policy-supported nurturing. In sectors where a country or region envisions potential industrial development, it is therefore essential to start capability-building processes as soon as possible. Appropriate policies and measures at the national level are key to these building processes and the development of low-carbon innovation in industry.

National policy: Appropriate protection

Countries that have succeeded in building strong technological and innovation capabilities have done so using appropriate protectionism. They have used protected local markets to help local firms – competing with each other within the national context – build up sufficiently strong capabilities before being exposed to competition from foreign firms in national and international markets (Chang 2002; Reinert 2007; Cimoli et al. 2009).

But not all infant-industry nurturing has been successful and so careful attention must be paid to the lessons of experiences around the world. In addition, new constraints on what is permissible under the international trade regime that were not in place while other countries were pursuing their 'catching-up' strategies need to be considered when devising protectionist policies (Cimoli et al. 2009; Cosbey 2013).

National policy: in an international context

Measures taken at the national level need to be implemented in a stable policy environment. Nationally Appropriate Mitigation Actions (NAMAs) and Low-Emissions Development Strategies (LEDS) could be useful tools for policy makers to help articulate clear visions and policies that enable such a stable environment. In energy-intensive industry, regulation or enforcement of BATs can be effective.

For some sectors – in particular those where studies show considerable cost-effective efficiency gains can be achieved – it can be effective in the short term to open up markets to let price pressure and international competition drive innovation processes. However, when there are multiple firms already competing in the domestic market, creation and protection of domestic markets could also prove effective and could help nurture innovation capabilities in firms in a less competition intense environment (see "Appropriate protection").

International assistance

Various international institutions, such as those operating under the UNFCCC, World Bank, multilateral development banks, UNIDO and UNEP, could also help in building-in an integral low-carbon element to this capability development. For instance:

- The Climate Technology Centre and Network (CTCN) as a condition supports innovation capabilities when responding to country requests. It can also manage centralised but industry-specific technology information (such as through its knowledge management system that is currently being developed). It may also be well-placed to help developing countries formulate capability-building programmes in specific technologies and sectors, working in cooperation with other technology and innovation centres such as the CICs (see next bullet point). For other, more specific, recommendations regarding the work of the CTCN, see for example Bhasin (2013).

- The Climate Innovation Centres (CICs) set up by the World Bank's infoDev programme have less of a focus on innovation capabilities but could expand their aims to incorporate such elements. This is particularly relevant as CICs are located in national contexts and so are better-placed to respond to national innovation system building opportunities and needs.
- The Green Climate Fund (GCF) is discussing a technology facility, which could include a sizeable collaborative R&D facility with explicit aims around low-carbon innovation capabilities in industry. In the same facility, the GCF could also set up a revolving fund where efficiency gains could be used to repay loans.
- Multilateral development banks should continue enforcing efficiency improvements in cement plants in sub-Saharan Africa that they (partly) financed through BAT requirements when countries do not implement them themselves. Similar opportunities to enforce BAT options may be available through investments in other energy-intensive industries.

Beyond targeting emerging industrial sectors, entire innovation systems around low-carbon goods and services need to be nurtured. Capability development is not limited to researchers or business. Users, NGOs and government also require capabilities that can enable them to participate constructively in innovation systems.

International: industry and other initiatives

On the international level, there are already initiatives from which to learn and on which to build. For example, the CSI has seen industry collaboration to reduce GHG emissions. These experiences could be used to develop energy, GHG or carbon efficiency standards that could proceed from voluntary agreements to *de facto* obligatory standards. And, finally, the RECP programme being implemented through UNIDO and UNEP, noted in the EE section above, could provide wide-ranging lessons for policy making relevant to many industrial sectors that mean longer-term cleaner production in developing countries.

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CDKN Climate & Development Knowledge Network

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