

Shifting Paradigms:  
Strategy and Policies for Low-Carbon Industrial Development

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1. Introduction: Late Industrialization in the Early 21<sup>st</sup> Century
2. Catching Up, Leaping Ahead
3. Finding a Place in the Low-Carbon Industrial Paradigm
4. Policies to Promote Low-Carbon Industrial Development
5. The International Context for Promoting Low-Carbon Industrial Development
6. Conclusions

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<sup>1</sup>The views expressed here are the author's and do not necessarily represent those of his affiliated institution.

## 1. Introduction: Late Industrialization in the Early 21<sup>st</sup> Century

The second half of the twentieth century saw rapid industrialization in a number of East Asian countries, beginning with Japan and continuing with its near neighbors. Japan not only managed to close the income gap with Western Europe but eventually surpassed the EU-15 average income. The Republic of Korea and Taiwan are both now middle-income countries. Other countries or territories which achieved varying levels of industrial development in the late 20<sup>th</sup> century include Singapore, Hong Kong, Malaysia, Thailand, Indonesia and the Philippines in Asia, Brazil, Chile and Mexico in Latin America, and Turkey in Europe. Eastern Europe and the states of the former Soviet Union had also achieved varying degrees of industrialization. Toward the latter part of the 20<sup>th</sup> century, the continental-sized economies first of China and then of India began their rapid industrialization, which continues till today.

All of these countries industrialized or began to industrialize during an era of relatively abundant and cheap fossil-fuel-based energy. Depending on other available energy sources, they have relied to varying degrees on fossil fuels but nowhere has such reliance been negligible.

The twenty-first century will be different. Addressing global climate change necessitates that 21<sup>st</sup> century industrializers find other means than fossil-fuel energy of powering their industrial development. If they do not, and if the international community does not significantly reduce greenhouse gas emissions over this century, the possibilities for sustained industrial development and economic growth may well be seriously compromised.

Another way of looking at the challenges to industrial and broader economic development over the coming century is to consider two extreme cases: one where the international community makes no further progress beyond the Kyoto Protocol to slow GHG emissions; the other where the international community agrees and keeps to ambitious reduction targets – say, of 80% below 1990 levels by 2050. In the first case, industrial and other economic activity will be geared increasingly to coping with the impacts of climate change. New technologies will need to be developed and exploited to build resilience and protect economic assets from damage and destruction by the human-altered forces of nature. No one knows at present how large a share of economic resources will need to be devoted to such coping and adaptation activities. It might be small but it might also be enormous<sup>2</sup>. In the second case, major

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<sup>2</sup> The World Bank has recently estimated adaptation investment needs at \$75-100 billion per year to 2050, roughly half in developing countries. This figure is modest but also assumes modest climate change and impacts.

new investments will be needed over the coming decades in new technologies, capital equipment and infrastructure to reduce GHG emissions from electricity generation, transport, industrial processes, agriculture, forestry and land-use changes.

In this paper, it is assumed that the international community chooses the second course, that of steeply reducing global GHG emissions. Then, what are the industrial development prospects for late industrializers? What new constraints and new opportunities will they face? What do those imply for public policy?

The paper does not prejudge the shape of an international agreement to reduce steeply GHG emissions over the coming decades (i.e., between now and 2050). Optimistically, some such deal will be sealed at Copenhagen in December. Whatever form of commitments developing countries (non-Annex 1 countries in the terms of the UNFCCC) may make (whether to emission reductions or to “bending the curve” of emissions growth), it is presumed that such commitments would be reciprocated and reinforced by commitments of technology, finance and capacity building by Annex 1 countries.

## 2. Catching Up, Leaping Ahead

The presumed shift away from fossil-fuel energy which will need to be accomplished over the next 50 years represents a paradigm shift in modern economies. There are two aspects of such a shift. First, economic activities of the 21<sup>st</sup> century will need to become ever more energy efficient, with a quantum shift downward in energy use per unit of economic activity. Second, the energy which is used in economic activities will need to be supplied from sources other than fossil fuels. So, two sets of technologies will prove crucial to this shift – those to conserve on energy use, and those to supply energy cost efficiently from non-fossil-fuel sources, including renewables and nuclear. A third possibility, not considered in detail here, is to develop technologies which permit the continued burning of fossil fuels with the capture and storage of the resultant carbon dioxide.

Many of these energy efficiency and alternative energy technologies already exist but are not yet widely deployed<sup>3</sup>. As the international policy framework and national policy measures strengthen incentives to adopt them, their use could be expected to grow rapidly, even exponentially at first. This will generate

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<sup>3</sup> Enkvist et al. (2007), “A cost curve for greenhouse gas reduction”, *The McKinsey Quarterly*, 1.

sizeable economies of learning and scale, making the technologies cheaper and more affordable to more users, including in lower-income countries.

There are two important questions which this scenario poses for late industrializers: how will the widespread adoption of low-carbon technologies affect the nature of industrial activities and the direction of industrial development? who will supply these technologies and the capital, intermediate and consumer goods in which they are embodied?

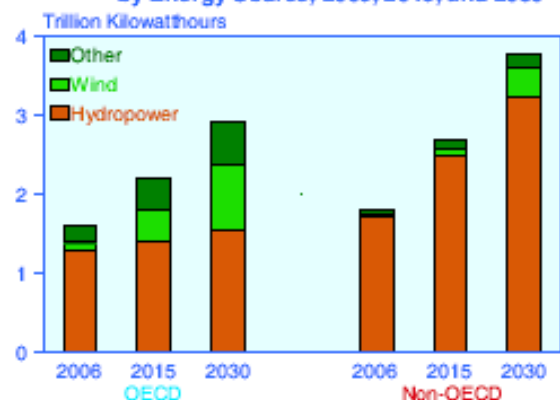
#### Low-carbon technologies, global markets, and industrial development pathways

An ambitious greenhouse gas mitigation effort will transform many markets. Even at their current modest level of ambition, climate policies of national governments and regional groupings are making their mark. For instance, the UNEP Sustainable Finance Initiative (2009) reports that for the first time in 2008 global investments in renewable energy exceeded those in fossil fuels. This represents roughly US\$40 billion in demand for related capital equipment and infrastructure. Likewise, the market for biofuels for use in transport has been growing rapidly in the past several years<sup>4</sup>. Projections of future growth in the markets for renewable energy technologies show great dynamism. Just how great will depend in large part on domestic policies in emerging (BRICS+) economies to promote renewables and low-carbon energy more generally. As these economies are projected to grow much faster than the Annex 1 countries over the coming decades, their climate and energy policies could have a strong influence on global demand for low-carbon technologies. If they were to adopt strong GHG mitigation measures, the markets for such technologies would take off.

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<sup>4</sup> In the 15 years from 1992 to 2007, ethanol production grew by 12.6% per year. Source: Renewable Fuels Association data.

Figure 7. World Renewable Electricity Generation by Energy Source, 2006, 2015, and 2030



Sources: 2006: Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site [www.eia.doe.gov/iea](http://www.eia.doe.gov/iea). Projections: EIA, *World Energy Projections Plus* (2009).

What incentives do the BRICS+ have to adopt such measures? Financial support from Annex 1 countries to cover the incremental costs of adopting low-carbon technologies would provide some incentive, but not a particularly strong one on its own as it would do little more than make investors indifferent as between the low-carbon option and the high-carbon one. A more powerful incentive would be the prospect of gaining a competitive advantage in a low-carbon technology (or technologies). This has been an important consideration, for instance, in Brazil's sustained support for its biofuels sector, which is an international cost and technology leader. China and India have credible chances of being industry leaders in certain other renewable energy technologies. Pursuing market share leadership may be possible based on an export strategy alone – e.g., much of China's photovoltaic production is for export – but technology leadership is likely to require a sizeable and sophisticated domestic market, which in turn requires supporting policies.

India can now make 700 megawatts of photovoltaic modules each year but aims to make 20,000 megawatts annually by 2017 and to establish expertise in solar thermal technologies. Total costs would be 85,000 and 105,000 crores (\$18.5 billion to \$22.8 billion) over a 30-year period. To help finance the project, the plan foresees a significant tax on gasoline and diesel — fuels the government currently subsidizes. The plan also foresees a feed-in tariff, solar power purchase obligations for Indian authorities, tax breaks for manufacturers, and exemptions on tariffs for imported equipment. A so-called Solar Energy Authority of India would be set up to manage the system (NYT, 5 June 2009).

An important impact of such policies should be to drive down the costs of renewable energy technologies, making them ever more competitive with fossil-fuel energy. While strong Annex 1 commitments to emission reductions would on their own stimulate demand for renewable energy technologies and lower their costs, the added advantage of strong renewables growth in the BRICS+ is that the cost curves of their renewable energy industries are already below those of many Annex 1 countries. While their technologies may also have somewhat lower performance, many customers may be willing to trade some performance for lower cost.

Other considerations may tip the balance in favor of renewable energy in a cost dead heat with fossil fuel energy. One is energy security, if the choice is between reliance on imported fossil fuels and use of domestic renewable energy supplies. Another may be expectations of future relative cost declines for renewables, given the projected evolution of global demand and learning economies on the one hand and of global prices of fossil fuels on the other. Long-term expectations are particularly relevant in the case of power plants where investments may have a productive life of a half century or more.

#### Low-carbon technologies: impacts on existing and prospects for new industries

There is an historical precedent in our lifetimes for the paradigm shift we are likely to witness in the coming half century, viz., the information technology revolution of the past half century. Especially since around the mid-1970s, computer and information technologies have developed at a phenomenal pace, literally transforming the global economy. Many modern-day economic activities are impossible to conceive without such technologies.

While the underlying innovations – the integrated circuit, microprocessor, personal computer operating system, mobile telephony, internet search engine and others – were made in the industrialized countries, the manufacture of many of the products which embody them is now dominated by rapidly industrializing countries of Asia. Indeed, it is no exaggeration to say that, for some of those countries, industrialization has been built on new information and communication technologies. This is nowhere truer than in Taiwan, Singapore and Malaysia. Today, China has come to dominate the manufacture of many electronic products, including personal computers and mobile phones.

The manufacture of computer and communications equipment and components on a large scale remains confined to a relatively few countries. Yet, those technologies are pervasive in use across the globe. Moreover, writing the associated software is an activity which is more diffuse, even if a few large

companies dominate strategic segments of the software business. The technologies themselves have permitted the geographic separation of productive activities which can be integrated over global communications networks. This is what has given rise, for example, to the global information technology (IT) outsourcing industry, in which India predominates and the Philippines also has a major presence.

Virtually instantaneous information flows across global networks have revolutionized finance, logistics, travel and tourism and certain other service industries as well.

The impact of ICTs has been not only on costs of various economic activities but also on the range of such activities and on the features of various products. Many goods and services simply did not exist or were far more limited in their functionality before the advent of ICTs.

So, ICTs spawned a paradigm shift in the sense that the social and economic landscape has been thoroughly transformed by their widespread application to virtually every aspect of life. At the heart of that paradigm shift is a simple relationship known as Moore's law, which encapsulates the radical cost reductions in computing power which have been made possible by progressive miniaturization of electronic circuitry. In short, a set of technologies has made possible the supply of a steady stream of product innovations at constant or declining unit costs.

How far does this ICT revolution provide a model for what we might expect in the 21<sup>st</sup> century as the result of the imperative to shift to a low-carbon global economy?

The first thing to note is that ICTs will play a central role in the shift to a low-carbon economy. Microelectronic controls are crucial, for example, to energy efficiency in building heating and cooling, furnaces, motors, and other applications. They are also crucial to optimizing material use and reducing wastage and, by implication, energy use. Communications technologies can be important substitutes for business-related travel. Satellite imagery is crucial to monitoring land-use change and deforestation. The list is long. Precisely because ICTs are so pervasive, they are almost certain to be integral components of any technological fixes for GHG emissions.

Secondly, other technologies which co-evolved with ICTs like new materials and biotechnology will continue to co-evolve and will also be central to the low-carbon energy and industrial revolution of the coming decades. Thus, industries built on these technologies and on their intersection with ICTs are likely to thrive in this new low-carbon era. For instance, wind turbine blades require high-strength

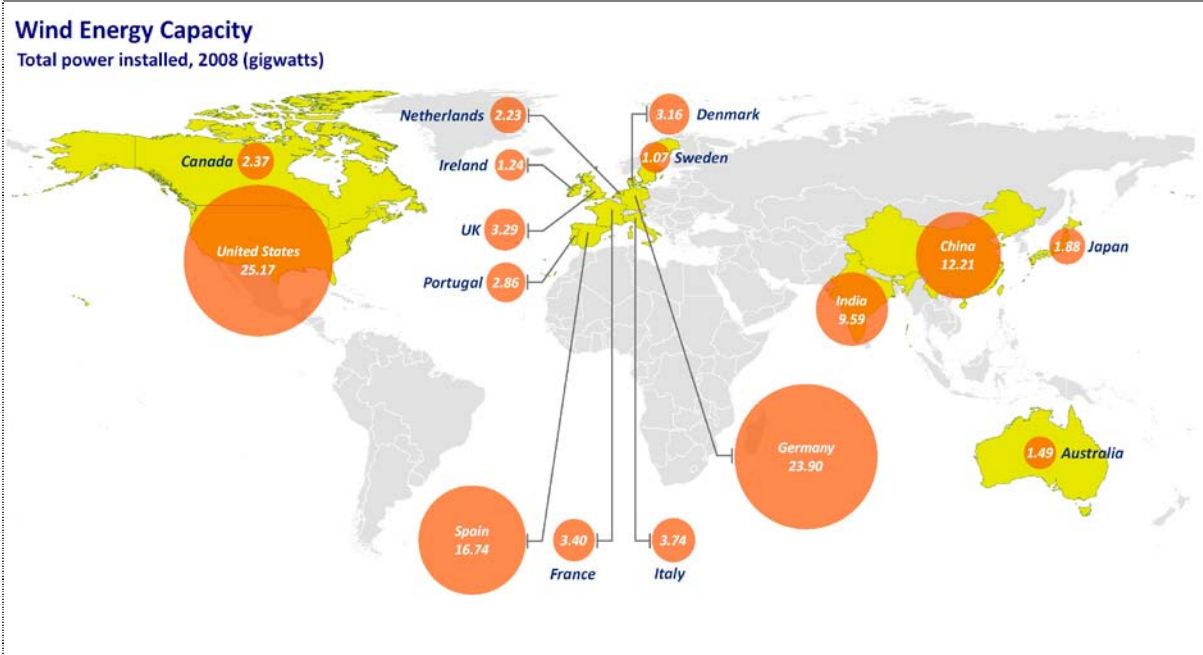
carbon fiber to withstand the torque. New, more efficient battery storage technologies and photovoltaics will depend on innovations in chemistry, materials and nanotechnology. Second-generation biofuels will depend on biotechnology know how. Thus, those countries which have established a foothold in these technologies will be well-positioned to benefit.

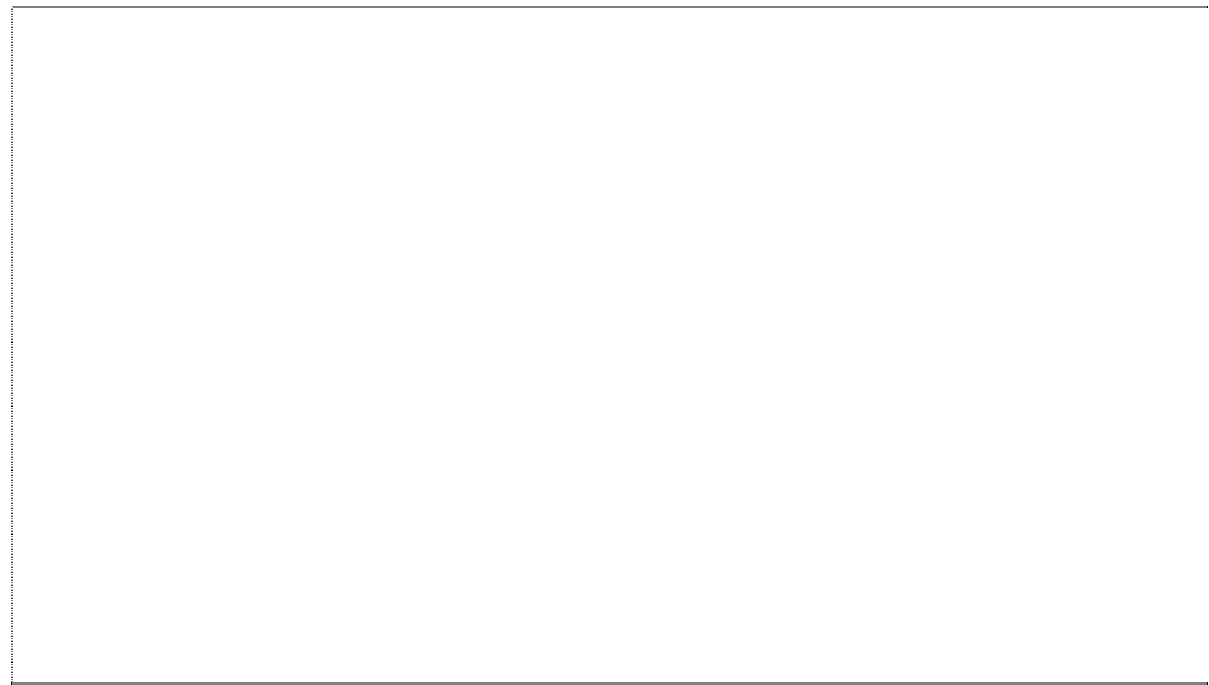
Can low-carbon energy technologies (LCETs) be considered “general-purpose technologies” (GPTs) in the sense of having pervasive applications, like ICTs, across the economy and providing a sustained boost to productivity growth? In part, they are simply a variant of an earlier GPT, electricity, whose impacts on productivity growth have already worked their way through the industrialized economies but are still doing so through less developed ones. The difference is that certain LCETs – viz., energy efficiency technologies -- can in principle boost considerably the energy productivity of late industrializing countries. Moreover, they do so in no small measure through the application of ICTs to energy management in all devices, systems and activities of production and consumption. In this sense, they are GPTs.

Will the technologies of the low-carbon industrial era overturn the established industrial order? While that seems unlikely, it is quite possible that there will be an opening for some late industrializers to establish a solid industrial base on key new low-carbon technologies. This is already being demonstrated by Brazil’s dominance in the bioethanol industry. The Republic of Korea is actively developing its renewable energy, low-emissions vehicle and other low-carbon technologies. China and India have demonstrated significant potential in the wind and solar power industries, with the Chinese government reportedly supporting domestic manufacturers through procurement policies of the power sector (NY Times, 14 July 2009). Given the enormous wind and solar capacity which these two countries could potentially install in the next 50 years, there is every reason to expect that they will be major producers of the associated capital equipment.

The following maps show installed capacity of wind power and photovoltaics. Those countries which have sizeable installed capacity of a particular low-carbon energy technology – e.g., wind or solar power – also tend to have large-scale production of the associated equipment (though imports may also be large). With time, there may be greater specialization and trade in these technologies, but early movers are likely to enjoy certain advantages, e.g., through the accumulation of skills and the development of specialized input and service suppliers which can lower costs and raise quality vis-à-vis latecomers. (Indeed, this is the basis of European renewable equipment manufacturers’ strategies in the face of stiff

competition from Chinese ones.) Moreover, even with specialization and trade, it is likely that there will be multiple suppliers of a number of the relevant technologies, while in others economies of scale and high entry costs may limit numbers. Which developing countries establish a foothold in which of the new industrial sectors of the low-carbon economy will depend in part on history – i.e., on whether they are producing related technologies, partly on industrial and technology policies aimed at developing or strengthening competencies in a given area, and partly on chance.





Our interest here is principally in what role industrial policies can play in helping countries acquire industrial competency in key sectors producing low-carbon technologies, ones with strong growth potential, strong linkages to other economic sectors and strong synergies with and potential for knowledge spillovers to other emerging technologies<sup>5</sup>.

### 3. Finding a Place in the Low-Carbon Industrial Paradigm

Countries differ widely in both their level of industrial development (as measured for example by the share of industrial value added in GDP) and in their industrial structures. Among developing countries, industrial capabilities range from those of a Republic of Korea, with its highly developed electronics, shipbuilding and automotive industries, to those of a Bangladesh, with its industrial sector still heavily dominated by textiles and garment making. A low-carbon paradigm shift is likely to have different implications for these different sets of developing countries.

Broadly speaking, one can categorize the effects of such a paradigm shift into six types: (i) effects on industries which make products whose consumption is low in energy demand but whose production uses energy to varying degrees; (ii) effects on industries producing energy-using products like

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<sup>5</sup> For a discussion of the importance of these attributes of industry sectors to knowledge and technology spillovers, see D. Rodrik (2008).

automobiles and consumer appliances, computers and other electronics equipment; (iii) effects on demand for new technologies of power generation, storage and distribution; (iv) effects on producers of a range of energy-using capital equipment; (v) effects on the design and construction of the housing and building stock; (vi) effects on relative prices of material inputs and hence on the material make-up of products.

Developing countries will experience different combinations of effects depending on their prevalent industrial structure. For example, some may have large industrial production of consumables and construction materials but little production of consumer durables. Some may have rather energy-intensive industrial structures, with a high concentration of production in so-called “heavy industry”, while others’ industrial sectors may consist predominantly of “light industry”.

In the first category are the industries of many developing countries, including the garment makers of Bangladesh as well as processed food makers and others making consumables. These industries differ in the energy intensity of their direct production processes as well as of the distribution of their products. Thus, they will be affected differentially by higher expected costs of carbon-based energy. Where energy represents a larger share of production costs, the incentives to energy saving and switching will be correspondingly greater. The basic product technologies may not be radically different in a low-carbon paradigm, but packaging technologies may well be as energy-intensive packaging materials become more expensive. Production methods could also change as incentives to use less energy in production become stronger. For many of these industries, however, the impact of a low-carbon paradigm shift may be incremental rather than radical.

The biggest potential impact could be on the location of production, if transport costs rise significantly as a share of total product costs. This could be a particular concern for those countries which are producing far from their ultimate markets goods which have a high weight to value ratio.

The second category of industry is likely to be much more profoundly affected by a low-carbon paradigm shift than the first. Automobiles, other consumer durables and other energy-using equipment will see design changes to alter their energy requirements. In the case of automobiles, these changes are likely to be the most radical, with the basic technology of the internal combustion engine affected. When such fundamental technological shifts are imminent, there is the possibility at least of new entrants gaining a significant advantage based on superior technological solutions. This possibility is enhanced

during the present economic crisis by the parlous state of some erstwhile leading auto manufacturers, notably in the United States. Just as the Japanese automobile industry established itself globally in response to the market opportunity offered by the oil price shock of the 1970s, there is an opening now for companies with low-cost, low-carbon automotive technologies, though Japanese car makers have established an early lead in hybrids. An efficient, low-cost, light, rechargeable battery technology would be a promising technological breakthrough in this regard, though not the only one.

The increased prices of fossil fuels would also provide an incentive to further development of rail and other mass transit, in particular electric-powered systems, as an alternative to the automobile. In developing countries where the transport infrastructure is still not highly developed, foresighted government policy to promote mass transit could preempt the emergence of a transport system dominated by the private automobile. In some developing countries (e.g., India), the rail network is already highly developed and could be further developed to accommodate increased passenger and freight traffic. The production of both track and rolling stock for an expanded rail network as well as of energy-efficient, low-emissions buses – e.g., for deployment in increasingly popular bus rapid transit (BRT) systems -- would need to be expanded in line with growing demand. The mass transport equipment sector could thus become an important pillar of industry in some developing countries.

A breakthrough in battery storage for motor vehicles would only hold promise for decarbonizing economies if linked to major advances in the generation of electrical power from non-carbon energy sources. That cluster encompasses the third set of industries mentioned above, to which we shall return momentarily, which produces equipment for non-fossil-fuel power generation and distribution. First, we consider other consumer durables – notably electrical appliances of various kinds (air conditioners, refrigerators, washing machines and dryers, etc.) and consumer electronics like televisions, DVDs, stereo systems, etc. – and computers, communications and other electronics equipment. There are significant economies of scale in the former group of industries, which tend to be dominated by a small number of global manufacturers, but these firms have widely dispersed operations – often in the form of joint ventures -- for the assembly of their appliances for local or regional markets.

There has been considerable convergence over the past few decades between consumer electronics and computers and communications equipment, with the process control and precision requirements for various components of both becoming increasingly demanding – witness for example widescreen video displays for home entertainment systems, microchips for cellphones and i-pods, etc. Entry into these

areas of manufacturing is becoming increasingly difficult not only because of high capital investment requirements but because of high engineering skill requirements.

Still, in a low-carbon industrial era, there will be an emergent demand for new display, chip and other electronics technologies which are far more efficient in their power consumption. Firms which can supply the energy efficient replacements (or enhancements) of existing technologies will enjoy considerable growth prospects. Where will such firms emerge? They may well be industry incumbents, but they may also be start-ups which challenge incumbents – if only eventually to be acquired by them. They are not, however, likely to emerge in a country with no significant manufacturing base of related enterprises and without relatively sophisticated technological capabilities.

In the case of home electrical appliances, the main impact of the shift to low-carbon economies will be on how the appliances manage power consumption, especially by their motors, compressors, heat coils and heat exchangers, and how they capture and re-use waste heat. All types of household appliances will be affected, albeit to varying degrees, by the demand for more efficient energy use. Once more, it is uncertain from whence the basic innovations for power saving will originate. Still, as the production capacity for such appliances tends to be widely dispersed – even if production of core components is less so – and as motor, compressor and other relevant technologies are mature and widely understood, sources of innovation may not be as highly concentrated as in the case of state-of-the-art electronics products. Moreover, as much consumer appliance production occurs in joint ventures, there is greater scope for sharing by developing country firms in the intellectual property rights associated with such energy-saving innovations.

The third cluster of industries considered is those making equipment for generation, storage and distribution of power from alternative sources to fossil fuels. The nuclear industry is well studied and will not be the focus here, even if a new generation of nuclear reactor technologies has opened up possibilities for significant expansion of nuclear power over the coming century. The focus is rather on renewable energy technologies. This cluster of technologies lies at the heart of the new low-carbon industrial paradigm. Setting aside nuclear power and carbon capture and storage (the potential of which remains highly uncertain), renewable energy will need to supply the balance of incremental energy demand in the global economy over the coming century (though there is also likely to be substitution in the short- to medium term from coal to natural gas). If high GDP growth rates are to be sustained in emerging economies and extended to other developing countries, and even if there is a strong assumed

decoupling of economic growth from energy consumption, energy demand can be expected to grow significantly. For example, even in the IEA's 450 scenario, China's energy demand is projected to grow by 46% by 2030 and India's is projected to double<sup>6</sup>.

This set of technologies and industries holds considerable potential for late industrializers, not only as manufacturers of the equipment and components for renewable power generation and distribution but also in the use of what will ultimately be a globally distributed network of hundreds of millions of power plants of widely varying scale, from micro-generators on rooftops to large concentrated solar thermal arrays and wind farms. Bioenergy (including biomass- and biogas-based power generation) may also become an important part of the energy mix in some countries. (In some it is already non-negligible – e.g., in some Scandinavian countries where woody biomass is used as fuel in thermal power plants<sup>7</sup>. In the limit, the whole planet would become one big renewable power plant<sup>8</sup>. Potentially, all economic units from individual households through farms and industrial establishments of various sizes to office buildings and factory complexes can be both consumers and producers of energy. Some will consistently be net suppliers of electricity to the grid, others consistently net purchasers, and many others alternately suppliers and buyers. Still others will be energy self-sufficient as individual establishments or complexes, producing electricity off-grid or in mini-grids. Whole countries and regions with sizeable renewable energy endowments may generate significant revenue from the export of electricity. Examples already exist – e.g., France's export of nuclear-generated electricity to its neighbors, Laos' export of hydroelectricity to Thailand – but the potential for others to participate in such trade is large – as for example with the development of solar farms in North Africa for electricity export to Europe<sup>9</sup>.

The development of the renewable energy infrastructure – not only for electricity generation and distribution but also for widespread use of electric motor vehicles (and perhaps in time hydrogen-

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<sup>6</sup> IEA (2009), *World Energy Outlook*, Special early excerpt, October.

<sup>7</sup> The west coast of Finland is home to the world's largest dry biomass fired co-generation plant, with a capacity of 240MW, relying on bark, sawdust, wood chips and cut peat as well as 10% coal or oil. Sweden, meanwhile, has established the first integrated gasification combined cycle power plant running on 100% biomass (straw).

<sup>8</sup> This may be quite literally true if recent interest in tapping geothermal power more extensively should bear fruit. A number of ventures are exploring this source of energy in the United States, but a venture in Switzerland several years ago which caused sizeable earthquakes offers a cautionary tale. James Glanz, "Deep in Bedrock: Clean Energy and Quake Fears", *NY Times*, 23 June 2009.

<sup>9</sup> This venture, Desertec, is featured in BBC online article, "Sahara sun 'to help power Europe'", 2 Nov 2009.

powered vehicles) – will itself require large-scale investments that can provide a sustained stimulus to industrial development over decades. The absence of such infrastructure, on the other hand, can be a major constraint to the further expansion of renewables-based power. For example, China is currently finding it difficult to connect all its wind-generated power to the electricity grid for lack of transmission lines from remote areas where they are situated.

The manufacture of renewable power equipment will eventually substitute for that of fossil-fuel-based power equipment. There are some commonalities in technology and skills, e.g., for turbine manufacture, hence possibilities for transfer. Yet, there are also considerable differences as, for example, between coal-fired power plants and wind farms. The technologies of renewables are generally less heavily dominated by a few large multinational engineering firms, allowing greater scope for entry by smaller enterprises, including those from developing countries. This is evident from the success which Danish, Indian and Chinese firms have had in entering the wind turbine industry, for example, and which Chinese firms have had in photovoltaic cells. Insofar as developing country enterprises have already established a foothold in technologies for fossil-fuel-based power generation, they face the same risk of technological obsolescence as developed country enterprises in that business and will need to diversify.

The fourth cluster consists of capital equipment producers. These are a combination of heavy engineering firms which make large furnaces, boilers, reactors, smelters and other process equipment to smaller scale specialists who make machine tools and specialized industrial equipment. The former set of firms is likely to face the biggest adjustments to a high carbon price, as they generally serve energy-intensive industries. There may well be large-scale switching in process technologies from more- to less-carbon-intensive ones (e.g., basic oxygen furnaces to renewable-powered electric arc furnaces in steel). Small machinery manufacturers have in all likelihood already had to adjust to the requirements of the information age, with the introduction of microcontrollers and other electronics, which should also result in material and energy cost savings.

The fifth cluster consists of those industries supplying the housing and building stock, both the construction industry per se and the building materials and fixtures industries. These industries feature prominently in the industrial development of most countries. The construction sector per se is essentially a non-tradable, while the sectors supplying building materials are shielded to some degree from import competition by high transport costs. These industries will be affected importantly by the need to improve energy efficiency of buildings and homes, which are major energy consumers and

greenhouse gas emitters. New and improved building materials, designs and construction methods will be necessary to achieve significant energy savings. With higher energy costs, incentives to adopt these innovations widely in the construction sector will increase. Given the high upfront costs of installing such energy saving improvements, innovative construction/housing financing arrangements may be needed (see discussion in next section).

The construction materials industries are themselves often energy-intensive industries – e.g., bricks, cement, steel, zinc, aluminum, glass, plastics, ceramics, etc. Thus, these industries will need to find ways to produce more energy-efficient building materials using more energy-efficient production processes. Some have already begun to do so. It may also be that new composite materials, or innovative uses of traditional natural materials, will be developed which have significantly improved insulation or ventilation properties. Fixtures designs can also be improved to be more materials- and energy efficient (e.g., low-flush toilets, movement sensors for faucets). Probably to a greater degree than is the case with consumer electrical appliances, the construction materials and building industries have scope for making indigenous energy saving innovations.

The sixth cluster of industries consists of those which will be directly impacted by an increase in the relative prices of fossil fuels as a result of a stricter global carbon regulatory regime. These include the coal, oil and gas industries proper as well as petrochemical industries which use these fossil fuels as feedstocks. A number of economies – notably in the Middle East and North Africa – are heavily dependent on such industries. They will need to pursue adaptive strategies to diversify towards other industries. Some have already been doing so successfully, the most notable case being Dubai. Besides fossil fuels, many of these economies are also richly endowed with solar energy and should be able to develop this resource for commercial exploitation, both for domestic use and for export.

In summary, developing countries are highly heterogeneous in terms of their industrial development, and their starting points will condition the likely impacts of a global shift towards low-carbon development. Industries will be affected to varying degrees and will need to adjust in different ways (see Table 1).

Table 1: Summary of Industrial Impacts of High Carbon Price

<u>Effects of carbon pricing on sectors making:</u>	<u>Nature of effect</u>	<u>Magnitude of effect</u>	<u>New technologies</u>
Consumer non-durables	energy efficiency gains, possibly changes to logistics, location	incremental	more efficient motors, boilers; improved packaging
Consumer durables	more energy efficient appliances; hybrid, electric vehicles	large	smart energy mgt electronics; efficient car batteries
Energy supply equipment	switch to renewables: wind, solar, wave, etc.	major structural change in industry; possibility of new entrants	more efficient solar; hybrid systems: wind/solar; wind/gas, etc.
Other capital equipment	process equipment, batch processing equipment	large effect on process equipment, smaller one on batch process equip	process switch to less carbon-intensive processes
Building supplies	produce more energy-efficient materials using more energy-efficient methods	large as sector important source of emissions both in production and consumption	new design, new materials; advanced building environmental controls
Materials	overlap with building supplies though also for other applications; includes petrochemicals	high fossil fuel prices will have major effect on feedstock prices	greater reliance on recovery, recycling; switch to new materials, e.g., bioplastics

Naturally, energy use is the common thread running through the story. Even here, however, experiences differ. For instance, Brazil's heavy industries can be powered by hydroelectric power to a degree not possible in countries less well endowed with hydro potential. Heavily coal-dependent economies will face probably the biggest adjustment costs as they must build alternative energy infrastructure and possibly scrap some existing plant and equipment. Still, some of the largest coal-dependent economies also have considerable technological know-how in renewable energy and in nuclear power, which should ease the adjustment. They also possess significant electrical and other engineering capabilities

which should enable them to implement advanced energy efficiency technologies both in products and processes.

Nevertheless, for countries like China and India, the costs of a major shift away from coal dependence in the power sector would be non-trivial. In the near term, while they will continue to develop their renewable industries, they will also continue to invest in coal-based power. For them, then, a high near-to medium-term priority for local industrial development will be to build and to make the equipment for significantly more efficient coal-fired power plants.

The challenges facing low income and other middle income developing countries will depend on a number of factors, including their pre-existing energy mix, their level of industrial development and the extent of their engineering skills. Countries with limited existing energy infrastructure and sizeable renewable energy endowments have the possibility to develop from scratch a renewables-based energy system. Making major energy efficiency improvements in existing industries will often require investments in new process technologies, which may or may not be affordable to domestic enterprises. Energy efficiency also depends importantly on optimal operation and maintenance of existing equipment and processes, which demand solid engineering and technical skills. Whether domestic industry is capable of energy efficient product innovations cannot be known *a priori*. If the industry has shown product innovation capacities more generally, then innovations to improve energy efficiency are certainly possible. Even if not, if domestic industry is producing/assembling products to imported designs, then improvements in those designs should be translated into more energy efficient domestically produced products. Such dependence on foreign product designs does, however, leave domestic industry dependent on the innovative capabilities of foreign firms -- not a very secure state.

#### 4. Policies to Promote Low-Carbon Industrial Development

Thus far, the discussion has had a heavy technological focus and has been comparative static rather than dynamic. Industrial development is a dynamic process which involves the progressive mastery of ever more sophisticated technologies -- mastery in the sense of being able to apply those technologies to cost-competitive production of industrial goods and related services. It also involves a progression from application of existing technologies to improvement of those technologies and thence to development of new ones. This section is principally concerned with the dynamics of industrial development and with how government policies – both broad macroeconomic and related policies and more narrowly focused

industrial policies – can influence the dynamics to enhance overall growth performance and also to broaden the distribution of benefits.

The familiar KLEM (capital-labor-energy-materials) production function provides a useful starting point for the analysis. At the level of the macroeconomy, growth is a function of: (i) increases in one or more productive factors – capital, labor, energy, or materials, and/or (ii) increases in the productivity of one or more such factor as a result of technological progress.

The assumption here is that strict international controls on carbon emissions would raise the global carbon price and, by implication, the price of carbon-based energy<sup>10</sup>. As this is the bulk of energy consumption at present, the average energy price should rise, causing a substitution away from E in the production function. The ease of substitution will vary across industries, depending on technologies. Those factors which are net complements to energy in the production function will also experience declining relative demand, while those which are substitutes will experience increasing demand.

While only a stylized fact needing empirical validation, capital is often considered to be a complement to energy in production. Thus, a high carbon price would, all else equal, dampen demand for capital. Conversely, labor is generally considered a substitute in production for energy and as such would experience increasing demand. (At the aggregate level, this could happen in part via a shift in industrial structure away from heavy industries towards more labor-intensive goods and services.)

In the shift to a low-carbon paradigm, there will also be an acceleration of technological innovation focused on energy use (E). This innovation will result not only from the incentive provided by a higher carbon-energy price but also from explicit government support for such innovation in the form of public R&D spending and/or incentives to private R&D on energy saving and alternative energy.

The effect of such innovation will be to increase the productivity of energy, all else equal, partially or wholly neutralizing the effect on relative factor costs and demand of a high carbon price (the rebound effect).

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<sup>10</sup> Recall the assumption that all countries resolve to lower carbon emissions – initially, emissions growth in the case of developing countries – with Annex 1 countries providing financial and technological support to non-Annex 1 countries. Hence, there is a carbon constraint and an implicit carbon price even in developing countries, though there need not be a single global carbon price.

The E factor can be decomposed into energy from different sources, with the relevant distinction for our purposes being between carbon-based and non-carbon-based energy. The strengthening of the global climate change regime should also induce an innovation effort focused on non-carbon energy sources, and presumably government energy R&D policy would have the same focus. If successful, this should eventually cause substitution in production towards non-carbon energy.

Given an initial situation, however, in which non-carbon energy cannot generally compete on cost with carbon energy, and given the possibly considerable time lag between the non-carbon-energy R&D effort and output, government may choose to employ other policies to accelerate the uptake of non-carbon energy.

Looked at differently, the global climate policy regime will raise the energy price level because most energy is still carbon-based. Still, a supplier of renewable energy would avoid the cost penalty of an implicit or explicit carbon tax. Yet, it would only be able to capture demand from carbon-energy suppliers if its production costs were lower than the sum of the production costs plus the carbon tax facing carbon-energy suppliers. In other words, what matters is whether:

$$(C_{nce} - C_{ce}) >> P_c, \text{ where } P_c \text{ is the carbon price.}$$

In practice, in many contexts, the differential in supply cost between the non-carbon energy supplier and the carbon energy supplier is still greater than the carbon price.

This cost differential, combined with the expectation of its narrowing and eventual elimination with cumulative investment in non-carbon energy capacity, is the basis for a range of policies used to accelerate the diffusion of renewable energy. The main ones in use at present are renewable portfolio standards (RPS) and feed-in tariffs (FIT). The former require electrical utilities to source a certain proportion of their electricity supply from renewable sources. The latter guarantee suppliers to utilities of renewable-generated power a price which covers their costs with a profit, even though the price is higher than that paid for the fossil-fuel-based alternative. These are essentially quantity- and price-based policy instruments, respectively, to achieve the same policy objective of increasing renewable energy penetration in the power sector.

Both policies work by spreading the higher costs of electricity occasioned by the renewable energy purchases over all utility customers. The two are not identical, however, in terms of their dynamic

properties. Costs of renewable energy supply are expected to decline over time. So, if initially the price in a FIT were set at a level which would achieve the same renewable penetration as with a given RPS, and if the supply curve were then to shift downward due to cost-reducing technology improvements, the equilibrium effects would be different with the two policies [see Annex Figure 1]. In the FIT case, the price of energy would be unaffected, but more would be supplied from renewable sources. In the RPT case, the price of energy to customers would be reduced but the penetration of renewables would remain little changed (unless the marginal cost of renewable energy was to fall below the price of fossil-fuel energy at the mandated renewable energy share). So, assuming the ultimate policy objective is to achieve the highest possible penetration of renewables, an FIT would be the preferred policy option. As the FIT has the effect of keeping energy prices high, it may have the added benefit of encouraging energy efficiency, but it may also have a regressive effect on low-income consumers in the absence of targeted consumer subsidies.

What are the implications of these policies for industrial development? There are a few likely ones. First, the subsidy to renewable energy should stimulate demand for capital equipment needed for renewable power generation. Investment will be reallocated away from less profitable carbon-based power generation towards renewables. Will this stimulate the development of local industries supplying renewable energy equipment and components, or will it rather stimulate imports? The answer to this will depend in part on industrial policy, in part on tariff or other protection enjoyed by the industry.

In some cases, a local renewable energy industry may emerge with minimal direct government support. The demand stimulus provided by the carbon price combined with a FIT or RPS may suffice. If, however, given existing levels of protection, domestic suppliers are not cost competitive with imports, government needs to weigh the long-term benefits of developing the local industry against the costs to electricity users of the higher costs which would be associated, at least in the near term, with local sourcing vs. imports. Much depends on the current domestic cost disadvantage and the rate at which local industry can be expected to narrow it. The latter in turn depends on the expected growth in demand and the prospects for achieving scale and learning economies.

#### Industrial policies for a low-carbon economy

Assuming a policy decision is made to support a renewable energy industry, a variety of industrial policy instruments can be employed to that end: tax exemptions, directed credit, loan guarantees and

investment subsidies. The main caveat is that some measures may be prohibited by the WTO Agreement on Subsidies. In particular, it prohibits the use of subsidies which take the form of fiscal expenditures conditioned on export performance, but it also renders “actionable” the use of subsidies that have the effect of increasing exports even if they are not directly conditioned on exports (Rodrik 2009).

Rodrik argues the need to relax WTO subsidy disciplines and to make greater space for industrial policies targeted at tradables in developing countries, in order to compensate for the likely increased pressure (i.e., following the current economic crisis) on countries alleged to be using currency undervaluation as implicit industrial policy.

A second effect of FIT or RPS measures is, by raising the cost of electricity, to encourage both greater energy efficiency within industries and a shift in industrial structure towards less energy-intensive sectors. Here again there may be a role for industrial policy. For instance, directed credit to finance energy efficiency improvements in energy-intensive industries would be preferable to shielding those industries from higher electricity rates with preferential tariffs. Also, the banking sectors in many developing countries may not readily extend credit for energy efficiency improvements, in which case they may need to be directed by governments to do so.

Once again, the technologies to improve energy efficiency will need to be supplied domestically or imported, and governments need to decide how far they wish to promote domestic supply where it is not currently competitive. This assumes the technologies are already known and have simply not yet been adopted by local industries. If, however, the technologies have still to be developed or their performance improved, technology policy may come into play. Government, for example, may wish to encourage a common effort by a given industry to improve its energy efficiency. One approach could be to announce a technology prize to be awarded to innovators who develop technologies achieving (or exceeding) a benchmark energy efficiency improvement. The government would thereby acquire the rights to the technologies and be able to share them among all industry participants. Another would be to have relevant industry associations encourage their members to pursue cooperative research efforts for energy efficiency improvement.

As energy becomes an increasingly costly productive input, it seems likely that the demand will grow for energy management services, which may be differentiated by industrial sector. An analogy could be made to labor-management relations consultants, who deal with improving the working of a critical

interface in the production process. The energy audit business is already tasked with examining scope for energy efficiency improvements in enterprises, but this business is likely to grow in size, specialization and sophistication. Besides improvements in performance of specific equipment, there are also work flow and more systemic improvements to energy efficiency which are the work of systems integrators.

It is not altogether clear what the role is here for industrial policy. In a number of countries, there are government-supported “clean technology centers” (often with international donor backing) which provide advisory services to small- and medium-sized enterprises, including on energy efficiency improvements to their production processes. It is not clear whether these centers would continue to require public support if energy prices were to increase significantly as the result of climate policy. It is also unclear how effective they are in achieving significant energy efficiency improvements beyond those which can be achieved through incremental process adjustments.

#### Public finance for a low-carbon economy

An important role of the public sector in shifting the economy onto a low-carbon growth path and facilitating a low-carbon industrial transition will be in the area of finance.

The government will need to undertake major public investments in the infrastructure to support a low-carbon economy, from smart grids to distribute renewable electricity to public transit systems. It will need to invest significant sums in R&D and demonstration of low-carbon technologies. It will also need to ensure that private finance flows into the needed investments and that the financing is affordable.

One proposal recently advanced by the Center for American Progress (2009) in the US context is for the creation of a public Green Bank which would leverage private investment in low-carbon energy technologies, including renewable and energy efficiency. Such a bank could take a strategic approach, directing credit not only to those investments which achieve high short-term returns in terms of GHG reductions per dollar invested, but particularly to those investments with the potential for market transformation through technological innovation and the development of new industries.

Access to finance can be particularly problematic for small-scale renewable energy developers, especially those without a proven track record (Bazilian *et al.* 2008). In developed countries, venture capital or private equity is frequently available to finance such start-ups, but this is often not the case in

developing countries. In the latter, public venture capital may be able to fill the void. Public loan guarantees are another option that may reassure private lenders to back risky start-up projects. They can also be helpful in inducing private lending to energy efficiency projects.

The government also plays an important role as regulator of the financial sector which it uses to further public policy objectives. In most market economies, the government's regulatory powers have been applied lightly in recent years and have sought principally to discourage excessive risk-taking and protect savers. The recent financial crisis has forced a rethink of financial regulation and opened up debate on a more activist role for government to avert systemic risks to the economy from financial sector excess.

As yet, the focus of discussions on financial regulatory reform has been on the macroeconomic implications of financial sector activities. With climate change now high on policy agendas, it may be an opportune time to consider the ways in which governments could encourage the financial sector not only to consider systematically climate risks in its loan decisions (which is likely to happen increasingly in any case), but also to consider the (direct and indirect) GHG emission profiles associated with those decisions. This could involve a range of policy instruments, from lending targets for low-carbon investment projects – e.g., targets for reducing the carbon footprint of loan portfolios – to explicit bans on certain types of carbon-intensive project loan. The first type of policy would need to be supported by recognized methodologies for assessing carbon footprints of loan portfolios.

A number of private financial institutions already adhere to certain standards concerning their project finance and other lending and its environmental impacts, including on greenhouse gas emissions. The Equator Principles are the best known global initiative of this kind. As yet, relatively few developing country financial institutions subscribe to those principles, but much financing in developing countries for energy and other infrastructure projects is global, so the reach of the Principles is quite long. Also, the emergence of a global carbon market and carbon price should force financiers and project developers to factor carbon price and revenue into project evaluation.

It is not known *a priori* how significantly the carbon footprinting of loan portfolios would affect borrowing costs to low-carbon projects. It is possible, at least, that those costs could be reduced as capital is freed up from use in carbon-intensive investments and redirected to low-carbon ones.

## 5. The International Context for Promoting Low-Carbon Industrial Development

The global climate policy regime is still taking shape and will continue to evolve in years to come. The assumption made in this paper is the rather optimistic one that governments will agree, whether in Copenhagen or soon thereafter, to ambitious GHG emission reductions over the coming half century and that Annex 1 governments will agree to provide to developing countries the financial and technological support needed to move onto a low-carbon development path.

The amounts and forms of financial and technological support from developed to developing countries are still under intensive negotiation within the UNFCCC framework. Without prejudging the outcome, this section considers elements of the international trade and investment regimes which may be more or less conducive to low-carbon industrial development, and it considers as well the financing modalities to support such development.

#### International trade regime and low-carbon development

The international trade regime will be tested by the evolving climate policy regime. This has already begun to happen. Proposals have come from various quarters – most recently in the U.S. House of Representatives version of new climate change legislation – for border tax adjustments to offset the cost disadvantage of domestic carbon-intensive industries in countries imposing carbon constraints vis-à-vis competitors in countries with laxer or non-existent constraints. It is unclear how far trade policy will be used unilaterally as an instrument of climate change policy, and how far such use will withstand scrutiny and challenge under WTO rules. In the end, it may be that those rules will be rewritten in the light of new realities if climate change should come to dominate international policy discourse.

The focus here is on the intersection between the international trade regime and domestic industrial policy to promote low-carbon technologies and industries.

As mentioned above, the WTO disciplines on subsidies may need to be revisited and relaxed if developing countries are to be afforded sufficient policy space to promote low-carbon industries, especially as one effect of the global economic crisis is likely to be stronger pressures on countries not to employ currency undervaluation as an implicit form of industrial policy.

In the short run, there is often a tension between the global objective of minimizing barriers to trade in low-carbon technologies (on the assumption that lower trade barriers will facilitate low-cost access) and the national objective of encouraging the development of domestic industries supplying low-carbon

technologies (which may call for some form of infant-industry protection). It is also increasingly apparent that trade among developing countries in low-carbon technologies will emerge as a major component of global trade. As previously noted, countries like Brazil, China and India already have significant technological and production capacities in renewable energy technologies. For other, latecomer developing countries, then, the effort to develop domestic renewable energy industries (whether wind, solar, biomass or other) may impact on trade with those emerging economies as much as on trade with developed countries.

Looked at differently, there are new opportunities opening up for South-South investment and technology cooperation, as technology leaders find opportunities not simply for exporting but also for foreign direct investment and technology licensing. Brazil, for example, has been actively working with other developing countries – notably in Lusophone Africa but also in the Caribbean and elsewhere – to transfer its liquid biofuels technology and know-how and develop production capacity abroad. This should also benefit its automotive industry, which because of the country's longstanding lead in bioethanol, has also developed a lead in making flex-fuel engines and vehicles.

There will also be strong South-South competition in low-carbon energy technologies. Whether it makes sense for other countries to develop their wind turbine or photovoltaic or other renewable industries in the face of low-cost competition from China and India will depend on the size of their own markets and the importance of scale economies and other cost factors. If they do, they will need to consider selective industrial policies to help the relevant industry (or industries) become firmly implanted. Depending on the options for technology acquisition, they may seek to attract foreign investment and joint venture partners from the emerging market leaders, as with the Brazilian ethanol case just mentioned, or from developed country leaders. As the technologies of renewable energy production and utilization are likely to be smaller-scale and more decentralized than those of the fossil fuel era, it seems unlikely that the global market will be as heavily dominated by a few large global enterprises as it has been in the fossil-fuel era, at least in the initial growth phase.

#### International financial architecture for low-carbon development

As indicated above, it is assumed that the international community will create the institutional mechanisms and mobilize the resources to contribute to financing the low-carbon technologies and

infrastructure which developing countries will need to shift onto a low-carbon development path in coming decades.

What sort of institutional mechanisms are needed to finance what exactly? What is the role of international public finance in this resource mobilization and expenditure, and what the role of the private sector?

Public investment will be needed in the infrastructure to support a shift towards renewable energy – e.g., the new transmission grids to bring renewable energy to centers of energy demand – and developing countries will need international public finance to cover the incremental costs of such investments. The actual power generation investments will come from a combination of public and private sources, the mix depending on country and the extent to which the power sector remains state-controlled. The financing may, however, be made available on concessional terms – as for example when international financial institutions provide financing for energy sector development, borrowing at favorable rates in international capital markets and passing the low capital costs on to their borrowers, or when the International Financing Corporation takes a partial equity stake in a new renewable-based power project, or when the MIGA or bilateral agencies guarantee investments in developing country projects. Also, it is possible that investment sponsors would qualify for the UNFCCC's Clean Development Mechanism (CDM) and be able to borrow against expected future CDM offset revenues.

Existing financing mechanisms for low-carbon investments in developing countries are inadequate to mobilize resources on the scale needed to effect a major paradigm shift in energy and industry. Discussions are currently underway – principally within the UNFCCC -- on a number of proposals to remedy this situation. The proposals spelt out here are intended as a further contribution to those discussions.

Two major shifts have been identified above as central to a low-carbon development path – that from fossil-fuel-based energy to renewables-based (and nuclear) energy; that from low energy efficiency of production and consumption activities to very high energy efficiency.

### *A global feed-in tariff fund<sup>11</sup>*

The first proposal here relates to the first shift, taking into account the fact that renewable-based power is currently more expensive than fossil-fuel-based power in the major of situations and that, if the average consumer in developing countries is to be able to afford electricity generated by renewables, electricity will need to be subsidized. As explained in the policy section, this is currently done in a number of countries by means of feed-in tariffs (FIT). Adoption of FIT at national or local level assumes that the renewable-energy subsidy can be financed from higher average electricity tariffs for users (or, alternatively, from higher tax revenues). Where the majority of the population is poor, however, and where tax revenues are correspondingly low, this is not a viable option. Where income distribution is unequal and wealthy consumers together with industrial and commercial establishments account for a significant share of electricity consumption, there may be some scope for financing renewable subsidies via progressive (e.g., increasing block) tariffs (or income taxes) which fall disproportionately on those with greatest ability to pay.

Still, in most developing countries, a system of FITs adequate to encourage a large expansion of renewable-based generating capacity could not easily be supported through domestic measures alone. Hence the proposal here for a global feed-in tariff fund (G-FIT-F). This fund would provide resources to developing countries to support national FIT systems linked, e.g., to 2020 or 2030 renewable energy targets. In this case, the G-FIT-F would need to operate for a period of 10 to 20 years. Over that time, the costs of renewable energy could be expected to fall significantly with scale and learning economies. Thus, the unit (kWh) energy subsidy could be reduced such that, for a given level of funding, renewable-based electricity could be extended to a growing proportion of the population. One problem is how to know *ex ante* with reasonable certainty the shape of the cost curve so as to ensure a predictable intertemporal FIT schedule consistent with the financial viability of the renewable power sector.

Mechanics of a global-fund-supported FIT and its relation to other elements of a renewable energy investment program need to be further elaborated. There are many potential complications, as e.g. where the grid itself is underdeveloped, as in many poor countries, so investment in grid expansion needs to be closely coordinated with a FIT scheme, or where renewable energy is self-generated,

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<sup>11</sup> This discussion is an elaboration of a proposal advanced by Tariq Banuri, Director, Division for Sustainable Development, UN Department of Economic and Social Affairs, and roughly sketched in UN-DESA (2009a).

decentralized and off-grid. Also, the reality is that in many developing countries the poor cannot even afford currently provided, fossil-fuel-based electricity no less renewable-based electricity. So, a feed-in tariff would need to be supplemented by targeted subsidies for the poor.

The resource requirements of such a hypothetical G-FIT-F require study, taking into account different sets of assumptions about the size of the unit subsidy, the duration, the coverage and timing of renewable energy cost reductions. (This is the subject of ongoing research.)

How would such a fund be financed? There are a number of possibilities. One would be to add a small surcharge onto the electricity bills of consumers in Annex 1 countries. They will already pay higher electricity bills in response to national carbon constraints – and in many cases domestic FITs or RPTs – so the size of a surcharge has to be sensitive to political realities. Still, the fact that *per capita* electricity consumption in Annex 1 countries is on average several times higher than that in non-Annex 1 countries suggests that a modest surcharge per unit electricity consumption in the former could go some way towards financing renewable energy subsidies in the latter (even if the latter's total population is a few times larger). **[check]**

Another financing option is a levy on emission allowance allocations to Annex 1 countries. Such a financing proposal has already been advanced by the Norwegian government in the context of UNFCCC negotiations, though not explicitly linked to a G-FIT-F. Alternatively, a levy could be imposed on national carbon permit auctions (or regional ones as in the case of the EU's ETS). The limitation of this proposal is that national carbon control regimes vary and are not fixed by international treaty. Some countries may choose not to auction permits, and the proportion of permits auctioned will vary across countries and within the same country over time. (For example, according to the U.S. House of Representatives' climate change bill, most permits would be given away rather than auctioned until after 2020.)

Still another financing option is to calculate and collect an assessed contribution to such a fund – either from all Annex 1 countries or perhaps from all countries meeting certain criteria in terms of *per capita* income, GHG emissions, etc., as for example with the Mexican proposal submitted to the UNFCCC.

At least two important reservations can be anticipated from Annex 1 countries concerning a proposed G-FIT-F. The first is that, if renewable energy consumption in developing countries is to be subsidized by developed ones, this would need to be accompanied by firm safeguards against the former countries' protection of domestic renewable energy industries and exclusion of developed country suppliers from

developing country markets. The second is that developed country citizens are unlikely to agree to an unconditional subsidy to renewable energy consumption in developing countries, irrespective of the ability to pay of developing country consumers. On this argument, to be politically acceptable, internationally funded subsidies would need to be targeted to the poor. There is a certain tension between the two reservations in the following sense. If safeguards against protectionism were put in place, Annex 1 countries might be willing to support a broad-based renewable energy subsidy in non-Annex 1 countries as a way to stimulate their own renewable energy industries. In that event, a subsidy targeted only at the poor (or alternatively at “essential” electricity consumption) would provide a more limited stimulus.

How could such targeting work? One possibility is to use a measure like the threshold level of *per capita* energy consumption (of which some share electricity) beyond which a human development index shows only marginal further improvement<sup>12</sup>. UN-DESA (2009b) puts the threshold at 130 MJ *per capita* per year. Then, the globally financed renewable energy subsidy could be calculated as the incremental cost of renewable energy supply up to that threshold, country by country. There is still the need to ensure that an “adequate” amount of renewable-based electricity actually reaches the entire population, rather than the subsidy’s being captured mostly by better-off, higher *per capita* consumers. Since many of the poor (in some countries the majority) are not among the paying customers of electrical utilities, which would be the entities responsible for paying FITs to suppliers of renewable-based power, the FIT funds made available to those utilities would need to be conditional on their expansion of electricity access to poor households. In this way, a G=FT-F could also serve as a global financing mechanism for affordable clean electricity access for the poor. As pointed out above, an additional subsidy (above and beyond the FIT) would be needed to make renewable energy affordable to the very poor and, while this can be achieved in part through a progressive tariff structure involving rate cross-subsidization, international support will also be needed.

#### *International energy-efficiency-enhancement (I-triple-E) fund*

A few domestic financing options to promote energy efficiency enhancements were outlined above. The focus here is on international financial support. Already the Global Environment Facility (GEF) provides financing for such projects in developing countries and countries with economies in transition (as it does

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<sup>12</sup> This notion was developed in work by EcoEquity on Greenhouse Development Rights; see Baer *et al.* (2007).

for renewable energy projects). It seems probable that the financial resources of the GEF earmarked for climate change will be increased as a result of a global climate change agreement in Copenhagen<sup>13</sup>.

For maximum effectiveness, financing would need to be mobilized for broad sectoral energy efficiency enhancement programs, as the bulk of enterprises in any given sector and country often work with similar technologies and labor under similar inefficiencies. This is not to say that there are not leading enterprises whose energy efficiency is close to global best practice for a given sector, but that these are often a small minority of enterprises in developing countries. While, faced with the proper incentives, such enterprises may be able and willing to share their energy efficiency know how, the deployment of energy efficiency improvements may involve capital improvements and equipment replacement which need to be financed from some source. Moreover, it is possible that even the best enterprises in a given sector and country remain well behind the energy efficiency frontier and so need international technological assistance to close the gap.

This is the logic behind proposals for a sectoral approach to effecting energy efficiency improvements and deploying low-carbon technologies. The biggest obstacle to such an approach (involving, e.g., all major global producers of iron and steel, aluminum, cement, chemicals, other high-GHG-emitting sectors) is competitiveness concerns of both leader and laggard countries. Industries in the former have concerns about protecting intellectual property and those in the latter concerns about the costliness of improved technologies. An international energy-efficiency-enhancement (triple-E) fund (assumed to be under UNFCCC auspices), with dedicated industry windows, could help to overcome this obstacle. The fund would be used for two purposes. On one side the fund would support, via technology prizes, research yielding the largest energy efficiency improvements for major energy-using processes, sector by sector. The prizes would be awarded to winners from whatever country or combination of countries, with associated innovations becoming international public property (as historically with improved seed varieties developed by CGIAR-affiliated research centers). On the other side the fund would be available for low-cost financing of the investments needed to implement energy-saving technological improvements, whether based on new technologies or involving the adoption of best practice technologies employed elsewhere. The resultant energy efficiency improvements should be large

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<sup>13</sup> Still, short of major governance changes, it seems unlikely that the GEF would become the dominant financing mechanism recognized by the COP of the UNFCCC.

enough in many cases to allow the speedy amortization of investments. Resources from this global fund could be made available to developing country financial institutions which either have or agree to institute energy efficiency loan programs, thereby helping to unlock domestic funding channels for such investments<sup>14</sup>. There would need to be capacity building at intermediary financial institutions for officers charged with administering such loan programs.

One option for capitalizing the fund would be for governments to collect a small levy from their sectoral enterprises, differentiated according to a formula accounting, e.g., for global market share and home countries' *per capita* income level, to be deposited in the global fund. The revenues so collected could be earmarked by sector (for disbursement at sectoral windows) or put into a common pool, or some combination thereof. The fund would need a substantial upfront capitalization to support the technology prize competitions, but the portion of the fund's resources used to finance energy efficiency investments in developing countries and countries with economies in transition would be revolving, with loan repayments eventually covering a sizeable portion of new lending. Still, it could be expected that, as low-cost energy efficiency improvements are exhausted, both the funding for technological innovation (the prize money) and the funding for investments in increasingly sophisticated capital equipment and processes will need to increase.

The innovations contributing to radical improvements in energy efficiency may well be developed by innovators outside of the user sector(s). Thus, a technology prize or other means of fostering such innovation needs to be flexible enough to allow participation of sectoral outsiders. Also, the innovations may be "soft" in nature, more to do with management of information and organization of processes than with capital equipment and its improvement. Once more, technology competitions would need to allow for such unconventional innovations.

## 6. Conclusions

An ambitious global climate change agreement will alter fundamentally patterns of energy use in the global economy. It is argued here that this will represent a basic paradigm shift perhaps comparable in importance to the ICT revolution of the second half of the 20<sup>th</sup> century.

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<sup>14</sup> The I-triple-E fund could perhaps be channeled through national climate change funds if these are established as part of a Copenhagen agreement or thereafter.

Industrial development strategies and policies in developing countries will need to adjust to this new low-carbon-energy paradigm. The degree of adjustment will vary according to a country's energy endowments and industrial structure. The paper enumerated five main clusters of industries, differentiated according to how a shift towards a low-carbon economic paradigm is likely to affect them. Each country will have a unique combination of clusters and will need to make its own assessment of the implications for its industrial development.

Identification of strategic technologies and technological trajectories for the low-carbon age can help inform a country's industrial development strategy. Two broad classes of technologies discussed here are renewable energy technologies and energy-efficiency-enhancing technologies. These draw on a range of technical competencies and countries could usefully map the technological requirements of these emerging sectors against their existing competencies as basis for identifying promising directions for targeting industrial policies.

Governments will need to weigh carefully the make-buy choice for each of the emerging technologies (and technology clusters) of this low-carbon paradigm. While a government may want to position its industry early in a dynamic sector like wind turbines or photovoltaic cells, it will also want to consider what cost penalty for electricity would need to be incurred by domestic users (or otherwise covered from public revenues) to provide adequate infant-industry protection. In practice, the choice may not be so stark, as a country may acquire a comparative advantage in making a key component or material used in renewable energy equipment or other low-carbon applications, while not competing in all stages of production.

Important for industrial development is consideration of migration paths over time. Producing a product cost-effectively today is not enough. Governments and industrialists need to ask: What competencies does its production offer for making other products experiencing dynamic growth? How can technological capabilities be enhanced over time so that a country's industry moves from simply making the product efficiently to eventually developing innovative next-generation products? Policies and investment programs to stimulate the diffusion and uptake of renewable energy will be crucial to creating favorable conditions for industry growth. The international market may be an option from the outset, but very often production for the domestic market provides valuable learning experience. Policies to ensure that the financial sector provides adequate financing on affordable terms to renewable energy suppliers and adopters of energy efficiency improvements will be needed.

To be effective, domestic industrial and technology policies to promote low-carbon development must be reinforced by the global policy regime. It is assumed here that the climate policy regime will be favorable in the form of ambitious GHG mitigation targets accompanied by meaningful financial and technology transfers from developed to developing countries. The trade regime may need to be adjusted, however, to align it with global climate change objectives and to ensure that developing countries have adequate space to develop their own low-carbon technologies and industries. Also, financial innovations at the international level will be needed to address the particular challenges posed by: (i) a large-scale shift of the energy paradigm towards renewable energy; (ii) a quantum leap in the levels of energy efficiency achieved by industry leaders and the fastest possible catch-up to those levels by industry followers.

Proposed next steps are: (i) to refine the framework for analyzing the impacts of a low-carbon paradigm shift on prospects and pathways for industrial development in developing countries, (ii) to apply that framework to a selection of countries at different levels of industrial development and with distinctly different industrial structures, (iii) to assess its usefulness and make further refinements as needed, followed by (iv) a further set of country studies in an iterative process.

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Annex Figure 1: FIT and RPT Compared

