Introduction

Infrastructure Lock-in and a Low Carbon Growth Path for India

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Infrastructure and Lock-In

The infrastructure investments that are made today will play a critical role in determining whether India will be able to travel on a low carbon growth path tomorrow. This is because today's investments make it costlier to take one set of decisions as compared to another, tomorrow. As a nation, our choices in infrastructure lock us into other choices. Table 1 illustrates such consequences for three Organisation for Economic Co-operation and Development (OECD) countries.

United States' choice of a low density road-centric urban form is partly the reason why its transport sector emissions are almost three times as much as the UK and France, and partly the reason why it is the highest emitter of carbon dioxide, around 20 tonnes per capita, while its European OECD counterparts emit less than half that amount, even though they enjoy a similar standard of living. France's total emissions per capita, of only 6.2 tonnes of $CO_{2,}$ are comparable to the emissions by the transport sector alone in the US. Further, because France meets around three-fourths of its electricity needs from nuclear energy, it emits less carbon per capita than the UK, even though its electricity consumption of 7,814 kWh per capita far exceeds 6,216 kWh per capita in the UK, which was dependent on coal initially and now on a mix of coal and gas. Indeed, the difference between the per capita emissions of UK and France are almost entirely explained by the difference in the emissions attributable to electricity and heat. Table 1 again shows that there is no mandatory one-to-one relationship between emissions and development, and alternative growth paths have very different carbon consequences.

It is important to bear this in mind, as we in India have yet to make the decisions that will lock in our choices, as is evident from Table 1. Having made those decisions, it

Table 1 Consequences of Infrastructure Lock-in

	GDP per capita (constant 2005 USD PPP)	*Total emissions*	*Transport*	*Electricity and heat*	*Electricity use (kWh per capita)*
		(CO_2 tons per capita)			
United States (US)	42,591	19.5	6.1	9.1	13,582
United Kingdom (UK)	33,408	9.1	2.2	4.0	6,216
France	30,227	6.4	2.2	1.1	7,814
India	2,416	1.2	0.1	0.7	511

Source: Emissions data is from Climate Analysis Indicators Tool (CAIT) and other data is from World Development Indicators. All data refer to 2006.

is now difficult for the US to reorganize its cities so as to achieve European levels of transport emissions. It was a little easier, though still quite difficult, for the UK to move away from coal as its primary source of electricity, to gas, which emits less carbon; which it has done now to a considerable extent. However, a move to nuclear power, like France, is considerably more difficult for the UK, for both technical reasons and those related to public opinion, which is an equally valid consideration in democratic societies. In India too, as the chapter by Manpreet Sethi 'The Nuclear Energy Imperative: Addressing Energy Poverty, Energy Security, and Climate Change in India', notes, the public's concerns will have to be addressed before a substantial increase in the share of nuclear power can be achieved.

Different Kinds of Lock-in

These choices also illustrate two different kinds of lock-in. In the case of energy infrastructure, if India continues to grow at 8 per cent plus per annum, the capacity needed will roughly double every decade (assuming an energy elasticity of slightly less than one). If so, the current installed capacity will constitute only a quarter of the capacity in twenty years time (less if one accounts for retirements and obsolescence). As such, the energy mix can change substantially over this time frame, if incremental investments vary significantly from the installed base. The UK experience is an example of such a transformation. Technological lock-in is thus related to the life of the equipment and the rate of new investment, though the companies that benefit from incumbent technologies may actively try to prevent the emergence of new technologies in the market either through market action or through influencing the policy process. The success of such actions depends on the political economy milieu, which is discussed later in this chapter.

In the case of urban form, the lock-in can be much more severe. For one, the infrastructure shaping these decisions is much more long-lived. The road infrastructure laid down by Robert Moses in the 1930s and 1950s in and around New York City still survives and has defined, and will continue to define the settlement pattern in the future too. Second, these large infrastructure investments then shape a variety of numerous individual and local preferences, like decisions about where to buy a home, where to send your children to school, and indeed which localities will be chosen to establish schools. Such disparate decisions are much more difficult to alter precisely because they are disparate and also because they tend to build on past choices and therefore develop an internal logic of their own, like agglomeration economies. For example, in the US, once a certain school district is recognized as good, there is a tendency for people to move into that area. As such, bringing populations back to live in dense cities, as in Europe, may require city school systems in the US be improved substantially and more importantly, to ensure that this improvement is perceived by numerous individual parents who will make these decisions. This is a much higher order of difficulty than the choice of technology for the next power plant to be built and it is precisely such characteristics that make the lock-in of a much higher order of magnitude.

Different types of changes are thus needed to undo the distinct lock-in effects of inappropriate infrastructure investments; first, technological and the second and more difficult, changes in preferences. It is therefore, incumbent on us to examine the extent of technological lock-in and the effect on preferences that may result from the infrastructure investments that we are making today.

There is also a third kind of lock-in, which emanates from the imperatives of political economy and indeed, technological lock-in and preference lock-in are often mediated through this. Such political economy lock-ins, referred to earlier, are critical to a transition to a low carbon growth path but often neglected. As a result of such lock-in, even where solutions are available, there may be burdens to adoption, based on the differential ability of the affected parties to influence the policy process.

Against this background of different types of lock-in, it is useful to examine the various types of interventions that attempt to move to a lower carbon growth path. These can broadly be classified into three types, namely, (a) Cut carbon—initiatives that reduce the amount of carbon emitted, for example, increasing vehicle fuel efficiency, share of public transport, and the energy efficiency of industrial processes; (b) Capture carbon—initiatives like carbon capture and storage (CCS) from coal-fired plants and afforestation; (c) Change away from carbon—initiatives such as a switch to nuclear power or hydrogen powered vehicles.

A Framework for Organization

Each of these interventions can then generate possible lock-ins, for instance, in the adoption of technology. Investment in CCS could lock investment into large coal-based power plants at specific locations (suitable for carbon capture), which could then act as a barrier to the adoption of a decentralized generation system supported by a smart grid. Likewise, in a switch to solar power, solar photovoltaic has very different grid characteristics vis-à-vis solar thermal technologies and the choice of technologies could therefore lock-in very different structures of transmission grids. A large amount of infirm renewable energy in the grid would also need investments in balancing quick response generation, like gas-based power (a fossil fuel source) as well as regulatory changes.[1]

Similarly, urban planning interventions to decongest cities are often based on the development of satellite cities, with specified minimum plot sizes and investment in road infrastructure to connect relatively isolated communities. In the US, albeit for different reasons, the development of scattered communities has meant that a significant part of the population lives in large suburban houses, relatively far from markets. Their energy consumption in storage of food and air-conditioning of living space is likely to be high, as evidenced by the much higher electricity and heating emissions per capita in Table 1, as is water consumption in watering lawns, etc., as compared to those living in apartments in dense cities in close proximity to amenities. Long years of living in suburbia could generate preferences for a suburban lifestyle and an aversion to the hustle and bustle of the city. The imposition of carbon taxes would affect people with these set of preferences more acutely than others.

Investments in technology and construction of preferences would make sets of actors reluctant to either change their technology (which involves incurring financial cost) or their preferences (emotionally costly and possibly financially too, for example if the value of the suburban property declines after a carbon tax). These actors then try to avoid these costs by influencing the process of policy formulation (see, for example, Kotkin 2010), that is, leading to a political economy lock-in. An Indian example is the extent to which the recommendations of the Expert Committee on Pricing of Sensitive Petroleum Products were implemented by the Government of India (see Box 1). Such an environment is a hurdle in the path of solutions, such as those advanced in the chapter by Rita Pandey 'Pollution-Energy-Carbon Intensity of Urban Transport in India: Dynamics of Government Policy Intervention'.

In this respect, one could argue that the political economy lock-in is derived from either a preference lock-in or a technological one. However, since political positions often exhibit hysteresis, as for example the aversion to

Box 1
Interaction of Technology and Political Economy Lock-in

The case of fuel pricing in India is instructive. Recently, the Government of India decided to allow pricing freedom for the price of petrol.[2] However, the price of diesel is still under the oversight of the government and the taxation on diesel is considerably less than that of petrol, leading to a lower price for diesel at the pump, in contrast to most other countries (see http://www.aip.com.au/pricing/internationalprices.htm).

Consequently, diesel passenger car owners save on operating costs as compared to petrol car owners. Realizing this, the car manufacturers charge a higher price for diesel cars as compared to petrol cars, even though the costs of production for the two types of cars are comparable. Most of the benefit of the subsidized diesel prices thus accrues to the manufacturers of diesel cars in the form of higher margins.[3] The Expert Committee on Pricing of Sensitive Petroleum Products (popularly known as the Kirit Parikh Committee) recognized the political economy problems of freeing up the price of the major transport fuel in a situation of volatile prices. However, to prevent percolations of this subsidy to passenger car manufacturers, it suggested levying a compensatory surcharge on diesel passenger cars linked to the capitalized saving emanating from the differential pricing of petrol and diesel. Based on the existing sales pattern, such a tax could yield upwards of Rs 5,000 crore or well over a billion dollars. However, adoption of such a measure would hurt car manufacturers who specialize in diesel cars since their production capacity and technology is locked into diesel vehicles. To forestall a reduction in their margins, they would lobby for the non-imposition of such a surcharge. Till date, there is neither the surcharge nor much public discussion about the efficacy of such a measure. One can interpret this as an instance of the technology lock-in of car manufacturers being translated into a political economy lock-in of indirect tax policy.

[1] India is relatively liberal in this respect. As chapter 2 by Pramod Deo and Vijay M. Deshpande, 'Low Carbon Path for Meeting the Electricity Needs of the People: Role of Regulatory Commissions' notes, under the new Grid Code of the CERC (Central Electricity Regulatory Commission), the financial burden of all the fluctuations from schedule in case of new solar energy plants and fluctuations within ±30 per cent of schedule in case of new wind energy plants will be shared by all the users of the inter-state grid, removing the financial disadvantage of infirmness from renewable energy. Some would consider this overgenerous.

[2] This is a freedom which has ostensibly been available to oil marketing companies since the demise of the Administered Pricing Mechanism in March 2002 (see http://petroleum.nic.in/webfiles/gazette.pdf), which has never been formally resurrected. This illustrates the distinction between formal and informal structures of control.

[3] This assumes a degree of market power or else this rent would be competed away.

taxation among US legislators, they may turn out to have an independent life of their own, even when the underlying conditions that gave rise to the gridlock may have altered. Besides, the need to use the policy process in order for both technological and preference lock-ins to be effective means that it may be important to look at it independently and separately. A possible framework to view the set of options available is therefore as follows:

Lock-in Potential of Interventions

Table 2 illustrates some of the interlinkages between types of intervention and potential for lock-in. Most of the contributions in this volume, with a few exceptions, refer to initiatives that cut the amount of carbon emissions. Beyond afforestation, whose role in carbon capture can be significant, as noted in the chapter by Bhaskar Sinha, Anoma Basu, and Anuj Singh Katiyar 'Towards A Carbon-Neutral Rural India: Carbon Sequestration Options in Forestry', technologies to capture carbon are still in development. The largest current potential to change away from carbon is in renewable and nuclear energy. The scope for renewable and decentralized options is examined in the chapter by Ashish Garg, Manisha Gulati, and Nachiketa Tiwari 'Moving Towards Low Carbon Economy: The Need for Renewable Energy Solutions: Renewable Energy in India: Capability, Challenges, and Prospects', who also discuss the institutional prerequisites for wider adoption of such technologies in some detail and Chandrashekar Iyer, Rajneesh Sharma, Ronnie Khanna, and Akil V. Laxman in 'Decentralized Distributed Generation for an Inclusive and Low Carbon Economy for India'. In both the chapters, while there is a significant role for change-away technologies like wind and solar, there is also considerable attention paid to biomass, where carbon management needs to be over the life cycle and therefore needs to be supported by strong institutions. However, this can cut both ways. As the chapter by Anoop Singh 'Economics, Regulation, and Implementation Strategy for Renewable Energy Certificates in India', and Pramod Deo and Vijay M. Deshpande, (Chapter 2 of this report) note, support for renewable energy may become excessive in some circumstances, and it is possible that it may lock-in inappropriate technologies, as also inappropriate policies. Lock-in can be present even in areas like afforestation, where the choice of plant species can change local ecosystems in significant ways. Nuclear power, of course, has significant lock-in implications emanating in no small part from the need to decommission the plant at some stage.

There are a number of strategies to cut carbon emissions. A large number of them are about increasing the efficiency of processes, such as using less energy in production, less electricity and heat in air-conditioning, improved fuel efficiency of vehicles, etc. All these involve various technological choices, each of which is subject to lock-in. Evaluating these investments from a technological lock-in potential would require, for instance, examination of the ratio of capital investment to operating expenditure. The higher this ratio, the greater the lock-in potential, since a decision to switch away from such technology will involve the comparison of low operating expenditure with investment that needs to be made in the replacement technology.

Strategies to cut carbon can also involve change in the composition of consumption. The most common example is a switch from personal to public transport. However, even within public transport systems, there are varying degrees of lock-in like vehicle technologies. Fixed infrastructure systems like Delhi's rail-based mass transit, have a higher degree of lock-in than flexible infrastructure systems like an intelligently networked bus system or a bus rapid transit intervention. One has to consider these effects in making a decision about the choice of intervention.

1. Initiatives to cut carbon can also mould preferences. In rural India, as D'Sa and Murthy (2004) suggest, 90 per cent of rural households still depend on traditional form of biomass, composed of firewood (64 per cent), crop residues (13 per cent), and cow dung (13 per cent) for cooking. This is in principle renewable, but firewood collection is not always sustainable. In this context, recent efforts to move rural areas to fuels like LPG, rather than

Table 2 Illustrative Types of Intervention and Potential for Lock-in

Interventions/ Lock-in	*Cut carbon*	*Capture carbon*	*Change away from carbon*
Technology	Efficiency initiatives; choice of public transport technology	Carbon capture and storage, choice of plant species	Renewable energy options; nuclear power
Preferences	Promoting LPG in rural areas; urban building envelopes	Creating demand for national parks	Change in food habits
Political economy	Access policy for captive power	Afforestation policy	Renewable energy policy

options like biogas (which has the additional co-benefit of methane capture as noted in Chapter 11 of this report) and solar cookers (as suggested, for example, in Chapter 10 Part 1) illustrates the possibility that, in the process of moving households away from existing practices, they may be locked-in to an unsustainable fossil fuel, both technologically and through preferences.

Finally, the various policies now being enunciated to either cut carbon capture carbon, or shift away from carbon can themselves become locked-in, driven by the various interest groups that would emerge from the implementation of such policies. This can prevent the growth or even the introduction of superior alternatives in the future, as more investment is directed globally to respond to the challenge of climate change.

Actors and the Policy Process

The contributions in this volume address a number of these challenges and suggest a number of very useful interventions. However, it is important to ask, whether the key actors, who are supposed to intervene in the process of transition to a low carbon economy, have both the financial and institutional ability, and willingness to do so. Both the ability and willingness of the actors may be constrained by different types of lock-in referred to earlier. We consider some of the key actors in the discussion below.

Organized Private Actors

In the case of organized private actors, for example organized industry, it is reasonable to assume that they either have or can acquire the ability to undertake the necessary interventions, such as in improving energy efficiency. In such cases, the interventions need to be focused on increasing their willingness. This can perhaps be realized with appropriate price signals, such as changes in electricity prices, increasing fuel/carbon taxes, etc. Faced with these price signals, these actors should undertake actions to reduce their carbon consumption, for example, by improving energy efficiency. Organized private actors are however, going to resist making changes unless their financial costs are addressed. In many instances, as indicated in the chapter by Dhruba Purkayastha, Manisha Gulati, and Sunder Subramanian 'Financing Low Carbon Infrastructure in India', such actions can be self-financing and the required public intervention may be in ensuring the availability of finance and increasing the awareness of such opportunities. The rapidly growing, though still small, Energy Service Company (ESCO) industry in India points to the potential of such opportunities. Delio et al. (2009) estimated ESCO industry revenue in 2007 to be around USD 17 million, with over 95 per cent of this coming from industry (62 per cent), government (24 per cent), and commercial buildings (9 per cent). This revenue is almost doubling every year.

As the price of energy services and/or electricity rises, such efficiency initiatives become more financially sensible. However, organized private actors can also resist initiatives for such efficiency if they perceive the rise in prices as not due to market forces, such as the rise in the price of crude, which they believe they cannot influence, but due to taxes, such as carbon taxes, which they think they can affect. In such cases, these actors may become unwilling to adapt and expend effort in neutralizing or reversing the intervention. It is here that political economy considerations would become relevant in determining whether such taxes would be levied and collected.

Government Actors

The client mix of the ESCOs in India also point to the challenges in extending such interventions beyond organized private industry. The unorganized private sector, even if it had the willingness (the benefits from energy efficiency may be much larger, given that the energy efficiency of capital is likely to be lower in the sector) lacks the resources and the access to credit required to undertake such actions. The public sector in India, for the most part, on the other hand, lacks both the ability and the willingness to engage in such initiatives. Indeed, the chapter by Patricia Clarke Annez and Thomas Zuelgaray 'High Cost Carbon and Local Government Finance' points out that the current structure of taxing authority in most federal systems would mean that local governments would be at a severe fiscal disadvantage in the event of a rise in carbon prices. As such, overcoming the resistance from such entities would involve modifications to the current federal tax sharing structure, not an issue that is on the minds of most who work on climate change.

In the US, however, the government sector provides much of the demand for services of ESCOs. As noted in Goldman et al. (2002), prior to 1996, 67 per cent of ESCO projects were in the government sector which rose to 75 per cent between 1996 and 2002. The largest segment of this was educational institutions, both local schools (33 per cent) and universities (8 per cent). One can surmise that the funding of local schools directly from local property taxes (it is one of the most visible uses of tax payments by people) may have played a role in their wanting to reduce costs by utilizing the benefits of ESCOs. The manner in which government institutions are structured may therefore play a significant role in determining their willingness and ability to undertake mitigation.

Individual Actors

A third group of actors are individuals/individual households. In this case, those who have the willingness, that is households that spend a relatively larger share of their budget on direct or indirect energy consumption, may not have the ability to modify their behaviour (for example, move from burning firewood for fuel), while those that have the ability may not be as willing, since the relatively lower share of their budget on direct or indirect energy consumption makes them reluctant to modify behaviour beyond a point (for example, switch to public transport or reduce consumption of air conditioning). For most of Indian households, however, the scope for lifestyle changes is limited, since they are already quite low carbon. In 2004–5, only 26 per cent of urban and 8 per cent of rural households owned motorized two-wheelers and just 5 per cent of urban Indians and less than 1 per cent or rural Indians owned cars. The average annual electricity consumption (for electrified households in 2004–5) was only about 630 kWh for rural areas and 1200 kWh for urban areas.[4] The immediate opportunities are not in the household segment, with the particular exception of the top quintile in metropolitan cities. For example, in a large metropolis like Delhi, over half the households in the top 20 per cent consumption bracket own cars, while over 40 per cent of the households in the top 40 per cent consumption bracket own motorized two-wheelers.[5]

These richer households can prove to be a bottleneck in the transition to low carbon growth. They rely on private transport and are increasingly moving to locate in self-contained private housing developments on the outskirts of cities (where it is easier for developers to aggregate land), where they self-provide continuous supply of electricity, using diesel generating sets, and obtain water by pumping groundwater. These households are thus similar to suburban households in the US, with high energy consumption for both living and transportation. Their lifestyles are based on even more private goods than in the US, like private healthcare and education. If they are able to mobilize politically, they would agitate against the kind of compact city forms envisaged by many of the authors in this report such as Dinesh Mohan in 'Urban Transport and Climate Change: Issues and Concerns in the Indian Context'; Ramakrishna Nallathiga in 'Low Carbon Intensity Urban Planning Strategies for India: The Growing Cities of India: Towards Sustainability and Emission Reduction'; Sweta Byahut in 'Low Carbon Intensity Urban Planning Strategies for India: Climate Change and Urban Planning Strategies for India'; Shaleen Singhal, Jim Berry, and Stanley McGreal in 'Linking Regeneration and Business with Competitiveness for Low Carbon Cities: Lessons for India'.

Along with compact cities, issues relating to urban transport, brought out lucidly by Kaushik Ranjan Bandyopadhyay in his chapter 'Reconciling Economic Growth with Low Carbon Mobility in India: Addressing the Challenges' could become a battleground. Already, as Akshima T. Ghate and Sanjivi Sundar in the chapter 'Putting Urban Transport Sector on a Low Energy and Low Carbon Path: A Focus on the Passenger Transport Sector in Million-Plus Cities' bring out, there is significant growth in emissions from passenger transport in India. To counter this trend, Sanjiv N. Sahai and Simon Bishop in their chapter 'Multi Modal Transport in a Low Carbon Future' propose a seamless multi-modal urban transport network with rail, bus rapid transit, and a novel bus concession system that relies on gross cost contracts, on performance-based, management-based on intelligent transport systems, and information integration. However, this kind of scenario becomes a challenge, not so much because it is technologically difficult to design[6] or because existing investments in infrastructure will become stranded, but because it will be politically difficult to execute. While Chapter 20 by Dinesh Mohan (in this report) recognizes this, the trade-off is largely posited as one between personal and private transport. However, there is a further twist to this tale.

Even between different public transport modes, like rail-based and road-based transport, the choice is unlikely to be technical. Both Sanjiv N. Sahai and Simon Bishop

[4] In urban Delhi, which was the highest among all states, it was 2,000 kWh per year per household. This is based on the National Sample Survey (61st Round) conducted in 2004–5. This refers to residential consumption and is not comparable to the figure given in Table 1, which divides the total electricity consumption (including non-residential consumption) by the total population.

[5] Chakravarty et al. (2005) argue that the richer among such households in countries such as India have a relatively high carbon consumption pattern and construct a scheme to allocate carbon allocations by incorporating the income distribution of different countries, to address the criticism of national averages, that rich households in poor countries get a free pass, riding on the poverty of their fellow citizens.

[6] There is also a significant technological challenge. In order to be attractive to the urban resident in India, the public transport system must replicate the benefits of door-to-door travel offered by private transport as closely as possible, at the operating cost of a two-wheeler, which is less than 2 cents or Re 1 per km.

(in Chapter 19 of this report) and Dinesh Mohan (in Chapter 20 of this report) seem to favour road-based solutions as being more amenable for India. However, it is also a fact that rail-based solutions entail much larger expenditure and contract values. If the political and bureaucratic establishments were to intrinsically prefer such solutions because it makes their 'empire' larger or because it offers more opportunities for illegal gratification, then the more expensive solution could be locked-in for political economy reasons, even it were less appropriate.

Adaptation

Much of our discussion thus far has been on the mitigation, consistent with the theme of a low carbon growth path. However, it must be recognized that the existing levels of CO_2 and most plausible scenarios require that we pay attention to scenarios where adaptation to climate change becomes a necessity. These may be along the lines depicted in part by Kala Seetharam Sridhar in her chapter 'Carbon Emissions, Climate Change, and Impacts in India's Cities', focusing on localized effects, but it also involves the recognition that some resources like water may become scarce in a broader sense. This is especially so in India, where scenarios developed by Revi (2008) show that drought and water stress are very possible.

In this context, one infrastructure sector that finds mention by several authors in this report is water. The use of water by humans in urban areas in India consumes considerable amounts of energy. Some of this is expended in pumping the water out of the ground for purposes of irrigation or for transportation from remote sources to large urban areas and for pumping them into large overhead storage tanks by municipal governments. Some more energy is consumed in treating the raw water to make it fit for human consumption. Another significant percentage is used to transport the wastewater to various treatment plants and then treat this water to bring it to a level fit to be discharged into water bodies. In the US, for example, this comprises about 4 per cent of the country's electricity consumption. Viewed from an energy conservation point, the effort is to make these processes more efficient. Climate change requires consideration of additional perspectives; for example, re-examining the processes, such as reducing the need to transport sewage by replacing centralized with decentralized treatment of wastewater and recognizing that water sources may become much more scarce, necessitating more expensive treatment for reuse and supplementation with energy intensive sources such as desalination.[7]

India offers many opportunities to save energy in water use. To begin with, the provision of 24×7 water supply at reasonable pressure would take away the need for millions of households to pump water into their individual overhead storage tanks. Similarly, as noted by Sreenath Dixit, J.V.N.S. Prasad, B.M.K. Raju, and B. Venkateswarlu in the chapter 'Towards A Carbon-Neutral Rural India: Challenges and Opportunities in Agriculture', and Jyoti Gujral, S. Davenport, and S. Jayasuriya in the chapter 'Is There a Role for Agricultural Offsets in Sustainable Infrastructure Development?: A Preliminary Assessment', the adoption of water-saving irrigation practices in crops such as rice (in addition to the increase in energy efficiency of pumps) would reduce the need to pump water. In new urban areas, the prevalence of housing colonies that aggregate multiple households make it institutionally easier to implement decentralized water treatment and reuse. Concomitantly, the rapid growth in new construction makes the installation of dual piping for such reuse more feasible. However, all of these involve substantial institutional interventions in areas like municipal governance and agricultural extension.

Concomitantly, it must also be recognized that much of the water transportation in rural areas currently involves human energy, whether in pulling water out of a well, pumping it using a hand pump or transporting it in pitchers carried by women. There is also little energy used in treatment of water or wastewater. All this is latent demand, which will likely overwhelm savings opportunities referred to above. This however does not detract from the need to undertake these actions, for it would still constitute a considerable reduction from the counterfactual.

More broadly, adaptation and its supporting infrastructure can take various forms. The building of houses in cities for those currently living in informal housing (to enable them to prevent storm damage, flooding, etc.) can be construed as adaptation infrastructure, as would construction of village water ponds, to adapt to water stress. Of course, it is also infrastructure for poverty alleviation. This dual-use property of adaptation infrastructure could be an issue, were there to be a climate deal that provided funding from developed countries to countries like India to defray the costs of investment in adaptation and

[7] In the United States, energy consumption for water treatment and supply is around 0.4 to 0.5 kWh per kilolitre and an additional 0.3 to 0.5 kWh per kilolitre for treatment, based on the nature of treatment technology. In comparison, desalination uses about 5 kWh per kilolitre.

mitigation infrastructure in response to climate change. In addition to any development benefits it may have, mitigation infrastructure has a clear co-benefit in terms of carbon reduction or capture, but the same is not true of adaptation infrastructure, which is designed as a precaution against effects of climate change. Ex post, just like an insurance premium, the more efforts to combat global warming succeed, the more infructuous investments in adaptation will appear, thus affecting their political support.

Way Forward

In the immediate future in India though, there is enough low-hanging fruit, feasible reductions in carbon emissions with limited lock-in. As brought out in many of the chapters in this report, such as by Lenora Suki in 'Drivers of Energy Efficiency Industries: Indian and International Experience in Infrastructure', many interventions have short payback periods from reductions in energy cost. At the grid level, as Pramod Deo and Vijay M. Deshpande notes (in this report), regulators are trying to reduce the electricity tariffs by compelling improvements in generation, transmission, and distribution efficiency, which also result in reducing CO_2 emissions. Many other non-disruptive opportunities also exist in traditional sectors like coal where, even without CCS, as Malti Goel shows in the chapter 'Implementing Clean Coal Technology in India: Barriers and Prospects', there are opportunities for reducing the carbon impact of coal-based energy. Malti Goel also shows how research may be locked into particular technologies like Integrated Gasification Combined Cycle (IGCC), which has received more attention than technologies such as Circulating Fluidised Bed Combustion (CFBC), despite the possibly greater suitability of the latter for the quality of coal available in India.

These opportunities exist not only in the realm of industry but also equally in the realm of services, as Yenneti Komalirani and Joshi Gauravkumar bring out in 'Carbon Dioxide Emission Reduction Potential from Civil Aviation Sector: A Case Study of Delhi–Mumbai Air Route' on increasing the carbon efficiency of operating practices in the airline industry. Exploiting these may however require aggressive outreach about opportunities, which organizations like Bureau of Energy Efficiency (BEE) are engaged in. This will also lead to a culture of carbon-awareness and carbon-efficiency in industry. Indeed, the BEE is going far beyond just awareness-building. It has already begun monitoring large energy users, and using its expansive powers, may mandate energy efficiency interventions in the future. Less visible opportunities, such as interventions in rural cooking and the possible lock-in risks, have already been mentioned earlier. Furthermore, in addition to the direct payback from reductions in energy cost, there may also be additional financial benefits available in the CDM (clean development mechanism) market.[8]

However, going beyond large users still has significant institutional problems, as well as difficulties with accessing CDM benefits. Programmatic CDM was an approach that was supposed to address this problem, but has had limited success. Ashok Singha, Papia Chakraborty, Suvra Majumdar, and Vijay Mahajan in 'Towards India Evergreen: The Role of Micro-Finance Institutions' advocate a complementary approach based, inter alia, on aggregated voluntary emission reduction transactions (AVERT) which avoids the problems that remain even with initiatives such as programmatic CDM. To the extent that it is possible to build the kinds of frameworks envisaged in such mechanisms, one can even envisage the benefits of efficiency being reaped by smaller actors. Such a large but a still relatively limited set of such small actors (compared to interventions in rural cooking) are the numerous captive power plants below 1 MW, which as Tirthankar Nag in 'Captive Generation in India: The Dilemma of Dualism' notes, constitute an aggregate capacity comparable to the larger (above 1 MW) captive plants. Developing an institutional structure to enable these disparate, but numerous actors to access carbon finance is one of the challenges for the future.

For the two actors that seem to have the ability to act, namely, the organized private sector and the richer households, a simple way of increasing their willingness would appear to be to raise the price of carbon. Doing this directly through a formal carbon tax appears difficult, given our current knowledge about the carbon content of various products.

However, a robust intermediate intervention is possible in the form of taxes on universal intermediate items whose carbon content is well-known, such as fuel and electricity. The revenues from such taxes can then be dedicated to supporting efficiency improvements in actors that have the willingness but not the ability, such as the informal manufacturing sector, where the potential for efficiency benefits is high. In this context, there is a vigorous debate (see Box 2) on the effectiveness of cap-and-trade (C&T)

[8] Though the paperwork involved in CDM projects is substantial, there is now growing expertise in Indian consultants to handhold potential beneficiaries through this complex process.

vis-à-vis carbon taxes (CT).[9] In India too, there are plans to introduce tradable renewable energy certificates as an indirect way to develop a carbon market. Theoretically, C&T can attain the required reduction in emission at the lowest possible cost. However, quantification of both baseline and current emissions remains a challenge and, as noted in Box 2, it is limited to points of obligation. In addition, the impermanence of reduction and leakage into non obligated entities could weaken the effectiveness of the C&T regime. A CT regime, or its surrogate, on the other hand, has the potential to increase the price of carbon across the board and provide incentives to all actors, big and small, to reduce carbon consumption.

Like other interventions to reduce carbon emissions, both CT and C&T will need progressive new legislation before they can be put into effect. However, legislation is just a necessary first step. India has some of the most stringent legislation to protect the environment, but its implementation is quite distant.[10] It is thus necessary to consider the machinery that will implement legislation to bring down carbon emissions. Like C&T, the incidence of CT too may be limited to a small number of actors, due to lacunae in implementation and the informality of economic activity that could limit coverage for both options. Of the two, C&T requires the administrative machinery to ensure that every individual point of obligation does not exceed its permitted emissions. In India (and possibly in many other countries), the experience of our state pollution control boards (SPCBs) does not inspire confidence in our ability to monitor individual emitters.

CT, on the other hand, relies on the tax collection machinery. Over the years, this aspect of the Indian

Box 2
Cap-and-trade vis-à-vis Carbon Taxes

Under a CT, each tonne of CO_2 emitted or tonne of carbon contained in fossil fuels would attract an additional specified tax. Entities would cut their emissions, if it were less costly than paying the tax. At a point in time, the tax would be an upper limit on the cost of reducing emissions, but the total amount of CO_2 emitted in a given year would be unpredictable. Since the tax can be levied on most consumption using current administrative mechanisms, beginning with surrogates and making it more precise as better data becomes available on carbon content, it can potentially move the entire economy to a low carbon path.

A C&T scheme limits total CO_2 emissions and mandates points of obligation[11] to possess allowances in order to emit. The initial allowances are allocated based on a proportion of past emissions or through an auction (in which case the government can raise revenue similar to a tax), and are tradable amongst the entities. Entities emitting less than their allowance can sell to those who would be exceeding the allowances they currently posses. They would be willing to pay a price based on the profits they would forego by reducing production. This price then becomes the cost of reducing emissions. A C&T programme would place an upper limit on the amount of emissions but the cost of reduction would vary. *However, this only applies to points of obligation. Emissions from other entities outside the scheme, such as households, would not be directly affected by the scheme*. Instead, since the price of goods and services (for example, transportation or electricity) with higher carbon content would rise as higher costs are passed to consumers, this can then be expected to induce them to move to a lower carbon consumption path.

The European Union's Emissions Trading Scheme (a C&T system to limit CO_2 emissions) has been in operation since 2005. In June 2009, the US House of Representatives passed the American Clean Energy and Security Act of 2009 (ACES) with a narrow margin (219 to 212) and it is now under consideration of the Senate. Popularly known as the Waxman Markey Bill, it establishes a C&T system to limit US CO_2 emissions. It thus appears that C&T is becoming the instrument of choice for limiting emissions. In the US, its adoption is driven partly by its perceived success with SO_2 emissions (Acid Rain Programme), which covers about 700 power plants, where it is thought to have reduced SO_2 emissions at lower than expected cost. But is it really a better choice than a carbon tax? The Congressional Budget Office, in its evaluation (see CBO (2008)), came out in favour of CT vis-à-vis C&T as a more efficient method of reducing emissions largely on the grounds of more widespread incentives; administrative simplicity; and higher predictability of cost, permitting firms to plan ahead and greater possibility of international co-ordination.

So, is the support emanating from the belief that while C&T is not necessarily better, it is clearly more politically feasible, since CT is a political no-no, given the US legislator's aversion to taxes? As Nobel winning economist Paul Krugman puts it '[The US has] a real chance of getting a serious cap and trade program in place within a year or two [and] no chance of getting a carbon tax for the foreseeable future'. Is it political economy lock-in that is driving this policy?

[9] See Chapters 9 and 25 of this report, where C&T trade is discussed in some detail.

[10] See, for example, the various reports of the *Supreme Court Monitoring Committee on Hazardous Wastes*, available at http://www.toxicslink.org/art-view.php?id=64

[11] A person or organization (such as a business) that has a legal responsibility to monitor and report emissions and, at the end of each reporting period, to hold and surrender a quantity of 'emission units' equal to their emissions.

government has improved substantially, especially in collection from larger units, both in terms of direct and indirect taxes and is likely to improve further with the implementation of the Goods and Services Tax (GST). At this point, therefore, it would appear that our ability to implement CT is substantially better than C&T. Our mix of instruments should be informed by such evaluations. In the final analysis, the choice will depend on relative coverage of the extent of carbon emissions. In terms of the two options, it may well turn out that both kinds of regimes may be needed, a C&T that focuses on large emitters and a CT regime that tries to bring the smaller actors into the net.

Once there is effective implementation of regulations that impact carbon emissions, there will be a demand for technologies that can meet this need. This demand will drive the innovation and development of more such technologies and, more importantly, the growth of institutions and firms that will deploy and diffuse them. As Pinaki Bhattacharyya and Shishir Maheshwari in 'Private Equity Financing for CleanTech Infrastructure' argue, India has all the desirable conditions for providing scale opportunities for private equity investments in clean technologies.

Conclusion

The significance of the informal sector and the need for interventions in rural cooking and captive power plants illustrate the singular context for developing a low carbon growth path in India. None of these areas constitute a significant opportunity in developed countries. In addition, in India a critical actor is its independent institutions like electricity regulators, who are taking a proactive stance on energy efficiency and promotion of renewable energy, through feed-in tariffs, demand side management, etc., as seen in the chapter by Pramod Deo and Vijay M. Deshpande. In this, they are following earlier precedents set by courts in the environmental arena, as noted in Chapter 1 'Infrastructure Regulation for Low Carbon Economy: Survey of Key Issues and Concerns' by Videh Upadhyay. In contrast to such proactive efforts from regulators, the chapter by Dilip Kumar Ghosh 'Local Dynamics in the Adoption and Implementation of Low Carbon Technologies: The Case of West Bengal' points to the limited engagement with rural local government, who remain unfamiliar with climate change. Yet, changing the thinking of such leaders is critical to drive 'action that may seem unconventional to the local populace'. This is especially the case in agriculture, given the considerable reduction in emissions possible, with limited lock-in fears, as detailed in chapters 24 Part 1 and 25 of this report. It is thus clear that India may have only limited benefit from foreign models, and would need to develop its own playbook. This is both an opportunity and a challenge.

The disparate and numerous emissions sources in India also mean that traditional CDM or even programmatic CDM can only be of limited benefit. This is especially true for adaptation infrastructure, due to its dual use nature, as noted earlier. India will have to go beyond CDM in financing its adaptation and mitigation efforts and a domestic carbon tax and/or auctioning of C&T permits may be a source of such resources.

These features of the Indian environment indicate that the chances of being locked into inappropriate infrastructure may be high. The National Action Plan on Climate Change (NAPCC) has reinforced a sense of urgency. However there is a danger in pushing too hard. Since the off-the-shelf solutions currently available are not customized for Indian conditions, an unthinking transplantation of technology in the hurry to be energy efficient may lock us into inappropriate technology. A good example of this is the LEED Green Building Standards, which relies on input characteristics rather than output metrics like kWh per square metre, such as BEE. Thus, where part–time, part-space cooling may be more appropriate, and efficient, but full-time, full-space solution for air conditioning may well end up using more energy (see Jiang (2009)).[12] Similarly, in the attempt to tailor solutions to the demands of the CDM market, we may lock ourselves into inappropriate technologies or policies or focus on sectors where the mitigation potential may be smaller, but the applicability of CDM more evident, and neglect sectors that have large mitigation potential but limited applicability of CDM. Concomitantly, positive interventions do exist. It is also possible to lock ourselves into a low carbon path, for example, by investing in seamless facilities for our cities, that makes public transport more convenient and comfortable, with journey times comparable to personal transport, while it stays affordable. This could build preferences for public transport, replacing today's status premium on private transport. Lock-in could thus help as well as harm.

[12] For the US, while Newsham et al. (2009) find that the average LEED building consumes less energy than non-LEED buildings and over 30 per cent of LEED buildings consume more energy than similar non-LEED buildings, Scofield (2009) finds that LEED buildings are statistically equivalent to non-LEED buildings.

Haste is necessary when Earth's survival is at stake, but it is also important to ensure that the infrastructure we build as we hurry does not make matters worse. Ensuring that it needs foresight and wisdom and lots of common sense, all rare qualities today.

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