Physical Capital: The Role of Infrastructure in Green Growth Strategies

Key Messages

- Infrastructure policies are central to green growth strategies, because of the huge potential for regret (given the massive infrastructure investments required and the inertia they create) and substantial potential for co-benefits (given the current gap in infrastructure service provision).
- The infrastructure gap offers opportunities to “build right” and leapfrog; but huge unmet needs also can imply difficult trade-offs between “building right” and “building more,” particularly given financing and fiscal constraints.
- A framework for green infrastructure must build on efforts to address overall constraints on infrastructure finance (including cost recovery issues) and must develop strategies to both minimize the potential for regrets and maximize short-term co-benefits to address social and political acceptability constraints.

Getting infrastructure “right” is at the heart of green growth. It is critical because infrastructure choices have long-lived and difficult-to-reverse impacts on the carbon, land, and water intensity of future patterns of development. Infrastructure also offers substantial co-benefits: many investments needed for growth and improved living conditions are also good for the environment.

The challenges and opportunities of greening infrastructure in developing countries must be understood in the context of the huge unsatisfied needs that remain: the fact that much remains to be built creates an opportunity to build right; the fact that needs are so large implies important trade-offs between “building right” and “building more.” While the additional costs of building green are relatively modest, they occur in a context of frequently binding financing and fiscal constraints. Complicating matters is the dramatic rise in population and growing urbanization. As such, a framework for green infrastructure needs to offer strategies to minimize the potential for regrets and maximize short-term local benefits; and it must build on efforts to...
address overall constraints on infrastructure finance.

This chapter focuses on long-lived infrastructure systems such as energy, water, sanitation and transport infrastructure, although it recognizes other infrastructure—for example, buildings—also play a key role in driving the demand for infrastructure services (irrigation is covered in chapter 5).

**Infrastructure as the heart of green growth**

Infrastructure policies are central to green growth strategies because of their unique characteristics, namely the large potential for regret (linked with the large inertia embodied in infrastructure investments) and the substantial potential for co-benefits (linked to the current gap in infrastructure service provision).

**A massive potential for regret**

Infrastructure decisions are long-lived (table 6.1). They influence the purchase of consumer durables and the location choices of households and firms. As such, they create substantial inertia in socioeconomic systems. Because the economic system reorganizes itself around infrastructure, this inertia can even exceed the physical lifetime of specific infrastructure investments. A delay in greening investments may therefore prove extremely costly if it results in a lock-in into technologies that turn out to no longer be appropriate (because of their excessive carbon, land, or water intensity) or settlement patterns that prove vulnerable to changing climatic conditions. The infrastructure already in place now will raise global temperatures by 1.3°C–1.7°C unless it is retrofitted or retired before the end of its useful life (Davis and others 2010; Guivarch and Hallegatte 2011).

Inertia is particularly evident in urban policies and the transport-related decisions that shape cities. The consequences of these decisions are illustrated by the contrast between Atlanta and Barcelona, two cities with roughly the same population and income but dramatically different densities and, hence, dramatically different options in terms of urban transportation and housing (figure 6.1). Once a city is developed, it is difficult to change its form. This irreversibility makes the idea of “growing dirty and cleaning up later” inapplicable in this domain (box 6.1).

The consequence of the inertia in infrastructure development is an enormous potential for regret if decisions are made without adequate consideration of how conditions—socioeconomic, environmental, and technological—will change over time. The potential for regret has always been a challenge for infrastructure policy; it is made much more complex by climate change, which introduces deep uncertainty about future climatic conditions, technologies, and environmental standards and prices.

**Uncertainty about future climatic conditions.** This complicates decision making, given the importance of weather and climatic conditions for infrastructure design and performance (Hallegatte 2009). In the energy sector, weather directly affects demand (which varies with temperature) and supply. Water availability affects electricity production from hydropower and thermal plants (because of cooling needs), and wind and nebulosity determine wind and solar power. Electricity networks are also highly vulnerable to extreme events

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**TABLE 6.1 Sectors in which inertia and sensitivity to climate conditions are great**

<table>
<thead>
<tr>
<th>Sector</th>
<th>Example</th>
<th>Time scale (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>Dams, reservoirs</td>
<td>30–200</td>
</tr>
<tr>
<td>Land-use planning</td>
<td>New development in flood plain or coastal areas</td>
<td>&gt;100</td>
</tr>
<tr>
<td>Coastal and flood defenses</td>
<td>Dikes, sea walls</td>
<td>&gt;50</td>
</tr>
<tr>
<td>Building and housing</td>
<td>Insulation, windows</td>
<td>30–150</td>
</tr>
<tr>
<td>Transportation</td>
<td>Port infrastructure, bridge, roads, railways</td>
<td>30–200</td>
</tr>
<tr>
<td>Urbanism</td>
<td>Urban density, parks</td>
<td>&gt;100</td>
</tr>
<tr>
<td>Energy production</td>
<td>Coal-fire plants</td>
<td>20–70</td>
</tr>
</tbody>
</table>

Source: Hallegatte 2009.
FIGURE 6.1 Urban densities determine cities’ options for greening
(built-up areas of Atlanta and Barcelona, represented at the same scale)

(such as strong winds and snowstorms, as illustrated by the January 2008 snowstorm that left millions of people stranded across China or the repeated power outages caused by heavy snow in the United States). Transport infrastructure, which affects urban development and land use, including in flood-prone areas, must also account for long-term climate changes.

Uncertainty about how technologies evolve. This has a particularly important effect on cities. With current technologies, low-density single-home suburban developments lead to high carbon emissions. But they may become sustainable in terms of emissions (albeit maybe not in terms of water and land consumption) with efficient electric vehicles, decarbonized electricity production and low-energy-consumption houses (box 6.2). Uncertainty about the evolution of energy technology costs complicates the design of energy policy (Kalkuhl and others 2011). Anecdotal evidence suggests that uncertainty is also leading investors to postpone investments for fear of being stuck with an older and uncompetitive technology.

Uncertainty about environmental policies and prices for energy, oil, or carbon. Energy-intensive development may create deep vulnerabilities and loss of competitiveness in a future with high carbon or energy prices (Rozenberg and others 2010; World Bank 2010). Dense cities are less vulnerable to shocks in energy—hence transportation—prices (Gusdorf and Hallegatte 2007).

The combination of sensitivity to uncertain parameters and the high level of inertia creates a high risk of lock-ins into situations that will be undesirable in the future. Avoiding these lock-ins—and the corresponding regret or retrofitting costs—should be a priority for decision making on infrastructure (see chapter 7).

The vast potential for co-benefits

The second reason why infrastructure will play a key role in green growth strategy is that
BOX 6.1 The case for immediate action in the transport sector

Transport is a major contributor to CO₂ emissions. It is also one of the fastest-growing sources of emissions. Not surprisingly given the 1 billion cars already on the road, road transport accounts for about two-thirds of total transport emissions.

Developing countries, which still face a huge transport infrastructure gap, have the opportunity to choose their transport development path: low-emission transport or car-dependent transport (box figure B6.1.1). Experience suggests that demand for car ownership increases dramatically at annual household incomes of $6,000–$8,000. If history repeats itself, an additional 2.3 billion cars will be added by 2050, mostly in developing countries, given expected economic growth and past patterns of motorization (Chamon and others 2008). Without policies to encourage high-density urbanization and public transport, high reliance on individual car transport will ensue.

If public transport is included as a major part of modal structure in urban transport, there is no conflict between a low emission transport sector and rapid growth or high income. In fact, economies with some of the lowest ratios of energy consumption to gross domestic product (GDP) in the world—including Japan, Singapore, and Hong Kong SAR, China—have experienced extraordinary development over the past few decades.

FIGURE B6.1.1 As income rises, will countries choose low energy consumption in road transport?

(relationship between per capita income and energy consumption from the road sector)

**BOX 6.2 The impact of technologies on transport policies—not enough?**

Given the significance of emissions from road transport, the green growth path of transport depends on how rapidly vehicle technologies develop. If low- or zero-emission vehicles become available in the near future, relatively small changes in existing transport infrastructure stock would be required. People could continue relying on individual cars without harming the climate. But this may not be realistic.

Technical standards in transport can also help reduce emissions in the sector. Emissions per kilometer of new cars have historically been reduced through better gasoline and diesel internal combustion engines, better lighting and air conditioning, and better tires. The aviation fleet has also reduced emissions in accord with international efficiency agreements. There is also an opportunity to reduce emissions levels through Intelligent Transport Systems—for instance, by allowing drivers to access timely traffic reports, identify available parking spots, and optimize routing.

But technical standards are unlikely to lead to massive reductions in emissions, so barring the rapid emergence and global adoption of low-carbon engine technologies, modal shifts will be needed. An average bus emits only half as much CO₂ equivalent per passenger kilometer as a small car. For travel between distant cities, railways are even more environmentally friendly than buses: emissions from light-rail transit can be as much as half of average bus emissions. But the efficiency and feasibility of modal shifts depend on urban forms, with mass transit requiring minimum levels of density, and on tackling market structure and coordination failures.

Modal shifts will also imply addressing consumer preferences, and here the “nudging” and social marketing campaigns discussed in chapter 2 are an important complement to price incentives and supply-side interventions. In a world in which major automobile companies spent some $21 billion worldwide on advertising in 2009—an increasing percentage of which is aimed at emerging markets—public transport agencies across Africa, Europe, and North and South America are beginning to apply to public transportation the same marketing approaches used by the auto industry to bolster sales to shift demand for public transportation (Weber and others 2011).

infrastructure is a domain in which substantial synergies exist between economic growth and the environment. Infrastructure systems are indeed designed to provide welfare-improving and productivity-enhancing services, which are critical for development, but they also often provide environmental benefits.

Providing service to the unserved—who usually pay a higher price for water and energy than connected households—provides both social and environmental benefits (box 6.3). Universal access to water and sanitation is good not only for welfare and economic growth—with impacts on health and human capital, especially for the poor—but also for the environment. (For instance, providing sanitation services to the slums surrounding the Guarápiranga Lake helped slum dwellers but also preserved the water source of 25 percent of São Paulo’s 18 million inhabitants in the early 1990s.) This is also true for energy. When reliable network electricity is available, pollution is reduced and competitiveness increases, as firms no longer need to rely on expensive back-up diesel generators. Photovoltaic (PV) solar systems are optimal solutions for isolated, low-density areas; hydroelectricity is the cheapest and most reliable energy source for some countries (box 6.4). Better public urban transport reduces congestion and air pollution, with large economic and health impacts.1

An additional source of co-benefits is linked to distributional effects. Infrastructure consumption subsidies are both regressive and bad for the environment (Komives and others 2005). Subsidies not only distort demand, with financial and environmental consequences, they also often fail to reach the very poor they are supposed to help (see chapter 2). The poor do not own cars and often are not served by utilities; if they do, they consume
BOX 6.3 Benefits from using photovoltaic electricity in rural areas

Power grids in Africa are available only in cities and high-density areas. In most rural areas, kerosene and candles are the main source of lighting, while dry cell batteries are used to power radios. All are expensive (1 liter of kerosene can cost more than $0.80 and provides about 20 hours of light). PV systems are superior solutions. For example, a solar home system may be sized to power a refrigerator and television (costing $1,000); a large television and three lamps (for $250); a small television, three lamps, and a radio (for $100); or a lamp, radio, and cell phone charger (for as low as $50—about the same cost as a cell phone).

Africa offers a huge market for modern, energy-efficient lighting products. Although the market has a low profit margin, its strength is in the high number of clients (if the right product for the right price can be offered). The GTZ-sponsored pico-PV program and the World Bank Group’s Lighting Africa are examples of two initiatives that aim to transform the lighting market from fuel-based products to clean, safe, and efficient modern lighting appliances.

Source: ESMAP 2009.

BOX 6.4 Hydropower as a green choice for lower-income countries

For lower-income countries, sustainable hydropower represents an important clean energy source—and one that will assume a larger share of the world’s energy production as these countries develop further. Africa is exploiting only 7 percent of its hydropower potential; if the region developed it to the same extent that Canada has, its electricity supply would be multiplied by a factor of 8.

The reality, however, is that hydropower projects are complex—with impacts on agriculture, water management, irrigation, food production, climate change, and the sustainability of communities. They require detailed planning and studies before a shovel breaks the ground. Social and environmental impacts have to be assessed and addressed, consultations must be held, and regulations need to be developed. In some cases, new institutions have to be created and made viable. None of this is easy or cheap, but it is essential, because well-managed hydro projects can generate an array of benefits, including flood control, drought management, provision of water supply, and environmental benefits.

Storage facilities for hydropower are essential to adapt to changes in the hydrological cycle that are expected to occur as a result of climate change. With increasing water scarcity in some regions, there is a need to develop multiyear storage that is economically, environmentally, and socially feasible. Where the intensity and frequency of floods increases, storage is required to manage flows. Multipurpose storage facilities can also provide water services to agriculture, water supply, and environmental flows.

Box text contributed by Diego Rodriguez.

Small quantities of water and electricity or transport fuel. The lion’s share of consumption subsidies benefits wealthier segments of the population (Arze del Granado and others 2010). The urban poor may enjoy some spillovers, but the rural poor seldom do.

There are also trade-offs between infrastructure development and the environment. A first trade-off is related to infrastructure’s direct environmental footprint. Building the infrastructure that is needed for development will have detrimental impacts on natural areas, biodiversity, and the environment (Geneletti 2003). Another trade-off is linked to the fact that building better (cleaner, more resilient, or both) can be more expensive. This trade-off raises the fear that countries faced with severe financing constraints may need
to choose between “building right” (which may make both economic and environmental sense) and “building more” (which may be what is required socially).

But the additional cost of building greener infrastructure should not be overstated. In some sectors, green infrastructure is more expensive—where electricity grids are present, solar or wind energy is more expensive than electricity produced from coal, for example. But thanks to innovation and economies of scale, the difference in cost is narrowing rapidly, and green energies are now competitive in some contexts (where the hydropower endowment is large, where electricity is produced off-grid, or where carbon is priced). In the transport sector, providing public transport is more expensive than building roads, but public and individual transports are imperfect substitutes: in highly congested cities, public transportation becomes necessary for economic reasons, and the environmental benefits can be reaped with no or little additional cost. In the construction sector, the additional cost to build lower-energy buildings—thanks to better insulation and more efficient heating systems—may not exceed 5 percent, and this additional investment cost is rapidly recouped by reduced energy bills.

One case in which additional costs may create trade-offs is the retrofit of existing buildings. Indeed, retrofitting the lowest-efficiency buildings into average-efficiency buildings costs €500 per square meter in France (Giraudet and others 2011). However, energy savings can pay back upfront costs in many instances. The main constraint is thus one of access to capital rather than financial or economic viability, as many green investments pay for themselves over the medium to long term.

### Recognizing the need for efficiency: Meeting large unsatisfied infrastructure needs within tight fiscal constraints

Developing countries are characterized by large unsatisfied needs, including needs met by infrastructure such as drinking water and reliable electricity (table 6.2). The scale of unmet needs is particularly great in Sub-Saharan Africa, where less than a third of households have access to electricity. Connectivity also remains low in the developing world, particularly in rural areas, where only 70 percent of the population has access to an all-weather road (33 percent in Africa). Access to water has increased, but 780 million people still lack access to an improved water source (WHO-UNICEF 2012).

Globally, the challenge is greater for sanitation than for water supply. The percentage of the population with adequate access to potable water increased from 74 percent in 1990 to 89 percent in 2010. Sanitation figures are much lower, having increased from 44 percent in 1990 to just 63 percent in 2010 (WHO-UNICEF 2012). The difference partly reflects the greater “public good” and “externality” element of sanitation and sewerage—that is, individuals feel the welfare impacts of inadequate access to water, whereas other sectors and members of society feel the effects of inadequate sanitation (through impacts on water quality and corresponding health and productivity impacts). Estimates of the costs of inadequate water and sanitation in the Middle East and North Africa are about 1 percent of GDP in the Arab Republic of Egypt and 2.8 percent in the Islamic Republic of Iran (Hussein 2007). With 2.5 billion people lacking access to improved sanitation, the achievement of the Millennium Development Goal (MDG) on sanitation is unlikely.2

### TABLE 6.2 Gaps in access to infrastructure in developing countries remain large, particularly in Africa

<table>
<thead>
<tr>
<th></th>
<th>All developing countries</th>
<th>Africa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of households with access to electricity</td>
<td>75</td>
<td>31</td>
</tr>
<tr>
<td>Improved water source</td>
<td>89</td>
<td>61</td>
</tr>
<tr>
<td>Improved sanitation facilities</td>
<td>63</td>
<td>31</td>
</tr>
<tr>
<td>Percentage of rural population with access to an all-weather road</td>
<td>70</td>
<td>33</td>
</tr>
<tr>
<td>Telecom: mobile and fixed lines per 100 inhabitants</td>
<td>85</td>
<td>46</td>
</tr>
</tbody>
</table>

Source: Roberts and others 2006 for roads; World Bank 2011d for telecom; IEA 2011 for electricity; and WHO-UNICEF 2012.

Note: Road access data are for 2005 or the latest year available up to that date; telecoms, for 2010; water and sanitation data are for 2010. Averages are weighted by country population. The road access indicator measures the share of the rural population that lives within 2 kilometers of an all-season road.
Filling the infrastructure gaps in developing countries—to address household needs and expanding infrastructure so that firms have access to the kind of energy and transport services they need to compete—will cost an estimated $1.0–$1.5 trillion a year, or 7 percent of developing-country GDP (Fay and others 2010). Developing countries are currently investing about half that amount, although the amount varies dramatically by region and income level. In Africa, infrastructure needs were projected to reach 15 percent of the region’s GDP in 2008, about twice the level actually spent (Foster and Briceño-Garmendia 2010). Moreover, given the constraints on poor households’ budgets, increases in infrastructure services need to be provided in a way that is affordable.

In the energy sector, the challenge is to provide all people with modern energy to meet their basic needs at affordable costs while ensuring the sustainable growth path of energy consumption (through conservation and greater energy efficiency) and making energy sources more environmentally sustainable (box 6.5). Thus, the goals of the

**BOX 6.5 The energy challenge: Expanding access and increasing supply in an efficient, clean, and cost-effective manner**

How will countries meet the goal of the United Nations Sustainable Energy for All initiative of providing universal energy access at affordable costs while ensuring environmental sustainability through improved efficiency and an increased role for renewables? The answer is through a portfolio of technologies (World Bank 2010).

To achieve universal access to electricity by 2030, countries need to develop not only grid systems but also off- and mini-grid power systems, at least as a transition solution. The International Energy Agency estimates that about 45 percent of electricity will come from national grids, 36 percent from mini-grid solutions, and the remaining 20 percent from isolated off-grid solutions serving remote and low-density areas. Off- and mini-grid technologies can be complemented by other solutions at the end-user level. For instance, the Lighting Africa initiative lowers entry barriers to the off-grid lighting market by establishing quality standards, developing a good investment climate, and supporting product development while educating consumers on the benefits of solar lighting products. In 2010, more than 134,000 solar portable lamps that had passed Lighting Africa quality tests were sold in Africa, providing more than 672,000 people with cleaner, safer, better lighting and improved energy access.

Energy-efficiency policies could potentially contribute a quarter to a third of averted greenhouse gas emissions by 2050 (World Bank 2010). Technologies that increase energy efficiency are typically not costly or innovative: existing technologies alone could reduce energy consumption 30–40 percent across many sectors and countries. For instance, 70 percent of lighting (which consumes 20 percent of total global electricity consumption) can save 50 percent of energy use just by using current technologies alone. A problem is that the transaction costs for energy-efficiency projects tend to be high, compared with their relatively small amount of investment. Relatively long pay-back periods may still be a considerable barrier to financing these projects (World Bank forthcoming).

Among renewable sources of energy, large-scale hydropower tends to be the least expensive. It can be competitive with conventional thermal generation. Geothermal energy can also be cost competitive, making it another suitable candidate. Both types of energy involve large upfront costs and long lead-times for development, however. At the opposite end of the spectrum, solar energy is more expensive, but it may still be the least-cost option in remote, isolated areas.

One challenge in developing renewables is the temporal variation in the availability of electricity. Demand for electricity varies continuously, with large fluctuations during the day and even larger variation from season to season. Rapid variability of some renewables can add to the challenge of maintaining a balance between supply and demand at all times. A proper mix of generation technologies with varied output control characteristics (for example, hydropower with storage and fast-responding gas units), well-developed transmission systems, and improved forecast and grid operations capacity will help cushion the effects of variability.
United Nations Sustainable Energy for All (UN SE4ALL) initiative are to achieve universal access to modern energy, doubling the global rate of improvement of energy efficiency, and doubling the global share of renewable energy.

And providing modern energy services to all does not need to be done at the expense of the environment—in fact, the environmental impacts are likely to be modest to positive, even when using brown technologies. This is because the poor consume little even when they are connected to modern infrastructure services, particularly in comparison to the rich. For instance, the additional emissions produced by providing electricity using standard technologies to the 1.3 billion people who currently lack service could be offset by a switch of the U.S. vehicle fleet to European standards (World Bank 2010). Greening, infrastructure does not need to come at the expense of universal access—in fact, universal access is likely to be good for the environment.

In the water sector, developing countries will need to invest an estimated $72 billion a year to reach the MDG targets on improved water supply and sanitation, 75 percent of which is needed just to maintain existing facilities (Hutton and Bartram 2008).

Meeting infrastructure needs, protecting the environment

Even with significant synergies between infrastructure service development and environmental consideration, greening growth will increase investment needs in the infrastructure sector. As an illustration, an analysis of mitigation scenarios from four models suggests that the global energy investment needed to achieve a greenhouse gas concentration of 450 ppm CO$_2$-eq (parts per million CO$_2$ equivalent) could amount to $350 billion–$1.1 trillion a year by 2030 (figure 6.2). A 550 ppm target appears much easier to achieve, requiring $50–$200 billion of additional annual investments. (These figures are gross investment costs; they do not take into account the benefits from higher energy efficiency and reduced operating costs.) These additional investment needs are significant, but they remain a small share of total world investments, at least for the 550 ppm target. They do not include the cost of adapting infrastructure to a changed climate, which could cost developing countries an additional $15–$30 billion a year by 2050 (World Bank 2010).

Financing infrastructure: Efficiency and cost recovery to improve access and sustainability

Investment in infrastructure in the developing world is inadequate partly because infrastructure is expensive and “lumpy”—capacity can be increased only in large increments, not through a continuous process. In addition, when investments require public funding, the financing gap is linked to limits to the borrowing capacity. Even when a project is economically beneficial and will generate sufficient tax revenues to pay back the upfront cost, it is difficult to mobilize private finance because of information asymmetry, long return on investments, and political risks. Doing so would require shifting the risk-adjusted return upward, by increasing returns or reducing risks, so that proposed projects can compete with other categories of investment.

Another reason for the insufficiency of investment in infrastructure is that economic and fiscal sustainability has long been a major challenge in the infrastructure sector. Full-cost pricing continues to be an elusive goal, and infrastructure often involves significant technical and nontechnical inefficiency. Colombia grappled with both issues successfully (box 6.6). In Africa, quasi-fiscal deficits caused by underpricing, technical losses, and nonpayment amount to about 2 percent of GDP. Eliminating these problems could offset about a third of the financing gap (Briceño-Garmendia and others 2008). In South Asia, more than 20 percent of electricity produced is lost because of technical and nontechnical reasons, including illegal connections (World Bank 2011d); 30–45 percent of water
is leaked from the network or not accounted for (IBNET 2011).

What can be done? Addressing these inefficiencies would help improve both infrastructure coverage and the greening of infrastructure. Strengthening cost recovery would not only contribute to the financial sustainability of energy sector development, it would also encourage consumers to use energy wisely. Efficient management of metering, billing, and collection would improve the financial performance of service providers. New metering technologies based on information and communications technology are facilitating this activity in many places, including small, off-grid private service providers and large publicly owned distribution utilities. And more efficient management of utilities would eliminate waste and reduce environmental impacts.

In addition, incentive mechanisms should be tightened at the utility and end-user levels. The biggest hurdles to doing so are accountability and enforceability in implementing tariff setting and collection. The cost of energy imports and power generation can be volatile; it needs to be passed on to consumer prices, although smoothing mechanisms may be required. Adjusting tariffs will greatly improve the financial sustainability of utilities. But utilities will also have to take measures against illegal connections and nonpayers.

Chapter 2 discusses the difficulties in eliminating subsidies to infrastructure services. It suggests complementary actions to mitigate undesirable distributive impacts of these measures (such as connection subsidies or targeted cash transfers).

Another measure in the arsenal may be cross-country collaboration. Because infrastructure exhibits significant economies of scale and scope, cross-country collaboration—for instance, through regional power pools—is generally helpful, particularly for small countries.

In Africa, where many countries are too small to build national power plants at an efficient scale, $2 billion of energy investment could be saved if trade in power trade was fully exploited (Foster and Briceño-Garmendia 2010). Regional power pools (for example, in West and East Africa) can help capture benefits from economies of scale and smooth the intermittency of solar and wind energy. Trade and cross-country coordination also help countries manage natural resources (such as shared water resources) and improve reliability.

Hydro-meteorological services also benefit from cross-country collaboration. An analysis of South Eastern Europe estimates that the financing needed to strengthen national hydro-meteorological services in seven countries without regional cooperation and coordination would be about €90 million (ISDR and others 2011). With deeper cooperation, the cost would be 30 percent lower.

Managing demand

Improving the delivery of infrastructure services is critical. But in infrastructure, increased supply often translates into
In 1964, only 50 percent of people in Bogota and other large cities had access to electricity, water, and sanitation. And coverage rates were even worse in smaller cities (about 40 percent for water and electricity and 20 percent for sanitation). Today, Colombia has almost universal access to basic services in cities of all sizes. But achieving convergence took more than 40 years (box figure B6.6.1).

How did Colombia achieve near universal coverage? The key was a series of policy reforms in the 1990s that brought tariffs toward cost recovery levels. In the water sector, average residential tariffs per cubic meter were increased from $0.33 in 1990 to $0.78 in 2001 (World Bank 2004). With almost 90 percent of households having metered connections, the price increase triggered a decrease in household water consumption from 34 to 19 cubic meters per month over the same period—in the process reducing the need for major new infrastructure. But even with higher prices, water remains relatively affordable for the average household. The tariff structure allows the Colombian government to cross-subsidize the poorest consumers from richer households and industrial users. As a result, the average poor household spends less than 5 percent of its income on utility services.

In the electricity sector, in the 1990s the rules on who gets to generate and sell electricity were changed. After two major black-out periods (1983 and 1992/93), the government grappled with increasing capacity or increasing efficiency. Given severe financial constraints, increasing capacity was not an option. Deregulation was therefore undertaken to improve the efficiency of existing capacity (Larsen and others 2004). As part of the reforms, electricity was unbundled into generation, transmission, distribution, and commercialization. In the 1990s, the electricity sector represented a third of Colombia’s public debt stock. By 2004, this had fallen to less than 5 percent and Colombia had become a net exporter of electricity.

Box text contributed by Somik Lall.
increased demand, making a supply-side-only approach both costly and ineffective. For instance, building new roads is often ineffective in reducing congestion because it incentivizes the use of individual vehicles, leaving congestion unchanged. For this reason, action is also needed to manage demand. Policy makers can choose from an array of tools that includes price instruments, regulations, and integrated planning of supply and demand.

**Prices: Important but hampered by low elasticity**

Price elasticity—that is, the percentage change in quantity demanded in response to a change in price—is relatively low in the transportation sector, at least in the short term. This is, in part, because consumers may be slow in responding to price signals. But it is also because the real cost of transport (sometimes referred to as the generalized cost) includes both the monetary cost of transport and the cost of the time spent in transportation. And sometimes the cost of time is larger than the monetary cost of transportation. Elasticity is greater in the long run, because individuals can adjust their choice of where to live, means of transportation, or lifestyle. For instance, the price elasticity of automobile fuel demand ranges from −0.1 to −0.4 in the short run and −0.6 to −1.1 in the long run (Chamon and others 2008).

This low elasticity explains why the rebound effect (whereby people may increase their driving when the cost of car use decreases as a result of improved efficiency) is relatively limited, even though it may be greater at lower income levels. Sorrel (2007) finds that this effect should remain below 30 percent (that is, less than 30 percent of the gain in efficiency will be “taken back” by the increase in demand). Greene and others (1999) find that the rebound effect for individual transport in the United States is about 20 percent.

Various price instruments have proven efficient. Singapore’s Area Licensing Scheme—the first-ever comprehensive road pricing scheme in the world—required drivers to pay an area license fee of S$3 ($1.25) a day to enter the central business district during peak hours. The number of vehicles entering the restricted zone declined by 73 percent, and average speeds increased by an estimated 10–20 percent (Federal Highway Administration 2008). Modal shift can improve the efficiency of such price-based transport policies and help mitigate their negative consequences (such as the significant spatial inequality they can create) (see Gusdorf and others 2008). But it requires investments in public transport multimodal coordination (such as creating parking lots next to train stations), and urban planning (to maximize access to public transit and ensure that passenger density is high enough to justify the required investments).

In the water sector, different uses have different elasticities. Residential use has a low price elasticity, estimated at about −0.1 to −0.3 (Nauges and van den Berg 2009; Nieswiadomy and Molina 1989). Agricultural use has a higher elasticity, and subsidies (whether to water or to the electricity needed for pumping) in this sector can thus create distorted incentives, favoring activities with high water consumption. And disincentives to water conservation are greatest where the resource is scarcest (Frederick and Schwarz 2000). Removing subsidies and raising prices can thus be efficient in this sector.

**Demand-side actions, standards, and regulations: Critical complements to prices**

Price-based instruments can be made more efficient if complemented with appropriate demand-management actions. Large quantities of water can be saved in India through better irrigation technologies, obviating the need to exploit new raw water sources. In China, industrial water reuse systems can save water, reducing the need to build expensive water conveyance systems. Many of the technologies that can make a difference already exist and are in use in developed countries. Further application needs to be supported by institutions and promoted by sector leaders. India’s Total Sanitation campaign is a successful example of using
noneconomic incentives to promote greener options (box 6.7).

Standards and regulations may also be useful where price elasticity is limited or the political economy of price reform is complex. Examples of such instruments include renewable portfolio standards, in which regulators require utilities to include a given percentage or an absolute quantity of renewable energy capacity in their energy mix.

In transport, fuel economy standards are common for new vehicles (see chapter 2). In 1995, Japan introduced fuel economy standards to reduce new car fuel consumption by 19 percent, achieving the target by 2004. A new target, set in 2006, aims for another 23.5 percent reduction (An and others 2007). In Europe, improvements in fuel economy occurred largely as a side effect of air pollutant regulations, although automobile manufacturers agreed with the European Commission on a voluntary fleet average emission target of 140 grams of CO₂ per kilometer for new passenger cars. Governments can also create automobile restricted zones to limit passenger car traffic in urban areas, as Denmark did in the city of Aalborg.

Promoting clean cooking and heating solutions is another case in which standards and public investments are likely to be more helpful than pricing instruments. Replacing traditional three-stone cooking fires with advanced stoves could significantly reduce emissions and health risks (World Bank 2011b). Without drastic interventions, 2.7 billion people may still lack clean cooking facilities in 2030 (IEA 2011).

Integrated market development, including technology standards, is needed to promote the use of clean and efficient solutions at the household level. The Global Alliance for Clean Cookstoves, launched in September 2010, aims to enable 100 million households to adopt clean and efficient stoves and fuels by 2020. The alliance works with public, private, and nonprofit partners to help overcome the market barriers that impede the production, deployment, and use of clean cookstoves in the developing world.

**Green infrastructure requires planning and strong institutions**

Because infrastructure is lumpy, infrastructure systems cannot be grown incrementally and continuously, and they need to be planned in a holistic manner. A road or train line cannot be designed without considering other parts of the transport system, land use regulations, and urban planning.

Moreover, different infrastructure systems interact across sectors and cannot be designed in isolation. Water availability affects electricity generation, and electricity is critical in water management (for groundwater pumping, for example). Transportation and energy interact closely: energy production often requires transport infrastructure, and different transport modes have different energy needs (from liquid fuel transport to electricity grids for electrified cars). Smart use of information and communication technologies can green the urban environment and improve the efficiency of other infrastructure systems (box 6.8). Thus, much can be gained from

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**BOX 6.7 Using noneconomic incentives to reduce the demand for water and sanitation**

India’s Total Sanitation Campaign, launched in 1999, focused on communication, education, community mobilization, and the provision of toilets in government schools, mother/child centers, and low-income households (World Bank 2011c). There was little government contribution to the capital cost of sanitation facilities. Instead, the focus was on private investment and private behavior change.

Part of the effort involved the Clean Village Award Program—awards to local councils that achieved the status of “Open-Defecation Free and Fully Sanitized Uni.” The awards—inspired by a program initially introduced in Maharashtra (the “Sant Gadge Baba”)—helped increase reported sanitation coverage from 21 percent in 2001 to 37 percent in 2008.
a planning system that can integrate various objectives and infrastructure systems at both the country and regional level to significantly reduce infrastructure costs.

**Developing cities: Managing rapid expansion to tap the potential for efficiency gains**

Rapid urbanization is both a driver and a feature of economic development, with serious consequences for infrastructure design (World Bank 2009). In many developing countries—particularly countries transitioning from low- to middle-income status—the next few decades will see a dramatic increase in the share of people living in cities. In fact, the number of people living in urban areas in developing countries is expected to double, from 2 billion to 4 billion, between 2000 and 2030. And this massive increase is expected to triple the physical footprint of urbanized areas from 200,000 to 600,000 square kilometers. The public policy and investment challenges of managing the social and environmental implications while promoting cities that are economic drivers of the economy are substantial. Fortunately, practical options exist to efficiently green the urbanization process.

The first priority is designing policies and institutions that can help anticipate future urbanization. These policies should enable existing urban areas to be redeveloped and should prepare the peri-urban fringe to accommodate new settlements. For this to work, land markets need to be functional. Urban land markets mediate demand and supply and enable the efficient use of land and optimal development of constructed floor area, both of which shape a city’s spatial structure. Developed countries typically rely on market data from transactions and property attributes to reveal land and property prices. In contrast, most developing countries lack the basic institutional machinery to value and price land.

Higher land prices routinely lead to higher density—which enhances productivity spillovers, potentially increases the supply of affordable housing, and helps manage the demand for transport. But this mechanism is sometimes impaired by land regulations—in many Indian cities the floor-space index is limited to 1 (as opposed to 5–15 in other Asian cities). As a result, high land prices coexist with low density and sprawl, creating both housing affordability and transportation issues.

Also, when “official” land prices do not reflect demand and are depressed at the urban periphery, it is likely that sprawl or suburbanization will be excessive. How the peri-urban expansion is managed will be a critical determinant of whether cities can harness agglomeration economies and induce efficient...
resource allocation. The absence of a functioning land market creates a major urban governance challenge, as the scale at which urban and metropolitan economies now operate often does not coincide with their physical and administrative boundaries. The institutional arrangements that can enhance coordination across these entities is likely to be context specific, but significant efforts are needed to make them emerge.

The second priority is redeveloping older, obsolescent areas to promote more efficient development and achieve higher densities. Older areas typically share several common traits. Their network of streets and alleys is often irregular and highly granular—limiting the ability of developers to build modern high-rise buildings. An alternative is to redesign these areas to accommodate higher densities. Doing so typically requires assembling small plots into larger and more efficient parcels and ensuring that the redeveloped area has adequate infrastructure (particularly transport, water, electricity, broadband Internet, and public services) to support higher population densities. These actions should be designed using consultations with the local population, to make sure they benefit. For instance, rehabilitation projects need to account for the fact that slum dwellers often gain more from slum upgrading than from relocation (World Bank 2006).

The third priority is integrating land policy with urban mobility and transportation (Viguié and Hallegatte 2012). Options for urban transportation are closely tied to urban land development and can create both positive and negative externalities as cities grow. Problems arise when there are inconsistencies between new developments and mass transit investment—as in Hanoi, where new dense urban development projects are not being located near the planned transit network. This kind of planning creates a double risk of having too few users of a public transit system, threatening the financial and social return on investment, and increasing the number of cars on the roads, with consequences on congestion and air pollution.

Urban transport is best addressed as part of integrated urban strategies that can address the interests of multiple user groups and anticipate long-term needs for which no one is yet advocating but that will become critical in the future. Although public transport tends to be more sustainable than personal motor vehicles, it is often unviable in low-density agglomerations (table 6.3).

Although planning and developing public transit is likely to generate co-benefits for economic integration and manage demand for private modes of motorized transport, these strategies should not come at the expense of allowing a wider range of transport options that can enhance the poor’s mobility. Surveys show that many people cannot afford public transport. In Sub-Saharan African cities, walking represents between 5 percent (in Kigali) and 80 percent (in Conakry) of all urban trips, with public transportation ranging from 10 percent to 90 percent (World Bank 2008). A significant share of households

<table>
<thead>
<tr>
<th>Population density</th>
<th>Typical region</th>
<th>Modal model split (%)</th>
<th>Automobile use (km/person/yr)</th>
<th>Public transport use (trips/person/yr)</th>
<th>Petrol consumption for transport (MJ/person/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low (25 people per ha)</td>
<td>North America and Australia</td>
<td>80 10 10</td>
<td>&gt;10,000</td>
<td>&lt;50</td>
<td>&gt;55,000</td>
</tr>
<tr>
<td>Medium (50–100 people per ha)</td>
<td>Europe</td>
<td>50 25 25</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>High (more than 250 people per ha)</td>
<td>Asia</td>
<td>25 50 25</td>
<td>&lt;5,000</td>
<td>&gt;250</td>
<td>&lt;15,000</td>
</tr>
</tbody>
</table>

Source: Gomez-Ibañez 2012.
Note: — = not available.
reports no public transport expenditure, but the average share of income spent in public transport ranges from 3 percent (in Addis Ababa) to 14 percent (in Lagos), reaching about $12–$16 a month in most cities. This implies that at low-income levels, the wider availability of different service levels and modes at different prices is a necessary strategy for providing urban transport services. In particular, improving sidewalks, streetlights, and other measures to protect pedestrian users should be parts of an urban transport strategy.

Urban transport also plays a key role in spatially integrating urban labor markets. As cities around the world expand their spatial footprints, the limited reach of walking trips may exacerbate slum formation, as many people trade off housing quality to be close to jobs. It can also severely limit labor market opportunities for people who live farther away from economic centers. Bovenberg and Goulder (1996) suggest that higher commuting costs can decrease labor supply. Graham (2005) finds that productive firms are located in accessible and densely populated places.

A fourth priority is integrating urban planning with natural risk management—still rare, especially in low-income countries. In 2005, the global community adopted the Hyogo Framework for Action, a 10-year plan to make the world safe from natural disasters. To date, 70 percent of high-income countries are carrying out urban and land-use planning under the framework, but only about 15 percent of low-income countries are doing so (figure 6.3). This low participation matters because cities are increasingly vulnerable to natural hazards, including floods that are becoming more destructive in many parts of the world. And considering the limited protection offered by dikes and sea walls, only risk-sensitive land-use planning can mitigate flood losses over the long term (Hallegatte 2011).

Given the role of urbanization in development, a green policy able to develop cities without increasing risks and negative environmental outcomes would help maintain or increase cities’ attractiveness and produce economic benefits (World Bank 2009). It is an open question as to how cities can
accommodate the huge increase in urban population that is expected in many regions without experiencing a hike in disaster losses (World Bank 2010). That said, a recent World Bank study uses Alexandria, Casablanca, Rabat, and Tunis to illustrate how flood risks and climate change can be integrated in urban planning (World Bank 2011a). Transportation infrastructure has a key role to play to make it possible for the population to live in safe locations while retaining access to jobs and services (Hallegatte 2011).

Infrastructure robustness and redundancy are critical to maintaining the functions of the economic system after disasters, especially in urban environments, where the failure of one component (such as electricity, transport, water, or sanitation) can paralyze activity. In many cases, indirect disaster impacts caused by the loss of lifeline and essential infrastructure services are of similar magnitude to direct disaster losses (Hallegatte 2008; Tierney 1997). However, increasing robustness and redundancy is costly, creating trade-offs between the resilience of the economic system and its efficiency in normal conditions (Henriet and others 2012).

Minimizing the potential for regrets and maximizing short-term benefits

Some infrastructure investments that are required from a development and economic perspective and useful from an environmental point of view cannot be implemented because of financial, institutional, or planning constraints. Given these constraints, a green growth policy should seek to minimize the risk from regret and maximize short-term benefits.

To do so, one needs first to identify what investments made today can lead to irreversibility that will cause regret in the future. An example is urban planning and urban form, which are being decided on now in many countries and cannot be easily reversed in the future. Next, one needs to identify what policies (such as removing subsidies or imposing an environmental tax) or additional investments in infrastructure (such as sanitation systems) can yield large co-benefits and synergies between economic and environmental objectives. An example is the provision of urban public transport in crowded cities with high congestion and air pollution levels, where public transport can increase economic efficiency and improve environmental conditions. Sometimes the synergy is between the environment and welfare, without being uniquely mediated by economic efficiency (an example is sanitation infrastructure, which improves water quality and thus population health).

Previous chapters have shown that many actions and policies can green growth and capture synergies between environmental protection and development. Designing a green growth strategy requires policy makers to choose among these options, based on what is most important and urgent. The next chapter proposes a methodology to identify priority actions, as a function of the inertia and irreversibility they imply and of the trade-offs and synergies they create.

Notes

1. Transport externalities in the United States are estimated at $0.11 per mile (Parry and others 2007). Traffic congestion not only increases emissions, it also increases local pollutants and noise.
2. WHO-UNICEF (2012) projects that by 2015 the share of people without improved water will have fallen to 8 percent, exceeding the target of 12 percent. In contrast, about 33 percent of the world’s population is projected to lack access to improved sanitation, far from the 23 percent target.
3. Investment needs is a relative concept, as it depends on what the target level of coverage and quality is. No firm data exist on how much countries invest in infrastructure, although efforts have been made to collect information for Africa and for private investments in infrastructure (see Fay and others 2010; MDB Working Group on Infrastructure 2011).
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World Bank. 2004. *Colombia: Recent Economic Developments in Infrastructure (REDI):*