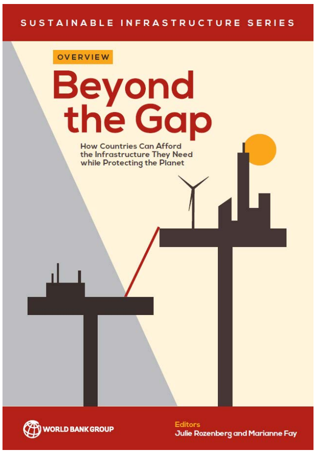


Overview

MARIANNE FAY AND JULIE ROZENBERG

KEY MESSAGES

- *How much countries need to spend on infrastructure depends on their goals, but also on the efficiency with which they pursue these goals.* By exploring thousands of scenarios, this report identifies the most important drivers of cost for future infrastructure investments and exposes the implications of different policy choices. It finds that new infrastructure could cost low- and middle-income countries (LMICs) anywhere between 2 percent and 8 percent of gross domestic product (GDP) per year to 2030 depending on the quality and quantity of service aimed for and the spending efficiency achieved to reach this goal.

- *With the right policies, investments of 4.5 percent of GDP will enable LMICs to achieve the infrastructure-related Sustainable Development Goals (SDGs) and stay on track to limit climate change to 2°C.* This report identifies policy mixes that could enable LMICs to achieve universal access to water, sanitation, and electricity; greater mobility; improved food security; better protection from floods; and eventual full decarbonization—while limiting spending to 4.5 percent of GDP per year on new infrastructure.

- *Infrastructure investment paths compatible with full decarbonization by the end of the century need not cost more than more-polluting alternatives.* Investment needs remain between 2 percent and 8 percent of GDP even when looking only at the scenarios that achieve climate change stabilization at 2°C. Instead, spending efficiency is key and depends on the quality of the policies accompanying the investment.

- *Investing in infrastructure is not enough; maintaining it also matters.* Improving services requires much more than capital expenditure. Ensuring a steady flow of resources for operations and maintenance (O&M) is a necessary condition for success. Good maintenance also generates substantial savings, reducing the total life-cycle cost of transport and water and sanitation infrastructure more than 50 percent.

INTRODUCTION

The infrastructure gap is large: 940 million individuals are without electricity, 663 million lack improved sources of drinking water, 2.4 billion lack improved sanitation facilities, 1 billion live more than 2 kilometers from an all-season road, and uncounted numbers are unable to access work and educational opportunities due to the absence or high cost of transport services. In LMICs, infrastructure—defined here as water and sanitation, electricity, transport, irrigation, and flood protection—falls short of what is needed to address public health and individual welfare, environmental considerations, and climate change risks, let alone achieve economic prosperity or middle-class aspirations.

The solution, many argue, is to spend more. Thus, the question of how to attract more resources to infrastructure (in particular, from the private sector) has dominated much of the conversation in international forums such as the Group of Twenty. The international community's SDGs and rising concerns about the urgency of action on climate change goals have added further impetus to the debate about how to entice the private sector to invest more in infrastructure.

But the story is not so simple. How much is needed depends on the objective pursued, and the objective pursued lies with the contexts, economic growth aspirations, and social and environmental objectives of individual countries. Further, the focus should be on the service gap, not the investment gap, and improving services typically requires much more than just capital expenditure. For example, ensuring that resources are reliably available to maintain existing and future infrastructure is a perennial challenge. And paying too much attention to the need to spend more risks diverting attention away from the need to spend better—an imperative for fiscally constrained LMIC economies—and the critical importance of establishing the needed institutions to pursue infrastructure goals sustainably.

This report aims to shift the debate regarding investment needs away from a simple focus on spending more and toward a focus on spending better on the right objectives with the use of relevant metrics. It contributes to that ambitious agenda by offering a careful and systematic approach to estimating the spending (capital as well as O&M) needed to close the service gap, moving away from single estimates of new capital investment needs. The objective is to highlight the sensitivity of the results to the ambition of the goals and the assumptions made—about pricing, technology, demand, climate change and climate policy, and other key factors—in ways that can help to inform policy choices.

In so doing, the report offers a framework for turning estimates of investment needs into useful tools for policy making. Estimates are structured in an "if-then" framework (*if* this is what is wanted and these are the assumptions made, *then* this is how much it would cost). To identify the most relevant objectives and assumptions in each sector, dozens and sometimes hundreds of scenarios are explored and the "cost drivers"—that is, the decisions and assumptions that best explain the spread in infrastructure costs—identified.

The report begins with a look at the complex relationship between infrastructure and growth and welfare, before presenting its methodological framework (chapter 1). It then presents detailed results for water and irrigation (chapter 2), electricity (chapter 3), transport (chapter 4), and flood protection (chapter 5). A final chapter examines what disruptive technologies could mean for the future of infrastructure services in LMICs.

The rest of this overview develops these messages and presents some sectoral results.

HOW MUCH NEW INFRASTRUCTURE IS NEEDED?

Infrastructure services depend on much more than just a stock of capital. Therefore, although a large literature on the impacts of infrastructure on growth, employment, and welfare has developed in the last decades, it is hardly conclusive. Possible explanations include the following:

- Most infrastructure is in the form of networks, which creates threshold effects and returns that vary with the stage of completion of the network and the number of users. Thus, the U.S. interstate highway system is believed to have had extremely large impacts on the U.S. economy up to its completion, after which additions to the network had limited effects.
- Transport and electricity services depend not only on roads and power plants but also on consumer durables (like cars, buses, trucks, and refrigerators) and machinery. The economic returns to these services are likely to be greater when the household or firm is located close to markets. In part because of this dependence on complementary inputs, impacts can be slow in coming. But because infrastructure is typically long-lived, the impacts may last a long time.
- Infrastructure may be built in pursuit of goals other than growth. Investments may be aimed at promoting social equity, environmental preservation, public health, political goals, or even personal enrichment. And in the absence of market signals, notably about future demand, it can be difficult to know where to build what and at what scale.

This complex relationship implies that it is not possible to determine an optimal level of infrastructure—and the existence of trade-offs between competing goals means that infrastructure planning and investment are inherently a political choice. Nevertheless, estimates of investment needs can help to inform that choice.

The most common methodology used to estimate infrastructure investment needs is, unfortunately, not the most useful. It relies on cross-country benchmarking that consists of looking at the average stock of infrastructure that countries typically have had at different levels of income, urbanization, and economic structure. Projections of future growth and socioeconomic change are then used to estimate the cost of maintaining the historical relationship derived from global estimates. This approach has several limitations: (a) there is no assumption of optimality—if infrastructure was under- or oversupplied in the past, the gap will remain, and (b) the estimates are highly sensitive to the projected values for growth and socioeconomic changes, with the sensitivity seldom explored.

A better approach, but one that applies only to cases where specific goals have been identified, is to price them using costing models. We use this approach for the access targets defined by the SDGs: universal access to safe water and sanitation, universal electrification, and improved accessibility to rural transport. For these targets, we rely on existing costing models, expanded and adapted to serve our needs.

Where objectives are more complex—such as a reliable electricity sector or a transport system adapted to a country's geography and trade patterns and compatible with low-carbon pathways—we use economic-engineering models. These are partial or general equilibrium models that, unfortunately, sometimes treat demand as exogenous. They do, however, offer a good representation of power systems and, more rarely, transport. Since no single model can do a good job of capturing the sectors in which we are interested, we rely on 14 different models that have been developed by various institutions for the different sectors and subsectors we study.

The main innovation of our approach, however, is in how we use these models. We draw from best-practice, long-term decision-making approaches to generate scenarios or "if-then" approaches. These approaches expose cost drivers and clarify the implications of assumptions, often implicitly made, about uncertain parameters (such as climate change policies or impacts, the evolution of technology, population growth, and urbanization). Our framework starts by identifying objectives and the metrics used to measure success; it then examines a variety of technical and policy options available to reach the objectives, along with exogenous factors that influence the cost and success of the investments in delivering the services.

As such, our approach has many advantages relative to previous estimates. First, we rely on numerous scenarios to explore uncertainty and the consequences of policy choices. Second, we use only models that have been published and peer reviewed and avoid proprietary, black-box models. Third, unlike many recent reports on investment needs that collate results from varying studies, we develop our results specifically for this report, following a consistent approach and timeline. Fourth, we systematically estimate not just capital expenditure for new investments, but also replacement capital costs as well as maintenance for new and existing infrastructure. Fifth, we provide estimates for both access and climate goals.

In the process, we make clear how misleading single-number estimates can be. Capital investments needed for electricity, transport, water and sanitation, irrigation, and coastal protection vary by a factor of 1 to 4 (or from 2 percent to 8 percent of GDP), depending on the ambition of the goal, the technologies adopted, how they are rolled out, their costs, and assumptions regarding socioeconomic pathways, notably population growth and urbanization (figure O.1). Even if we focus on investment plans that are compatible with a 2°C path, the range does not get narrower, as the goal of climate change mitigation is not the main driver of cost. We thus identify policy mixes that could enable countries to achieve the infrastructure-related SDGs: universal access to water, sanitation, and electricity; greater mobility; improved food security; better protection from floods; and eventual full decarbonization, while limiting spending on new infrastructure to 4.5 percent of GDP per year (table O.1).

We also offer an in-depth look at what disruptive technologies could mean for infrastructure. These technologies can come from enabling (and cross-cutting) innovations (such as the Internet of Things [IoT], artificial intelligence, machine learning, 3-D printing, and batteries) or from sector-specific ones (such as autonomous or electric vehicles and new biological water filtration techniques). But the disruption lies in how they are adopted, not simply in their availability.

SCENARIO APPROACHES ALLOW FOR INFORMED POLICY MAKING

Turning to sector-by-sector results, a clear finding is that, for every single sector, the two most important determinants of cost are the ambition of the goal in terms of access and quality—underscoring the need for policy debates on infrastructure to focus on this issue—and spending efficiency to reach the goal. Spending efficiency depends on the quality of complementary policies and on measures to reduce unit costs (like better procurement, planning, or execution). But the technologies used are also important given that they often involve trade-offs regarding the quality of service or other objectives (such as equity or environmental sustainability). The time horizon also matters: the solution that is least expensive over the next 15 years may result in higher costs later on.

Water: Lower-Cost Technologies Can Help to Achieve the SDGs

SDG targets 6.1 and 6.2 set out the goal of universal access to *safely managed* water, sanitation, and hygiene services and an end to open defecation by 2030. This goal can be achieved using more or less expensive technologies (for example, relying on septic tanks rather than on sewerage systems with treatment) and following different pathways. One option is to roll out universal access to *basic* water and sanitation services (an "indirect" pathway) before upgrading to safely managed

FIGURE O.1 The cost for infrastructure investments ranges from 2 percent to 8 percent of GDP per year in low- and middle-income countries

Average annual cost to develop infrastructure for the preferred scenario and full range of results, by sector, 2015–30

Scenario	Electricity	Transport	Water supply and sanitation	Flood protection	Irrigation	Total
Minimum spending scenario: less ambitious goals, high efficiency	Strongly reduce demand for energy through energy efficiency measures; invest now in renewable energy and energy efficiency; gradually ramp up access in poorest areas **US$298 billion 0.90% of GDP**	+ Increase the utilization rate of rail and public transport; densify cities; reduce demand for transport **US$157 billion 0.53% of GDP**	+ Provide only basic water and sanitation **US$116 billion 0.32% of GDP**	+ Keep coastal flood risk constant in relative terms; accept increased risks from river floods based on cost-benefit analysis **US$23 billion 0.06% of GDP**	+ Subsidize irrigation infrastructure only; promote low-meat diets **US$43 billion 0.12% of GDP**	= **2.0% of GDP (US$640 billion)**
Preferred scenario: ambitious goals, high efficiency	Invest now in renewable energy and energy efficiency; gradually ramp up access to electricity in poorest areas **US$778 billion 2.2% of GDP**	+ Increase the utilization rate of rail and public transport; densify cities; promote electric mobility **US$417 billion 1.3% of GDP**	+ Provide safe water and sanitation using high-cost technology in cities and low-cost technology in rural areas **US$198 billion 0.55% of GDP**	+ Adopt Dutch standards of coastal flood protection for cities; accept increased risks from river floods based on cost-benefit analysis **US$103 billion 0.32% of GDP**	+ Subsidize irrigation infrastructure only **US$50 billion 0.13% of GDP**	= **4.5% of GDP (US$1.5 trillion)**
Maximum spending scenario: ambitious goals, low efficiency	Do not invest in energy efficiency or demand management; provide high access to electricity using fossil energy for 10 years and early-scrap these capacities to switch to low carbon **US$1,020 billion 3.0% of GDP**	+ Let cities sprawl; favor rail investments without accompanying policies to increase the utilization rate of rail **US$1,060 billion 3.3% of GDP**	+ Provide safe water and sanitation using high-cost technology everywhere **US$229 billion 0.65% of GDP**	+ Adopt Dutch standards of coastal flood protection for cities; keep river flood risk constant in absolute terms **US$335 billion 1.0% of GDP**	+ Subsidize both irrigation infrastructure and electricity for water extraction **US$100 billion 0.20% of GDP**	= **8.2% of GDP (US$2.7 trillion)**

TABLE O.1 In the preferred scenario, investment costs are the highest for Sub-Saharan Africa and South Asia

Average annual cost of investment in the preferred scenario, by sector and region, 2015–30

% of regional GDP

		SSP region						
		Africa and Middle East		Asia		Latin America and Caribbean[a]	Former Soviet Union[b]	
		World Bank region						
Sector	Type of investment	Middle East and North Africa	Sub-Saharan Africa	South Asia	East Asia and Pacific	Latin America and Caribbean		Eastern Europe and Central Asia[b]
Electricity	Capital	1.3		2.4		1.2	5.3	
	Maintenance	0.3		0.7		0.2	1.1	
Transport	Capital	3.2		0.8		1.4	0.0	
	Maintenance	1.0		1.6		0.6	1.8	
Water supply and sanitation	Capital	0.9	1.6	0.8	0.3	0.5		0.4
	Maintenance	0.3	0.6	0.3	0.1	0.2		0.1
Irrigation	Capital[c]	0.1	0.4	0.3	0.1	0.1		0.0
Flood protection	Capital	0.2	0.8	0.5	0.3	0.2		0.06
	Maintenance	0.04	0.11	0.07	0.08	0.08		0.01
Total[d]	Capital	5.6	7.2	4.8	4.0	3.4		
	Maintenance	1.6	2.0	2.7	2.5	1.1		

Note: Country groups differ between sectors due to the different regional aggregation of models used. SSP = shared socioeconomic pathway, as used by the Intergovernmental Panel on Climate Change.

a. The following countries and territories are included in the SSP country group, but not in the World Bank country group: Aruba, The Bahamas, Barbados, Chile, French Guiana, Guadeloupe, Martinique, and Uruguay.

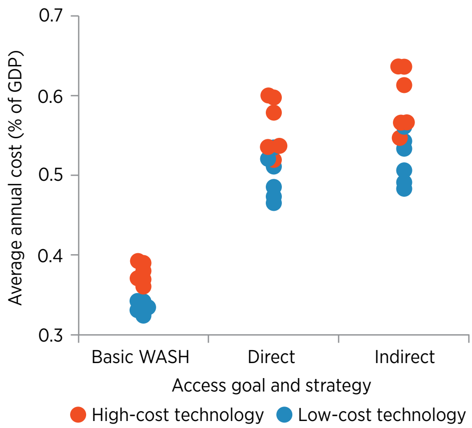
b. The Russian Federation is included in the SSP Former Soviet Union group, but not in the World Bank Eastern Europe and Central Asia group because it is classified as a high-income country.

c. Includes maintenance.

d. Based on countries that are included in all studies.

FIGURE O.2 The goal and the choice of technology are the main drivers of investment costs

Average annual cost of capital investment in water and sanitation, by access goal, strategy, and choice of technology, 2015–30



Source: Based on Hutton and Varughese 2016.
Note: Each dot corresponds to 1 of 36 scenarios based on variations across three goals (basic WASH, direct, indirect), two technologies (high cost, low cost), three possible rates of population growth and associated urbanization, and a high and a low estimate of capital cost. The graph (like others in this overview) is a "beeswarm" plot, which plots data points relative to a fixed reference axis (the x-axis) in a way that no two data points overlap, showing not only the range of values but also their distribution. The "direct" pathway is one in which every new household served is provided with safely managed water and sanitation; the "indirect" pathway first rolls out universal access to basic services before upgrading to safely managed services. Estimates include capital costs both to expand access and to preserve it for those currently served. WASH = water, sanitation, and hygiene.

services, as opposed to providing all newly served households directly with *safely managed* services (the "direct" pathway). We therefore examine the cost of achieving access to both basic and safely managed water and sanitation (two different levels of ambition) by varying technologies, pathways, and assumptions regarding population growth and urbanization as well as capital costs.

Our results show that while the total capital cost to achieve universal access to basic water and sanitation ranges from US$116 billion to US$142 billion, the cost to achieve the SDG targets ranges from US$171 billion to US$229 billion (0.5 percent to 0.6 percent of GDP). This cost includes the capital costs of extending coverage to persons who are currently unserved—which ranges from US$67 billion to US$129 billion (0.2 percent to 0.4 percent of GDP) for achieving SDG targets 6.1 and 6.2—as well as the cost of replacing *existing* assets that have reached the end of their useful life (US$100 billion).[1]

The principal driver of capital cost beyond the ambition of the goal is the choice of technology (figure O.2). The high-cost-technology option divides the results into two distinct groups, meaning that, regardless of capital cost overruns and population and urbanization rates, the low-cost technology remains less expensive. The pathway chosen (direct or indirect) makes little difference overall, although the indirect one is slightly more expensive.

The low-cost-technology option thus appears to be the most cost-effective means of achieving SDG targets 6.1 and 6.2. For most countries, it could make sense to start with low-cost technologies where the conditions (population density, urbanization) allow, notably for wastewater and sanitation, and then phase in the implementation of conventional sewerage and wastewater treatment—at least in the less densely populated areas. Such an approach facilitates building up the economic and financial sustainability of both the service and the utilities tasked with providing it.

There are several caveats to this point. First, in many countries, unfortunately, water quality norms and laws force cities to comply with very strict standards without allowing for gradualism. Second, non-network solutions (our low-cost option) are cost-effective in periurban areas, but not necessarily in dense urban areas. Non-network solutions may simply be impractical in very large, dense cities, while networked solutions create economies of scale in large cities. Finally, the low-cost option does not allow countries to achieve SDG target 6.3 ("By 2030, improve water quality by reducing pollution, … halving the proportion of untreated wastewater") and target 6.6 ("By 2020, protect and restore water-related ecosystems")—both of which require wastewater treatment facilities. As such, the choice is not so simple. Besides, new technologies described in chapter 6 of this report, like ultraviolet rays and photocatalysts powered by solar panels and new trencher systems to make pipe laying much quicker and less costly, have the potential to accelerate progress toward targets 6.1 and 6.2 at a relatively lower cost.

Irrigation: Public Support Boosts Food Security but Can Pose Issues for Other SDGs

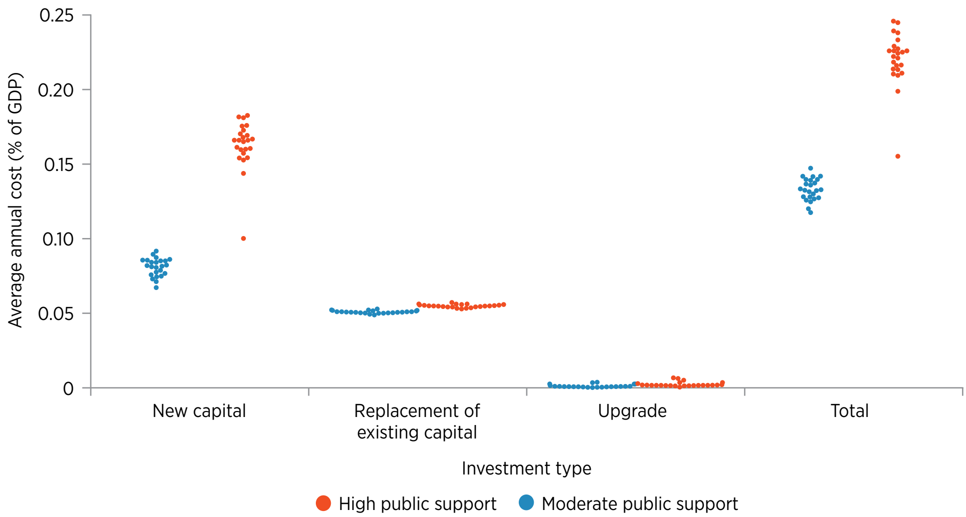
Where irrigation investments are justified, public support for irrigation is necessary because transforming traditional rainfed systems or upgrading water-inefficient irrigation systems to become productive irrigation systems typically requires investments that go well beyond the economic means of farmers. We thus model two strategies for public support for irrigation, which differ in the degree to which they subsidize irrigation capital and water use. We assess the cost of these two strategies across multiple scenarios, varying trade openness for food markets, climate change, and changes in diets.

The primary driver of future investment costs for irrigation is the extent of public support. Under the high public support policies—which fully subsidize water for farmers, resulting in irrigated land extending to its full potential—irrigation investments reach 0.15 percent to 0.25 percent of GDP per year, on average, between 2015 and 2030 in LMICs. This cost is substantially higher than under moderate public support policies that cover only capital expenditure (figure O.3). As with water and sanitation infrastructure, a large share of total spending is to replace existing capital (0.05 percent of GDP per year between 2015 and 2030).

At the regional level, the relative importance of new investment versus replacement of existing capital varies greatly, given that 33 percent of the world's total irrigated area in 2010 was in South Asia and 32 percent was in East Asia and Pacific, but only 6 percent was in Latin America, and only a few percent was in the other low- and middle-income regions. Total costs range between 0.08 percent to 0.16 percent of GDP annually for the

FIGURE O.3 Public support policies drive investment costs in irrigation

Average annual cost of investment in irrigation, by investment type and level of public support, 2015–30



Source: Based on Palazzo and others 2019.
Note: High public support policies fully subsidize irrigation capital expenditures and water for farmers. Moderate public support policies cover only capital expenditures.

Middle East and North Africa and 0.32 percent to 0.72 percent of GDP annually for Sub-Saharan Africa.

Moreover, while investments in irrigation would lead to improved food security overall under both high and moderate public support strategies—and in all scenarios—regional outcomes vary. In fact, similar public support policies to increase irrigation to its full potential would lead to unequal outcomes across regions with regard to an increase in food availability—from 10 kilocalories per capita per day in Europe and Central Asia to 51 kilocalories per capita per day in South Asia.

In addition, investments in irrigation can have negative impacts on environmental flows and on forests (because of the rebound effect created by higher yields, which increase the expansion of cultivated land) and thus on greenhouse gas emissions and biodiversity. Further, in dry areas, irrigation can lead to maladaptation, whereby farmers drain finite underground water resources or specialize in "thirsty" crops ill-suited for the local climate. Thus, complementary policies are needed to limit the negative impacts on ecosystems and provide farmers with climate-smart practices and technologies.

The most desirable strategy in our analysis is perhaps to provide moderate public support for irrigation, which subsidizes irrigation equipment but not water, so that farmers gain a sense of increased water scarcity when too much water is extracted. This strategy would cost LMICs around 0.13 percent of GDP per year.

Power: A Choice of "Basic" Electrification or Much More?

As with water, the SDGs set a goal for electricity, namely, universal access by 2030. To understand the cost drivers for universal electrification, we rely on a costing tool created to estimate country-level funding requirements for Sub-Saharan Africa and extend it to another six countries (Afghanistan, Bangladesh, India, Myanmar, the Philippines, and the Republic of Yemen) that, together with Africa, account for around 95 percent of the population without access to electricity.

The analysis explores several strategies pertaining to the tier of service (or consumption level it allows—from enough power to charge a phone and power a few light bulbs for a few hours per day to enough power to run high-consumption appliances reliably). Each tier is assessed across multiple scenarios built with uncertain parameters (like rate of population growth and urbanization, growth of industrial demand, evolution of technology cost, and fuel price).

The analysis shows that what drives the investment cost for universal electrification is the tier of service offered to newly connected households (table O.2). Governments may choose first to offer basic service to newly connected households or instead to offer high-quality service immediately. The annual investment required to reach universal access by 2030 varies between US$45 billion and US$49 billion (0.9 percent of countries' GDP) for the basic-service strategy to between US$53 billion and US$58 billion (1.1 percent of GDP) for the high-service strategy.

Providing access via lower tiers of service may also help to tackle demand-side constraints such as consumers' low willingness or ability to pay. A recent World Bank study estimates that, in Africa, demand-side constraints account for some 40 percent of the access deficit (Blimpo and Cosgrove-Davies 2018). Adapting the tier of electrification offered to the socioeconomic situation of the households or regions targeted could help to reduce these demand-side constraints. Newly connected households need not stay in low tiers of service in the long run.

TABLE O.2 Policy choices on tiers of service drive costs of electrification

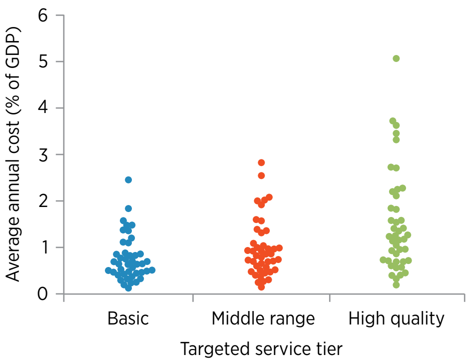
Average annual cost of investment in electrification, by tier of service provided, 2015–30

Indicator	Basic	Middle range	High quality
Amount (US$, billions)	45–49	47–52	53–58
% of GDP	0.92–0.94	0.95–0.98	1.1–1.2

Note: Costs are for Sub-Saharan Africa, Afghanistan, Bangladesh, India, Myanmar, the Philippines, and the Republic of Yemen. "Basic" corresponds to tiers 1 and 2 of the multitier framework of the Sustainable Energy for All global tracking framework; "middle range" refers to tier 3; and "high quality" refers to tiers 4 and 5. Variations within tiers of service are driven by assumptions regarding population growth, urbanization rate, industrial demand growth, technology cost evolution, and fuel price.

FIGURE O.4 Within Sub-Saharan Africa, the financial burden of reaching universal electricity access varies significantly

Average annual cost of investment in electrification in Sub-Saharan Africa, by targeted tier of service provision, 2015–30



Note: Each dot represents one Sub-Saharan African country. All uncertain parameters are set to "reference scenario" values. See Nicolas and others (2019) for a presentation of the reference scenario (demography parameters: SSP 2; fossil fuel prices: medium; technology cost evolution: medium; industrial demand growth rate: growing with SSP 2 GDP). SSP = shared socioeconomic pathway.

However, the electrification pathway could begin with tailored technological solutions instead of directly aiming to connect the whole population to the grid. This pathway may also be the only affordable way forward for many countries (figure O.4). The emergence of new technologies and business models for mini-grid and off-grid electrification should help to reduce costs and facilitate the journey toward universal access.

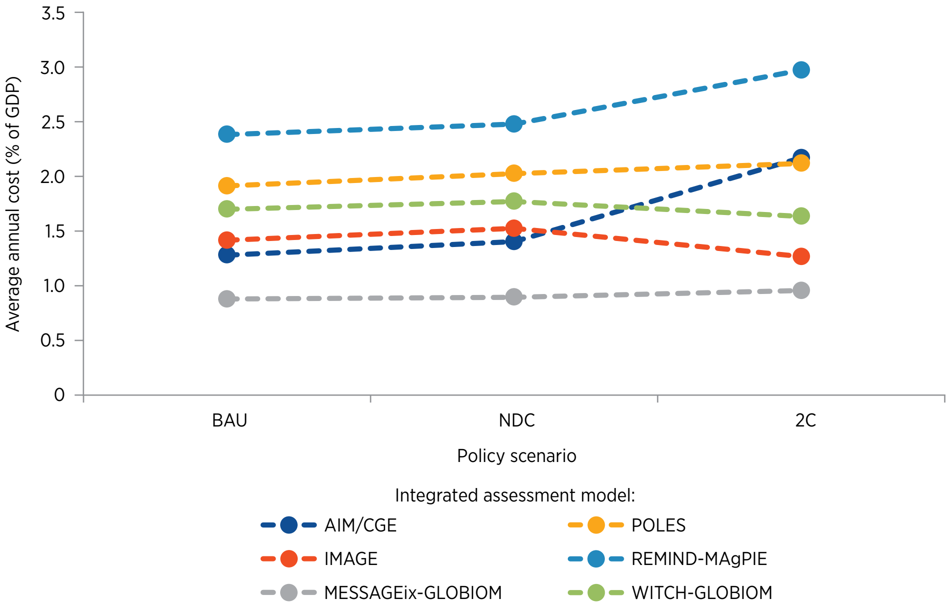
In addition to providing access to the millions without it, the goal is to continue to provide reliable and affordable electricity while moving toward a decarbonized power system that is consistent with the 2°C target or the 1.5°C target of the Paris Agreement. Many economic engineering models have examined this challenge by relying on different assumptions and strategies. We examine six of them to compare the costs of a business-as-usual strategy with those of a 2°C strategy (the costs associated with a 1.5°C target are discussed in box 3.3 in chapter 3).

The conclusion that emerges from this multimodel analysis is that, depending on the assumptions made regarding socioeconomic pathways, technological change, and policy choices, a 2°C pathway could be either more or less expensive than a business-as-usual one for the power sector. Two models anticipate higher investment costs (up to 3 percent of GDP), while the more optimistic one anticipates lower costs regardless of the pathway chosen (0.96 percent of GDP) (figure O.5).

The variables (or cost drivers) that explain this divergence of estimates across models include (a) the capital cost of low-carbon technologies (renewable and carbon capture and storage), (b) energy efficiency improvements and demand management (as captured by the elasticity of demand parameters in the models), and (c) the extent to which the transition results in stranded assets (for example, thermal power plants that need to be retired early). Each model has a different way of employing these levers, which results in very different possible costs and futures. The only consistent finding across models is that costs increase with stranded assets and consumption per capita, but models vary significantly regarding the extent to which they rely on stranded assets and lower per capita consumption as levers in achieving a low-carbon pathway (figure O.6).

FIGURE O.5 A 2C world may cost less than the business-as-usual one—or a lot more

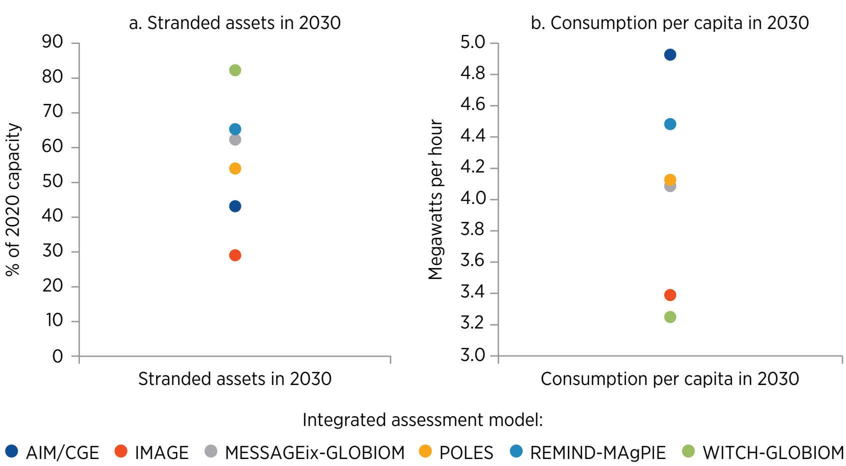
Average annual cost of investment in the power sector, by policy scenario and integrated assessment model used, 2015–30



Source: Based on McCollum and others 2018.
Note: Results exclude high-income countries. BAU = investment needed if countries follow a business-as-usual trajectory; NDC = cost of implementing measures announced by countries in their nationally determined contribution to the Paris Agreement on Climate Change; 2C = measures needed for an emissions trajectory consistent with keeping climate warming below 2°C.

FIGURE O.6 Models vary as to the extent to which decarbonization relies on stranded assets and reduced consumption

Extent to which decarbonization relies on stranded assets and reduced consumption, by integrated assessment model used



Source: Based on McCollum and others 2018.
Note: Stranded assets are calculated as total early retired and idle coal power plants in 2030 as a percentage of 2020 capacity. The assumptions are shown for a pathway consistent with a 2°C goal.

Our "preferred" pathway limits stranded assets, has a relatively high per capita consumption due to electric mobility, and invests mostly in renewable energy and storage. It results in capital costs of 2.2 percent of GDP per year, on average, for LMICs to increase electricity supply while decarbonizing their power systems.

Transport: Costs Are Shaped by Choice of Mode and Complementary Policies

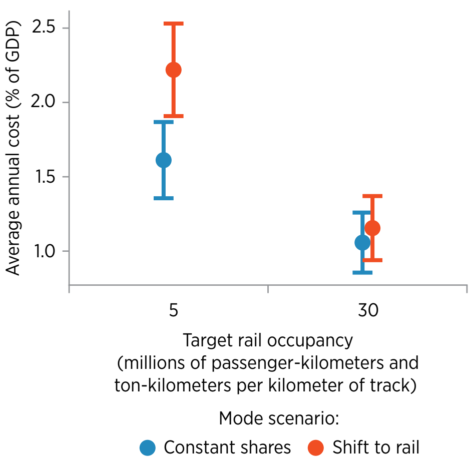
Transport investments need to respond to demand for mobility and to manage pollution, including emissions of greenhouse gases. But demand for mobility is endogenous and varies with socioeconomic changes. As such, we use one of the rare models that not only simulates decarbonization pathways but also captures a detailed evolution of the transport sector within the global economy. This model allows us to simulate future mobility scenarios for both freight and passenger transport across hundreds of scenarios that combine varying socioeconomic pathways, consumer preferences, spatial organization, climate policies and ambitions, and technical challenges to mitigation policies (such as availability and cost of low-carbon technologies).

The range of estimates across these many scenarios is extremely large. Transport investment pathways could cost anywhere from 0.9 percent to 3.3 percent of LMICs' GDP per year, depending on the assumptions made and the policy instruments rolled out. Among the dozens of parameters explored, the two main cost drivers are the choice of mode shift for terrestrial transport—constant shares or shift to more rail and bus rapid transit—combined with policies to increase rail transport occupancy (figure O.7).

The message is similar if we focus on urban transport—which we do using a separate model that allows for a much more detailed analysis of urban transport. We compare three strategies: (a) "business as usual," (b) "robust governance," which relies on classic instruments to promote low carbon use (such as pricing and regulatory policies, including stringent fuel and vehicle efficiency standards, and investments in public transport), and (c) "integrated land-use and transport planning," which adds land-use policies to the previous toolbox. The third strategy is

FIGURE O.7 The choice of terrestrial mode and rail occupancy drive transport investment costs

Average annual cost of capital investment in transport, by choice of terrestrial mode and rail occupancy, 2015–30



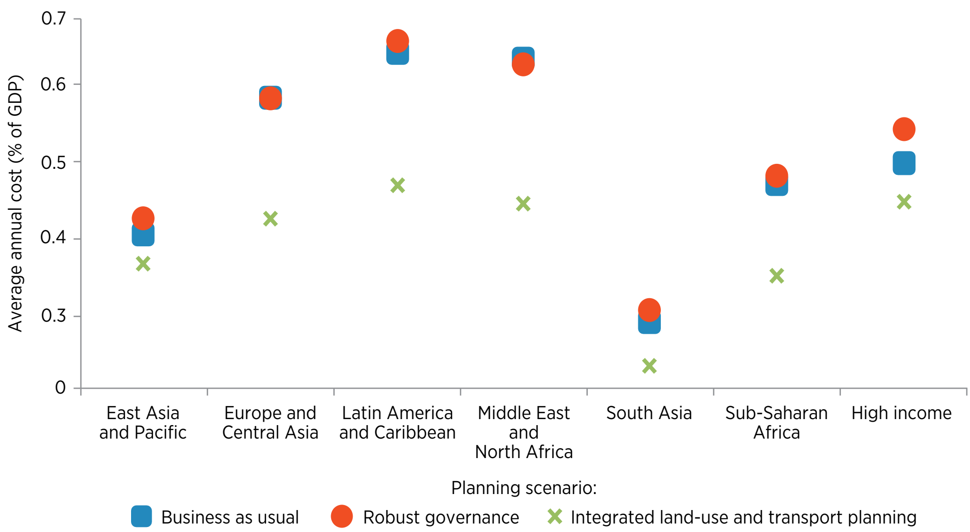
Source: Based on Fisch-Romito and Guivarch 2019.
Note: Numbers exclude Organisation for Economic Co-operation and Development countries. The bars represent the range of estimates, generated by hundreds of scenarios, while the central dots represent the median value across estimates.

systematically less costly than any of the others, a finding that holds across regions (figure O.8).

A clear result of these two studies is that future demand for mobility can be supplied at relatively low infrastructure investment costs and low carbon dioxide (CO_2) emissions with a shift toward more rail and urban public transport—if it is accompanied by policies that ensure high rail occupancy and land-use policies to densify cities (table O.3).

FIGURE O.8 The biggest burden in urban transport investment is on upper-middle-income countries

Average annual cost of investment in urban transport, by region and planning scenario, 2015–30



Source: Based on ITF 2018.

TABLE O.3 The preferred scenario uses low-carbon modes and accompanying policies for rail and public transport

Average annual cost of investment in transport infrastructure, by scenario, 2015–30

% of GDP

	Entire transport sector		Urban transport sector only	
Mode	Accompanying policy for high rail occupancy	No accompanying policy	Land-use planning	No land-use planning
Low carbon (rail, bus rapid transit)	**1.3**	2.3	**0.37**	0.47
Business as usual (roads)	n.a.	1.7	n.a.	0.45

Note: The preferred scenario is in bold. n.a. = not applicable.

Our "preferred scenario" for the entire transport sector would cost 1.3 percent of LMICs' GDP per year and would be consistent with full decarbonization after 2050. For urban areas, our preferred scenario is the integrated land-use and transport planning strategy, which would cost 0.37 percent of GDP per year.

We also look at the rural transport subsector, for which an indicator is mentioned in SDG 9 ("Proportion of the rural population who live within 2 kilometers of an all-season road"). However, no target is specified for this indicator—likely because it is unclear how a global target regarding rural accessibility could be set. To explore the challenge, we build a model to prioritize rural road investments based on two simple criteria: (a) maximizing the rural access index (RAI), which is defined as "the number of rural people who live within 2 kilometers of an all-season road as a proportion of the total rural population," and (b) providing connectivity with the primary and secondary network.[2] We price the investment option of upgrading existing tertiary roads or track to an all-season (paved) road.

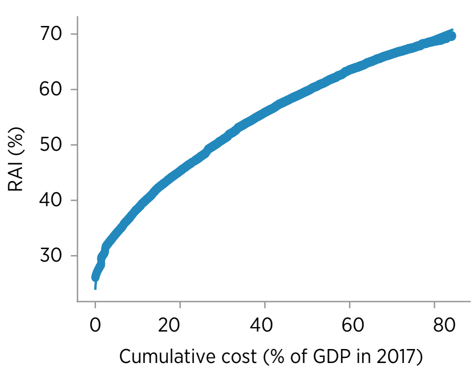
Results show that setting a simple universal goal—for example, 80 percent accessibility—is neither realistic nor appropriate. The incremental cost of increasing rural accessibility increases rapidly with the ambition of the goal and, for many countries, rapidly becomes prohibitive. To illustrate: paving Sierra Leone's tertiary roads would increase its RAI from 28 percent to 70 percent but cost more than the country's GDP in 2017 (figure O.9). Increasing the country's RAI by 1 percentage point would cost US$30 million when the RAI is 30 percent (about 1 percent of GDP), but US$200 million when it is 70 percent.

Given that it is impossible to cost rural access overall, because goals and costs are too country-dependent, we reverse the question and examine how much access countries could gain by 2030 by spending 1 percent of their GDP on new rural roads every year. Our results show that with optimistic assumptions regarding GDP growth, the increase in access could range from 9 percentage points, on average, in East Asia to 17 percentage points, on average, in Sub-Saharan Africa (table O.4). But across all LMICs, rural accessibility would increase only from 39 percent to 52 percent.

The implication, then, is that achieving universal access to paved roads may not be a realistic goal for many countries. Instead, rural roads should be prioritized carefully and other solutions sought for increasing social integration in

FIGURE O.9 Upgrading rural roads in Sierra Leone becomes costly—fast

Cumulative cost of increasing access from 28% to 70%



Note: RAI = rural access index.

TABLE O.4 Universal access to paved roads is not within countries' reach by 2030

Ability to achieve universal access to paved roads by 2030, by level of spending and region

% of rural population within 2 kilometers of a primary or secondary road

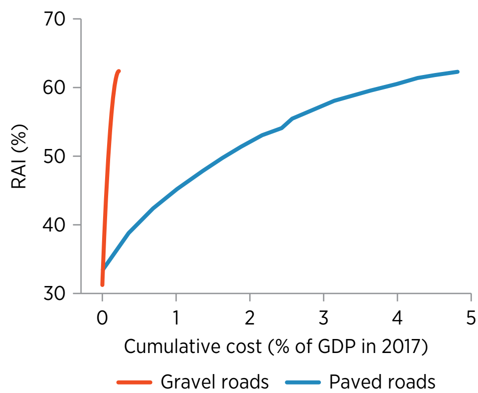
Region	2017	If all countries in the region spend 1% of their GDP per year by 2030
East Asia and Pacific	52	61
Europe and Central Asia	29	40
Latin America and Caribbean	34	45
Middle East and North Africa	39	51
South Asia	43	57
Sub-Saharan Africa	29	46

Note: GDP for each country grows following the shared socioeconomic pathway 5, which has the highest growth rate.

low-density areas. Options might include cabotage in coastal areas, smaller roads better suited for bicycle and motorcycle traffic, gravel roads (figure O.10), or even drones to deliver medical supplies and other essentials.

FIGURE O.10 The cost of greater accessibility is much lower using gravel rather than paved roads in dry climates

Cumulative cost of increasing rural access with gravel and paved roads in Morocco



Note: RAI = rural access index.

Floods: The Desired Levels of Protection Matter More Than Socioeconomics or Climate Change

Flood damages are expected to increase significantly over the 21st century as sea-level rise, more intense precipitation, extreme weather events, and socioeconomic developments combine to threaten an ever-increasing number of people and an ever-more expensive value of assets at risk in coastal and riverine floodplains (where cities and economic activities have often flourished). We therefore propose a comprehensive quantification of future investment needs in coastal protection infrastructure and complement it with an existing quantification of investment needs in riverine flood protection. These two studies rely on specialized models that consider (a) different *levels* of protection (reflecting different levels of risk aversion); (b) different *means* of providing that protection (through different protection technologies, like surge barriers or river dikes); and (c) uncertainties surrounding the cost of protection, future socioeconomic changes, and climate change (Nicholls and others 2019; Ward and others 2017).

Three strategies are studied for river floods: (a) achieving an optimal level of protection based on a simple cost-benefit analysis (CBA) that minimizes the sum of protection cost (capital and maintenance) and residual flood damage (to assets) to 2100; (b) keeping the current *absolute* level of flood risk constant in each country, in U.S. dollars; and (c) keeping the current *relative* level of flood risk constant in each country, as a percent of GDP.

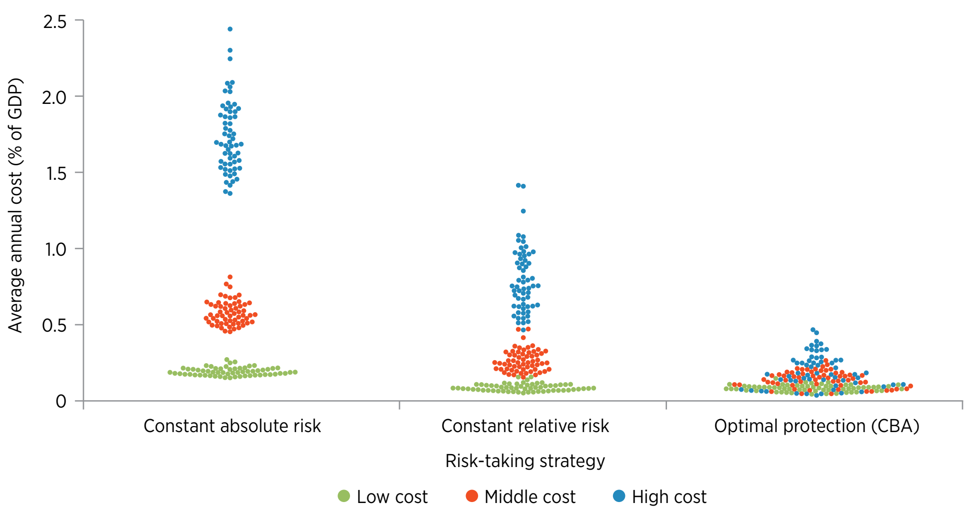
The same three strategies are explored for coastal protection, along with a fourth: (d) the "low-risk-tolerance" strategy, which entails keeping average annual losses below 0.01 percent of local GDP for protected areas (defined on the basis of density). This is the level of protection that Amsterdam and Rotterdam set for themselves in 2005. We take this (high) Dutch standard as the acceptable risk standard in a low-risk-tolerance world.

Capital costs for river flood protection are an annual average of 0.04 percent to 0.47 percent of LMICs' GDP for the least expensive strategy (optimal protection), but 0.15 percent to 2.4 percent of GDP for the most expensive strategy (constant absolute risk) (figure O.11).

For coastal protection, future investment needs in LMICs also span a wide range depending on construction costs and the protection strategy pursued. Costs are between 0.006 percent and 0.05 percent of LMICs' GDP, on average, every year for the least expensive strategy (constant relative risk) and between 0.04 percent and 0.19 percent of GDP, on average, every year for the

FIGURE O.11 The choice of protection level, combined with construction costs, shapes river flood protection capital costs

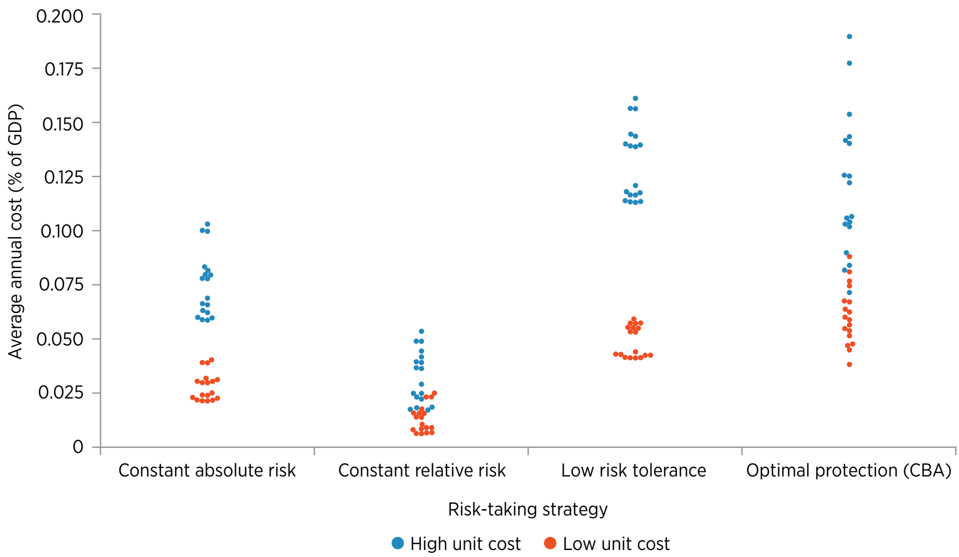
Average annual cost of investment in river flood protection, by construction costs and risk-taking strategy, 2015–30



Source: Based on Ward and others 2017.
Note: Each dot represents one scenario, with the 60 scenarios in each subgroup derived by combining the three socioeconomic pathways, four radiative forcing scenarios (representative concentration pathways), and five global climate models. Numbers exclude high-income countries. CBA = cost-benefit analysis.

FIGURE O.12 Construction costs, combined with risk aversion, shape coastal protection capital costs

Average annual cost of investment in coastal protection, by construction costs and risk-taking strategy, 2015–30



Source: Based on Nicholls and others 2019.
Note: Each dot represents one scenario, with the 18 scenarios in each subgroup derived by combining the three socioeconomic pathways, three representative concentration pathways, and two choices of technology (river dike or storm surge barrier). Numbers exclude high-income countries. If low- and middle-income countries with no coast were excluded, the points would be between 0.05 percent and 0.20 percent. CBA = cost-benefit analysis.

most expensive strategy (optimal protection based on CBA) (figure O.12). Uncertainty surrounding sea-level rise or socioeconomic change plays a secondary role, while the choice of technology for hard protection has only a minor impact on overall costs. Although these costs appear low, this is partly because the cost of what is a very localized and partial protection is being spread over national GDPs.

Construction costs for dikes are difficult to assess, because they are highly heterogeneous (they depend on soil characteristics and availability of nature-based solutions) and vary with the selected technology and with material costs that are challenging to predict (like availability and cost of sand and cement). Although Nicholls and others (2019) found in their detailed analysis of unit costs that costs can vary up to threefold within one country, Ward and others (2017) explored unit costs that vary from one to nine between the "low" and "high" scenarios.

If we use the middle-cost estimate from Ward and others (2017), which falls within the range defined by Nicholls and others (2019), investment costs in river flood protection range between 0.05 percent and 0.26 percent of LMICs' GDP for the optimal protection strategy based on CBA and between 0.45 percent and 0.81 percent of GDP for the constant absolute risk strategy.

Overall, in our "preferred" strategy (which minimizes overall costs and relies on what we consider "reasonable" assumptions), LMICs would have to spend 0.33 percent of their GDP annually on capital investments for both coastal and river flood protection by 2030. (This is an average over all climate change scenarios.) Although these estimates appear relatively modest, investment costs might be higher in practice if protection strategies have to be made robust to the many different futures that could arise as a result of unpredictable patterns of future climate change and urbanization. In addition, flood protection investments will need to be accompanied by complementary policies such as land-use planning to prevent people from settling in flood-prone areas or nature-based solutions to increase water storage and decrease runoff (and decrease investment costs in hard infrastructure). These investments will also have to be complemented by early-warning systems and communication about residual risk.

Disruptive Technologies: Governance Trumps Innovation

How might new technologies shape the future of infrastructure in LMICs? We explore scenarios depicting the ways in which infrastructure sectors can evolve as a result of cross-cutting innovations (such as IoT, artificial intelligence, machine learning, 3-D printing, and batteries) or sector-specific ones (such as autonomous vehicles, electric vehicles, and new biological water filtration techniques). But here, instead of using models, we used expert elicitation in structured interviews and workshops. The resulting three scenarios—"leapfrog," "lopsided," and "lock-in"—describe how various policy choices and external forces can lead to contrasting futures for infrastructure.

One aspect of the disruption is that these new technologies allow for more decentralization of infrastructure services, thus making it possible for people who can afford it to buy the service directly from the private sector and thereby get around large-scale infrastructure networks and the cross-subsidies that historically have funded service for poorer individuals. For example, in cities the availability of ride sharing and autonomous vehicles can encourage the better-off to shift from mass transit to private rides, thus threatening to bankrupt mass transit agencies.

Another aspect is the fact that technology disruptions create losers and winners. A failure to smooth the transition sufficiently for incumbents or, alternatively, excessive protection for incumbents are twin risks that need to be navigated carefully.

The key message that emerges from this expert elicitation is that the main forces that shape the way technology will affect infrastructure and the services it provides are the ability and success of governments, planning authorities, and regulatory authorities to fulfill their enabling and distributive functions. By enabling function, we mean their ability to put in place backbone infrastructure, financial incentives, and regulatory frameworks.

By distributive function, we mean their role in enacting measures to ensure that the spread of new technologies is not limited to the wealthy and does not decrease opportunities and access for the rest of the population.

Thus, the uncertainty regarding technology relevant to infrastructure over the next 15 or 20 years is not about the success of technology research and development, but rather its deployment in LMICs. That deployment, in turn, depends on how effective governments are in their enabling and distributive function.

OPERATIONS AND MAINTENANCE PLAY A MAJOR ROLE IN COSTS

O&M is a perennial challenge in infrastructure. All countries—rich and poor—struggle to assess properly the O&M resources needed to turn infrastructure stocks into reliable flows of services. While not unique to LMICs, this struggle is particularly central to the development agenda, given the general preference of donors to "cut ribbons" on new infrastructure rather than to finance what they consider to be the country's or the users' responsibility. Efforts have been made to resolve the issue by strengthening institutions (such as utilities or budgetary rules), creating a reliable source of funds (such as the Road Funds common in Africa), and increasing cost recovery at least to cover recurrent costs.

Yet this challenge is not systematically incorporated as an element to consider while deciding on an investment strategy. This is a serious problem, given that different types of infrastructure have very different implications for recurrent costs. Think about electricity: renewables have high capital (up-front) costs but negligible O&M costs; in contrast, thermal plants are typically much less expensive to build, but have high O&M costs, with volatile fossil fuel prices introducing great uncertainty as to future O&M costs.

The argument, therefore, is that "investment needs"—or rather the strategic decisions made about what technology to use to increase infrastructure stock—should be based on an analysis of *total* costs, with careful consideration of the choices or assumptions made about the cost of capital, discount rate, and future ability to cover O&M costs. CBAs and associated expected rates of return on infrastructure investments typically assume that the power plant, road, or water treatment plant will be functional during its expected lifetime. If that does not occur—due to the absence of fuel, chemicals, or maintenance—the economic calculus and associated ranking of options change dramatically.

This said, options with lower O&M costs will not always be the best ones, as they may reduce the flexibility of the investment. For example, in urban transport, a choice may be made to favor more flexible solutions (like buses rather than light rail) even if they exhibit higher operating costs. One reason to favor more flexible solutions, even if more expensive, could be the uncertainty surrounding new technologies that can disrupt the sector (see chapter 6 for a discussion).

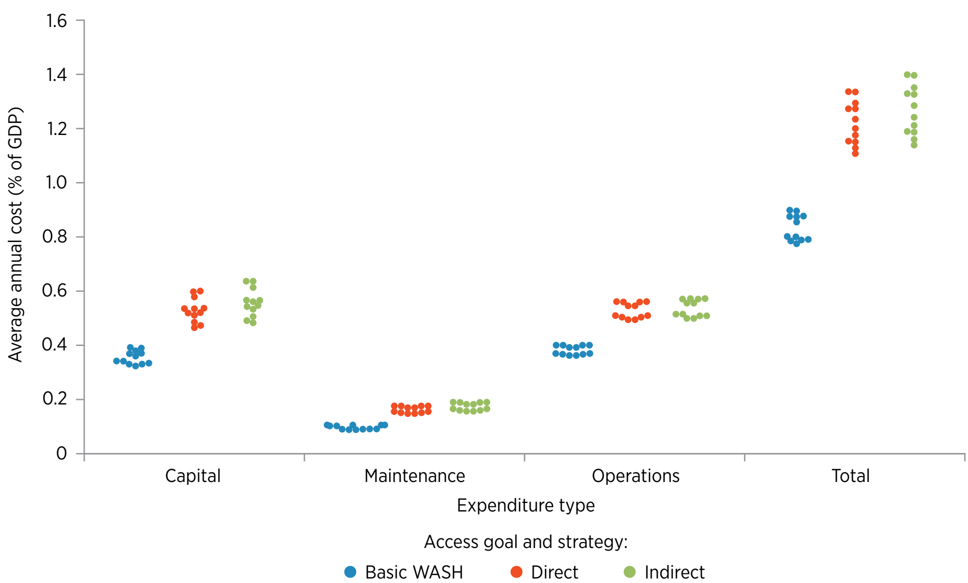
Water and Sanitation: O&M Costs Account for More Than Half of Financing Needs

For water and sanitation, average annual O&M costs exceed capital costs in all of the scenarios considered, accounting for 54 percent to 58 percent of the total annual expenditure needed to deliver the service. When operations and maintenance are included, meeting SDG targets 6.1 and 6.2 costs between 1.1 percent and 1.4 percent of LMICs' GDP (figure O.13). Failure to perform routine maintenance would reduce the useful life of installed capital and increase overall capital replacement costs by at least 60 percent.

The fact that O&M constitutes the bulk of overall costs means that countries need to think about the affordability of expansion plans. It is not enough for donors to raise funds and for governments to make room for capital investments. Allowance for an equivalent amount, or more, must be made for O&M in order to ensure service sustainability. Whether this is

FIGURE O.13 Operations and maintenance spending matters as much as capital spending for water and sanitation

Average annual cost of capital and operations and maintenance in water and sanitation, by access goal and strategy, 2015–30



Source: Based on Hutton and Varughese 2016.
Note: Capital, operations, and maintenance costs are for both new and existing users. They represent the amount needed both to expand service and to continue serving existing users. The "direct" pathway is one in which every new household served is provided with safely managed water and sanitation; the "indirect" pathway first rolls out universal access to basic services before upgrading to safely managed services. WASH = water, sanitation, and hygiene.

covered through tariffs or paid for by taxpayers is a choice that each country or municipality will need to make, based on the population's ability to pay. (Currently, only 60 percent of utilities in LMICs fully cover O&M through user fees.) But a failure to raise the resources needed for operations and timely maintenance will result in the waste of scarce capital resources.

Beyond investing in infrastructure, additional resources will be required to strengthen water and sanitation institutions and regulations, given that infrastructure alone has never been enough to achieve sustainable provision of water, sanitation, and hygiene services. Policy, institutions, and appropriate regulations are needed if financial flows are to deliver the infrastructure needed and if this infrastructure, in turn, is to deliver the service desired.

Power Sector: O&M Costs, Especially Fuel Costs, Are Critical

The low uptake and willingness to pay that prevail across Africa can be explained (at least partially) by the poor reliability of power supply. In most African countries (79 percent), less than a third of firms report reliable access to electricity. In 2014, more than 50 percent of connected households in Liberia reported that they never have power; this share was around 30 percent in Sierra Leone and Uganda. In Madagascar, only about 300 megawatts of the 500 megawatts of installed capacity was operating in 2017, while in the Democratic Republic of Congo, 29 percent of hydropower plants and 57 percent of thermal plants are currently unable to operate. In Benin, the Comoros, Guinea-Bissau, and Sierra Leone, less than 20 percent of installed generation capacity is functioning and available.

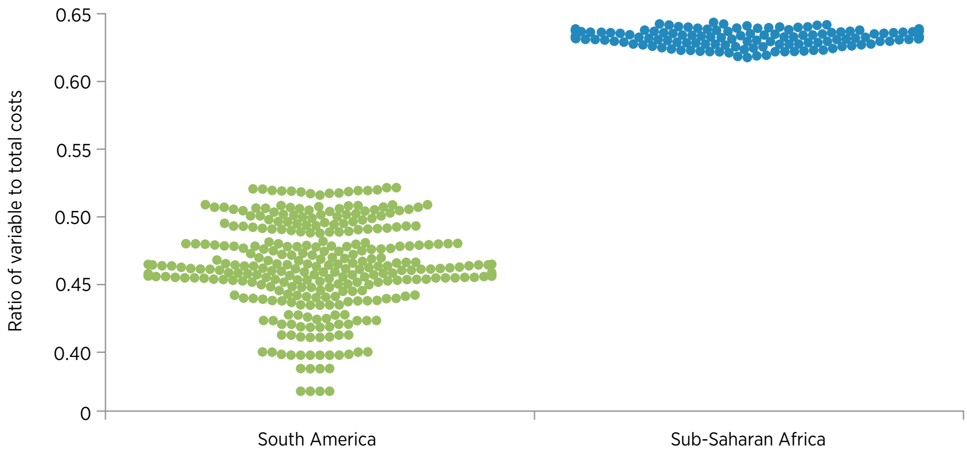
Thus, the question of universal access cannot be restricted to capital investment needs. It has to include improving existing service, maintaining future infrastructure, and weighing the financial implications of today's investment choices on tomorrow's variable costs.

In the power sector, annual maintenance costs are generally estimated at around 3 percent of the cost of investment, on average, across all installed capacity (costs vary between 1 percent and 6 percent, depending on the plant technology). Given our estimates of the total installed capacity in LMICs, we estimate that maintenance costs add up to around US$136 billion. For Sub-Saharan Africa alone, maintenance costs could represent between US$2.5 billion and US$3.6 billion, on average, per year over the 2015–30 period, on top of the US$14.5 billion to US$22.6 billion needed for capital costs.

Making matters worse, maintenance costs pale in comparison with fuel costs, at least for countries heavily dependent on thermal plants. In Africa, variable costs, such as fuel costs, add up to US$24 billion to US$35 billion, which is significantly more than what will be needed in new investments. The exact amount depends on the extent to which access is expanded on- or off-grid (and new investments favor renewables), but it remains extremely high across all scenarios. This is because the current energy

FIGURE O.14 The technology mix for electricity determines the variable cost burden

Ratio of variable to total investment costs in South America and Sub-Saharan Africa



Note: Each dot represents a scenario. There are many more scenarios for South America than for Sub-Saharan Africa, as more sources of uncertainty are explored. The large difference in the ratio of variable to total costs between them can be explained by the fact that Africa relies largely on thermal plants, while South America gets the bulk of its electricity from hydropower.

mix is dominated by thermal plants—in contrast with a region such as Latin America, whose electricity is derived primarily from low-variable-cost hydroelectricity and whose O&M (including fuel) costs are substantially lower as a result (figure O.14).

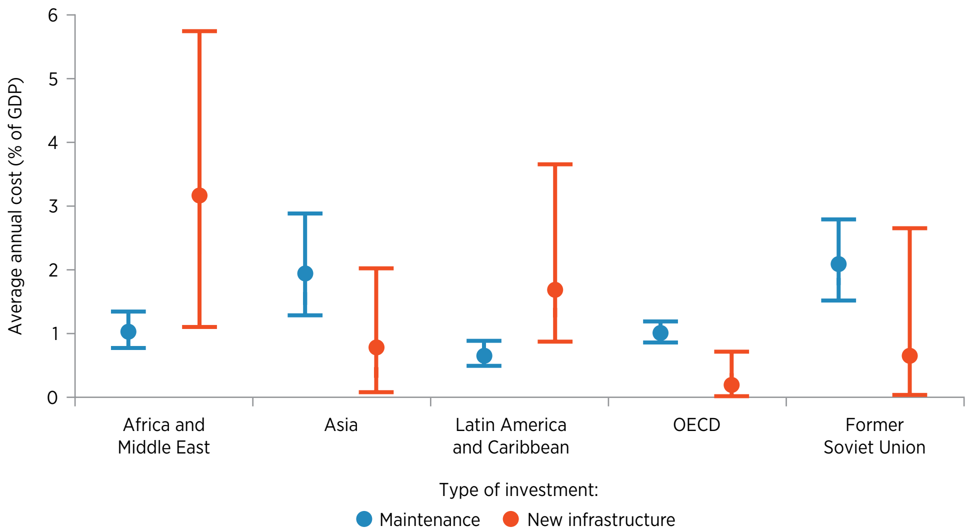
Transport: Overall Maintenance Costs as Much as New Investment

Maintenance costs for all existing and future transport infrastructure in LMICs could amount to 1.1 percent to 2.1 percent of GDP per year, on average, between 2015 and 2030—which is almost as high as what is needed for new capital investment. The costs of maintenance are even higher than the costs of new investment in countries that already have large transport networks, such as those in Asia and the former Soviet Union (figure O.15). Failure to perform routine maintenance would increase overall capital and rehabilitation costs by 50 percent.

For urban areas, operating costs for public transport dwarf the costs of both maintenance and new investment. While total maintenance costs amount to 0.19 percent to 0.21 percent of GDP per year, on average, over 2015–30, depending on the strategy, the operation of public transport infrastructure could represent 1 percent to 1.3 percent of GDP per year, on average, in LMICs—or twice as much as new investment costs. This represents between 1 percent of countries' GDP in South Asia and 2.3 percent in Sub-Saharan Africa annually. While some of these operating costs should be recouped through passenger fares, cost recovery is typically low. In European countries, subsidies for public transport represent up to 60 percent of the total

FIGURE O.15 Maintenance may cost as much as or more than new investments in transport

Average annual cost of investment in maintenance and new transport infrastructure, by region, 2015–30



Source: Based on Fisch-Romito and Guivarch 2019.
Note: The bars represent the range of estimates, generated by hundreds of scenarios, while the central dots represent the median value across estimates. The regional breakdown is that of the IMACLIM-R model and is *more* aggregated than the usual World Bank regional breakdown. OECD = Organisation for Economic Co-operation and Development.

operation costs. Cities should be prepared to spend on the operation of their public transport system at least as much as they spend on new infrastructure, on average, every year.

Flood Protection: Lives Depend on Good Maintenance

Flood protection infrastructure creates countervailing risks—that is, risks that arise as a result of an action taken to reduce a target risk—because it creates an incentive for people to settle in at-risk locations that now appear safer. These countervailing risks reinforce the importance of the commitment made by the initial capital investment. Failure to maintain the protective infrastructure can create the risk of catastrophic failures and put lives, not just assets, at risk.

By 2030, the cost of maintaining existing and future coastal protection infrastructure is between 0.02 percent and 0.07 percent of LMICs' GDP, on average, every year—depending on the protection strategy and construction costs (maintenance costs are estimated as a fixed fraction of construction costs). For river flood protection, the cost of maintaining new infrastructure is between 0.002 percent and 0.04 percent of LMICs' GDP annually by 2030.

While these costs appear affordable, the development of appropriate institutions and governance mechanisms to deliver maintenance, as well as the necessary funding streams, is essential for an infrastructure-based protection strategy to be effective. The Netherlands and the Thames Estuary (London) offer good examples of major flood defense systems that have been actively maintained over decades and upgraded as needed. These systems are linked to strong flood management institutions and long-term planning looking many decades into the future. For protection to be successful elsewhere, similar arrangements would be required, including guaranteed funding streams for maintenance.

If this commitment cannot be delivered, alternative coastal adaptation approaches are recommended—such as accommodation, nature-based solutions, or retreat. Further, even if well-maintained, defenses are always associated with residual risk, and appropriate measures need to be put in place for their management, especially in coastal cities. Appropriate flood warnings and disaster preparedness mechanisms remain essential, even if a good protection and maintenance regime is in place.

IN SUM

We have demonstrated that exercises to estimate infrastructure investment needs could generate helpful policy insights if carried out within a scenario framework and designed to identify cost-effective ways of achieving a given goal. This report attempts to shift the debate on infrastructure needs and should be seen as a starting point for further analysis. In particular, the approach explored here can be used at a more local level to help decision makers to build long-term infrastructure plans.

The choices and uncertainties driving future infrastructure needs at the local level might differ from the ones assessed in this report, but the method that decision makers can use to identify them would be the same. The key message is that it is both possible, and important, to explore how multiple investment and policy choices would play out in multiple futures, according to multiple objectives and metrics for success. This approach allows identifying the factors that matter, the trade-offs between objectives, and the most robust policy choices.

Looking ahead, a few questions stand out that we could not do full justice to in the context of the present work. First is the issue of nature-based infrastructure and how it may be a critical complement to hard infrastructure, reducing costs and increasing resilience. We touch on the subject in chapter 5 on flood protection, but wetlands, floodplains, forests, and mangroves are critical for water services (including hydroelectricity) and resilience of infrastructure more generally. This subject is now the focus of a separate World Bank report (Browder and others, forthcoming).

Another issue is that of spending efficiency. Unit costs vary greatly across countries in a way that defies easy explanations. Reporting this variation—and exploring its sources and potential ways of reducing costs—is a much-needed undertaking. For example, the U.K. government reports having reduced construction costs in public sector projects by 20 percent, thanks to the adoption of digital construction modeling. A 20 percent reduction in construction costs would be equivalent to tripling or quadrupling private investments in infrastructure from their current level.

Spending better, rather than just spending more, is at the center of the infrastructure challenge. Thus, for an investment needs assessment to be useful, it must be designed to shed light on how to do so.

NOTES

1. All existing assets—be they for basic or for safely managed service provision—are assumed to be replaced at the end of their useful life, creating new investment needs, irrespective of the choice of policy strategy.
2. An "all-season road" refers to "a road that is motorable all year round by the prevailing means of rural transport." The RAI is below 60 percent in most LMICs—meaning that less than 60 percent of the rural population live more than 2 kilometers from an all-season road—and is below 20 percent in 24 countries (Mikou and others 2019).

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