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## THE BOTTOM LINE

The World Bank is responding well to its clients' demand for financing of transmission and distribution projects. By helping to reduce losses, encouraging the integration of renewable energy, and expanding networks to increase supply, supported projects will improve the financial health of utilities, service for consumers, and economic growth. Regional interconnection projects, in particular, are lowering the cost of power, boosting reliability and shrinking the reserve requirements imposed on generation systems. Private sector participation and systemwide analysis will be the keys to the success of future projects.

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# Supporting Transmission and Distribution Projects: World Bank Investments since 2010

### Why is this issue important?

## Universal access to electricity and sustained economic growth depend on vast investments in the transmission and distribution of electricity

The United Nations' Sustainable Energy for All (SE4ALL) initiative envisions a world in which access to electricity will be universal, renewable energy will play a much greater role, and energy will be used much more efficiently (World Bank and IEA 2014). The transition to that world will be built on policy and regulatory changes, strong institutions, and significant investments in infrastructure, including enormous investments in the transmission and distribution (T&D) of electricity. The International Energy Agency (IEA) estimates in its "New Policies Scenarios" that more than 40 percent of investments in the power sector will go toward building and refurbishing 62 million kilometers (kms) of T&D networks, enough to circle the earth 1,500 times (IEA 2014).[1]

There is a strong link between electricity access, poverty reduction, and economic development, but, beyond access, reliable energy supply is an essential driver of economic growth. As an example, the use of backup generators as a hedge against unreliable supply is estimated to cost African economies between 1 percent and 5 percent of GDP each year (IRENA 2012). In South Asia, firms lose nearly 6 percent of sales to power outages and face an average of 26 power outages in a typical month (World Bank and IFC 2013).

Regular and planned investments in T&D networks are needed to keep up with the expansion of generating capacity and growth in demand. Without such investments, the T&D system can quickly become a bottleneck to efficient power operations and quality of service. Because India's southern regional grid is poorly connected to the rest of the country, electricity prices in the south are often much higher than in the rest of the country, even when spare electricity is available in the north.[2] The situation is expected to improve significantly once three major transmission lines become operational in the south during the second half of 2015. Constraints in the distribution network can affect the quality and reliability of power supply to consumers, making it more difficult for utilities to attract new customers.

In some markets, transmission constraints can exclude new players and reduce competition, greatly increasing energy prices. During a drought in Brazil in 2001, major congestion on tie-lines between the south and southeast regions pushed energy spot prices in the southeast up to the regulated price ceiling of about $300/MWh compared with a price of about $2/MWh in the south (Barroso and others 2004).

The growing share of renewable energy in the generation mix requires investments in T&D networks not only because it affects power flows on the grid, but also because renewable energy plants are built where resources are abundant, which tends to be away from major settlements and load centers. Although distributed or embedded generation is often beneficial to power grids and can reduce grid investment costs,[3] the remote location of many renewable energy plants may well require new transmission infrastructure to connect power plants to load centers. The information and

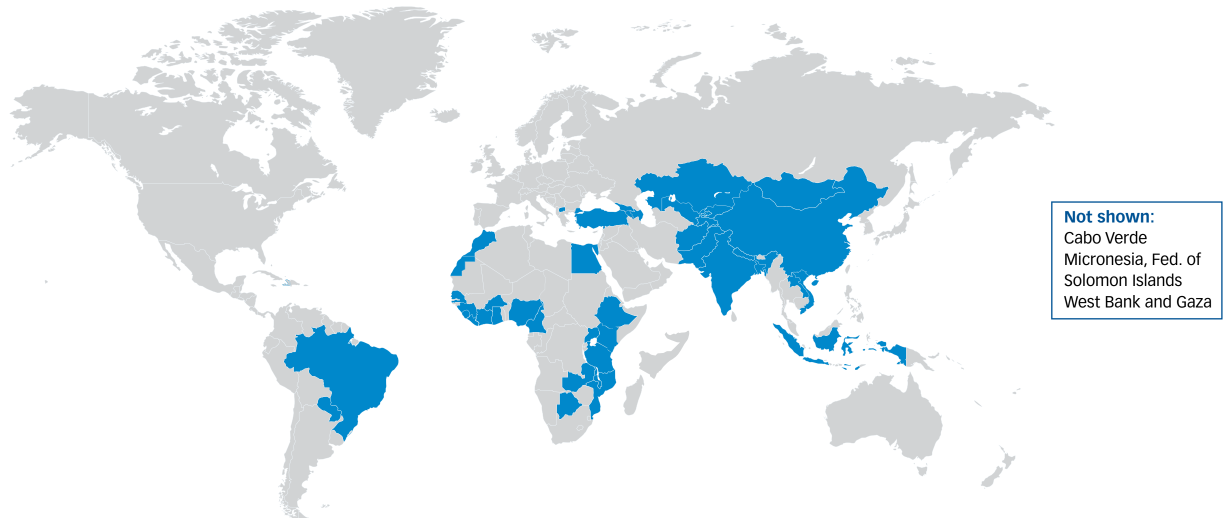
1 Decentralized solutions will need to be combined with the expansion of T&D grids to meet the goal of global access.

2 http://www.business-standard.com/article/economy-policy/one-nation-one-grid-plan-hurts-power-supply-in-the-south-115040600901_1.html.

3 Embedded generation is located at the point of consumption, eliminating the need to construct long lines to transmit and distribute power.

"The growing share of renewable energy in the generation mix requires investments in T&D networks not only because it affectspower flows on the grid, but also because renewable energy plants are built where resources are abundant, which tends to be away from major settlements and load centers."

**Figure 1.** Countries in which the World Bank made T&D investments between FY2010 and FY2014




*Source:* World Bank.

communication technologies that have made "smart grids" possible are also needed to plan the T&D network and manage flows. T&D investments must therefore include the deployment of suitable equipment such as communication-enabled power equipment, intelligent devices, and smart meters to manage those devices.

The resilience of grids to increasing climate variability is another important issue. The U.S. Department of Energy estimates that weather-related power outages between 2003 and 2012 cost the U.S. economy an inflation-adjusted annual average of $18–33 billion (Council of Economic Advisers and US DOE 2013). Developing countries often find it more difficult than industrialized countries to recover from climate-related events and therefore should ensure that their T&D networks are as robust as possible.

Methods for improving the resilience and reliability of the grid include both high- and low-tech solutions—among them (i) evaluating policies, plans, and actions with an eye to reducing the impact of a given hazard on people, property, and the environment; (ii) burying cables where possible and upgrading poles and structures with stronger materials in areas prone to storms; (iii) cultivating appropriate vegetation to help prevent damage to T&D infrastructure; and (iv) allowing for grid reconfiguration or grid isolation so that damaged segments are quickly separated from the grid and then resynchronized after normal conditions are restored (Council of Economic Advisers and US DOE 2013).

It is clear, then, that varying types and levels of investments in T&D networks are required to support the policy goals of reducing poverty and boosting shared prosperity in a sustainable and resilient manner.

This rest of this note considers the World Bank's T&D investment portfolio for the fiscal years 2010 to 2014,[4] highlighting where and how commitments have been focused. The Bank's investments are driven by client demand, so understanding the portfolio provides evidence of where demand exists, how it has changed over time, and what support clients need to meet their policy goals. Figure 1 illustrates the countries in which the Bank has made loans for T&D projects.

[4] July 1, 2009–June 30, 2014. The World Bank is composed of the International Bank for Reconstruction and Development and the International Development Association. The investments reviewed here are from the World Bank, except as otherwise noted. The World Bank Group also includes IFC and two other entities.

"Between fiscal 2010 and 2014, the World Bank committed $8.4 billion to 69 projects with transmission and/or distribution components."

### How has the Bank supported T&D?

## Bank funding has been focused on transmission projects in areas where access deficits are highest

Between fiscal 2010 and 2014, the World Bank committed $8.4 billion to 69 projects with transmission and/or distribution components. These commitments ranged from a million to $1 billion. Half of the T&D projects individually received less than $50 million, and only a very few received more than $250 million.

Sixty-three percent of the supported projects occurred in Sub-Saharan Africa and South Asia, where access deficits are the most significant (figure 2). The total commitment includes the use of the World Bank's guarantee mechanisms, which help attract more capital for project implementation by mitigating risks. The 44 transmission components in which the Bank invested (against 29 distribution components) made up 68 percent of total T&D lending, reflecting higher unit investment costs and a larger number of projects. The lowest commitment to T&D projects in the range examined occurred in 2012, but the dip reflects a general reduction in energy sector projects in that year.

The top three recipients of lending for T&D projects were in South Asia, where India and Bangladesh were the two largest beneficiaries (figure 3). On average, T&D accounted for 27 percent of the Bank's energy sector portfolio over the past five years (figure 4).

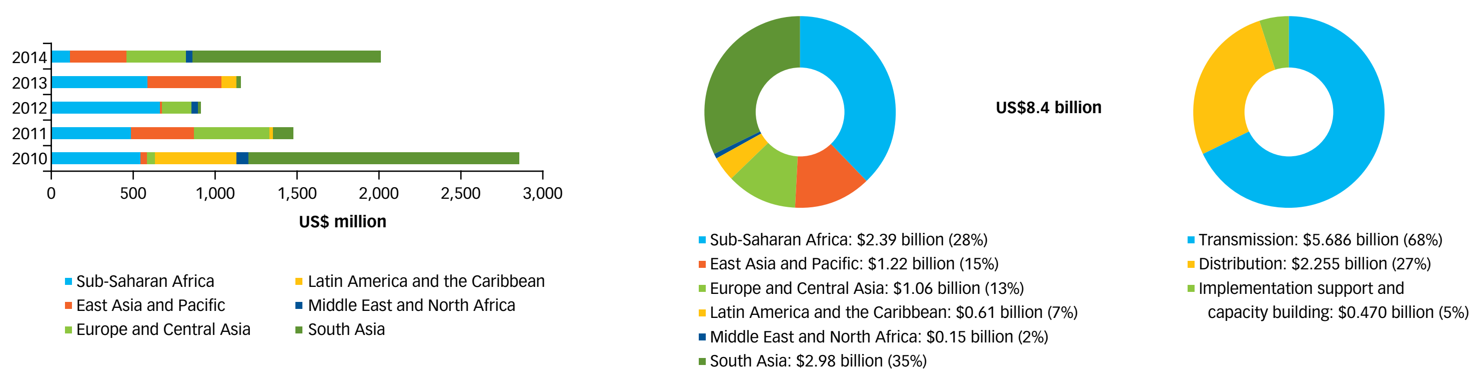
These investments are expected to add more than 10,400 circuit kilometers of transmission lines and to rehabilitate more than 4,000 circuit kilometers of T&D lines at various voltage levels in 51 different countries. The length of the lines constructed and rehabilitated in these five years is nearly twice the length of South America.

Beyond constructing and rehabilitating lines and substations, several projects have helped finance the deployment of smart-grid elements such as advanced metering solutions to reduce commercial losses, system control centers, and so-called SCADA/EMS (supervisory control and data acquisition with energy management systems). A total of $595 million was committed to smart grids in distribution systems; $220 million to smart grids in transmission systems (figure 5).

In most projects, the Bank has partnered with other development institutions. World Bank financing accounted for approximately 72 percent of the total costs of the T&D projects in which it invested over the review period. Other development institutions contributed 14 percent with borrowers and clients supplying the rest (figure 6). All T&D activities in this review were funded as standard public sector projects with no private sector participation in financing.

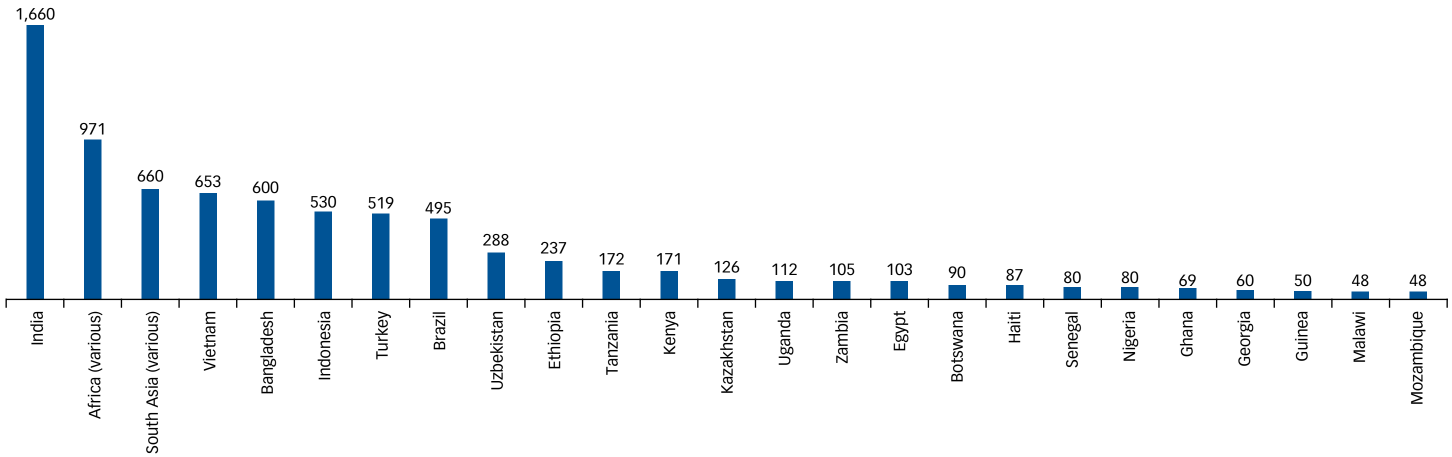
Although this note focuses on the investment portfolio, the Bank also uses other instruments to support the expansion of power systems. Over the review period, nearly $1.5 billion in "development policy lending" was delivered to clients to help create the enabling

**Figure 2.** World Bank lending for transmission and distribution projects, FY2010–14




*Source:* World Bank.

**Figure 3.** Top 25 recipients of T&D lending, FY2010–14 (US$ million)

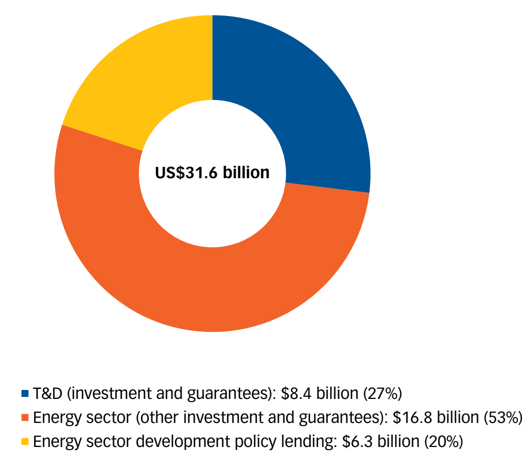



*Note:* "Africa (various)" and "South Asia (various)" refer to multicountry projects, including interconnection lines.
*Source:* World Bank.

"Almost all investment projects include a technical assistance component to support the use of software to review investment plans, third-party quality assurance and contract management, reviews of organizational structure, and reengineering of business processes to support efficient utilization of investment."

environment for T&D projects. Also, almost all investment projects include a technical assistance component to support the use of software to review investment plans, third-party quality assurance and contract management, reviews of organizational structure, and reengineering of business processes to support efficient utilization of investment. And World Bank–managed trust funds continue to complement other forms of development assistance. As an example, the North East Power Sector Improvement Project, now under preparation in India, has used trust funds to carry out sector diagnostic studies and to develop a plan for capacity building and institutional strengthening that is being used to design the technical assistance component of the project. The Bank has also provided stand-alone technical assistance to utilities to help them to develop a long-term business plan following unbundling and corporatization or to award and manage large contracts to develop critically needed infrastructure. It also supported a new employee-performance-management system. Further, funds such as the Clean Technology Fund and the Bank's carbon fund have channeled nearly $197 million to various countries to integrate renewable energy generation.

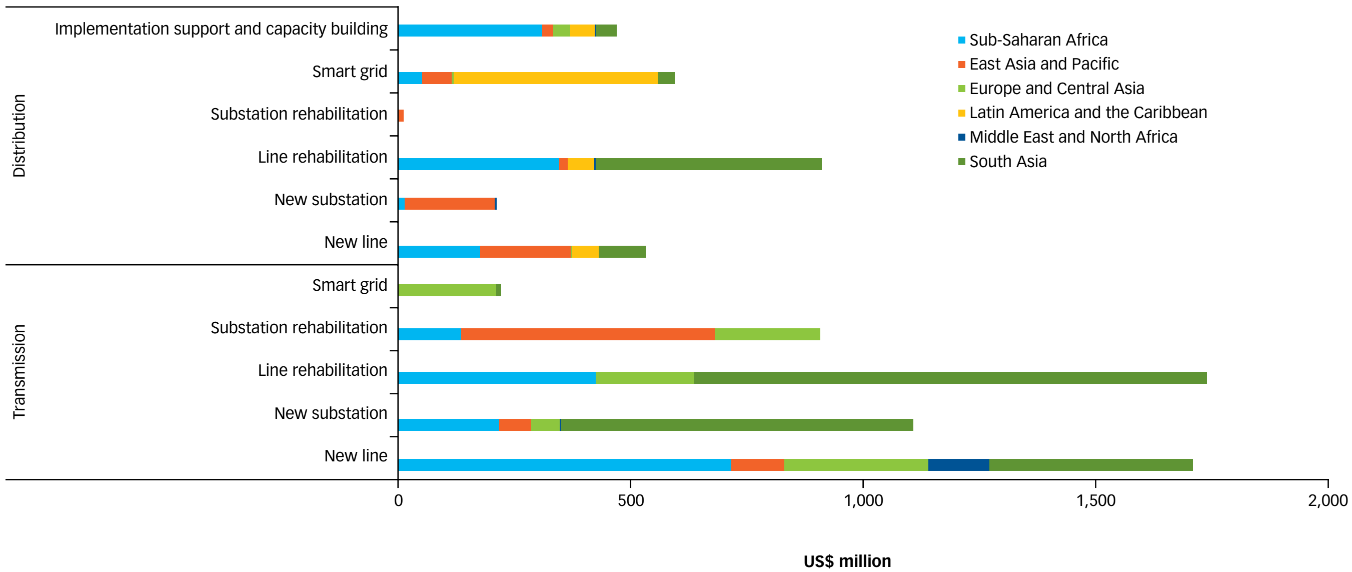
**Figure 4.** Lending for transmission projects as a share of total lending of the Energy and Extractives Global Practice, FY2010–14




*Source:* World Bank.

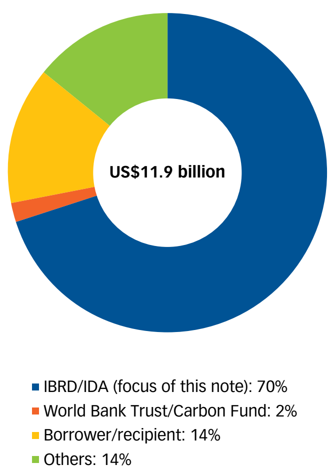
"Projects supported over the review period are expected to help expand T&D systems, improve reliability, reduce losses, promote cross-border trade of energy, and connect power plants to the grid, including plants using renewable energy sources."

**Figure 5.** Focus of T&D projects supported by the World Bank, FY2010–14




*Source:* World Bank.

**Figure 6.** Sources of financing for T&D projects receiving support from the World Bank, FY2010–14




*Source:* World Bank.

## What are the expected benefits of T&D investments?

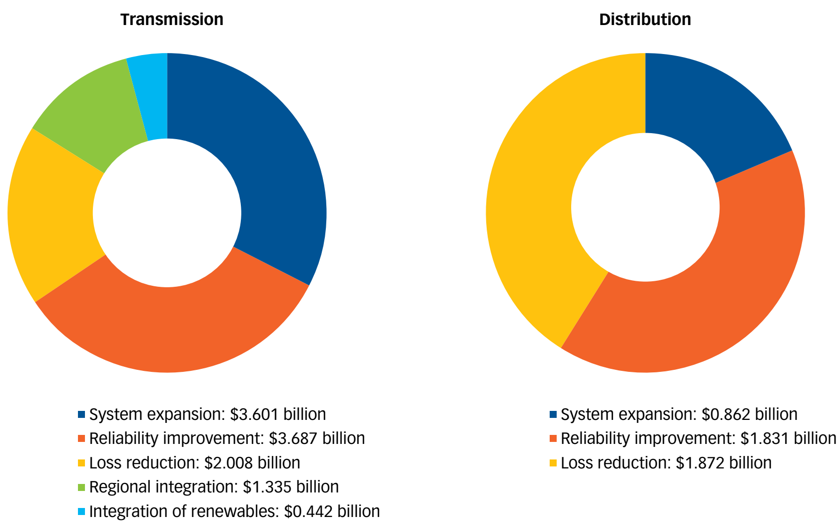
### Substantial benefits will flow from greater reliability, integration, smart grids, efficiency, and trade

Projects supported over the review period are expected to help expand T&D systems, improve reliability, reduce losses, promote cross-border trade of energy, and connect power plants to the grid, including plants using renewable energy sources (figure 7).

**Reliability.** A total of $5.5 billion was committed to constructing and rehabilitating T&D networks with the primary, secondary, or tertiary objectives of removing bottlenecks or improving the reliability of supply (see figure 7). Reliability is often affected by aging equipment, including transformers, switchgear, and line insulators. Changing system conditions, such as increased fault levels, can also reduce reliability, necessitating new equipment having higher short-circuit ratings, which also increases the capacity of the grid.

"Integrating high levels of variable renewable energy into power system operations is always challenging, but by enabling digital communication among grid components and thus increasing the efficiency, flexibility, and intelligence of power systems, "smart grids" facilitate the integration onto the grid of energy from renewable sources."

**Figure 7.** Objectives of World Bank T&D projects worldwide, FY2010–14




*Note:* Projects often have multiple objectives and the numbers cannot be added.

The energy access project in Kenya approved in 2010 is providing additional finance to eliminate operational problems caused by aging and poorly functioning equipment. The objective is to reduce fault frequency, locate and restore faults more quickly, and intensify connections in both urban and rural areas. The upgrading and rehabilitation of the communication and protection systems is expected to enhance system monitoring and control and to increase the capacity of substations in the project area from 669 MVA to 1,443 MVA. Beyond replacing equipment, the project includes "soft" measures such as master plans and standard design and construction manuals for distribution. The reduction in fault frequency and duration, coupled with the increased number of customers, will raise the utility's revenue.

In India, the Bank has a partnership of more than two decades with the country's Central Transmission Utility. The partnership has undertaken five power system development projects since the utility's inception in the early 1990s. It also has resulted in the emergence of a strong central institution that successfully manages one of the largest transmission grids in the world. The partnership's early projects focused on building institutional capacity related to procurement, financial management, safeguard management, and technical expertise for the establishment of state-of-the-art SCADA systems and a communication network to manage the power system (and serve various commercial purposes). The later projects have focused on building strong transmission networks to transfer power from generating stations located in the north and east of India to the industrialized but power-poor regions in the south and west, including links that are part of a 765 kV "highway" being constructed to increase reliable power exchanges between regions and states of the country. A report on the latest project indicates that it has already exceeded its targets for power exchange.

**Integration of variable renewable energy.** Investments in generating facilities are accompanied by interconnection or reinforcement projects necessary for the reliable delivery of power. These include the integration of renewable energy plants. Over the review period, five projects were directly associated with the delivery of power from variable renewable energy plants, one being a project to develop wind power in Egypt (table 1).

**Smart grids.** Integrating high levels of variable renewable energy into power system operations is always challenging, but by enabling digital communication among grid components and thus increasing the efficiency, flexibility, and intelligence of power systems, "smart grids" facilitate the integration onto the grid of energy from renewable sources, as well as delivering other benefits (Madrigal and Uluski 2015).

Over the five-year period, the World Bank invested $816 million in projects devoted solely to incorporating smart grid elements into T&D networks. These projects include SCADA/EMS systems to improve monitoring and control and advanced metering solutions to reduce commercial losses. To support the integration of increasing amounts of wind power, the Bank is supporting Turkey's effort to upgrade the hardware and software of its national power control center, national emergency control center, and nine regional control centers, as well as to establish a "renewable energy resource operator desk" that will have a SCADA/monitoring function to accommodate variable renewable energy.

**Table 1.** Projects to support the integration of renewable energy financed from World Bank resources (FY2010–14)

| Country | Commitment (US$ million) | Activity | RE Technology | Objectives |
|---|---|---|---|---|
| Egypt | 70 | Transmission infrastructure | Wind | To develop business models and transmission facilities for scaling up wind power, and to increase transmission capacity in targeted areas. |
| Turkey | 215.15 | Various transmission infrastructure | Wind | To increase the reliability and capacity of the power transmission system in Turkey and improve its ability to integrate renewable energy into the system |
| | 25 | 500 MVA substation | Wind | To assist Turkey in meeting its increased power demand by strengthening the transmission system and facilitating large-scale renewable energy generation |
| | 32.5 | Smart grid investments | Wind | To strengthen grid operation and management, enabling it to accommodate larger amounts of wind energy |
| | 67.2 | 4.35 km submarine power cable | Wind | To better connect wind energy locations with other parts of Turkey |

*Source:* World Bank.

"Learning from past projects, the Bank will screen transmission projects ... using a software-based transmission planning tool that takes a systemwide view. Availability of data is the main challenge, but, with increasing automation of transmission systems, the data deficit will shrink over time."

**Reducing losses.** In Uzbekistan, smart grids are being used for a different purpose: to reduce commercial losses by improving metering, billing, and management systems. This is to be achieved by installing some 1.2 million advanced meters, equipping distribution companies with systems to manage metering data, and installing a centralized system for managing energy data and customer relationships. In India, the Bank is supporting one of the largest advanced-metering-infrastructure (AMI) packages in the country, involving around 80,000 high-value consumers of low-voltage power. Although the main purpose of this project is to reduce losses, it also includes a data analytics tool to improve operational efficiency.

Utilities in countries such as Haiti and the Republic of Congo, where aggregate technical and commercial losses are 55 percent and 46 percent, respectively, are losing significant amounts of revenue. Utilities in Germany, by contrast, report aggregate losses of only about 4 percent (World Bank 2015).

During the period under review, the Bank committed $3.9 billion to projects aimed at reducing technical and commercial losses. These projects not only improve the financial health of utilities but also, by reducing carbon emissions, have a positive impact on the climate. Additionally, loss-reduction projects are well aligned with the sustainable development goal of increasing the rate of energy efficiency. By the fifth year of its implementation, a transmission project in Ukraine is expected to save 430 GWh annually, the equivalent of more than 2.8 million tons of carbon dioxide.

Some of the activities in loss-reduction projects include replacing old, inefficient, or overloaded transformers; installing capacitor banks and other flexible alternating-current-transmission devices; and replacing conductors. Measures to reduce losses often improve terminal voltages and therefore the quality of service.

**Regional trade in energy.** The Bank committed a total of $1.3 billion to 17 cross-border power or regional interconnection projects during the review period. Those projects included transmission lines, substations, and smart grid elements. In Africa, the Bank is involved in the West African Power Pool (WAPP) and the Eastern Africa Power Pool, which allow the countries of each region to pool resources for greater operational flexibility and commercial benefits. For example, the 500 kV HVDC Eastern Electricity Highway Project under the First Phase of the Eastern Africa Power Integration Program will allow Kenya to purchase relatively cheaper hydropower energy from Ethiopia and support Ethiopia's system when water is scarce.

Such interconnection projects allow utilities to share reserve margins across a wider operating area, thus reducing the need for installed capacity to meet reserve requirements. Regional interconnection becomes even more important as the penetration of variable renewable energy grows.

**Table 2.** New regional transmission lines financed by World Bank resources (FY2010–14)

| Countries | Region | Length (km) | AC/DC | Voltage (kV) | Capacity (MW) | Objectives |
|---|---|---|---|---|---|---|
| Ghana, Burkina Faso | Sub-Saharan Africa | 210 | AC | 225 | | To reduce the cost and improve the security of electricity supply to Burkina Faso, while increasing Ghana's electricity export capacity. |
| Côte d'Ivoire, Liberia, Sierra Leone, Guinea | | 1,349 | AC | 225 | 145 | To reduce the cost and increase the supply of electricity; to increase the export capability of Côte d'Ivoire; and to increase the technical integration of the WAPP network. |
| Ethiopia, Kenya | | 1,045 | DC | 500 | | To increase the volume and lower the cost of electricity supply in Kenya and to provide revenues to Ethiopia. |
| Nepal, India | South Asia | 415 | AC | 400 | 1,000 | To establish cross-border transmission capacity to facilitate electricity trade and increase the supply of electricity in Nepal. |
| Tajikistan, Afghanistan, Pakistan | | 750 | DC | 500 | 1,300 | To create the conditions for sustainable electricity trade between the Central Asian countries of Tajikistan and Kyrgyz Republic and the South Asian countries of Afghanistan and Pakistan. |
| Kyrgyz Republic, Tajikistan | | 475 | AC | 500 | | |

WAPP = West African Power Pool.
*Source:* World Bank.

"Recognizing the important role of skilled manpower in the sustainable operation and maintenance of T&D systems, the Bank regularly supports capacity building through technical assistance."

Recognizing the important role of skilled manpower in the sustainable operation and maintenance of T&D systems, the Bank regularly supports capacity building through technical assistance. In nearly 60 percent of projects reviewed, the World Bank provided 100 percent of the financing for capacity building and project management even though a number of other partners were involved in financing the infrastructure.

For example, the WAPP Interconnection Project between Côte d'Ivoire, Liberia, Sierra Leone, and Guinea is strengthening WAPP's Planning, Investment Programming, and Environmental Safeguards Department and its Information and Coordination Center. Technical assistance will support the process of certifying network operators and the development of standardized market operating rules for the WAPP zone. In the Indian state of Haryana, the Haryana Power System Improvement Project is supporting the plan for capacity building and institutional strengthening adopted by T&D utilities. The plan emerged through Bank-supported workshops involving a large number of stakeholders. The same project is also supporting the first large AMI package in the country. Because distribution of electricity is the link in the value chain where revenues are generated, and given the huge losses faced by India's power distribution sector, the building of the distribution utility's capacity and the automation of billing are vitally needed.

Although optimal technical solutions for a transmission system cannot be determined without reference to the system's plan, not all projects are subjected to detailed planning analysis. This could affect the choice of future projects. For example, even though the need to rehabilitate a substation may be obvious, some analysis will be necessary to determine the capacity, type, and ratings of new equipment to be used, based on forecasted demand and sector goals (to align with a smart grid roadmap, for example). Learning from past projects, the Bank now intends to screen transmission projects, to the extent possible, using a software-based transmission planning tool that takes a systemwide view. Availability of data is the main challenge, but, with increasing automation of transmission systems, the data deficit will shrink over time.

## MAKE FURTHER CONNECTIONS

Live Wire 2014/1. "Transmitting Renewable Energy to the Grid," by Marcelino Madrigal and Rhonda Lenai Jordan.

Live Wire 2014/6. "Measuring the Results of World Bank Lending in the Energy Sector," by Sudeshna Ghosh Banerjee, Ruchi Soni, and Elisa Portale.

Live Wire 2014/17. "Incorporating Energy from Renewable Resources into Power System Planning," by Marcelino Madrigal and Rhonda Lenai Jordan.

Live Wire 2015/38. "Integrating Variable Renewable Energy into Power System Operations," by Thomas Nikolakakis and Debabrata Chattopadhyay.

Live Wire 2015/44. "Mapping Smart-Grid Modernization in Power Distribution Systems," by Samuel Oguah and Debabrata Chattopadhyay.

## What challenges lie ahead?

### Future projects should focus on attracting private participation

The review summarized here shows that the World Bank is responding well to clients' demand for financing for T&D projects. By helping to reduce technical and commercial losses, supporting the integration of renewable energy, and expanding networks to increase supply, these projects are expected to help improve the financial health of utilities. Regional interconnection projects are raising revenue for exporting countries and providing much-needed energy for importing countries, resulting in a lower overall cost of supply, increased reliability and security, and smaller generation reserve requirements for individual systems. Overall, supporting critical infrastructure such as T&D helps governments meet their policy goals and provides much needed support for economic growth and social well-being.

Between fiscal 2010 and 2014, the World Bank committed $8.4 billion to 69 projects with transmission or distribution components across the institution's six regions. An additional $1.5 billion was delivered to clients in the form of development policy lending to help improve the enabling environment for T&D projects.

While the T&D activities reviewed were funded as standard public sector projects with no private participation, governments around the world are showing growing interest in private sector partnerships in infrastructure, reflecting the fact that huge needs for infrastructure cannot be met with public funding alone. There is ample evidence that, given the right conditions, the private sector can and will provide capital to improve the efficiency and quality of service in a cost-effective manner. For these reasons, future projects should explore the possibility of involving the private sector in raising finance for T&D projects.

It will also be increasingly important for the Bank to draw on systemwide analysis to reduce the risk of investing in projects that are quickly overwhelmed by rapid growth in demand or that become bottlenecks in system operations.

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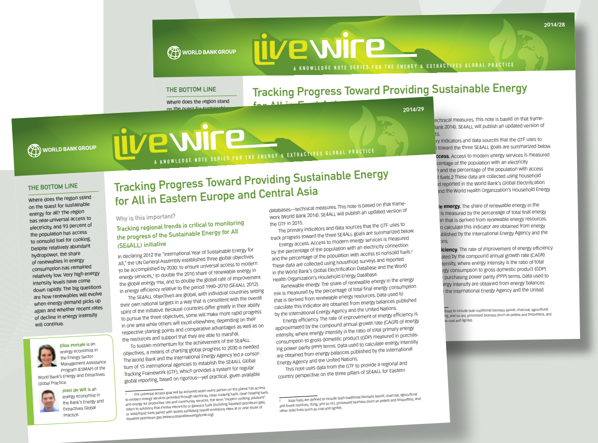

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