WORLD BANK GROUP

2015/24

93208

livewire

A KNOWLEDGE NOTE SERIES FOR THE ENERGY & EXTRACTIVES GLOBAL PRACTICE

# Capturing and Storing Carbon: The World Bank's Role

## THE BOTTOM LINE

Developing countries will be increasingly important players in the quest to reduce emissions of greenhouse gases. By 2035, non-OECD countries will account for 66 percent of primary energy demand and, in the meantime, for 90 percent of growth in demand. Among the steps necessary to ensure that carbon capture and storage fulfills its potential to cut emissions are more powerful policy incentives, including a global carbon price; testing of new technologies in demonstration projects; and development of storage infrastructure.

**Nataliya Kulichenko** is a senior energy specialist in the World Bank's Energy and Extractives Global Practice.

**Richard H. Zechter** is a lead carbon finance specialist in the Climate and Carbon Finance Unit of the World Bank Group's Climate Change Group.

**Asad Ali Ahmed** is an energy analyst in the Bank's Energy and Extractives Global Practice.

### Why is this issue important?

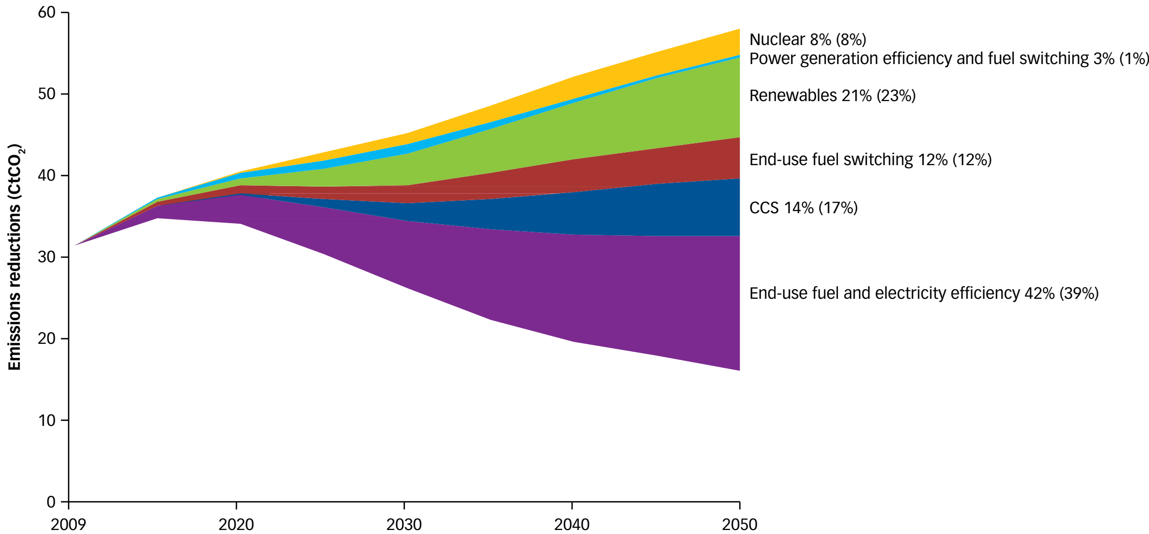
### Carbon capture and storage can help mitigate climate change and ensure a sustainable energy future

To address climate change, a mix of technologies will be required, including carbon capture and storage (CCS). The International Energy Agency (2012) expects CCS to account for 14 percent of the cumulative emissions reductions required to keep the increase in the average global temperature by 2050 to no more than 2ºC (figure 1).

With rapid growth in populations and incomes, developing countries are consuming more energy and will be increasingly important players in the quest to reduce emissions. The International Energy Agency (IEA) estimates that countries outside the Organisation for Economic Co-operation and Development will account for 66 percent of primary energy demand in 2035 and for 90 percent of growth in demand between now and then. To meet that demand, capital investments in energy are soaring, creating opportunities to enhance the role of CCS in the power and industrial sectors.

**Figure 1.** Sources of emissions reductions through 2050 in the IEA 2ºC scenario

*Percentage share in cumulative emissions reductions **by** 2050 (and share **in** 2050)*

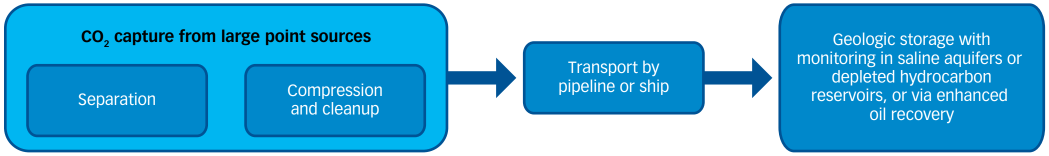



*Source:* IEA 2012.

CCS involves three processes (figure 2). First, carbon dioxide ($CO_2$) is separated from a mixture of gases, captured, and compressed. Second, the highly pressurized stream of $CO_2$ is transported to an appropriate storage site. Third, it is injected into a geologic formation where it can be confined and monitored (IEA 2013).

Through technical assistance and pilot projects, the World Bank—acting through the Multi-Donor CCS Capacity Building Trust Fund established in 2009—assisted nine partner countries or regions (Botswana, China, Egypt, Indonesia, Jordan, Kosovo, the Maghreb region, Mexico, and South Africa) that have fossil fuel–intensive

**Figure 2.** The CCS value chain




*Source:* IEA 2013.

"The IEA estimates that excluding CCS from a low-carbon electricity future would increase the capital cost of mitigating climate change by 40 percent. Beyond the electricity sector, CCS also makes it possible to moderate CO2 emissions from chemical and other industrial processes."

energy and industrial sectors and a promising amount of storage capacity to evaluate the potential of applying CCS, gain experience with the use of CCS technology, integrate CCS-inclusive policies into low-carbon energy strategies, and move toward commercial-scale implementation of CCS projects.

## What do we know about CCS?

### CCS is an evolving technology

Although the elements of CCS technology have been used for decades in various industrial energy processes (IPCC 2005), deployment of CCS is still limited for various reasons, including: (i) the continuing need to bring down costs, (ii) inadequate policy incentives that vary from country to country in the absence of a global carbon price, (iii) insufficient data on available sites for permanent storage of $CO_2$, and (iv) higher auxiliary energy consumption in power plants equipped with CCS units, which reduces net output—a phenomenon known as the "energy penalty." Such output losses presently range from 20 to 40 percent; ongoing research and development programs are targeting a rate close to 15 percent.

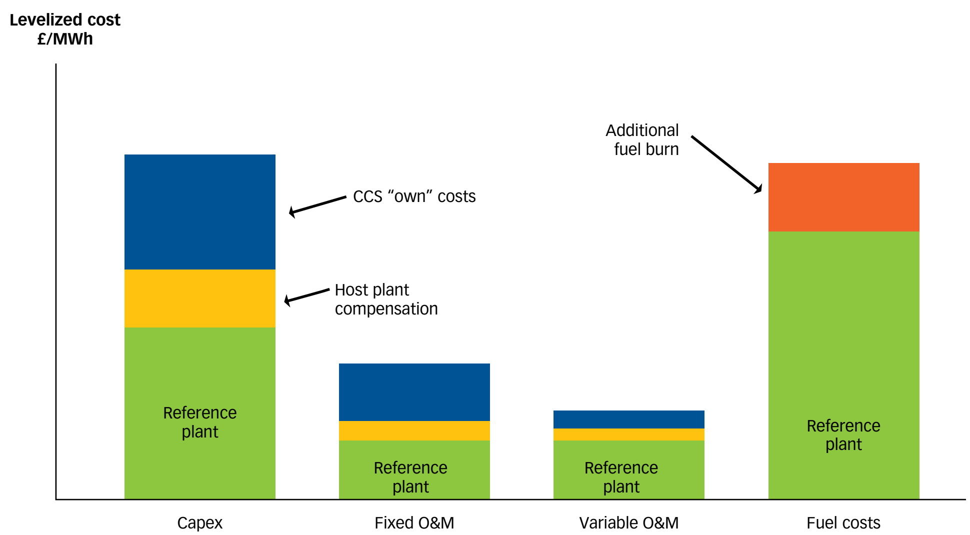
Despite these limitations, several important characteristics point to the potential of CCS as a tool for mitigation. First, even with its current limitations, CCS is not the most costly way of avoiding $CO_2$. In fact, the IEA (2012) estimates that excluding CCS from a low-carbon electricity future would increase the capital cost of mitigating climate change by 40 percent. Beyond the electricity sector, CCS also makes it possible to moderate $CO_2$ emissions from chemical and other industrial processes.

Equipping a power plant with a CCS system raises the cost of generating electricity in four ways (figure 3). The additional costs of capital investment and operations and maintenance (O&M) are the most important.

Some areas where the additional costs imposed by CCS in its present form might be cut include the following.

- **Advances in design and materials:** advanced membrane-based air-separation units; new materials for absorber vessels and advanced solvents; advanced well types and monitoring technologies; new materials for well cements to reduce risk leakage

**Figure 3.** Effects of carbon capture on the cost of generating electricity




*Source:* Department of Energy and Climate Change 2012.

*Note:* Capex = capital expenses; O&M = operations and maintenance.

"To catalyze the number and range of the demonstration-scale projects required to drive down costs and set the stage for commercial-scale deployment, stronger policy incentives and public financing—as currently provided for renewable energy technologies—will be needed."

- **Optimized construction logistics and product standardization** affecting elements commonly used in commercial deployments
- **Economies of scale:** larger CCS projects with larger storage sites
- **Reduced design margins:** use of fewer components, thus lowering monitoring requirements
- **Increased competition with growth in the CCS business** (although manufacturers with proprietary technology may protect margins)
- **Lower input prices:** emergence over time of low-cost manufacturing capacity in China and elsewhere; reductions in prices of oil and gas equipment and supplies used for storage
- **System integration/optimization:** improved solvents and integration of energy flows to reduce energy penalties; in storage, improved well design, injection, reservoir use, monitoring, modeling, risk assessment, and prediction of subsurface performance

## What is the new thinking?

### For large-scale deployment of CCS systems, stronger policy incentives and public investment in investigating storage sites and storage infrastructure will be needed

Approximately 12 large-scale CCS projects can be found around the world—far from the large-scale deployment that will be needed to meet global climate goals. To catalyze the number and range of the demonstration-scale projects required to drive down costs and set the stage for commercial-scale deployment, stronger policy incentives and public financing (as currently provided for renewable energy technologies) will be needed. The governments of the United States, the United Kingdom, and Canada have signaled greater support for low-carbon technologies, including CCS, with the aim of promoting projects with carbon intensities lower than those of subcritical coal-fired plants.

Some of the steps that must be taken to ensure that CCS fulfills its substantial potential to cut emissions of greenhouse gases are: (i) more powerful policy incentives, including a global carbon price; (ii) testing of new technologies in demonstration projects; (iii) development of storage infrastructure; and (iv) mainstreaming of CCS in power sector planning.

**Policy incentives.** Loan guarantees, regulatory mandates to facilitate tariff/rate approvals, tariff incentives (corresponding to feed-in tariffs for renewable energy), and certificate programs that reward utilities for reducing $CO_2$ emissions through CCS are among the incentives that can promote CCS. Policies can also incorporate CCS into long-term strategies to boost low-carbon development, as commitment to the technology would help it expand and mature. Legislation and regulations are also needed to address liabilities related to long-term storage and to reward pioneering project developers.

The absence of a global price (tax) on carbon is a major barrier to worldwide development and deployment of CCS on a commercial scale. CCS is currently a relatively costly abatement option and, unlike renewable energy and energy efficiency, it does not generate revenues (except through a few $CO_2$ utilization options, such as enhanced oil recovery). Scaling up CCS will require a strong carbon price signal in high-emitting countries through carbon taxes, emissions trading, or direct regulation of emissions from fossil fuel–fired plants. Kulichenko and Ereira (2011) estimate that a carbon price signal of US$50/ton at the country level could help develop 10.2GW of CCS-equipped power generation capacity in the Balkans and Southern Africa, abating 240 million tons of $CO_2$ by 2030.

**Technology development.** Success in and experience with CCS demonstration projects in versatile applications (including enhanced oil recovery) are key to reducing costs and risks for stakeholders and investors. To ensure that CCS demonstration projects are successful and leverage resources cost-effectively, globally coordinated research and development are needed, not only on CCS processes (such as reducing the energy penalty), but also on the business model for risk sharing between the public and private sectors. Developing pipelines of new demonstration projects can help ensure that new and improved CCS technologies move quickly to commercial scale and become available in technology markets. Because breakthroughs in cost reduction can stimulate investment in CCS in emerging as well as developed economies, high-emitting middle-income countries must include the development of CCS

"The absence of a global price (tax) on carbon is a major barrier to worldwide development and deployment of CCS on a commercial scale …. Scaling up CCS will require a strong carbon price signal in high-emitting countries through carbon taxes, emissions trading, or direct regulation of emissions from fossil fuel–fired plants."

applications in their industrial and power generation sectors early on as part of their low-carbon growth strategy.

**Infrastructure development.** CCS requires transportation and storage infrastructure that may take a long time to put in place, so these matters typically must be handled before projects are developed. The right storage site can decrease risk during demonstration phases. Barriers to entry for CCS projects can be lowered by developing CCS networks that include $CO_2$ trunk lines offering industrial emitters access to large storage sites to which specific facilities would be connected at a later date.

**Proactive planning.** CCS needs to be factored into long-term spatial plans for power and industrial sector development. In particular, storage sites, like potential renewable energy sites, need to be taken into account when planning power and large industrial infrastructure. The location of storage facilities could affect the location of future thermal plants (inducing them to locate close to storage sites) and have implications for the design of transmission infrastructure. A least-cost expansion plan that included CCS would consider the trade-offs between facility locations close to storage at the cost of building larger transmission and $CO_2$ transport infrastructure or locating plants close to demand centers and requiring more infrastructure to transport $CO_2$.

## How is the World Bank supporting its clients?

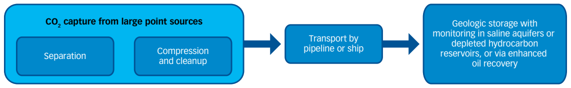
### The Bank is helping countries understand CCS and integrate it into their low-carbon growth plans

In December 2009, the World Bank organized the Multi-Donor CCS Capacity Building Trust Fund to support activities that build CCS-related capacity and knowledge in partner countries and to facilitate the inclusion of CCS in countries' low-carbon growth strategies and policies. Initial donors to the fund were the Norwegian government and the Global Carbon Capture and Storage Institute. After additional contributions from Norway and the United Kingdom, the trust fund now stands at US$57 million. Phase I of the trust fund work programs in nine countries included assessments of geological storage and the applicability of capture technologies, as well as training and workshops on various aspects of CCS. To date, US$8.3 million has been allocated to these work programs, of which US$3.9 million has been disbursed (figure 4). More detail on Phase 1 of the country programs financed through the trust fund is presented in table 1.

Complementing those activities, the trust fund supported studies of the challenges facing CCS within the policy and regulatory context of developing countries and countries in transition. One such study (Kulichenko and Ereira 2011) assessed the possible economic impact of future CCS deployment in the Balkans and southern Africa, analyzed policy incentives and legal and regulatory frameworks related to CCS deployment in those areas, assessed the role of climate finance in CCS investment in developing countries, examined models that multilateral development institutions could use to finance power plants equipped with CCS, and projected the effect of CCS deployment on electricity rates.

In Phase 2, the trust fund will focus on capacity building through implementation of pilot $CO_2$ storage and capture projects in countries that include CCS as part of their energy and climate change policies. South Africa and Mexico were identified as countries whose domestic policies support the development and deployment of CCS. In these two countries, the trust fund will co-finance pilot CCS activities supported by the national governments. The expected outcomes include: (i) gaining a better understanding of regulatory requirements for CCS deployment (including environmental impacts); (ii) defining

**Figure 4.** Breakdown of allocations by Multi-Donor CCS Trust Fund, 2009–14 (US$ millions)




*Source:* World Bank.

"In Phase 2, the Multi-Donor CCS Capacity Building Trust Fund will focus on capacity building through implementation of pilot CO2 storage and capture projects in countries that include CCS as part of their energy and climate change policies."

**Table 1.** Country/regional level activities of the World Bank's Multi-Donor CCS Capacity Building Trust Fund, 2009–14 (commitment amounts in millions of U.S. dollars)

| | |
|---|---|
| Botswana (1.4) | • Identification of sites suitable for CCS geological storage or enhanced coal-bed methane recovery summarized in a CCS storage atlas<br>• Identification of at least one potential CCS pilot project<br>• Formation of the Carbon Working Group<br>• Identification of key stakeholders to define and bridge information gaps<br>• Creation of a carbon secretariat under the Ministry of Energy, Water, and Resources<br>• Organization of at least three thematic workshops |
| China (1.8) | • Investment decisions reached by the China Power Investment Corporation (CPI) for at least one CCS project, leveraging the company's enhanced capacity achieved through the current project<br>• Comprehensive evaluation of at least two CCS project proposals, including issues related to environmental, social, and other safeguards<br>• Final reports consistent with the Ministry of Science and Technology's outline for the development of CCS technology in China<br>• Presentation at public workshops on CCS development in China of findings on technology costs and of recommendations from the pilot project study, as deemed appropriate for public dissemination by CPI |
| Egypt, Arab Republic (0.3) | • Improved knowledge and enhanced capacity of key stakeholders to plan, prepare, and implement CCS activities and projects in Egypt<br>• Egypt positioned to implement large-scale CCS projects over the next decade<br>• Deliverables including: (i) report on the country's CCS potential; (ii) "CCS Country Barriers" report; (iii) capacity assessment report; (iv) two capacity building and assessment workshops with stakeholders to discuss and disseminate interim and final results; (v) two webinars; and (vi) project final report |
| Indonesia (0.85) | • Assistance related to economic, technical, operational, and environmental analysis of CCS readiness of selected coal- and gas-fired power plants<br>• Exploration of market for enhanced oil recovery market at selected sites<br>• Strengthening of stakeholders' CCS capacity through workshops and training events to share study findings |
| Jordan (0.15) | • Preparation of report: (i) assessing Jordan's CCS potential, institutional capacity, and barriers to CCS activities; and (ii) offering recommendations for removal of barriers and options for building capacity to plan and implement CCS activities and projects<br>• Workshop in Amman (December 12–13, 2011); regional dissemination workshop in Cairo (October 2012) to enhance understanding of CCS and promote regional cooperation and participation of key organizations and communities |
| Kosovo (0.4) | • Investigation and analysis of recent geological, geophysical, and hydro-geological data in Kosovo and investigation and analysis of archived records outside Kosovo<br>• Paper on options for $CO_2$ capture at proposed KRPP facility<br>• Training and thematic workshops for key stakeholders and study tour to raise awareness among stakeholders |
| Maghreb: Algeria, Morocco, and Tunisia (0.4) | • Assessment of institutional capacity (in both public and private sectors) to implement CCS activities in the region<br>• Identification of barriers that may inhibit the implementation of CCS activities and recommendations to overcome them<br>• Recommendations for capacity-building activities to enhance ability to implement CCS activities in the three countries, possibly through regional initiatives<br>• Dissemination of findings and recommendations through at least one regional workshop and possibly country workshops and targeted meetings |

*(continued)*

**Table 1.** Continued

| | |
|---|---|
| Mexico (1.3) | • Drafting of roadmap based on pilot plant developments by Pemex and CFE<br>• Study of feasibility of $CO_2$ capture pilot plant to build on work by CFE and Pemex<br>• Assessment of Pemex enhanced oil recovery site for storage purposes; recommendation of monitoring requirements<br>• Review of existing laws and regulations applicable to enhanced oil recovery and $CO_2$ storage; recommendation of whether to modify existing legal provisions or implement new ones<br>• Capacity building activities including workshops, study tours, and participation in university programs on CCS<br>• Public engagement at national and local levels with help from advisory panel of communication experts |
| South Africa (1.35) | • Building of regulatory and policy framework that includes CCS under the current legislative regime to enable implementation of Pilot $CO_2$ Storage Project and encourage development of CCS operations in South Africa<br>• Development of industrial CCS roadmap, including an assessment of capture technologies suitable for industrial applications, related cost assessments, and matching of emission sources with potential sinks<br>• Training of at least 25 representatives of Department of Energy and other stakeholders<br>• Thematic workshops to discuss technical and related issues surrounding CCS, exchange views with stakeholders on concerns and issues, and disseminate information<br>• Site visit to CCS operation or test injection site<br>• Public engagement plans, one national and one local, for the Pilot $CO_2$ Storage Project |

"In South Africa, the trust fund will support two pilot CCS projects that will serve as a proof of concept and enable implementation of subsequent stages of the South African CCS Road Map."

the costs of $CO_2$ capture, transport, and storage; (iii) informing the public; and (iv) enhancing in-country knowledge and skills related to CCS.

In South Africa, the trust fund will support two pilot CCS projects that will serve as a proof of concept and enable implementation of subsequent stages of the South African CCS Road Map. Two potential CCS storage sites will be identified, and subsequent field exploration will be carried out to make the final site selections prior to procurement and construction. A pilot capture unit may be installed at an existing coal-fired power plant. Activities to build local technical capacity to undertake, evaluate, and regulate CCS projects will also be funded.

In Mexico, the trust fund will support the selection, design, procurement, construction, and operation of a pilot capture plant at a site that has yet to be selected.

The World Bank established a framework to govern its engagement in CCS in its 2013 Energy Directions Paper, which envisages support for projects that offer strategic potential and positive global effects, offsetting their high cost and risk. Under the framework, the Bank will consider support for CCS in greenfield coal-fired power plants and in coal-fired power plants undergoing rehabilitation to increase their efficiency.

## References


Department of Energy and Climate Change (United Kingdom). 2012. "Potential Cost Reductions in CCS in the Power Sector." London.

GCCSI (Global CCS Institute). 2011. "The Cost of CCS and Other Low-Carbon Technologies." Issues Brief 2011, 2.

IPCC (Intergovernmental Panel on Climate Change). 2005. *Special Report on Carbon Dioxide Capture and Storage*. UNFCCC.

IEA (International Energy Agency). 2012. *Energy Technology Perspectives 2012: Pathways to a Clean Energy System.* Paris: OECD/IEA.

———. 2013. *Technology Roadmap: Carbon Capture and Storage.* Paris: OECD/IEA.

Kulichenko, N., and E. Ereira. 2011. "Carbon Capture and Storage in Developing Countries: A Perspective on Barriers to Deployment." World Bank, Washington, DC. http://siteresources.worldbank.org/INTENERGY2/Publications/22992118/World_Bank_CCS_report.pdf.

World Bank. 2013. "Toward a Sustainable Energy Future for All: Direction for the World Bank Group's Energy Sector." World Bank, Washington, DC.


*The peer reviewers for this note were Efstratios Tavoulareas (Stratos), senior operations officer at IFC Business Advisory Services; Reynold Duncan, operations adviser in the World Bank's South Asia Region, and Charles M. Feinstein, a director in the World Bank's Energy and Extractives Global Practice.*

# Get Connected to Live Wire

"*Live Wire* is designed for practitioners inside and outside the Bank. It is a resource to share with clients and counterparts."

The *Live Wire* series of online knowledge notes is an initiative of the World Bank Group's Energy and Extractives Global Practice, reflecting the emphasis on knowledge management and solutions-oriented knowledge that is emerging from the ongoing change process within the Bank Group.

Each *Live Wire* delivers, in 3–6 attractive, highly readable pages, knowledge that is immediately relevant to front-line practitioners.

*Live Wires* take a variety of forms:

- **Topic briefs** offer technical knowledge on key issues in energy and extractives
- **Case studies** highlight lessons from experiences in implementation
- **Global trends** provide analytical overviews of key energy and extractives data
- **Bank views** portray the Bank Group's activities in the energy and extractives sectors
- **Private eyes** present a private sector perspective on topical issues in the field

Each *Live Wire* will be peer-reviewed by seasoned practitioners in the Bank. Once a year, the Energy and Extractives Global Practice takes stock of all notes that appeared, reviewing their quality and identifying priority areas to be covered in the following year's pipeline.

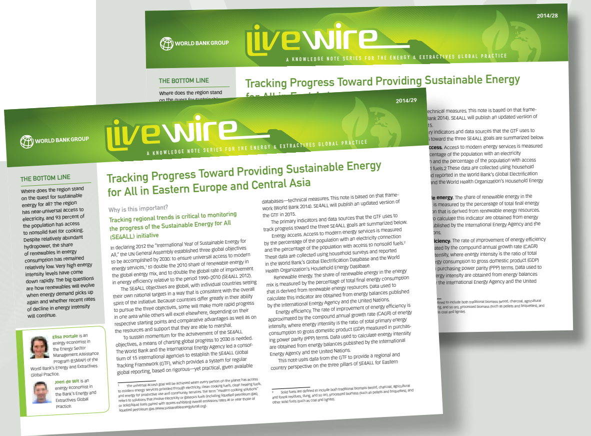
*Live Wires* are designed for easy reading on the screen and for downloading and self-printing in color or black and white.

For World Bank employees: Professional printing can also be undertaken on a customized basis for specific events or occasions by contacting GSDPM Customer Service Center at (202) 458-7479, or sending a written request to cgsdpm@worldbank.org.

Printing & Multimedia Services
General Services

**Please visit our Live Wire web page for updates:**
**http://www.worldbank.org/energy/livewire**

OKR OPEN KNOWLEDGE REPOSITORY



# Contribute to *Live Wire*

## Do you have something to say? Say it in *Live Wire!*

Those working on the front lines of energy and extractives development in emerging economies have a wealth of technical knowledge and case experience to share with their colleagues but seldom have the time to write for publication.

*Live Wire* offers prospective authors a support system to make sharing your knowledge as easy as possible:

- Trained writers among our staff will be assigned upon request to draft *Live Wire* stories with staff active in operations.
- A professional series editor ensures that the writing is punchy and accessible.
- A professional graphic designer assures that the final product looks great—a feather in your cap!

*Live Wire* aims to raise the profile of operational staff wherever they are based; those with hands-on knowledge to share. That's your payoff! It's a chance to model good "knowledge citizenship" and participate in the ongoing change process at the Bank, where knowledge management is becoming everybody's business.

If you can't spare the time to contribute to *Live Wire,* but have an idea for a topic, or case we should cover, let us know!

We welcome your ideas through any of the following channels:

Via the Communities of Practice in which you are active

By participating in the Energy and Extractives Global Practice's annual *Live Wire* series review meeting

By communicating directly with the team (contact Morgan Bazilian, mbazilian@worldbank.org)