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To send comments or request copies, e-mail us: McKinsey_on_SRP@McKinsey.com.

Editorial Board: Johan Ahlberg, Dorothée D'Herde, Stefan Heck, Robert Mertz, Tomas Nauclér, Scott Nyquist, Jeremy Oppenheim, Matt Rogers, Jonathan Woetzel

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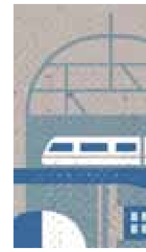

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Introduction

Scott Nyquist and Jeremy Oppenheim

In the coming decades, demand for resources is set to continue to rise precipitously even as supply constraints multiply, posing challenges for economic growth, the environment, and social well-being. Yet many of these challenges could be overcome if organizations were to adopt existing technologies and approaches—and invest in developing new ones—that improve resource productivity and increase sustainability.

In launching *McKinsey on Sustainability & Resource Productivity*, our goal is to serve as a catalyst for action, presenting insights and approaches that organizations can use to seize the opportunity to transform how they manage resources and drive sustainable growth.

Our research suggests that rapid economic development in emerging markets could bring as many as three billion more consumers into the middle class in the next 20 years, raising demand for a wide range of goods and the resources required to produce and use them. At the same time, supply constraints are multiplying. Inadequate production capacity, actual shortfalls, and political uncertainty are just a few factors that could make it more difficult to gain access to many resources. Prices for resources are likely to rise as a result, but they are also likely to be more volatile. And depletion of resources such as water and the planet's carbon-carrying capacity could cause irreversible damage to the natural environment, in addition to posing threats to quality of life.

But if the scale of the resource challenge is unprecedented, so, too, is the know-how available to address it. Existing solutions could dramatically alter current trends, and many technologies and approaches are verging on breakthroughs that could bring about transformational change. Battery and renewable-generation technologies are improving at rapid rates, and companies are pursuing business-model innovations that enable them to increase efficiency across their value chains while delivering more sustainable products and services to their customers.

In this inaugural issue of *McKinsey on Sustainability & Resource Productivity*, we offer a set of articles that we hope will inform institutions in the private, public, and social sectors as they rethink how they manage resources. Most of the articles emphasize the importance of innovation, and each contains practical ideas about how to get started.

We open the issue with "Using resources differently: An interview with Chad Holliday," which touches on many of the themes developed in other articles. Holliday was a champion of sustainability before becoming CEO of DuPont in 1998, and he remains deeply engaged with industry players and public institutions that are committed to addressing the resource challenge.

Three articles home in on technological innovation. “Energy = innovation: 10 disruptive technologies” discusses technologies that could reshape the North American energy landscape in the next 10 to 20 years. “Solar power: Darkest before dawn” provides a perspective on how the solar industry could evolve, as well as what players can do to thrive as the industry restructures. And “Shale gas and tight oil: Framing the opportunities and risks” highlights the potential benefits and risks of unconventional natural gas and oil.

Two articles focus on operational and business-model innovation. “Manufacturing resource productivity” presents a framework that manufacturers can use to manage resources more efficiently across their value chains. “Battle for the home of the future: How utilities can win” identifies strategies that utilities can pursue as residential power markets are reshaped by new energy technologies for the home.

Two more articles illuminate innovative strategies countries can pursue. “New models for sustainable growth in emerging-market cities” introduces the urban sustainability index, a tool for identifying best practices for cities to emulate. “India: Taking on the green-growth challenge” outlines an agenda the country could adopt to set the conditions for its continued rapid growth.

Another set of articles focuses on ways to increase the world’s access to vital resources. “Transforming water economies” outlines strategies that countries can pursue to avert impending water shortfalls. “Reducing deforestation: The land-use revolution” highlights emerging insights that could advance national and international efforts to reduce deforestation and forest degradation.

A final piece, “The business of sustainability,” discusses the results of a survey of business leaders about how their organizations are pursuing sustainability.

We will continue to contribute ideas through future issues of *McKinsey on Sustainability & Resource Productivity* and on our Web site, McKinsey.com. But our greatest ambition is to help put ideas to work, and thus we look forward most to assisting organizations around the globe as they lay the foundations for a new era of sustainable growth.

Scott Nyquist is a director in McKinsey’s Houston office, and **Jeremy Oppenheim** is a director in the London office.

Using resources differently: An interview with Chad Holliday

Sustainability is about more than climate, says the former chairman and CEO of DuPont. Organizations that excel at managing resources and working across institutional boundaries will set a new standard for success.

Charles "Chad" O. Holliday was an early advocate of sustainability in business. During his tenure as chairman and CEO at DuPont, the company established its mission to achieve sustainable growth, which entails increasing shareholder and societal value while decreasing the company's environmental footprint. His 2002 book, *Walking the Talk: The Business Case for Sustainable Development*, argued not only that sustainability is good for business but that solving social and environmental problems is essential for future growth.

In recent years, Holliday has worked with a broad spectrum of organizations in the private, public, and social sectors to bring a business perspective to the international debate about sustainability and to advance social objectives such as reducing poverty and expanding energy inclusion. His many current roles include chairman of the board of directors of Bank of America, member of the board of directors at Shell, member of the board of directors of the ClimateWorks Foundation, and cochair of the United Nations Secretary-General's High-Level Group on Sustainable Energy for All.

McKinsey's Matt Rogers sat down with Holliday in Washington, DC, to discuss the

changing dynamics in sustainability and the ways businesses and other organizations can advance sustainability objectives, both for their own and for society's benefit.

McKinsey on Sustainability & Resource Productivity (MoSRP): *What has changed since you published your book,* Walking the Talk: The Business Case for Sustainable Development*, in 2002?*

Chad Holliday: What's clearer to me today is just how interrelated energy, water, and food are—sustainability is about more than just climate change. If we only worry about climate and ignore water, food, and nutrition patterns, we will be in trouble in 30 years. I understood this while I was at DuPont, but its importance has become clearer as I've worked more with organizations such as ClimateWorks, the American Energy Innovation Council, and the United Nations.

MoSRP: *Where will we be with respect to resource productivity and sustainability in 10 years?*

Chad Holliday: Ten years from now, I think it's going to be generally accepted in the United States that we have to do something different. Somewhere along the line, people will wake up to the reality that the world has changed and that they need to adapt. They will begin to understand that technology can help us deal with the resource challenges we face. They will start looking for opportunities, and they will find that using resources differently is the opportunity. Organizations that determine how to manage resources differently will have an advantage.

MoSRP: *What can companies do?*

Chad Holliday: I'm the chairman of the Global Federation of Competitiveness Councils, and we envision industry—groups of companies or individual companies—coming together with government through public-private partnerships. Companies won't have much credibility if they claim that they can't do anything until government changes. They should bring specific ideas and commitments to the table and then explain what they need from government to carry them out.

There is a big opportunity in the United States to launch an infrastructure-improvement effort to increase the energy efficiency of commercial buildings. I think financial institutions would be willing to provide loans for such an effort if state or local governments share some of the risk through guarantees—which would be a very smart use of government money because it would create so many jobs. You might get materials from elsewhere, but installation would obviously have to happen in the United States, and so many installation-related jobs require exactly the skills we have here.

I'm on the board of Bank of America, which has set aside $20 billion to invest in sustainability projects. It has already put $11 billion to work, including financing a deal for $2.6 billion to install solar panels on warehouse roofs, a project partly supported by government guarantees. Bank of America has also developed proposals for efforts to improve the efficiency of commercial buildings. So I think financial institutions are willing partners.

MoSRP: *What can companies do to drive sustainability internally?*

Chad Holliday: You have to strike a balance when you are trying to get traction for new ideas. Early on, it's important to segregate and protect efforts to give them room to grow. But once ideas reach a certain point of development, you have to find ways to disseminate them, because you limit their growth if you keep them protected. DuPont handled this by moving people around its organization. If a new idea emerged in biotech, DuPont might shift staff from its chemicals group to its biotech group for a while, and then send them back to chemicals. This allowed them to spread ideas themselves. DuPont also built an innovation center that brought people together from different areas so they would bump into one another and pick up new ideas. As a CEO, you can't really order people to take up ideas. They have to figure out how ideas work in their particular context in some kind of hands-on way.

MoSRP: *What about international efforts? Does sustainability need an international consensus?*

Chad Holliday: The international community has had successes. Through the Montreal Protocol, we agreed to phase out production of chlorofluorocarbons (CFCs). In that case, nations agreed and stuck to their agreements. The objectives were relatively simple compared with some of the challenges we face today, but we can still learn from the CFC effort. Namely, objectives must be clear, concrete, and easy to understand. I cochair the United Nations Secretary-General's High-Level Group on Sustainable Energy for All, which set three goals for global energy use by 2030: first, to provide electricity to the 1.3 billion people currently without access to it; second, to improve energy efficiency by 50 percent; and third, to double the world's use of renewables. These goals are easy to understand, although achieving them will be challenging. And sustainable energy is a more saleable concept than climate change—it is more concrete. There's still so much fog around the climate issue.

I also believe more solutions will be regionally focused. In the United States, solutions may emerge at the state rather than at the national level—or even from areas within states. Policy issues may get in the way when organizations try to implement new strategies. But those can be the best occasions to address policy, rather than trying to make grand changes in advance. I have asked governors who were very successful making changes in their states how they secured legislative support for the necessary policies. They say that they get people to support these policies, and the people in turn get their legislators to support them. You have to get out and spend enough time talking about the issues. It comes back to communication.

MoSRP: *Could you say more about how to communicate to advance sustainability?*

Chad Holliday: It's critical to start with concrete examples. If you do that, people will be more likely to listen to your theoretical approach. All my experience at DuPont suggests that it's the stories that really capture people's imagination. Through Sustainable Energy for All, I have heard stories about grandmothers in India who are installing solar panels in their communities; they are taking the lead themselves. We have to get those stories out. Simplicity is essential. If you come across as too academic, people won't listen.

Chad Holliday

Vital statistics
Born 1948

Education
Graduated from University of Tennessee in 1970

Career highlights
Bank of America
(2009–present)
Chairman of the board of directors

DuPont
(1998–2008)
Chairman of the board and chief executive officer

Fast facts
Serves on the board of directors of Deere & Company, Royal Dutch Shell, ClimateWorks Foundation, CH2MHill, the Nicholas Institute for Environmental Policy Solutions, and the National Geographic Education Foundation

Cochair of the United Nations Secretary-General's High-Level Group on Sustainable Energy for All

Member of the National Academy of Engineering and the American Academy of Arts and Sciences

Founding member of the International Business Council

MoSRP: *What about at the corporate level?*

Chad Holliday: At DuPont, we recognized great achievements and really highlighted good ideas so people would understand what the company valued. We gave out sustainable-growth awards every year. We had hundreds of submissions, and we established an external board to evaluate a short list of about 12 ideas. The board rotated, which helped us develop a new set of external ambassadors each year. Ultimately, we would pick one submission and really feature it—talk about why it was a good idea and why people should look for ways to replicate it in their own areas. That really worked, particularly because people in different roles saw merit in initiatives that otherwise might have been overlooked. It's also important to communicate so that people understand that the company is balanced and concerned about the short, medium, and long term.

MoSRP: *How should companies communicate with shareholders about sustainability?*

Chad Holliday: It depends on the industry. Companies that focus on natural resources are likely to come under a lot of pressure. I'm on the board of Shell, and its corporate-social-responsibility committee meets regularly with environmentally focused shareholders and nongovernmental organizations (NGOs) to talk about what the company is doing. The board brings line leaders to these meetings. For example, the chief engineer of wells is there to talk about wells. Shareholders really like talking to the person in charge, and they ask good questions. We talk about the really tough issues on their minds, and we bring experts to explain what the company is doing. That helps. Many shareholders are still focused on the short term, and when it comes to sustainability, many are still concerned mainly about whether something negative will emerge. I think shareholders' thinking about sustainability will shift, but the shift will be slow.

MoSRP: *DuPont involved NGOs in its planning process. In what ways were the dialogues with NGOs most productive?*

Chad Holliday: Twice a year, DuPont invited about 10 NGOs to a meeting with about 10 of the company's business leaders. As CEO, I'd present the company's strategy, and each NGO would provide three recommendations on how we should change it. The business leaders then took a day to discuss these recommendations and how we could incorporate them. The first meeting we had was tough, but it was amazing how the experience opened us up. It helped us understand the sensitivities in a variety of areas, as well as how NGOs thought, and we went about accomplishing our strategy differently as a result. Sometimes we actually identified market opportunities as a result of the dialogues. Those meetings didn't take much time—four days a year, for me—but they were really useful.

These experiences also enabled us to avoid a lot of conflicts because we learned where the "hot spots" were. And we developed such good relationships with NGOs that they were willing to help us. When DuPont did face a situation and the press called these NGOs, they were able to explain our views because they knew us. But you have to put some chips in the bank with NGOs. It's a multiyear process: they need time to really get to know the company, and companies need to know NGOs as well. Many companies don't really understand which NGOs they're "reporting to" and which ones will give them problems or help them out. Every company should invest in understanding the NGOs in their area before they have to face a situation, particularly because many NGOs are opinion makers.

MoSRP: *What other advice would you give to business leaders who are trying to have impact in sustainability?*

Chad Holliday: Leaders should spend quality time with people outside their industries—people who think differently. Sam Allen, CEO of Deere & Company, once spent four days with a few senior members of his team working on a farm in a rural area of India. When he came back, he said he understood agriculture in India in ways he hadn't before. There is something about actually being there that can really be eye-opening. People have to find their own techniques, but they also need to get alternative views and new perspectives.

At DuPont, we looked for opportunities to send senior businesspeople into communities where there were conflicts between commercial interest, civil society, and government. The idea was to help our people develop leadership skills by helping communities reach solutions. DuPont had no stake in these conflicts; we just wanted our staff to get experience dealing with complicated issues where multiple stakeholders had differing interests. For example, we once sent people to act as facilitators in a conflict over usage of a dock in a fishing community in New England. Our staff had to understand a variety of points of view, which helped them become better listeners. It is difficult to find situations where communities will allow companies to get involved, but they can be great development opportunities when you find them.

MoSRP: *How important is it for companies and leaders that are interested in sustainability to be able to work across boundaries between the private, public, and social sectors?*

Chad Holliday: Companies must have staff who can reach across these sectors. I've done a lot more work across boundaries since I left DuPont, and one of the things I've noticed is that in many circles, there is a bad feeling about industry that most people in the business world don't understand. This negative feeling, even from very responsible people, is much deeper than I had thought.

I found this while working with a group that was focused on climate issues and included people in the worlds of business, technology, academia, and government. The businesspeople were outcasts to some degree; you felt it. It was a two-year project, and the members of the group understood one another a lot better over time, but we never closed the gap. The lack of trust remained. People assumed business leaders had a profit motive; they thought we were trying to shape the project to help ourselves. We sought a balanced outcome, but others didn't see that.

In another case, someone actually resigned from an organization when I joined, because I'm from the business world. I explained that I had helped companies do a lot of really good things, including creating important products that people use every day. I was really shocked. The lack of respect from other sectors is a concern for industry—the lack of trust could really hold all of us back. So it is critical to forge better bonds between these sectors. There are real opportunities out there, but success will often depend on the ability to bring different communities together. The companies that can do that will find a way to break through.

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Energy = innovation: 10 disruptive technologies

Innovation in energy technology is happening more quickly than expected—and it could accelerate economic growth and improve sustainability as early as 2015.

Matt Rogers

The world is approaching a tipping point in the development of energy technologies that could generate increases in energy productivity on a scale not seen since the Industrial Revolution.

Most of the technologies that could prove disruptive are familiar—including unconventional gas, electric vehicles, solar, and lighting from light-emitting diodes (LEDs)—yet many managers will be surprised when they arrive. That is because most organizations have been watching them develop for so many years that they find it difficult to believe that these technologies could reach scale any time soon. This view rests on a misunderstanding of the nature of technological change. The accelerating pace of energy innovation means that some technologies will achieve commercial viability much faster than most observers expect—in some cases, the shift could begin as early as 2015.

Technology may advance incrementally on the margins for long periods of time without substantially affecting established players. Indeed, developing technologies may remain uneconomical on average, even as leading innovators approach breakthroughs. But once a technology delivers cost and performance that is materially superior to the status quo, it

may well be adopted en masse. Such technologies can render existing ways of doing business untenable in less than a decade—the blink of an eye, in economic terms.

History shows that innovations in technology can cause dramatic increases in productivity, transforming industries and setting whole societies on new paths to growth. For example, the rise of wireless technology fundamentally altered telecommunications. PCs and smartphones, enabled by ever-smaller and faster chips, have revolutionized the consumer-electronics industry. And portable audio devices—starting with the Sony Walkman and continuing with the iPod—have radically transformed the way music is packaged and consumed.

Energy markets are on the verge of a similarly dramatic transformation. With prices for oil, steel, copper, aluminum, and other commodities soaring to historic highs, energy-technology innovators are taking advantage of developments in areas such as software and consumer electronics, semiconductors, and pharmaceuticals to greatly improve how the world produces and consumes energy.

The pace of change could be unprecedented. To succeed, companies must understand the major performance thresholds for each technology and the market shifts that breakthroughs will trigger. Those that are content merely to keep an eye on technological developments, betting on averages rather than positioning themselves to benefit from the cutting edge, may fail to survive in the new world these innovations create.

In the United States, five technologies have the potential to begin to affect energy productivity by 2015: unconventional natural-gas production, electric vehicles, advanced internal-combustion engines (ICE), solar, and LED lighting. Another five could do so in the period shortly after 2020: grid-scale storage, digital power conversion, compressor-less air-conditioning and electrochromic windows, clean coal, and biofuels and electrofuels. These technologies have broad applications, and they are mature enough to disrupt markets when their implementation costs drop below those of the technologies that currently dominate their industries.

The widespread adoption of any of these technologies could save customers hundreds of billions of dollars annually and help countries achieve economic growth without degrading the environment. Even if only a few of the technologies achieve breakthroughs, the world economy and the environment will benefit tremendously. These advances may also provide national-security benefits by reducing countries' reliance on fuel and other commodity imports.

While it is impossible to predict which of these technologies will thrive and to what degree, it is clear that some will. For many companies, survival will depend on the ability to navigate this "uncertain inevitability." A breakthrough in any of these technologies could mark the point of no return for an incumbent that is not prepared for it. As such, every company should take steps to ensure it is positioned to benefit if the following breakthrough scenarios come to pass.

Market impact could begin as early as 2015

Technologies that have rapidly declining cost curves and that save consumers money are developing much faster than technologies that rely on regulation to be economically viable. Each of the five technologies in this section benefits from software and consumer electronics to accelerate the rate of change, and each has six to eight competing pathways that could deliver breakthrough performance. Competition among countries introduces multiple forms of innovation to the market in parallel; Chinese low-cost engineering, Korean manufacturing scale and quality, German systems integration, and US product innovation are all important factors, and the intense competition benefits consumers. Competition among technologies (for example, solar versus wind versus natural gas and electric vehicles versus advanced ICE versus fuel cells) raises the bar and often accelerates innovation.

Unconventional gas. In the 1980s, massive unconventional natural-gas resources were identified in the United States, spurring advances in horizontal drilling, four-dimensional seismic imaging and software modeling, and hydraulic fracturing ("fracking") that enabled gas to be extracted from shale formations. The technology was implemented at scale for the first time in the early 2000s in response to significant tightening of supply in the US natural-gas market. Estimates of US natural-gas reserves were increased by 50 percent within five years, and prices fell rapidly, from more than $10 per thousand cubic feet in 2008 to about $4 per thousand cubic feet in 2011 and just over $2 per thousand cubic feet in 2012, as the market realized the new technologies could deliver low-cost gas reliably for decades. These new natural-gas supplies are already saving US consumers billions and enabling the country to reduce its emissions of greenhouse gases. The North American case is clear, and the technology has the potential to reshape global resource economics and politics as Europe, China, and India begin to evaluate and tap their unconventional natural-gas resources. While those harnessing the technology must address significant water and land-use challenges, it could still be the most important energy-technology innovation of the last 100 years.

Electric vehicles. The cost of advanced batteries is dropping precipitously. In 2009, advanced batteries cost about $1,000 per kilowatt hour. New battery-manufacturing facilities were able to deliver batteries at just over $500 per kilowatt hour in 2010, and the price could drop to $350 per kilowatt hour when these facilities reach full-scale production over the next few years. The cost of batteries could reach total-cost-of-ownership parity with ICE when the price drops to $250 per kilowatt hour, at which point the global market could increase to 15 million to 20 million sold per year, from 1 million to 2 million sold per year today. Of course, it could take three to five years from the time batteries become cheap until automakers can integrate these new designs into standard automotive platforms, pushing back consumer-benefit timelines. Nevertheless, once these vehicles are available on the market, the resulting improved fuel economy could save consumers more than $500 billion annually in the near term, replacing high-cost, mostly imported oil with lower-cost domestic electricity. Moreover, customers are discovering that electric vehicles often deliver better acceleration, safety, and comfort and may be able to support new vehicle-design innovations better than traditional technologies.

Advanced ICE. US corporate average fuel economy (CAFE) standards remained flat for nearly three decades, at 27.5 miles per gallon, while vehicle technology continued to improve. New CAFE standards will require automakers to achieve 35.5 miles per gallon in 2016 and 54.5 miles per gallon in 2025. Even then, US standards will remain below the European and Chinese standards that define automotive requirements in the rest of the world. Consumers are demanding vehicles that are more fuel efficient, and the material science and software controls are now in place to deliver them. Consumers stand to save almost as much from improvements made to the internal-combustion engine as they do from breakthroughs in electric vehicles—the competition among technologies is likely to create more attractive high-efficiency, low-cost alternatives for consumers.

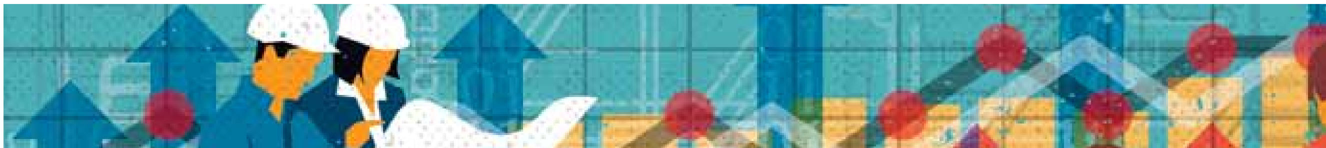
Solar photovoltaics (PV). The installed cost of solar power has fallen to about $2.50 per watt in 2012, down from $4 per watt in 2011, and from about $7 to $8 per watt as recently as 2009. The US solar market grew by about 40 percent due to the US stimulus program in 2009 and 2010, mirroring the global rate of growth driven by similar incentives provided in Germany, Italy, Spain, and China. Subsidies are likely to dry up, but the momentum could continue, supported by significant innovations in manufacturing scale, quality yield, and "balance of system" costs, potentially driving solar prices down to $1.50 per watt by 2015 and to less than $1 per watt by 2020. At these prices, solar PV will be preferable to retail electric prices for most new homes and big-box commercial businesses in sunny markets, providing an alternative to traditional power sources.

LED lighting. Lighting accounts for almost 15 percent of US electricity demand. LEDs, which rely on semiconductors, benefit from rates of improvement dictated by Moore's Law. Software increases the value in LEDs by adjusting their energy use based on needed lighting levels. A 100-lumen LED bulb cost $20 in 2011, down from $50 in 2009. The price should drop to between $8 and $10 for a 170-lumen bulb by 2015, which would render incandescent and compact-fluorescent bulbs obsolete. LED lighting currently accounts for approximately 2 percent of the global lighting market, but it could represent 30 percent by 2015 and 80 percent by 2020. If LED lighting reaches these levels, global consumers could save more than $50 billion annually by 2015 and more than $100 billion annually by 2020, which could enable a 1.5 percent decline in US electricity demand per year, the equivalent of more than 30 base-load power plants.

Market impact after 2020

Scientific and engineering innovations will be required for a subsequent wave of energy technologies to reach commercial scale at viable costs. These technologies will also likely depend on regulations to expand available markets. Not all of these technologies will succeed in the market—they will only earn a place if they can outdo top performers from the earlier wave. If successful, however, these technologies could render some of the earlier innovations obsolete.

Grid-scale storage. A variety of technologies, including batteries, flywheels, and ultracapacitors,



are being developed to enable large-scale storage of electricity within electric power grids, many of which are following an innovation pattern similar to auto batteries. Today, grid storage costs about $600 to $1,000 per kilowatt hour and can be used only when local geology supports pumped hydro or compressed-air storage systems. Innovations that make use of flow batteries, liquid-metal batteries, and other technologies could reduce costs to between $150 and $200 per kilowatt hour by 2020 and make it possible to provide grid storage in every major metropolitan market. At these prices, the United States alone would want to build more than 100 gigawatts of storage over a decade (the capacity equivalent of the current US nuclear generation fleet), significantly improving reliability and making solar, wind, nuclear, and coal much cheaper to deliver. Power companies can also use storage to smooth variability in power supply, which is more extreme for renewable technologies than for traditional generation technologies; doing so would significantly reduce distribution capital requirements.

Digital power conversion. Edison and Westinghouse invented large-scale, high-voltage transformers in 1885, setting the stage for widespread development of the electrical grid. The technology in use today remains virtually unchanged. A typical transformer costs $20,000, weighs 10,000 pounds, and takes up 250 cubic feet. High-speed, very reliable digital switches made of silicon carbide and gallium nitride have been developed for high-frequency power management in military contexts. They use 90 percent less energy, take up only about 1 percent as much space, and are more reliable and flexible than existing transformers. These digital transformers could begin to replace conventional technology at less than one-tenth the cost by 2020. China is particularly well positioned to benefit from adopting digital power electronics due to the scale of grid expansion it has planned.

Compressor-less air-conditioning and electrochromic windows. Today, it costs about $3,000 to $4,000 per year to run a high-efficiency air conditioner in a hot region, and the efficient windows now in common use allow 50 percent of this cooling energy to escape. New compressor-less air conditioners and electrochromic window technologies offer the potential to cut home heating and cooling bills in half. Today, these technologies are expensive, but by 2020, they could begin to cost only about half as much to install as current state-of-the-art cooling and window technologies.

Clean coal. Carbon capture and sequestration currently costs $8,000 to $10,000 per kilowatt. Innovative processes now under development could help coal-fired generators in the United States capture more than 90 percent of their carbon dioxide, enabling them to meet stringent new Environmental Protection Agency pollution-control requirements. Generators should be able to retrofit their existing plants with new clean-coal technology for less than $2,000 per kilowatt. About 200 US coal plants are currently slated for closure by 2020 due to their high cost relative to natural gas and their pollution output. New clean-coal technologies could enable many of these plants and similar plants in Europe and China to remain open for decades. However, clean-coal technologies are unlikely to be deployed at scale unless supportive carbon regulations are put in place.

Biofuels and electrofuels. With crude-oil prices reaching $100 per barrel, biofuels such as cane and corn ethanol have already rapidly increased their market share. But the supply of biofuels is limited by demand for food and the declining quality of available land, which drives costs up and minimizes the potential for growth. Genetic innovations that enable the use of cellulosic and algae-based biofuels can free producers from these constraints. The most innovative start-ups in this area are creating high-margin specialty chemicals and blend stocks, generating cash now and providing a pathway to begin to deliver biofuels at $2 per gallon or less by 2020. At the same time, biopharmaceutical researchers are developing electrofuels pathways that feed carbon dioxide, water, and energy to enzymes to create long-chain carbon molecules that function like fossil fuels at one-tenth the cost of current biofuels. The key question is whether these new technologies can scale.

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Not every technology we have discussed will come to fruition, but some will—and those that do will change energy markets dramatically and for good. Companies must understand cutting-edge technology if they want to succeed in the energy markets of the future. In particular, they must develop the ability to understand the technology road maps coming out of the software and consumer-electronics sectors and track innovators in key markets. They must know what particular countries are doing in their areas of competitive advantage, including understanding balance-of-system costs in China, consumer electronics in Japan and Korea, and the impact of software on product economics in Germany and the United States. Finally, companies must be aware of the price and performance thresholds that will trigger massive shifts in demand for each relevant technology. Those that neglect what is happening on the margins today put themselves at risk of being pushed to the margins themselves in the not-too-distant future.

Matt Rogers is a director in McKinsey's San Francisco office. Copyright © 2012 McKinsey & Company. All rights reserved.

Solar power: Darkest before dawn

Those who believe the potential of the solar industry has dimmed may be surprised. Companies that take the right steps now can position themselves for a bright future in the coming years.

Krister Aanesen, Stefan Heck, and Dickon Pinner

In less than a decade, the solar-photovoltaic (PV) sector has transformed from a cottage industry centered in Germany to a $100 billion business with global reach. Among the factors contributing to its growth were government subsidies, significant capacity additions from existing and new entrants, and continual innovation. PV prices have fallen dramatically, and by 2011, global installed capacity exceeded 65 gigawatts (GW).

PV prices are expected to continue to fall—even though subsidies are expected to dry up—as manufacturing capacity doubles over the next three to five years and underlying costs drop by as much as 10 percent annually until 2020. Indeed, our analysis suggests that by the end of the decade, costs could decline to $1 per watt peak (Wp)[1] for a fully installed residential system. But even if costs only fall to $2 per Wp, the industry is still likely to install an additional 400 to 600 GW of PV capacity between now and 2020.

Such a scenario could bring dramatic changes across the globe. Rapid growth of distributed generation could disrupt the regulated utility industry in countries that belong to the Organisation for Economic Co-operation and

Development (OECD). In non-OECD countries, distributed generation (in combination with inexpensive storage solutions) could bring electricity to millions of poor people living in rural areas, greatly improving their standard of living.

Given the potential economic benefits, competition—already fierce—would intensify under such circumstances. Manufacturing is likely to become more standardized and commoditized as the industry matures, reducing opportunities for upstream players to differentiate themselves. Our research suggests that the industry may consolidate across the solar value chain as participants compete for capital and access to customers.

Downstream players will have the greatest potential to generate value, particularly when demand for distributed generation hits an inflection point after 2015. The biggest winners are likely to be those that target the highest-value customers in the distributed-generation segment, delivering quality products and services in multiple regions at scale while keeping their customer-acquisition and operational costs low.

In this article, we highlight five customer segments that could be particularly attractive over the next 20 years, excluding subsidized sources of demand such as feed-in tariffs, renewable-portfolio mandates, and tax credits that constitute the majority of today's installed capacity. We also outline a number of steps upstream and downstream players could take to position themselves for success in this new environment.

Market evolution

Over the past seven years, the solar industry experienced unprecedented growth. The price of solar-PV modules dropped from more than $4 per Wp in 2008 to just under $1 per Wp by January 2012, and global installed capacity increased from 4.5 GW in 2005 to more than 65 GW today.

The subsidies that made solar PV economically attractive for many consumers set the conditions for the boom. Demand rose, new entrants flocked to the industry, and the pace of innovation accelerated. But the boom also laid the foundations for a bust. Manufacturing capacity increased dramatically—particularly after large-scale, low-cost Chinese manufacturers entered the space—and the market became oversupplied. Prices dropped precipitously, which fueled demand but put pressure on margins. In the near term, demand may not keep up with supply growth; governments are continuing to reduce subsidies due to the effects of the economic crisis, and the shale-gas boom is beginning to take hold in the United States. (See the sidebar "The global boom-bust cycle in solar PV" for more on how the market evolved from 2005 to 2011.)

It may therefore appear that the solar industry has run its course. A number of solar companies have already declared bankruptcy, many more are hovering on the brink, and the MAC Global Solar Energy Index fell 65 percent in 2011. Moreover, there is little doubt in the near term that existing players will face difficulties. Several global technology and manufacturing companies—including Samsung and Hanwha from Korea, TSMC from Taiwan, and GE from the

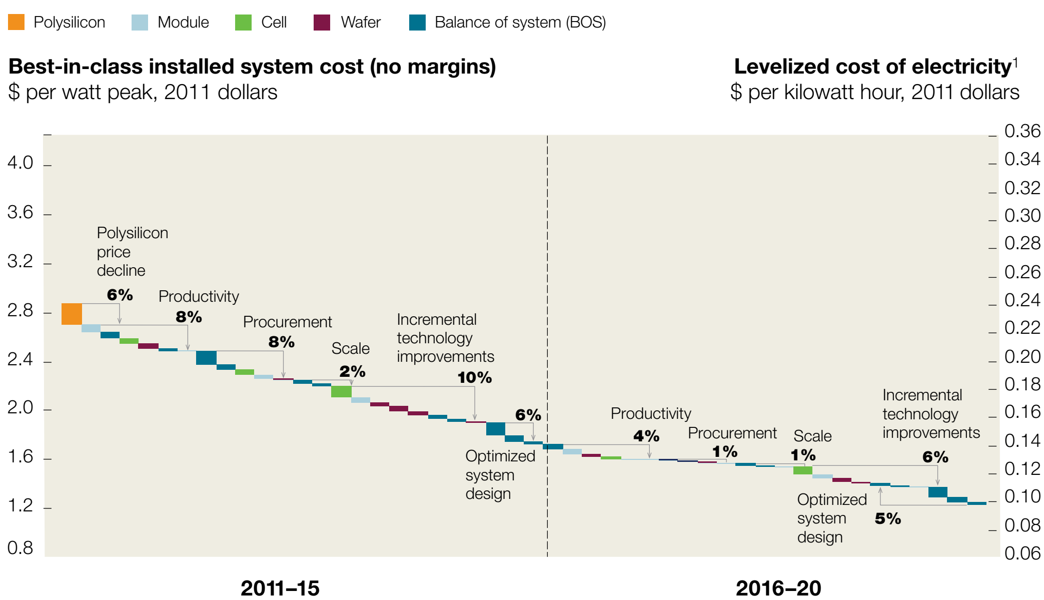
United States—have recently entered or announced their intention to enter the manufacturing segments of the solar value chain. Their efforts, combined with those of existing Chinese companies, could considerably increase global manufacturing capacity in the next three to five years, even as subsidies continue to shrink.

But these are natural growing pains, not death throes. The industry is entering a period of maturation that is likely to set the conditions for more stable and expansive growth after 2015. To succeed in this environment, companies must turn their attention to the relatively prosaic objective of reducing costs without giving up on the imperative to innovate, which has been critical to success thus far. Indeed, companies have an opportunity to reduce their costs dramatically by adopting approaches widely used in more mature industries to optimize areas such as procurement, supply-chain management, and manufacturing. For example, our analysis suggests that the cost of a commercial-scale rooftop system could be reduced by 40 percent by 2015, to $1.70 per Wp from roughly $2.90 per Wp, and by approximately another 30 percent by 2020—to nearly $1.20 per Wp (Exhibit 1). Thus companies could position themselves to capture attractive margins even as prices for PV modules decline.

Exhibit 1

Industrialization will yield significant cost reductions.

c-Si multicrystalline solar-photovoltaic system



[1] Levelized cost of energy; assumptions: 7% weighted average cost of capital, annual operations and maintenance equivalent to 1% of system cost, 0.9% degradation per year, constant 2011 dollars, 15% margin at module level (engineering, procurement, and construction margin included in BOS costs).

Source: Industry experts; Photon; GTM Research; National Renewable Energy Laboratory; US Energy Information Administration; Enerdata; press search; company Web sites; McKinsey analysis

Potential evolution of solar-PV capacity in the United States

The unsubsidized economic potential for distributed residential and commercial solar photovoltaic (PV) in the United States is likely to reach 10 to 12 gigawatts (GW) by the end of 2012. This is not the amount of PV capacity that will be installed, but the amount that producers could sell at a profit because it is competitive with other options (such as purchasing electricity via the grid from a traditional utility) on total cost of ownership.

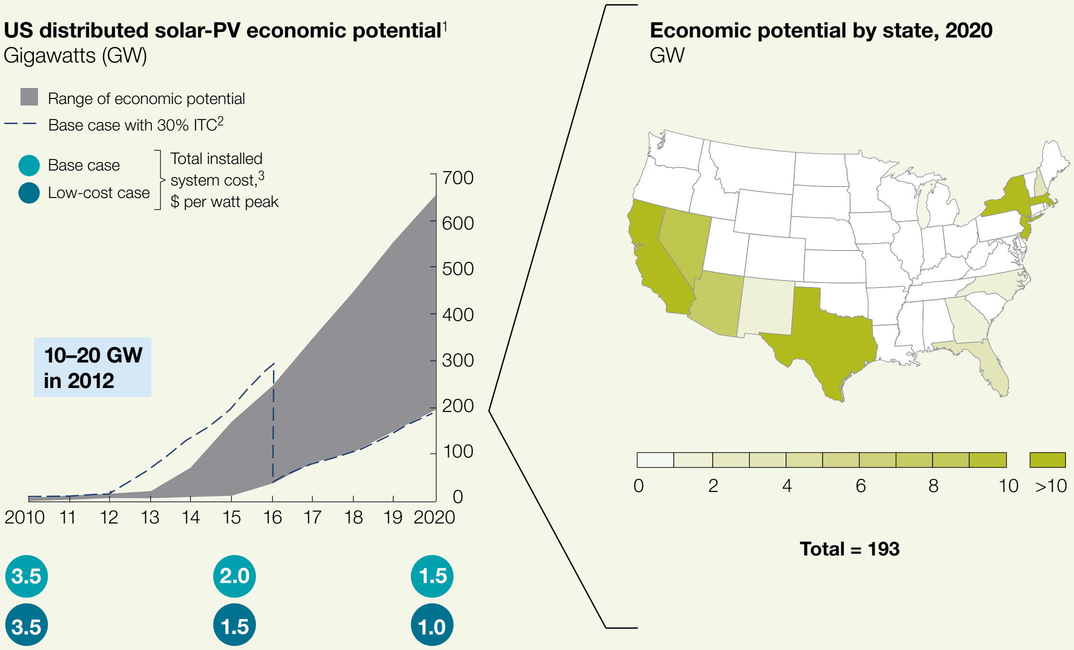
Growth is likely to continue in these segments after 2012, potentially reaching a tipping point in 2014 or 2016 that could enable unsubsidized demand for solar PV to grow to between 200 and 700 GW by 2020. Demand is likely to be concentrated in 10 states. Indeed, 50 percent of the available power delivered to the residential and commercial segments in some of these states may be generated by solar PV in 2020.

Our estimates increase dramatically when we include the effects of subsidies from the federal government's investment tax credit,[1] which could enable installed capacity of solar PV to climb as high as 70 GW by 2013 (exhibit).

[1]The investment tax credit, which is in effect through December 31, 2016, provides a reduction in the overall tax liability for individuals or businesses that make investments in solar-energy-generation technology.

Exhibit

Solar PV for distributed generation is approaching an inflection point in the United States.



[1]PV = photovoltaic; economic potential assumes 20-year lifetime and 8% cost of capital, computed separately for residential and commercial segments using actual retail rates, schedules, and tiers.
[2]Investment tax credit.
[3]Numbers quoted are for a best-in-class commercial rooftop system; residential systems modeled with 30% higher price to account for higher installment costs.

Source: US Energy Information Administration; Ventyx; utility filings; National Renewable Energy Laboratory; McKinsey US low-carbon economics toolkit

The prize: Distributed generation

Our analysis suggests that the global economic potential for total installed solar PV—that is, the amount of PV that could be operated at a lower levelized cost of energy (LCOE)[2] than competing sources—could exceed a terawatt (1,000 GW) by 2020. However, given the barriers to implementation, such as possible changes to the regulatory environment and access to finance, we expect installed capacity to increase to between 400 and 600 GW by 2020.[3]

At this level of demand, annual capacity additions would increase by a factor of three to four, climbing to 75 to 100 GW in 2020 from 26 GW in 2011. Price declines mean that the annual revenue generated across the value chain will probably remain flat, about $75 billion to $100 billion per year, despite the fact that margins may begin to rise around 2015. Nevertheless, our analysis suggests annual installations of solar PV could increase 50-fold by 2020 compared with 2005, achieving installation rates that could rival those of gas, wind, and hydro and that might outpace nuclear.

This growth will stem largely from demand in five customer segments over the next 20 years. Four of these segments are likely to grow significantly by 2020; the fifth is likely to grow significantly from 2020 to 2030 (Exhibit 2).

1. Off-grid areas. Solar power is ideal in places without access to an electric grid. Applications include delivering power to agricultural irrigation systems, telecommunications towers, remote industrial sites such as mines, and military field sites. Within this segment, the most significant potential resides in areas that use diesel generators to provide uninterrupted power supply for remote infrastructure, such as telecommunications towers in India. Off-grid applications have been economically viable in some locations for several years, but the lack of low-cost financing for remote sites—where credit risk is often relatively high—has made it difficult for companies and customers to afford the upfront costs of installation. The dearth of local distribution partners has also impeded growth. Nevertheless, our research indicates that demand in this segment could reach 15 to 20 GW by 2020.

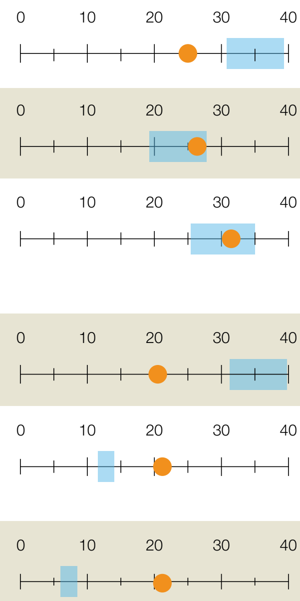
2a. Residential and commercial retail customers in sunny areas where power prices rise steeply at times of peak demand. Many businesses in places like California, Hawaii, Italy, and Spain already generate their own power using solar applications. In the near term, this segment's growth will depend on the availability of low-cost financing, customer-acquisition costs, and reactions from regulated utilities. For example, in the United States and Europe, there is a risk that utilities could request to modify their rate structures to make switching to distributed generation less attractive for customers. In Hawaii, regulations require anyone located in a region where distributed generation represents 50 percent of peak demand to undergo a lengthy and costly review process before adding distributed solar capacity.[4] In India, companies such as SunEdison (now part of MEMC) have partnered with organizations like the World Bank's International Finance Corporation and the Export-Import Bank of the United States to establish programs that enable preapproved financing. Our analysis suggests that the demand in this segment is likely to be between 150 and 250 GW by 2020.

Exhibit 2

Solar power is approaching a tipping point in a number of customer segments.

Photovoltaic solar power

Cost comparison, 2011, ¢ per kilowatt hour
● Solar ■ Other energy sources[1]



	Customer segment	Cumulative market potential,[2] 2012–20, GWp (gigawatt peak)	Timing of viability
1	**Off-grid:** applications in areas with no grids (eg, Africa, India, Southeast Asia, and parts of Middle East)	15–20	Now
2a	**Commercial and residential, good sunlight:** developed markets in sunbelts (eg, Australia, California, Italy, and Spain)	150–250	Now
2b	**Commercial and residential, moderate sunlight:** developed markets with moderate solar yields (eg, Canada, Denmark, Germany, Netherlands, and United Kingdom)	65–120	2012–13 and beyond
3	**Isolated grids:** small local grids primarily fueled by small diesel generators; large latent demand (eg, Africa)	25–30	Now
4	**Peak capacity in growth markets:** growth markets; large power investments (eg, Africa, China, India, and the Middle East)	150–170	2013–14 and beyond
5	**New large-scale power plants:** growth markets; large power investments (eg, China, India, and the Middle East)	Marginal	2025 and beyond

Total market potential = 400–600 gigawatts
(compared with 2011 installed base of 65 gigawatts)

[1]Alternative to solar power in given segment—eg, for residential customers, price for power from grid.
[2]Adjusted for implementation time.

Source: US Energy Information Administration; McKinsey analysis

2b. Residential and commercial retail customers in areas with moderate sun conditions but high retail electricity prices. A wide range of countries and regions fall into this segment, including parts of Europe and the United States, Japan, Canada, and some countries in Latin America. As in segment 2a, barriers to growth include access to low-cost financing and the ability to dramatically reduce customer-acquisition costs. New entrants from the security, cable, or broadband industries could leverage their existing customer relationships to acquire customers at a significantly lower cost than existing players. If the barriers are addressed, potential demand in this segment could range from 65 to 120 GW by 2020. (See the sidebar "Potential evolution of solar-PV capacity in the United States" for details about likely PV penetration in the country through 2020.)

3. Isolated grids. Small grids fueled by diesel generators require an LCOE of between $0.32 and $0.40 per kilowatt hour (kWh) to be economically attractive. These primarily provide power to remote villages in Africa,[5] India, Southeast Asia, and parts of the Middle East. We estimate that demand in this segment is already 25 to 30 GW. The current barrier to deployment is the limited availability of low-cost financing in non-OECD regions.

4. Peak capacity in growth markets. To be economically attractive, new solar-power plants used at periods of peak capacity require an LCOE of $0.12 to $0.14 per kWh. The largest potential for this segment lies in markets where substantial new electric-power infrastructure is set to be built (for instance, India, Brazil, the Middle East, and China) or in countries that rely heavily on imports of liquefied natural gas (such as Japan). Greater access to inexpensive natural gas from shale could erode solar economics, but demand may reach 150 to 170 GW by 2020.

5. New, large-scale power plants. New solar-power plants must reach an LCOE of $0.06 to $0.08 per kWh to be competitive with new-build conventional generation such as coal, natural gas, and nuclear. As with smaller peak-capacity plants, large-scale solar plants are most likely to be built in emerging markets that are expanding their infrastructure aggressively, where the cost of solar will be compared with the cost of a new coal, natural-gas, or nuclear plant. Companies must still achieve breakthroughs in manufacturing techniques to reach this cost threshold in solar; once they do, it will take time to implement the advances at scale. Extensive use of solar as an alternative to traditional base-load generation is not likely before 2020, but the segment could reach 110 to 130 GW by 2030, representing only 15 percent of the cumulative new solar build in the same period.[6] Margins will probably be set by the wholesale power price, however, and may be slim as a result.

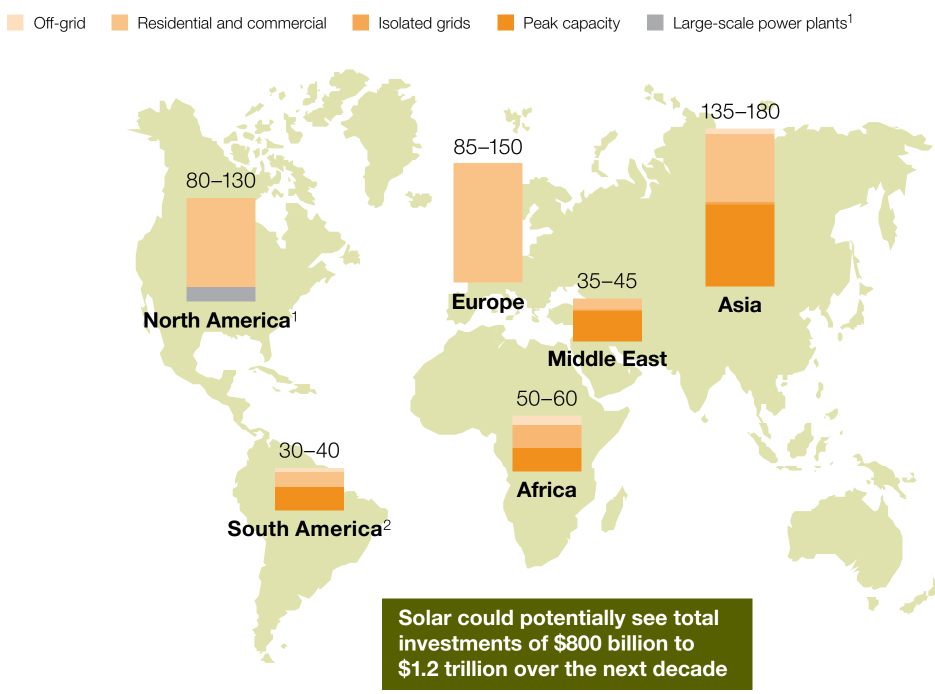
Across these five segments, distributed rooftop generation is likely to be the dominant source of solar demand in OECD countries; distributed ground-mounted generation is likely to dominate non-OECD countries (Exhibit 3).

In addition to these segments, many entrepreneurial opportunities will arise for new players and investors seeking to develop tailored business models in different markets and customer segments. Sets of companies focused on serving specific segments could emerge, and these players might become regional or even global champions in their chosen niches. For

Exhibit 3

Growth in solar PV may transform power markets.

Cumulative capacity additions, 2012–20, gigawatts



[1] Includes 10–20 gigawatts of regulated utility pipeline in the United States.
[2] Includes Mexico.

Source: Enerdata; McKinsey Global Solar Initiative

example, a phone company could make a play to provide solar power and water pumping in Africa. A global developer could help big retailers such as Wal-Mart and Staples to deploy solar and energy-efficiency approaches in their stores. Home-security companies such as ADT could add solar-power packages on to their existing value propositions.

Given the emergence of these pools of demand, we believe that leading solar companies could have healthier margins by 2015. Prices paid for solar are likely to continue to fall, but sales should rise as solar power becomes economically viable for an increasing number of customers. Additionally, because prices for solar-based power are likely to be set by prices for fossil fuels instead of subsidies (which have been falling annually), margins for leading solar players should increase even as their costs continue to decline.

How to win

Against this backdrop, competition among manufacturers is likely to intensify, but our analysis suggests that downstream segments of the value

The global boom-bust cycle in solar PV

Boom: 2005 to 2008

The solar industry was initially nurtured in Germany, Japan, and the United States, then gained strength in countries such as Italy, where government support designed to boost demand helped photovoltaic (PV) manufacturers increase capacity, reduce costs, and advance their technologies.

These subsidies helped spur demand that outpaced supply, which brought about shortages that underwrote bumper profits for the sector until 2008. The focus during this period was developing better cell and module technologies; many Silicon Valley–based venture-capital firms entered the space around this time, often by investing in companies in thin-film solar-cell manufacturing. Valuations for some of the more promising solar-cell start-ups at that time exceeded $1 billion.

The price to residential customers of installing PV systems fell from more than $100 per watt peak (Wp) in 1975 to $8 per Wp by the end of 2007—although from 2005 to 2008, prices declined at the comparatively modest rate of 4 percent per year. German subsidies drove value creation, with the lion's share of the value going to polysilicon, cell, and module-manufacturing companies in countries that are part of the Organisation for Economic Co-operation and Development.

Bust: 2009 to 2011

Encouraged by the growth of the industry, other countries—including France, Canada, South Korea, Australia, South Africa, India, and China—began to offer support programs to foster the development of solar sectors within their borders. Chinese manufacturers began to build a solar-manufacturing sector targeting foreign countries where demand was driven by subsidies, particularly Germany. Armed with inexpensive labor and equipment, Chinese players triggered a race to expand capacity that drove PV prices down by 40 percent per year; prices fell from more than $4 per Wp in 2008 to about $1 per Wp in January 2012. We estimate that balance-of-system (BOS) costs declined by about 16 percent per year in this period, from about $4 per Wp in 2008 to approximately $2 per Wp in 2012 (these are more difficult to track, in part because BOS costs vary more than module costs).

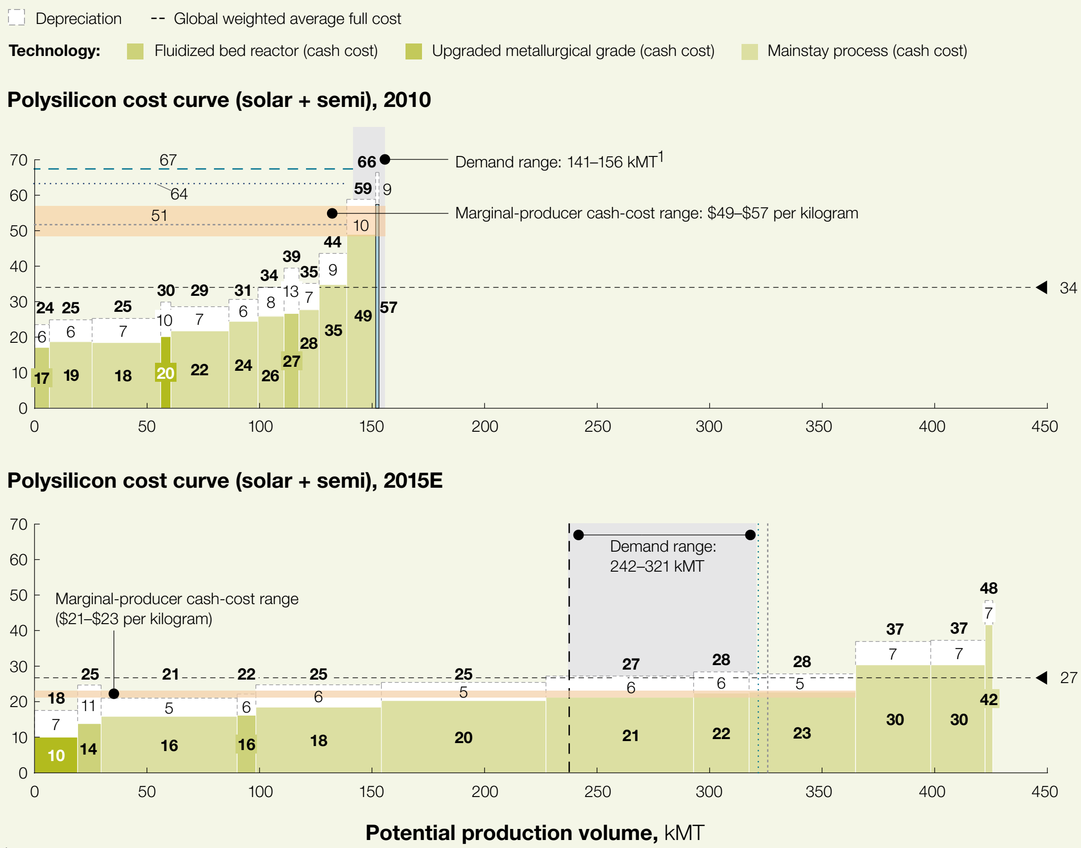
The cost curve flattened for many upstream segments of the value chain during this period. For example, costs converged for many polysilicon manufacturers from 2010 to 2012; one force that drove this trend was the entry of players such as South Korea's OCI Company Ltd. and China's GCL Solar, which contributed to polysilicon spot prices declining from about $50 per kilogram in 2010 to between $20 and $25 per kilogram today (exhibit). Solar-cell and module cost curves have flattened to similar degrees. As a result, value has migrated downstream to players that develop and finance solar projects and install capacity.

By 2009, venture-capital firms began to shift their new solar investments from capital-intensive solar-cell manufacturers to companies focused on developing innovative downstream business models, such as Solar City, SunRun, and Sungevity.

Exhibit

The polysilicon cost curve illustrates how upstream cost curves are flattening.

Production cost (cash cost and full cost), $ per kilogram



[1]Kilo metric tons.

Source: Expert interviews; literature search; iSuppli; Photon; Bernreuter Research; Solar & Energy; McKinsey analysis

Scale will be crucial for solar manufacturers; to achieve scale, they will also need strong balance sheets

chain will become increasingly attractive. Both upstream and downstream players will have to reduce costs dramatically to succeed, but they will also need to deliver distinctive products and services. Manufacturers can distinguish themselves by developing proprietary technologies; downstream players should focus on meeting the needs of particular customer segments.

Key success factors for upstream players

Scale will be crucial for solar manufacturers. A few years ago, manufacturers needed to have 50 to 100 MW of solar capacity to compete in the PV market; today they need 2 to 3 GW of capacity to compete. To achieve scale, they will also need strong balance sheets. We have identified three steps that manufacturers can take to get there.

Develop or own differentiated and scalable technologies. Companies can capture significant cost advantages by developing proprietary technologies. This is particularly important in manufacturing, where cost curves that were historically quite steep have already flattened significantly and will continue to do so. For example, MEMC and REC have commercialized the fluidized-bed-reactor (FBR) process to reduce the energy intensity of manufacturing polysilicon relative to today's mainstay polysilicon manufacturing process. As a result, the cost of polysilicon is expected to drop significantly by 2015, with the leading players that use the FBR process achieving cash costs of $14 to $16 per kilogram, compared with $16 to $18 per kilogram for leading players that do not use it. Others have developed cell technologies using copper indium gallium selenide that require much less photovoltaic material to harvest the solar energy than crystalline silicon technologies; these new technologies could therefore be less expensive.

Drive operational excellence in manufacturing. Manufacturers should examine every operational step to identify opportunities to reduce costs. They should consider adopting lean production approaches, implementing category-based procurement processes, developing strategic relationships with suppliers, and streamlining their supply chains. To drive operational excellence, leading players often recruit experienced managers from highly competitive industries such as automotives, electronics, or semiconductors. Manufacturers can increase productivity by 30 to 40 percent by pursuing these types of initiatives. They can also develop advantages by adopting practices from other industries to increase their productivity. For example, Taiwanese and Korean companies are applying low-cost approaches for manufacturing solar technologies that were originally developed for manufacturing semiconductors and liquid crystal displays.

Address balance-of-system costs. Solar components excluding PV panels—such as wires, switches, inverters, and labor for installing solar modules—represent more than half the cost of a solar system. These components are collectively referred to as the "balance of system" (BOS), and BOS manufacturers could significantly reduce their costs (and thus lower costs for the whole industry) by implementing techniques—such as modularization, preassembly, standardization, and automation—that are common in mature industries. BOS manufacturers could also reduce industry costs by increasing the durability of the components—for example, by developing technologies that significantly extend the lifetime of inverters relative to the 7 to 10 years typical today.

Large manufacturing companies may have the scale to excel at reducing costs and improving product performance, but they sometimes lack the capabilities needed to understand and fulfill customer needs. Incumbent manufacturers could seek to strengthen their positions by acquiring or partnering with companies that are closer to customers and that can support the development of tailored solutions.

Key success factors for downstream players

Since the bulk of the market in the next 5 to 10 years is expected to be in distributed generation, we focus here on downstream distributed-generation companies. These companies should focus on serving high-value customers at low cost. To do so, companies must know their customers well: they need to understand the solar conditions in the areas in which customers are located, the space customers have available for solar applications, the level of power they consume at different times of day and throughout the year, the amount they pay for power, and their ability to finance purchases. These companies must also reduce the cost of acquiring and serving customers.

Develop targeted customer offerings. Large commercial customers are likely to prefer suppliers that can install and operate solar systems across a global network of sites. Providers will also increasingly be asked to develop specialist solar applications—for example, direct-

current water pumps and mobile-charging units, or applications that combine solar with LED lighting. IBM uses solar applications to power its high-voltage, direct-current data center in Bangalore. Off-grid applications in emerging markets need robust equipment that is easy to install without sophisticated engineering and construction equipment. Companies could partner with local project developers to gain access to reliable distribution channels and secure access to finance for projects that carry risks specific to emerging markets. They could also partner with companies that already deliver products and services. For example, Eight19, a solar-PV start-up, partnered with SolarAid, a nonprofit, to provide Kenyans with bundled products and services that include solar-powered LED lighting and phone-charging options. Customers pay for the services as they use them via scratchcards validated through a text-message service. These products are inexpensive to manufacture, and the innovative pay-as-you-go approach enables partners to address some of the financing challenges that might otherwise stymie their efforts to serve poor communities.

Minimize customer-acquisition and installation costs. In the residential segment, acquisition costs for pure-play solar installers in places such as California vary from about $2,000 to more than $4,000 per customer. Acquisition costs are significantly lower in Germany, but best practices that have enabled German companies to reduce costs are not always transferrable given the regulatory environment and the lack of feed-in tariffs in the United States. For players in the United States to sufficiently reduce acquisition cost per customer, companies should minimize door-to-door sales efforts and prescreen potential customers for creditworthiness. Digital channels provide opportunities to meet marketing goals at a lower cost than traditional approaches allow. Companies may also be able to reduce acquisition costs by striking partnerships with companies in other sectors: for example, home builders, security companies, broadband providers, or retail power providers. They can reduce installation costs by optimizing logistics, predesigning systems, training employees to improve their capabilities, and clearly defining standards.

Secure low-cost financing. Many companies are partnering with other organizations to gain access to low-cost financing. MEMC's SunEdison joined with First Reserve, a financial provider, to secure a large pool of project equity. SolarCity secured funding from Google to finance residential solar projects, enabling Google to receive tax benefits in exchange for owning electricity-producing solar assets. Other potential innovative approaches include solar real-estate investment trusts,[7] which allow retail investors to provide funding for solar projects or offer options that let distributed-generation customers pay for their solar investments via their monthly utility bill. The cost of capital is often the most crucial factor determining returns on solar projects. To succeed in downstream markets, companies need strong capabilities in project finance—indeed, the entities that structure solar investments often achieve better returns than the companies that manufacture or install modules. Companies are increasingly likely to turn to institutional investors, asset-management firms, private-equity firms, and even the retail capital markets to raise the sums required to finance expected demand for solar, which could add up to more than $1 trillion over the next decade.

As the solar investment pool swells, financial institutions, professional investors, and asset managers are likely to be drawn to the sector, since solar projects that are capital-heavy up front but rely on stable contracts will become attractive in comparison with traditional financial products. New types of downstream developers and investment products will emerge to aggregate low-cost equity and debt and to structure financial products with risk-return profiles aligned with the specific needs of institutional investors.

• • •

The solar industry is undergoing a critical transition. The rules of the game are changing, and many current players could face significant challenges as the industry restructures. But those who believe the solar industry has run its course may be surprised. Solar companies that reduce their costs, develop value propositions to target the needs of particular segments, and strategically navigate the evolving regulatory landscape can position themselves to reap significant rewards in the coming years. ○

[1] In photovoltaics, the output of a solar generator operating under standard conditions is defined as its peak output, which is measured in watts or kilowatts and expressed as either watt peak (Wp) or kWp, respectively.

[2] Levelized cost of energy is the price at which electricity must be generated from a specific source to break even.

[3] At these levels, solar power would represent about 2 to 3 percent of power generated globally in 2020, which would nearly equal the projected total demand for power in Africa in 2020.

[4] The rule is designed to mitigate the risk that distributed generation might pose to the stability of the power grid. In 2011, the threshold was increased to 50 percent from its earlier level of 15 percent.

[5] According to the International Energy Agency, there are almost 590 million people with no access to power in Africa alone.

[6] Costs at this level could support the building of new power plants in the United States and some European countries in order to meet carbon-emission targets between 2020 and 2030. However, much will depend on the extent to which low-cost natural gas becomes available in these markets. The analysis therefore heavily discounts the potential in developed markets.

[7] In general, a real-estate investment trust (REIT) is a company that owns (and typically operates) income-producing real estate or real estate–related assets. REITs provide a way for individual investors to earn a share of the income produced through commercial-real-estate ownership without actually going out and buying commercial real estate. Solar REITs rent roof space to companies and utilities that can install and manage solar panels on top of buildings.

Krister Aanesen is an associate principal in McKinsey's Oslo office, **Stefan Heck** is a director in the Stamford office, and **Dickon Pinner** is a principal in the San Francisco office. The authors would like to acknowledge the valuable contributions of Timothy Ash, Nuri Demirdoven, Anton Diachenko, Rob Jenks, Svein Harald Øygard, and Kyungyeol Song. Copyright © 2012 McKinsey & Company. All rights reserved.

Shale gas and tight oil:
Framing the opportunities and risks

Discussions about broader access to unconventional natural gas and oil should account for a wide range of potential benefits and risks.

Tommy Inglesby, Rob Jenks, Scott Nyquist, Dickon Pinner

Much media and government attention has focused on disruptive innovation in the zero-emission renewables area of the power-generation landscape. But "old energy" has created some disruptive innovations of its own. With the scale-up of two technologies, horizontal drilling and hydraulic fracturing, producers in the United States have demonstrated the viability of extracting more than 50 years' worth of domestic natural-gas and oil resources—but in so doing, have raised important debates on the trade-offs between the potential economic and environmental implications of the new technologies. This article does not set out a view on where these debates should come out. That is the legitimate focus for policy makers in each country where shale-gas and tight-oil resources are located. Instead, it is intended to frame discussions on the potential benefits and risks associated with these new technologies.

In the United States, where shale-gas and tight-oil production have so far been adopted more than elsewhere, these new technologies have shown the potential for significant impact on the energy landscape, and indeed much change has already occurred. The share of natural gas in electric power generation has already increased significantly, for example, and there is great potential for increased use of

low-cost natural gas in transportation and industry. Such developments could enable increases in US economic output and employment—particularly if they facilitate reductions in consumer and corporate energy bills, increases in domestic energy production and reductions in oil imports, and reductions in air pollution and greenhouse-gas emissions (which could happen if natural gas displaces other fossil fuels).

However, the potential benefits need to be considered alongside potential risks. Natural gas is still a hydrocarbon that emits greenhouse gases, although in lower amounts than those of current coal technologies. In addition, methane leakage can worsen the carbon footprint of natural gas. The process of setting up and conducting hydraulic-fracturing operations required to free gas and oil from low-permeability rock creates environmental risks, including water contamination, local air pollution, and land degradation—some of which may be serious and some of which have yet to be fully understood.

Low-cost gas, held by some to represent a low-carbon bridge to a zero-emissions future, is resisted by others who believe it will slow near-term deployment of renewables, and—longer term—create "lock in" of natural-gas usage following large-scale deployment of the supporting natural-gas infrastructure.

Moreover, this is not just a US story. Much attention, and a great deal of money, is focused on the United States because shale-gas and tight-oil resources are more extensively characterized and commercially mature there, but many countries are watching the United States to see how it develops and oversees the use of horizontal drilling and hydraulic fracturing. Countries with significant "unconventional" resources include Abu Dhabi, Algeria, Argentina, Australia, Canada, China, Colombia, Germany, India, Indonesia, Mexico, Oman, Poland, Russia, Saudi Arabia, Ukraine, and the United Kingdom.

The complexity of the trade-offs involved with these disruptive technologies is reflected in the differing policy responses of governments around the world. Some have taken the position that based on our current knowledge, the risks of conducting hydraulic fracturing are too great, and they have banned the process pending further study. Others have proceeded with its development to a greater or lesser degree.

This article does not seek to set out "the right answer" or to suggest which policy decisions governments should take. Instead, it aims to frame discussion, analysis, and debate on the implications, uncertainties, and trade-offs of accessing shale-gas and tight-oil reserves. We describe the origin and evolution of these disruptive technologies and how they could change the ways that energy is used. We then describe the potential economic benefits that could be realized over the next 20 years and the potential environmental risks that must be understood and considered in decision making.

Emergence of new technologies

Producers have long known shale as "source rock"—rock from which oil and natural gas slowly migrated into traditional reservoirs over millions of years. Lacking the means economically to unlock the massive amounts of hydrocarbon locked in the source rock, producers devoted their attention to the conventional reservoirs. It was not until the mid-1990s that technological innovation allowed producers to access resources directly and economically from source rock.

Producers in the Barnett Basin in the Dallas area began to combine a number of reasonably mature drilling and completion technologies and test them on shale rock. Once the industry discovered how to combine two technologies—hydraulic fracturing and horizontal drilling—the extensive gas resources trapped in shale deposits became accessible. Today, the technology is being expanded to unlock both gas and oil resources in a range of low-permeability rock types in new and mature basins around the country.

In 2005, natural-gas prices were above $13 per million British thermal unit (MMBtu), and the United States was expected to be importing more than 20 percent of its gas and generating over 50 percent of its electricity from coal by 2020.[1] At various points in early 2012, gas prices fell below $2 per MMBtu. At the time of this writing, proposals are in place for the United States to export gas, and the share of coal in power generation has fallen from 50 percent in 2008 to less than 40 percent, while gas generation has increased from 20 percent to almost 30 percent.[2] Meanwhile, producers are working to unlock additional gas and oil resources, and service companies are developing new "super fracking" technologies that some industry experts believe could improve recovery rates by up to 70 percent.

Potential benefits

Shale gas and tight oil therefore represent disruptive technologies. They raise potential benefits and risks, all of which must be understood and considered in order for key stakeholders in the public and private sectors to make informed decisions.

Looking at potential benefits through a US lens, cheap gas could bring lower energy bills for consumers and businesses, increased competitiveness for US industry, greater domestic energy production, and increased employment and GDP. In addition, there could be reduced greenhouse-gas emissions in the power sector through the displacement of a considerable amount of coal-fired power generation, as well as increased energy security in the form of reduced oil imports for transportation. There are also likely to be significant opportunities beyond the United States.

Economic impact in the United States. At today's prices, greater adoption of natural gas would significantly reduce consumer and wholesale energy costs. In the residential segment, according to the US Energy Information Administration, lower-cost natural gas has cut annual energy costs for US households by an average of almost $800 per household, or 25 percent, since 2005.[3] Looking forward, consumers and commercial and industrial customers could gain further significant savings on their energy bills.

There could also be benefits to the US economy as a whole. Lower energy costs would make US industries more competitive and lead to higher output; reduced price volatility and the associated reduction in uncertainty could increase investment; and increased domestic energy production could lead to higher economic output and employment.

Greenhouse-gas emissions. CO_2 combustion emissions per unit of energy are lower for natural gas than for other fossil fuels, particularly coal. Efficient combined-cycle natural-gas power plants

produce less than half as much CO_2 per kilowatt hour as do typical coal-fired power plants, significantly less nitrogen oxides, and just 1 percent as much sulfur oxides.[4] Natural-gas-fueled vehicles could also produce fewer CO_2 emissions per mile than gasoline-fueled vehicles, and industrial facilities powered by natural-gas combustion could emit less carbon dioxide than plants powered by combustion of coal or petroleum products. (As discussed later in this article, assessments of the net impact of horizontal-drilling and hydraulic-fracturing technologies on greenhouse-gas emissions must also reflect an understanding of the ways in which the realization of shale-gas resources could increase emissions.)

Energy security. Natural gas has the potential to displace petroleum in the transport and industrial sectors. In addition, there has been a significant increase in US onshore tight-oil drilling. Producers are deploying horizontal drilling and hydraulic fracturing in various oil formations in the United States, with great early promise. For example, in the Bakken formation in North Dakota, oil production rose from fewer than 30,000 barrels per day (bbl/d) in 2008 to 469,000 bbl/d by the end of 2011.[5] By replacing some oil use with natural-gas use and satisfying some demand for oil by drilling for tight oil, the United States could significantly reduce its net liquid-fuel imports, bringing the country closer to energy independence.

Global opportunities. Significant opportunities exist to develop horizontal-drilling and hydraulic-fracturing technologies for use globally. The International Energy Agency estimates that global recoverable reserves of unconventional gas are nearly triple those in the combined United States and Canada, and that unconventional gas is present in virtually every country.[6]

Global investors around the world have invested more than $40 billion since 2008 in emerging unconventional gas and oil plays in the United States in order to gain the operational know-how required to develop shale plays in their own regions. However, it may be more challenging to develop unconventional resources in regions outside North America due to various factors, including geology, lack of pipeline infrastructure, regulatory and tax structure, and less developed upstream services industries.

As an example, the emergence of a shale-gas and tight-oil industry has been slow in Europe, where some governments have put moratoria on developing hydraulic fracturing until producers can guarantee greater levels of environmental safety.

In China, shale and tight-oil resources have the potential to unlock a gas resource base that is, by some estimates, 50 percent larger than that in North America.[7] Chinese companies have made substantial investments in North American operations. They are reviewing opportunities to take direct investments in the service sector as well. Were China and other countries to deploy horizontal-drilling and hydraulic-fracturing technologies at scale within their borders, they could change the economics of oil and gas globally, potentially affecting the competitiveness of different regions just as efforts in the United States are affecting global competitiveness today.

Potential risks

The potential benefits of shale-gas and tight-oil development, discussed above, should be considered in the context of the potential environmental risks these technologies could pose if they are scaled up. This will be particularly challenging given that the producer landscape is highly fragmented in the United States (where there are more than 2,000 onshore gas and oil producers), and drilling activity is highly dispersed (nearly 10,000 horizontal wells were drilled in the lower 48 states of the United States in 2011).[8]

The potential environmental risks include the effect on air quality and greenhouse-gas emissions and the impact on land and water. These challenges are complicated by the proximity of some shale-gas and tight-oil reserves to urban communities in states such as Texas, Pennsylvania, New York, and Ohio.

Air quality. Much of the equipment used in the drilling process for gas and oil wells is diesel-fired and emits NOx, SOx, and particulates that contribute to air pollution.

Greenhouse-gas emissions. Combustion of natural gas and oil results in emissions of carbon dioxide, the main greenhouse gas. Increased use of these fossil fuels will therefore increase greenhouse-gas emissions. Even though the combustion of natural gas emits lower amounts of CO_2 than other fossil fuels, increased production and distribution of natural gas can result in increased methane-gas emissions ("fugitive emissions"). Because methane is a much more potent greenhouse gas than CO_2 (more than 25 times stronger on a 100-year time scale),[9] even a small amount of fugitive emissions could negate the combustion benefit of natural gas. The life-cycle emissions of natural-gas production, distribution, and consumption, especially with increased shale-gas production, are a continued source of uncertainty that needs to be better understood.

Low-cost gas also has the potential to displace zero-carbon renewables, increase demand for energy overall, and catalyze the return to the United States of energy-intensive industries. Taking these effects into account, we estimate the net impact as ranging from a slight reduction to a slight increase in overall US greenhouse-gas emissions, depending on the level of fugitive methane emissions.

Land use. As drilling activity moves from fairly remote areas into more densely populated ones, the land-use impact of concentrated drilling operations—which can, in some areas, reach one well for every 40 acres—is more strongly felt. This is particularly so during the initial drilling process, when a typical shale-gas or tight-oil well may require over a month of continuous operation, with hundreds of truck trips to and from a site.

Water availability, contamination of aquifers, and treatment and disposal. Hydraulic fracturing at a single oil or gas well involves injecting up to five million gallons of water into low-permeability rock at high pressure. Today, 30 to 70 percent of that water remains within the natural fractures of the rock.[10] A great deal, however, returns to the surface with the gas, where it must be treated or otherwise disposed of.

At present, only a portion of such water is effectively recycled for reuse. As a result, water sourcing is a growing challenge for the industry. Some regions, such as the Marcellus Basin, offer ready access to surface water. However, water is less plentiful around the Barnett, Eagle Ford, and Haynesville Basins in North Texas, South Texas, East Texas, and Louisiana.

Another contentious issue is the potential contamination of local drinking-water aquifers. In December 2011, a preliminary US Environmental Protection Agency (EPA) report linked hydraulic fracturing to groundwater contamination.[11] However, it should be noted that the EPA has said that its findings need to be reviewed, and that the conclusions drawn were specific to the location.

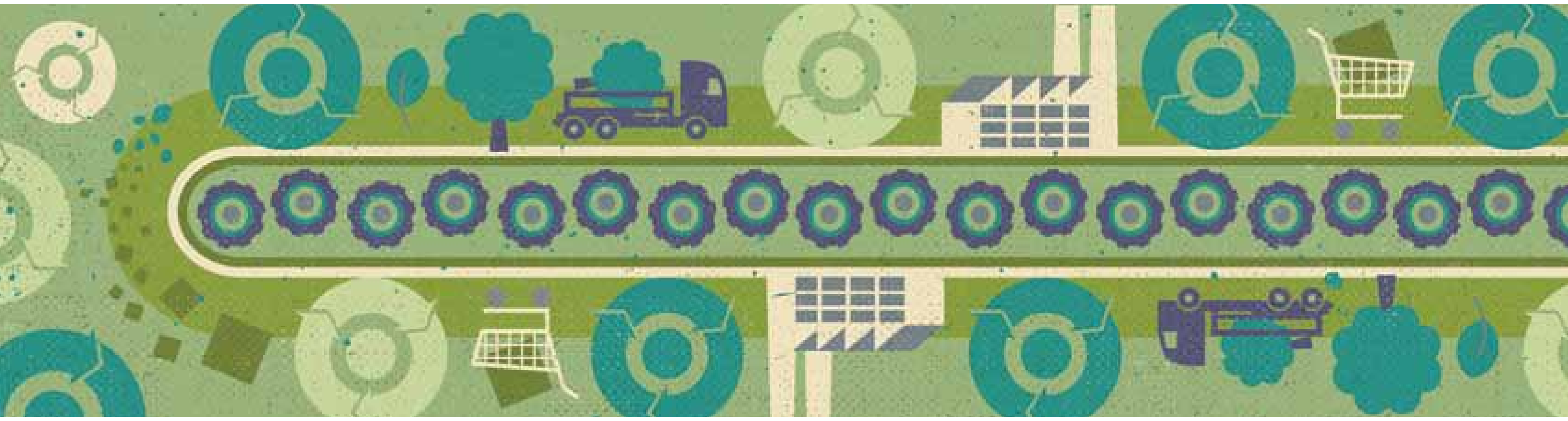
Water treatment and disposal are also potentially serious issues. Currently, the majority of water is disposed of in deep wells or treatment facilities, although treatment for reuse is increasing now that seismologists have linked deep-well injection to earthquakes in some regions.[12] But treatment has not always been adequate: there are cases in which operators have not sufficiently treated or disposed of "flowback" water.

Given the many water-related challenges, we are already seeing a proliferation of new water technologies, such as the use of propane to replace water as the fracking fluid. This area is likely to be the focus of considerably more technological innovation in the future.

Technological development presents what is possibly the biggest energy disruption in decades—with significant economic benefits and geopolitical consequences. But technological development also comes with potentially significant risks, which must be considered alongside these benefits. Decisions about how to realize shale-gas and tight-oil resources will need to be informed by an ever-increasing understanding of the implications and trade-offs involved.

[1] US Energy Information Administration, *Annual energy outlook*, 2005.
[2] US Energy Information Administration (www.eia.gov).
[3] US Energy Information Administration, *Annual energy review 2010*, October 2011 (www.eia.gov/totalenergy).
[4] US Energy Information Administration (www.eia.gov).
[5] North Dakota Industrial Commission, Department of Mineral Resources, Oil and Gas Division, February 19, 2012.
[6] International Energy Agency, *Golden rules for a golden age of gas: World energy outlook special report on unconventional gas*, May 29, 2012 (www.worldenergyoutlook.org).
[7] Energy Information Administration, "World shale gas resources: An initial assessment of 14 regions outside the US," April 5, 2011, and *Annual energy outlook: Early release overview*, 2012 (www.eia.gov).
[8] HPDI.
[9] Intergovernmental Panel on Climate Change, *Fourth assessment report*, Chapter 2, Table 2.14, 2007, p. 212 (www.ipcc.ch).
[10] US Department of Energy, Office of Fossil Energy and the National Energy Technology Laboratory, *Modern shale gas development in the United States: A primer*, April 2009.
[11] US Environmental Protection Agency, *Investigation of ground water contamination near Pavillion, Wyoming (draft report)*, December 2011 (www.epa.gov).
[12] The Oklahoma Geological Survey has suggested a link between shale-gas wastewater injection and a series of earthquakes of magnitude 3.7 to 5.6 in the Oklahoma area in November 2011. To date, earthquakes associated with shale operations have been tied to deep-injection wells, in which "flowback" water is repeatedly injected under pressure into deep caverns near old faults. Hydraulic fracturing itself at the well site has not been linked to earthquake activity.

Tommy Inglesby is a principal in McKinsey's Houston office, where **Scott Nyquist** is a director. **Rob Jenks** is a consultant in the Seattle office, and **Dickon Pinner** is a principal in the San Francisco office. Copyright © 2012 McKinsey & Company. All rights reserved.



Manufacturing resource productivity

Manufacturers can generate new value, minimize costs, and increase operational stability by focusing on four broad areas: production, product design, value recovery, and supply-circle management.

Stephan Mohr, Ken Somers, Steven Swartz, and Helga Vanthournout

Rapid growth in emerging markets is causing a dramatic increase in demand for resources, and supplies of many raw materials have become more difficult to secure. Commodity prices are likely to continue to rise and will remain volatile. Manufacturers are already feeling the effects in their operations and bottom lines, and these challenges will persist, if not intensify.

Consequently, manufacturers' variable costs have increased. Between 2000 and 2010, for instance, the variable costs of one Western steel company rose from 50 to 70 percent of its total production expenses, mainly due to jumps in commodity prices. For one Chinese steel company, 90 percent of production costs are now variable (Exhibit 1). And for a manufacturer of LCD televisions, energy represents 45 percent of the total cost of production.

But companies that take steps to increase resource productivity could unlock significant value, minimizing costs while establishing greater operational stability. Our experience suggests that manufacturers could reduce the amount of energy they use in production by 20 to 30 percent. They could also design their products to reduce material use by 30 percent while increasing their potential for recycling and reuse.

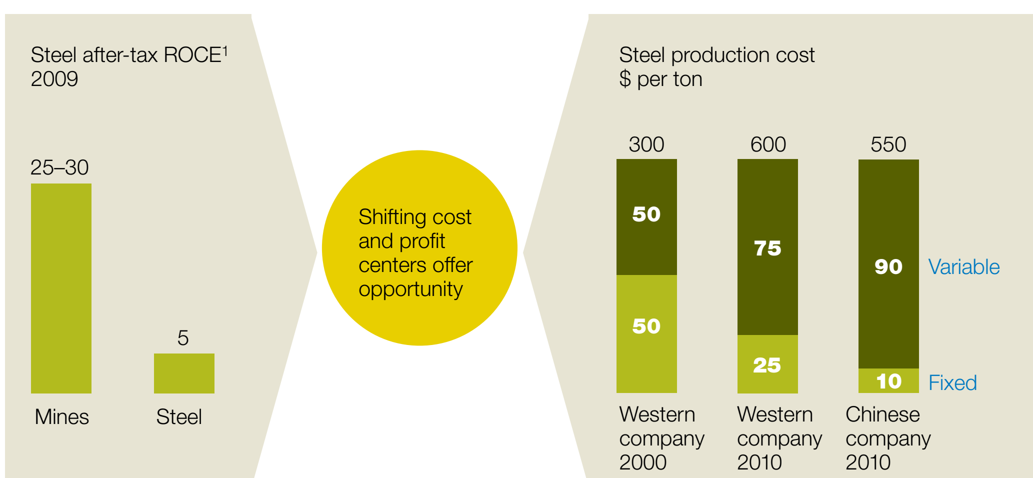
Indeed, companies could cut their product costs in half by reusing materials and components. Some companies have even begun to pioneer new business models that enable them to retain ownership of the materials used in the products they sell. This can involve establishing mechanisms that prompt customers to return a product to its manufacturer at the end of its consumer utility, enabling the manufacturer to extract additional value from it.

A number of manufacturers have launched resource-productivity initiatives that are already paying dividends. But most efforts focus on operational slivers within the four walls of their business, and classic improvement approaches—such as lean manufacturing and material-and-information-flow analysis—typically fail to fully address energy or resource costs and constraints. Because they lack a systematic approach that focuses attention on resources throughout the value chain, manufacturers have tended to think narrowly about what is actually a broad landscape of opportunity.

This article offers a practical set of tools to help manufacturers and waste-management companies capture the resource-productivity prize. Manufacturers are likely to achieve the quickest impact if they start by focusing on their areas of core competency. But to secure the full value of their efforts, companies must optimize their operations for resource productivity in four broad areas that cut across their business and industry: production, product design, value recovery, and supply-circle management (Exhibit 2).[1] By taking a comprehensive approach to resource productivity, companies can improve their economics while strengthening their value

Exhibit 1

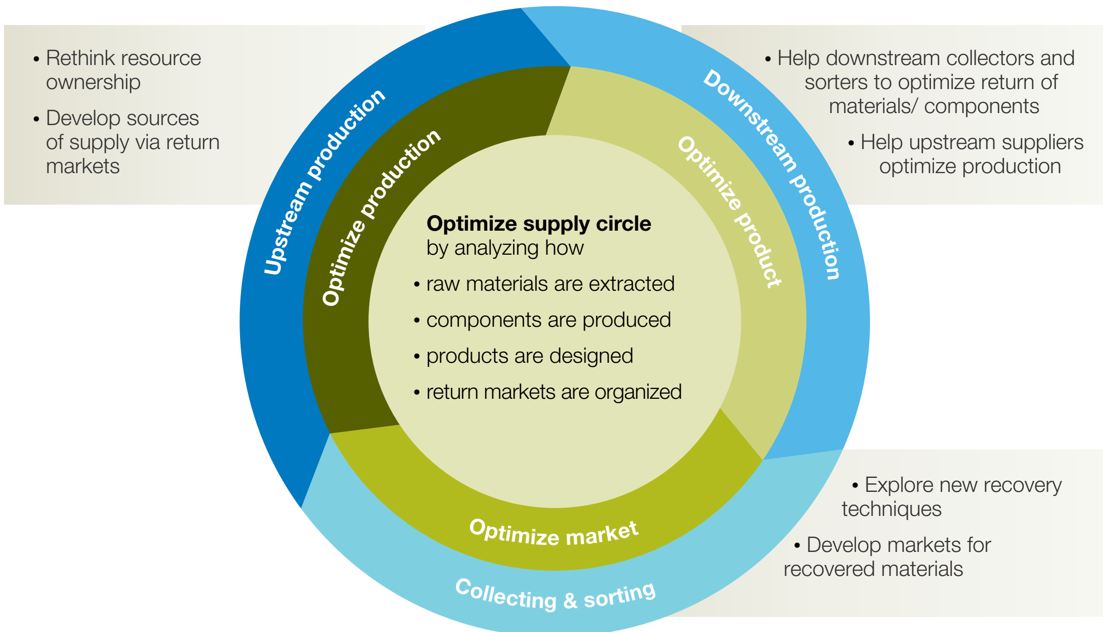
Manufacturers' variable costs have considerably increased.



[1]Return on capital employed.

Exhibit 2

To realize the full resource productivity opportunity, companies need to work across the full 'supply circle.'



How to do it?

Exercise influence in the supply circle where there is no direct control—both upstream and downstream.

Consider new business models—for example, lease rather than sell to retain ownership of materials embedded in products.

propositions to customers and benefiting society as a whole.

Prioritize areas of high impact

Companies should first focus on activities within their operations, where they can exercise the most control; they can turn their attention later to activities that require the cooperation of other organizations, customers, or other stakeholders. Specifically, companies should prioritize the activities that offer the greatest potential for impact given their position on the production circle.

Upstream manufacturers. Companies that are focused primarily on transforming materials into inputs used by other companies should start by optimizing production for resource productivity. Such companies have the most to gain by reducing the amount of material or energy they use in production. Indeed, the operations of mining companies are often as much as 10 times more energy intensive than the operations of companies that use their products. As a second step, manufacturers should prioritize waste recovery, which can enable them to secure access to materials through activities such as recycling and reuse.

Downstream manufacturers. Companies focused primarily on making components or final products should start by optimizing their products in order to use materials more efficiently. These companies will gain most by designing products to reduce material requirements, minimize energy consumed while using them, and ensure they are optimized to be recycled or reused at the end of their life cycle. Downstream companies can also benefit from reducing the energy required to manufacture their products, but this may be a second priority, since the operations of downstream players are not as energy intensive as those of upstream players.

Waste-management companies. Companies that handle waste materials—including those that collect, process, and manage waste—should start by optimizing processes and developing new markets for material reuse. They should develop the sorting and collection technologies and capabilities necessary to mine the highest-value materials from the general waste stream at the lowest possible cost. They should also develop business models to help other companies with their material-sourcing and reuse strategies.

Optimize for resource productivity

Depending on where they are located on the production circle, companies should prioritize four broad areas for resource productivity: production, product design, value recovery, and supply-circle management.

Production

Most manufacturers have already made tremendous gains by implementing programs to improve labor and capital productivity (for example, through lean manufacturing). Such efforts can improve resource productivity if they are adapted to include criteria for reducing the consumption of energy and raw materials. Here we focus on energy—a particular concern for upstream manufacturers, since energy costs can account for as much as 20 percent of their overall production costs. Manufacturers can take four steps to increase energy productivity.

First, companies can adapt the methodology for lean-value-add identification to map energy consumption at every step of their operating processes. This will enable them to calculate the thermodynamically minimum energy required and evaluate actual consumption relative to this theoretical limit (an approach known as "pinch analysis"). The analysis reveals where energy is wasted and how losses can be avoided.

One US surfactant maker that conducted a heat-value-add analysis found that only 10 percent of its steam-heat inputs were thermodynamically required to make its products; 90 percent were wasted. The manufacturer implemented about 20 measures and captured steam savings worth 30 percent of its baseline energy costs, enabling it to recoup what it invested to launch the effort within three years. One measure, which involved implementing a new software algorithm to control the company's heating and cooling control loop, enabled it to reduce its need for steam by 5 percent. Another company, a car manufacturer, reduced the amount of energy it used in assembly by 15 percent by optimizing ventilation processes.

Second, moving beyond pinch analysis, companies can extend their lean programs to improve energy efficiency by optimizing energy integration in heating and cooling operations. For instance, one chemical company changed its process to release heat more quickly during polymerization, allowing evaporation to start sooner, thus reducing the energy it used in the subsequent drying stage by 10 percent.

Third, companies can use lean approaches to identify process-design and equipment changes that can deliver greater energy efficiency. One Chinese steel mill saved 8 million renminbi (about $1.2 million) annually by lowering the leveling bar in a coke furnace an extra few centimeters, which reduced the mill's total energy cost by 0.4 percent. The mill achieved an additional 5 million renminbi ($0.73 million) in annual savings by adding an insulation layer to ladles used in steelmaking.

Fourth, lean-energy approaches can eliminate waste and capture savings by optimizing the interface between producers—for example, steam-boiler operators, cooling-water-unit operators, and power suppliers—and consumers. One chemical plant managed to avoid a $2 million investment to increase its boiler capacity by improving consumption planning—specifically, ensuring that demand would not pass the threshold that triggered pressure drops during demand spikes.

Product design

By incorporating energy and materials parameters into their product-design approaches, companies could reduce the use of materials that are hazardous, nonrenewable, difficult to source, or expensive. Changes to product design could increase opportunities for recycling and reusing components and materials at the end of a product's life cycle. And designers could prioritize the incorporation of sustainable features into their products to reduce the impact products have on the environment. These principles constitute a philosophy known as "circular design," which extends beyond products to systems and business models.

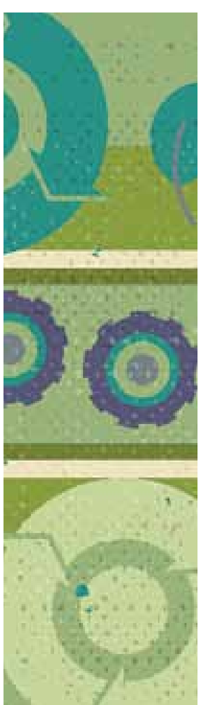
Companies that take these steps could reduce costs and facilitate compliance with regulations while bolstering their reputation and building relationships with consumers and other stakeholders. Additionally, they can often expand existing "design to cost" methodologies to quantify the financial or brand impact of incorporating sustainable features in their products.

Several approaches touch on product design: for example, companies can conduct product teardowns, disassembling and analyzing competitors' products to identify opportunities to increase resource productivity; they can use linear performance pricing, which enables comparisons among product attributes that provide different levels of performance for users; or they can pursue "design for manufacturing," which involves optimizing product design to minimize the resources needed during manufacturing and assembly.

One manufacturer, for example, redesigned its shampoo bottles so that they were thinner—but still met strength specifications—and reduced material consumption by 30 percent. The bottle's new shape enabled higher packing density during shipping, and with a flat "hat," it could be stored upside down, allowing customers to more easily extract all of its contents before disposal. The cap was redesigned to use the same material as the rest of the bottle, thus eliminating the need to separate materials before they could be recycled. The manufacturer also optimized the bottle's production process to reduce cycle time by 10 percent.

In another example, a vehicle manufacturer redesigned its forklifts to reduce fuel consumption and total cost of ownership for customers. Analysis showed that it could either redesign the power train or reduce the weight of the forklift to achieve its goal, but the power-train option was costly and complex. To reduce the weight of the forklift, the company increased the leverage of the cast-iron counterweight used to provide stability during lifting. This removed 200 kilograms (almost 450 pounds) of cast iron with no sacrifice in stability, which in turn allowed the manufacturer to reduce fuel requirements by 4 percent and cut material costs by $200 per vehicle.

And a home-appliance manufacturer analyzed its competitors' coffee makers and discovered an opportunity to improve heating efficiency by adjusting the insulation of hot pipes and optimizing the flow of water. It also changed the mounting of the heating system, using springs rather than screws, to make it easier to separate materials during recycling. Combined, these adaptations resulted in a product with an improved footprint at a lower production cost; such "win win" opportunities are not uncommon when focusing on resource productivity.



Value recovery

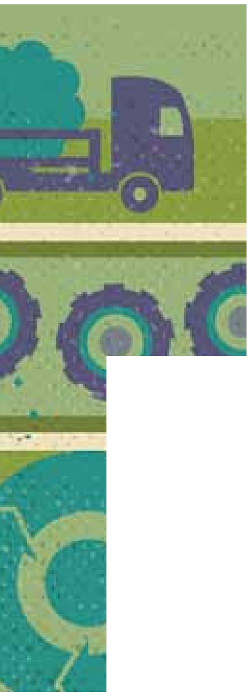
Companies may find they can satisfy their resource needs by recycling and reusing materials historically discarded as waste. Those involved in waste management have an opportunity to pave the way by developing services that allow manufacturers to capture value from materials left over after production or after a product has reached the end of its life cycle.

Great technological advances have been achieved in recycling, organics processing, and waste-to-energy conversion, and these have revealed opportunities in material and component recovery. Modern facilities recover much more material than was possible using manual systems, and they produce recyclates of a quality well above that required by most recycling protocols. These facilities can sort large volumes of varied waste, separating the valuable materials from those of less worth. They can also adjust sorting criteria to optimize selection based on scrap values in the spot market.

Waste-collection operators and recyclers should focus on building new business models by working with manufacturers to identify and develop opportunities for value recovery. This could involve helping manufacturers design products and production processes to facilitate material reuse; it could also involve helping develop logistical solutions that allow manufacturers to incorporate recovered material in their production cycle. Companies such as Veolia Environnement and SUEZ ENVIRONNEMENT have already begun to transform themselves from waste operators into raw-materials and energy suppliers, in part by advising other companies on how to design products that can more readily be recycled and reused.

Supply-circle management

Many of the activities that affect resource productivity and sustainability—such as acquiring and transporting raw materials, assembling parts used in the manufacturing process, and using and disposing of final products—take place outside the walls of manufacturers' facilities. Although companies do not have exclusive control over these activities, they can exercise



their influence to increase the productivity of their supply chains.

To that end, companies could transform their supply chains into supply circles. Whereas the phrase "supply chain" may evoke an image in which materials are collected in one place and ultimately disposed of in another, the phrase "supply circles" emphasizes that materials can be looped back into the production process after they have fulfilled their utility over the life of a product.

Companies looking to make this shift should first develop a complete understanding of their supply footprint. This involves considering not only which materials are used and in what volumes, but also how much energy is required to use them and what impact they have on the environment. The analysis enables companies to identify areas for improvement in internal, as well as supplier, operations. Companies can use the analysis to manage suppliers, reduce costs, and mitigate the risks posed by potential regulatory changes, supply scarcity, and volatile commodity prices—and to help initiate conversations with suppliers that could result in strategic relationships that enhance the capabilities of each party.

In most cases, a footprint analysis will reveal "hot spots" for manufacturers to prioritize to achieve environmental and economic impact. For example, one beverage producer realized that more than 35 percent of the carbon dioxide emissions generated to produce a half-gallon container of juice came from producing and applying fertilizer to groves where the fruit was grown. It became clear that working with farmers to reduce fertilizer use was one of the most important steps to take to minimize the company's carbon footprint.

Companies will benefit from adopting tools to monitor and manage their supply circles. Supplier scorecards and environmental profit and loss (EP&L) statements can be used to place a monetary value on environmental impact. Puma, for instance, developed an EP&L statement and pledged that by 2015, half its international product lines would be manufactured according to its sustainability standard. One objective is to ensure that its suppliers use more sustainable materials, such as recycled polyester. Desso, a European carpet manufacturer, substantially increased its market share and profits after it received Cradle to Cradle Certification for its entire product line.

In a resource-constrained world, value creation moves toward the owners of the resources. Companies should therefore consider developing new business models that enable them to retain ownership of the materials used in their products so that they can recycle or reuse the product at the end of its life cycle. This could enable companies to reduce supply risks while creating high-margin profit centers. The Ellen MacArthur Foundation championed this approach in a recent report, calling on companies to evolve from selling products to selling the services those products provide.[2] Chemical-catalyst manufacturers have done this for decades, essentially selling the functionality of catalysts to customers without transferring ownership of the materials themselves.

One lead-acid-battery manufacturer built a competitive cost advantage by controlling not only battery production but also post-use collection, disassembly, and reprocessing of batteries; control of the lead cycle gives the company access to a low-cost source of raw materials. To take an example from another industry, European manufacturers of household appliances and furniture are shifting their business models from customer ownership to lease agreements.[3]

Upstream extraction and processing companies could play the same game. Steel mills could retain ownership of the steel they sell and thereby reduce their exposure to prices for iron ore and coal. And waste-management companies may have opportunities to form joint ventures with manufacturers to retain ownership of the materials they sell back into the supply circle.

• • •

Over the past decade, supplies of various natural resources have become scarcer, and thus more expensive and subject to price volatility, increasing manufacturers' costs and risks. Nevertheless, the changing resource landscape also creates opportunities. To capture them, companies must embark on a journey to transform their operations and dramatically increase resource productivity. They will have to dedicate as much effort to optimizing resources in the future as they did to lean and other improvement initiatives in the past, while at the same time rethinking their business models to capture the value residing in resource ownership. If they get it right, the effort will enable them to increase the stability of supply and manage their costs while developing new products—and even lines of business—that generate sustainable bottom-line value. ○

[1] We use the phrase "supply circle" in place of "supply chain" because it more accurately reflects the closed-circle, end-to-end shifts in manufacturing processes and objectives that will be necessary to realize value in a resource-constrained world.

[2] *Towards the Circular Economy: Economic and Business Rationale for an Accelerated Transition*, Ellen MacArthur Foundation, January 2012 (www.thecirculareconomy.org).

[3] In the United States, a rental and rent-to-own industry already exists, though it is largely independent of manufacturers and not part of their supply circles.

Stephan Mohr is an associate principal in McKinsey's Munich office, and **Ken Somers** is a consultant in the Antwerp office. **Steven Swartz** is a principal in the Chicago office, and **Helga Vanthournout** is a consultant in the Geneva office. Copyright © 2012 McKinsey & Company. All rights reserved.

Battle for the home of the future:
How utilities can win

New technologies for the home will reshape energy markets, forcing utilities to develop new capabilities to capture value in the residential sector.

Giorgio Busnelli, Venkatesh Shantaram, and Alice Vatta

Energy consumption is growing more slowly in Europe as energy-efficiency measures begin to take hold. Our research indicates that if select existing technologies were to be fully deployed by 2020, a new home could consume about 90 percent less energy, whether gas or electricity, from the grid than it does today (Exhibit 1). For existing homes, which form the majority of housing stock, the energy-savings opportunity is also substantial: cuts of 35 to 40 percent could be achieved.

If such savings are realized, energy utilities will be hit with lower revenues and profits, both in retailing and generating power. For the latter, margins could fall by 30 percent in a scenario in which new homes become almost energy neutral. Even in our less aggressive deployment scenarios, margins would still drop significantly—by close to 10 percent. Our findings are likely to be relevant in any market where energy prices are high and regulations emphasize sustainability in the home, as is the case in Europe. They may be less relevant in markets such as the United States, where there is less regulatory pressure in this direction and where fewer incentives are in place to encourage energy efficiency.

In the very near future, business as usual will no longer be an option for most energy utilities. To cope with this discontinuity, utilities will

benefit from seeking new sources of revenues and profits in emerging energy-related businesses. These include building fabrics (for example, roof and wall insulation), central systems (including heat pumps and lighting), appliances and electronics (energy-efficient white goods), "smart" applications (home area networks and energy-storage devices), advanced metering infrastructure, distributed generation (for instance, small-scale wind turbines, combined heat and power systems, and solar panels), and the delivery of power for charging electric vehicles, as well as financing, insurance, and consulting services.

Energy utilities, with their technical competence in managing networks, see themselves as natural "owners" of the metering and infrastructure for charging electric vehicles. They are also potential players in distributed generation, energy-efficient products, and smart applications—areas in which they can draw on their brands, relationships with energy customers, and knowledge of consumption patterns. But in most of the categories listed above, utilities face stiff competition, including technology and telecom companies and retailers, as well as construction and media companies.

Our research covers four countries—Germany, Italy, Sweden, and the United Kingdom—that combined make a good proxy for the European market.[1] It shows how technology, regulation, and consumer behavior are likely to transform the residential energy market in the coming 10 years. To succeed in this new environment, utilities should place fine-grained bets on the segments in which they can best create value for themselves and develop winning capabilities beyond their traditional business, often by seeking partnerships with companies from other sectors.

Navigating uncertainties

A number of challenges face utilities looking to capture the value generated by innovations in energy-efficient products and services for the home. Successful utilities will need to establish a position in what promises to be a crowded market, where the rate of change in technology, regulation, and consumer behavior remains uncertain.

A crowded marketplace

More than 200 companies from a wide range of industries operate in this market, often as entrants exploring ways to compete most effectively.

Among these companies are utility incumbents that are moving fast, seeking to deploy portfolios of products and services from basic insulation to systems that automatically adjust energy consumption to the needs of people in their homes. Others are utilities that offer targeted solutions—for example, distributed generation—that have regulatory support from governments in the markets in which they operate. Some are utilities that are not yet responding at all.

Companies in other sectors—such as telecom, technology, media, finance companies, and home building—are also developing and selling energy-efficiency products. And automotive players are getting involved across the electric-vehicle value chain.

Technology development

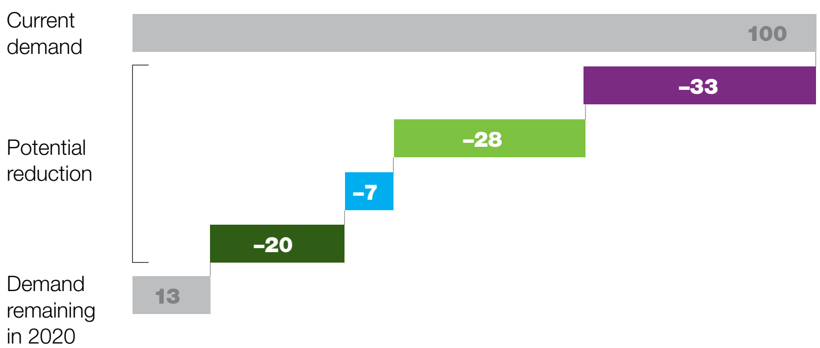
Consumer adoption will depend on the pace at which a range of relatively mature and emerging technologies develop and become commercially viable.

Many technologies already recoup their investments, sometimes with regulatory support. Such

Exhibit 1

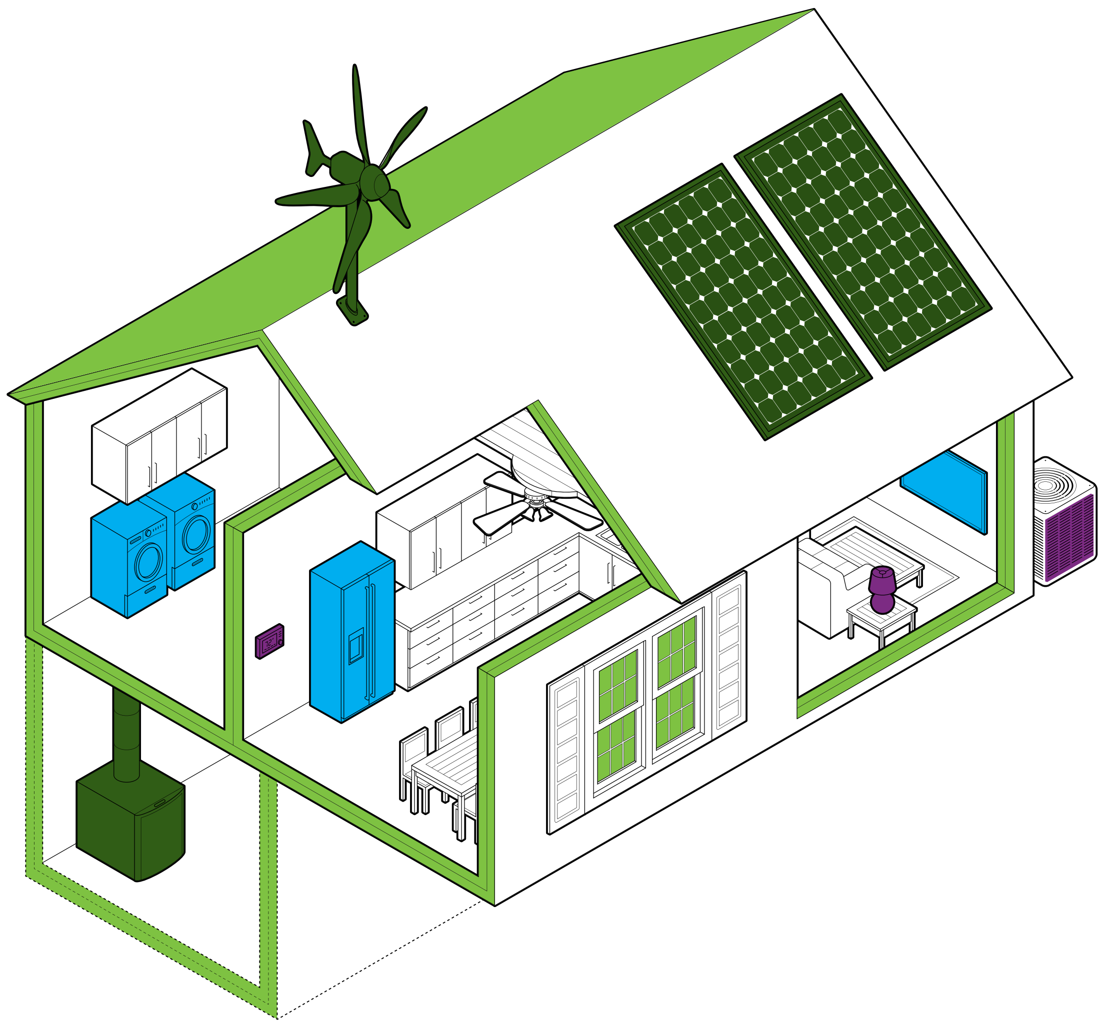
A broad range of technologies are likely to increase their share of the residential-energy-market value pool.

Energy needed from the grid,
baseline consumption = 100[1]



- **Central systems and smart applications**
  Electric heat pump, nanotechnologies and smart applications (eg, membrane in air-conditioning unit), energy-efficient lighting, home control network
- **Building fabrics**
  Insulation of roof and walls with aerogel, active windows, double-shell building
- **Appliances and electronics**
  Includes appliances and electronics with most advanced potential for reducing energy consumption: advanced washing machines, refrigerators, and freezers; energy-efficient televisions; and other electronics
- **Distributed generation**
  Solar-photovoltaic systems, mini-combined heat and power, microwind

[1]Baseline consumption index: 1-kilowatt consumption of all fuels = 100. Assumes 2010 volume and fuel mix; figures reflect weighted average of Germany, Italy, Sweden, and United Kingdom. Figures do not sum to 100 because of rounding.



technologies include heat pumps, double- and triple-glazed windows, energy-efficient lighting, and distributed-generation products (such as solar panels). Other technologies have a largely unexploited potential, most notably heating, ventilation, and air-conditioning systems using occupancy sensors that automatically manage when and where heating and air-conditioning are applied.

We do not expect truly disruptive home-energy technologies to be ready for mass-market adoption in the next 10 years. But there are technologies now under development that have huge potential and could be commercially viable by the end of the decade. One example is "active windows" with coatings that block incoming light when temperatures are high. When installed in new homes, such windows could recoup investments in less than three years.

Regulation

Many European governments are pursuing a mix of supply- and demand-side measures to meet the European Union's commitment to a 20 percent reduction in greenhouse-gas emissions by 2020. On the supply side, they can increase the share of low- or no-emission power-generation sources, such as natural gas, nuclear, and renewables. But there are challenges. In some cases, availability of natural gas may raise security-of-supply issues. Nuclear power is again under scrutiny in some European countries. And renewables require costly incentives—which may be harder to come by given current budget deficits—that make energy more expensive for all consumers. Therefore, we expect the push for low-energy homes, where energy-efficiency measures reduce demand for power, to remain strong or even be reinforced in some countries.

Because the regulatory outlook for different home-energy technologies varies by country, companies need to watch developments closely and act on opportunities as they arise. Sweden, for example, increasingly supports the conversion of electric heating to heat pumps and biofuels, and the United Kingdom is introducing a "green deal" to help consumers finance energy-efficiency packages.

Consumer behavior

Consumers are positive about saving energy, according to our market research in the United Kingdom. Yet rather than act on their own initiative, consumers expect business and the government to take the lead on the journey toward the low-energy home.

For most consumers, cost is the only reason to reduce energy consumption. But when people purchase appliances, features like functionality, technological simplicity, brand, and design take priority over saving energy. Most consumers perceive low-energy products to be below par on these attributes and on performance as a whole.

Our research suggests that consumers want to have more control over their energy usage. When they tested energy-management products and services, for instance, they were most excited about technologies, such as sensor-lighting and home-automation systems, that increased their level of control. But while consumers see utilities as possible suppliers of specific

products—for example, distributed-generation and insulation offerings—some are skeptical that utilities really want to help customers use less energy.

The path to value

To help utilities navigate a crowded and uncertain landscape, we developed three scenarios that characterize the likely evolution of the energy market leading up to 2020. The first assumes incremental reductions of technology costs, a relaxation of the European carbon-reduction targets, and uptake of only some measures that recoup consumer investments. The second scenario implies a faster reduction of technology costs, a regulatory push for meeting Europe's carbon targets through incentives, and the adoption by consumers of most measures that offer attractive returns. The third scenario assumes even faster development, in which many new homes are almost energy neutral (Exhibit 2).

We quantified the opportunities related to the three scenarios for Germany, Italy, Sweden, and the United Kingdom, looking at new and existing homes and apartments, as well as existing rented homes and apartments, where the motivation to invest in energy efficiency is lower. The 35 measures we analyzed ranged from window glazing and air heat pumps to smart dishwashers and solar distributed-generation gear.

The findings illuminate why utilities would benefit from looking for new revenue sources. Across the three scenarios and four markets, the potential profits that utilities could capture from new value pools would just about compensate them for their losses in power-retailing margins. But as more aggressive energy-efficiency measures are deployed, utilities' generation volumes and revenues are likely to decline.

Despite the challenges, there are significant opportunities for utilities to capture value from innovations in residential energy markets. Some will require deploying existing capabilities and resources in new directions; others will necessitate developing new skills to enter unfamiliar businesses. Success will depend in

Exhibit 2

Three key areas will affect the path toward energy-efficient homes in 2020.

Main drivers	Scenario 1 Incremental development	Scenario 2 Aggressive deployment	Scenario 3 Energy-neutral homes
Technology development	Reductions in technology costs follow past trends	Technology costs decrease, on average, by 15% over 10 years	Costs for new technologies decrease by up to 60%
Regulation	Regulators maintain status quo (implies relaxation of 2020 carbon targets)	Regulators push for meeting 2020 CO_2 targets through incentives	Regulators increase incentives to achieve 2020 CO_2 targets by 2018
Consumer behavior	Consumers adopt some economically viable initiatives	Consumers adopt a majority of the economically viable initiatives	Consumers adopt a majority of the economically viable initiatives

part on the ability to approach the challenge in a systematic fashion, informed by an understanding of the full range of available options.

We developed a three-step approach to help utilities pursue the opportunities that are most promising: define the strategy, select the most attractive business models, and establish critical enablers. Utilities can use the approach to prioritize and capture sources of value that are aligned with their overall strategic priorities.

Define the strategy

The first step to developing strategy is to understand where the money is, what customers want, and which products and services the organization is best positioned to deliver.

Prioritize sources of value. Until 2020, the majority of the opportunity to improve energy efficiency in the home is expected to be derived from products and services related to building fabrics and central systems. Such brick-and-mortar opportunities represent approximately half the total value pool across the four countries we considered. Appliances and electronics represent about 35 percent, and distributed generation represents another 11 percent. The remaining value is derived from smart applications, advanced metering infrastructure, electric vehicles, and enabling services. Although the market for smart applications such as smart meters is likely to grow rapidly, the value it represents probably will not add up to much until after 2020. The same is true for electric vehicles.

Develop a granular market perspective. Utilities should use two metrics to determine which opportunities can generate value for them and their customers in different markets and segments: the utility coverage ratio and consumer net present value (NPV). The coverage ratio is the difference between the value a utility can generate for itself by providing a product or service and the losses it will incur due to reductions in power consumption that result from use of the product or service. Consumer NPV is the difference, discounted back to the present, between the cost to consumers of using a traditional approach and the cost of implementing and using a new product or service over its lifetime. Companies should prioritize win-win opportunities that benefit them and their customers. For example, efficient building fabrics typically deliver high coverage ratios for utilities and high NPV for consumers.

Utilities should also segment markets to assess the value of particular offerings by customer group and region. We typically divide markets into six segments to identify priority opportunities: new apartments, both rented and owned; existing owned apartments; existing rented apartments; new homes, both rented and owned; existing owned homes; and existing rented homes. For example, central systems are typically a win-win in new homes, providing energy efficiency for consumers and a new revenue source for utilities.

Select a business model

Our research suggests utilities could pursue one of four business models to achieve their strategic priorities.

Distributor. Utilities could leverage their relationships with existing customers to develop businesses distributing energy-efficient products and services. The model may be most attractive in cases when the utility can build on existing businesses to develop the new offering. For example, a utility that already installs solar panels in homes could get into distribution by purchasing panels and reselling them to customers, leveraging existing relationships and skills to negotiate volume discounts from wholesalers.

After-sales specialist. Utilities could provide maintenance services for many types of equipment. Through its HomeCare program, for example, British Gas provides customers with options for maintenance and repair of boilers and central-heating units, regardless of where the equipment was purchased. This model can be especially attractive to utilities that have a well-developed field force and large concentrations of customers, typically located in urban areas. The pan-European utility RWE announced partnerships with Microsoft and eQ-3 to install central control units that link customers' appliances and the Renault-Nissan Alliance to test the performance of electric vehicles in commuter traffic in Germany.

Lead generator. Utilities could tap existing customers to provide leads to other companies that sell energy-efficient products and services in return for fees. Leads could be generated through home-energy audits conducted by utilities, or they could be generated at the point of contact when consumers engage utilities through existing channels. For example, a utility could use its call center to identify leads for companies that sell energy-efficient windows. Lead generation is a relatively easy business to launch and may represent a no-regrets opportunity for most utilities, but it is not likely to generate as much value as the other options.

Aggregator. Utilities seeking the broadest opportunity can become aggregators, coordinating the full range of activities for customers across a spectrum of product and service providers. The utility may deliver services itself when it has the capabilities, or it may engage other entities to provide them when it does not. Utilities can act as a single point of contact for customers, enabling them to access anything from financing to maintenance through one source.

Establish critical enablers

We suggest that utilities consider three areas in which to invest to ensure their new business models succeed.

Provide financing options. Utilities should consider establishing partnerships with financial institutions to help customers finance investments in energy-efficient products and services.

A utility could simply act as a sales channel for an existing financial institution, or it could establish an internal division that originates, processes, and distributes loans. Some utilities have developed nontraditional financing options. For example, British Gas has a "rent a roof" program through which it provides free solar power to customers. Under the program, British Gas maintains ownership of the panels, and it earns revenues when they generate extra power that is sold back to the grid.

Develop field-force capabilities. Utilities should train their field forces to act as advisers, consultants, and relationship managers, able to engage consumers at moments when they are likely to make decisions that could affect their energy footprint, such as when they are purchasing a mortgage. Field representatives should be able to help consumers at any point in the product or service life cycle, from weighing options and securing financing to providing postsales support and maintenance. Some utilities will be able to retrain their existing field forces to deliver the spectrum of energy-efficiency solutions. Others may need to hire and train a new cadre of representatives or even consider outsourcing parts of the job to third-party providers.

Extend brand credibility. Utilities should build on the brand attributes that they have already established with customers to persuade skeptics that they are reliable providers of energy-efficient products and services. This is one of the main assets utilities can exploit, leveraging brand equity as a competitive advantage in the relationship with customers vis-à-vis players from other industries. For example, Enel, Italy's largest power company, used its strong brand to expand into the renewable-energy market through Enel.si, which distributes photovoltaic, solar thermal, and mini-wind systems through an extensive network of retail franchises.

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The transition to low-energy homes will be a discontinuity for European utilities. But the pace of change is uncertain. Utilities that prepare for several possible scenarios, adapt their organization to the new competitive landscape, and make granular choices about where they can create the most value have an opportunity to shape a new future for themselves. By doing so, they will also deliver benefits to consumers and society as a whole.

[1] We chose Germany, Italy, and the United Kingdom because they are the largest retail energy markets in Central, Southern, and Northern Europe, respectively. We chose Sweden because smart meters have fully penetrated the market, which notably has not greatly shifted energy-usage patterns in the country.

Giorgio Busnelli is a principal in McKinsey's Milan office, **Venkatesh Shantaram** is a principal in the London office, and **Alice Vatta** is an associate principal in the Rome office. The authors would like to thank Antonio Volpin for his contribution to the development of this article. Copyright © 2012 McKinsey & Company. All rights reserved.

New models for sustainable growth in emerging-market cities

A new tool, the urban sustainability index, highlights five themes of sustainable development for cities in emerging economies.

Shannon Bouton, Molly Lindsay, and Jonathan Woetzel

The need to prioritize sustainability has never been more urgent than it is today. This is particularly true in emerging markets, which are entering a period of mass urbanization that could dramatically raise productivity and standards of living but that also poses environmental and other threats that could significantly reduce the benefits of growth.

Many emerging markets are already pursuing sustainable development—economic growth that improves lives without exhausting the environment or other resources—but the absence of accepted frameworks for evaluating success in emerging-market cities often prevents officials from discovering and implementing effective solutions.

We created a new metric, the *urban sustainability index*, to address this gap and help policy makers in emerging markets identify approaches that will work in their cities.[1] The index is designed to measure the performance of cities in five sustainability categories: how well they are meeting their citizens' basic needs, resource efficiency, environmental cleanliness, built environment, and commitment to future sustainability.

We turned to China as a test bed for the index for a number of reasons. It has more emerging cities than any other country, and they are growing faster than any other cities in the world. Moreover, the necessary data are increasingly available in China,

and the country's leadership is showing increasing commitment to urban sustainability.

By analyzing the policies and programs of some of China's most sustainable cities, we identified five common themes for achieving sustainability in emerging-market cities: industrial restructuring linked to land renewal, "green" urban planning, transparent standards and charges, integrated large-scale recycling, and cross-departmental coordination.

A question naturally emerges as to whether the insights gleaned in China would be relevant in emerging markets elsewhere. Certainly regional variations would yield differences in the particulars of policy, and ultimately cities will benefit from using the index to conduct analyses in their specific geographies. But in the interim, our experience working in cities around the world suggests that the themes we identified in China are generally valid across cities in emerging markets, and thus policy makers, companies, and civic organizations in other emerging markets can use the findings from China to advance sustainability in their own cities.

Rapid growth, little guidance on sustainability

Our analysis indicates that 423 emerging-market cities will generate more than 45 percent of global GDP growth from 2007 to 2025. The population of these cities will grow by an estimated 40 percent over this period, and the average income (measured in GDP per capita, adjusted for purchasing power parity) will more than double from $13,000 to $31,000. As a result, these cities will account for nearly 20 percent of the global population and about 30 percent of global GDP by 2025.[2] Cities in these regions lag significantly on sustainability when compared with cities in the developed world, but they face challenges so different that the benefits of the comparison are limited. Moreover, there is very little sustainability data on emerging-market cities, so it has been difficult even to identify reference points against which these cities could measure their performance.

When data are available, they can be difficult to compare across countries due to differences in language, standards of measure, and conventions for gathering and codifying information. The IT and administrative systems used by different countries are often incompatible. Indeed, countries use different criteria to determine what constitutes a city.

While the United Nations, the World Bank, and other institutions have made great contributions by developing approaches that measure sustainability in cities, incompatibility remains a challenge. As the World Bank's Dan Hoornweg has observed, "the vast majority of indicator programs have not proven sustainable over time for reasons of cost, complexity, or lack of political or institutional support. Many were developed just once. No single organization or Web site has emerged as a global portal for city indicators, and there is no one source that presents even the most basic information about city performance in a consistent, comparable manner."[3]

The urban sustainability index

We created the urban sustainability index to fill the gap in current analysis of sustainable development. The index measures the performance of cities in emerging markets on a common set of sustainability categories. Our goal was to gauge not only the environmental sustainability of cities but also city officials' commitment to handling their growing urban populations in a sustainable way, and their efficiency in using resources.

To that end, we created a comprehensive five-part definition of sustainable development, encompassing 18 individual indicators that are important in emerging economies and for which data are readily available (exhibit). For example, the index accounts for basic needs such as availability of drinking water, which, while nearly universal in developed economies, varies widely in emerging countries.

To determine elements that are critical to sustainability, we evaluated 112 cities selected by China's national government as the focus of sustainable development, using data for 2004 to 2008. We examined policy successes and failures in urban areas featuring similar financial constraints, policy environments, and experience.

Exhibit

A five-part index includes 18 indicators necessary for sustainable development in emerging economies.

Categories	Indicators	Description of the indicators
Basic needs	• Water supply • Housing • Health • Education	• Water access rate (%) • Living space (square meters per capita) • Doctors per capita • Student-teacher ratio (primary school)
Resource efficiency	• Power • Water demand • Waste recycling • % GDP from heavy industry	• Total electricity consumption (kilowatt-hour/GDP) • Water consumption (liters per capita) • Ratio of industrial waste recycled and utilized (%) • Heavy-industry GDP/total GDP (billion renminbi)
Environmental cleanliness	• Air pollution • Industrial pollution • Wastewater treatment • Waste management	• Concentration of SOx, NOx, PM10[1] (milligrams/cubic meter) • Industrial sulfur dioxide discharged/GDP (tons/renminbi) • Wastewater treatment rate (%) • Domestic waste collected and transported (10,000 tons per capita)
Built environment	• Urban density • Mass-transit usage • Public green space • Building efficiency	• Persons/square kilometer of urban space • Passengers using public transit (bus, trolley) • Public green space (square meters per capita) • Building heating efficiency
Commitment to future sustainability	• Green jobs • Investment in environmental protection	• Number of environmental professionals per capita • Amount of environmental sanitation funds/GDP

[1]Sulfur oxides, nitrogen oxides, and particulate matter.

Source: *The urban sustainability index: A new tool for measuring China's cities*, Urban China Initiative, a joint initiative of Tsinghua University, Columbia University, and McKinsey & Company, November 2010, p. 10 (www.urbanchinainitiative.typepad.com/files/usi.pdf)

The definition of sustainable development comprises five categories:

Basic needs. Access to safe water, sufficient living space, adequate health care, and education are fundamental priorities for urban populations.

Resource efficiency. A city's efficiency in such areas as the use of water and energy and the effective recycling of waste directly correlates to the quality of life of its citizens.

Environmental cleanliness. Limiting exposure to harmful pollutants is fundamental to a city's livability.

Built environment. Equitable access to green space, public transportation, and dense, efficient buildings makes communities more livable and efficient.

Commitment to future sustainability. An increase in the number of employees and the level of financial resources devoted to sustainability suggests how committed city governments are to implementing national and local policies and standards.

An encouraging finding is that sustainability does not come at the expense of wealth. Most of the critical indicators that drive sustainability—such as wastewater treatment, mass-transit usage, and environmental investment—were unaffected by level of economic development (see sidebar, "Sustainability does not hinge on wealth"). The only indicators for which we found even a weak negative correlation between sustainability and wealth were power consumption, industrial sulfur dioxide emissions, and GDP from resource-intensive sectors. Indeed, the best-performing cities in our study group improved sustainability while increasing GDP from 2005 to 2008 at an above-average rate.

Five themes for sustainable development

As a result of analyzing the policies and programs of some of China's best-performing cities, we identified five themes common to sustainable cities in emerging markets: industrial restructuring linked to land renewal, "green" urban planning, transparent standards and charges, integrated large-scale recycling, and cross-departmental coordination.

Industrial restructuring linked to land renewal. Rising costs and tighter national environmental standards—particularly for sulfur dioxide emissions—have made many city officials press heavy industries to shutter urban factories and build more modern plants in new industrial parks or in suburban development and economic zones. In Tianjin, for example, smokestack industries are moving east from the city center into some parts of the Binhai New Area, a development zone. In Qingdao, manufacturing industries are relocating across Jiaozhou Bay and into rural regions northwest of the city. Shenyang successfully removed almost all traces of heavy industry from its core from 2008 to 2010. This phenomenon is common to many growing markets in the industrialization phase.

Many industries that relocated have invested money raised by selling land-use rights in urban cores to buy state-of-the-art technology and emissions-control equipment, as well as to cover their relocation costs. In response to a national effort to cut industrial sulfur dioxide emissions by 10 percent, for example, Tianjin closed many small, inefficient power plants and used part of

Sustainability does not hinge on wealth

Affordability is often raised as a concern in discussions of sustainability in the developing world. Our research was encouraging in this regard, in that the index showed almost no correlation between a city's wealth and its ability to create sustainable growth.

This finding was reinforced by the segmentation analysis we conducted, which involved dividing the 112 Chinese cities we analyzed into four groups based on their performance: sustainable growers, sustainable stragglers, waverers, and unsustainable growers (exhibit).

The 33 cities that qualified as "sustainable growers" managed an above-average increase in GDP per capita during the study period, while at the same time improving their sustainability rankings. Their score in our index increased an average of 4 points, compared with a 9-point drop by the "unsustainable growers," and their GDP per capita grew an average of 12.3 percent a year, compared with 11.1 percent for the latter group.

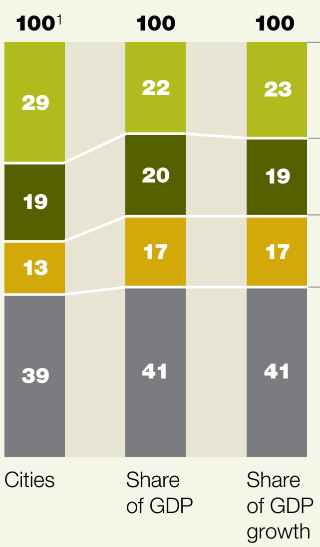
Since we found no deterministic relationship between economic growth and performance in our index, our research exposed an unmistakable opportunity for other cities in China to learn from the practices of their better-performing peers.

Exhibit

Best performers increased GDP while improving sustainability.

City growth and sustainability performance, 2005–08

%



	Description
Sustainable growers	Increase in sustainability with above-average economic growth
Sustainable stragglers	Increase in sustainability but below-average economic growth
Waverers	Slight decline in sustainability with middling economic growth
Unsustainable growers	Significant decline in sustainability regardless of economic performance

[1]100% = 112 cities.

Source: *The urban sustainability index: A new tool for measuring China's cities*, Urban China Initiative, a joint initiative of Tsinghua University, Columbia University, and McKinsey & Company, November 2010, p. 21 (www.urbanchinainitiative.typepad.com/files/usi.pdf) the funds from the sale of land-use rights to upgrade the infrastructure of their factories, now located in the Binhai New Area. Although the trend is just beginning, indications are that consolidating heavy industry away from urban centers brings economies of scale large enough to offset the costs of sophisticated infrastructure retrofits and new equipment.

That heavy industry can be moved without net cost is a crucial component of achieving urban sustainability. Equally crucial is "brownfield" redevelopment at the sites left behind. These sites provide large-scale opportunities for planning, because they are typically large plots of land in high-value inner-city locations.

Brownfield redevelopment usually requires intensive investments for site cleanup, so it is instructive to examine successful examples, one of which is offered by Shenyang. Spurred by tightened industrial and zoning regulations, industries began leaving the Tiexi district around 2003. In the following years, the city converted, redeveloped, and ultimately revitalized the area. The improvement enhanced the urban image of the city and helped it use real-estate investment to drive economic development.

Green urban planning. Chinese cities that have successfully balanced sustainability and growth incorporate both objectives when they create mass-transit networks and urban amenities. Efficient and attractive mass transit takes cars off urban roads, cutting emissions and congestion. Green space provides environmental oases that help refresh the air of cities and make them more attractive places to live and work. Urban forests and green areas serve as a net to filter dust particles caused by vehicles, industrial development, and other sources. They also absorb carbon dioxide, helping clean the air. The best-performing cities have recognized these benefits and included efforts to enhance mass transit and green space in their development programs.

The substantial bus ridership in Chinese cities is an indication of potential demand for transit-oriented development elsewhere. Ridership is significant even when there is little development in the immediate vicinity of bus stops. Since people generally prefer walking short rather than long distances to work, developers have an opportunity to increase ridership even further by encouraging business, commercial, or residential development and creating green space within, say, 600 to 800 meters of stops. Qingdao, for example, not only added routes and transit hubs, but also focused some of its redevelopment projects along bus lines to prod city residents and visitors away from private transportation. Between 2005 and 2008, bus ridership per capita increased by 17 percent in Qingdao. As part of the economic shift from manufacturing to tourism, the city has rezoned industrial space for commercial use and begun building mixed-use residential and entertainment-oriented developments along major transit lanes.

Guangzhou received the 2011 Sustainable Transport Award from the Institute for Transportation and Development Policy for the sustainable transportation and greenway projects it launched in 2010. Modeled on programs developed in Curitiba, Brazil (see sidebar, "Curitiba's model public-transportation system," p. 61), Guangzhou's bus rapid transit system carries more than 800,000 passengers per day. Its bike-sharing system deploys 5,000 bikes and 113 sharing stations. And its Donghaochong greenway project created four kilometers of off-street bikeway and walkway along the Donghaochong River.

Financing is perhaps the most difficult aspect of public transit. China's city officials are seeking ways to manage subsidies, expanding services with minimal public funds. Reasonable fares and a proper regulatory framework for private participation are essential for the long term. In Shenyang, for instance, the municipal public-transport company contracts with private operators and transport firms to supplement its own services. Hoping to minimize delays and improve the reliability of public-transit services, Shenyang has also followed smaller cities, such as Kunming, in giving buses priority on the roads.

To filter out dust particles emanating from vehicles, industrial development, and other sources, urban woodlands and green areas are essential. They also absorb carbon dioxide, helping to clean the air further. Nanning, in the southwestern province of Guangxi, created a "green city" during a 10-year program that included planting an average of two million trees a year. Along the banks of the Yongjiang River, the city has developed three major greenbelts outfitted with trail systems, water-conservation areas, and buffers between conservation areas and high-density and industrial areas. In 2009, Nanning proposed a new environmental design to integrate river and marsh systems into the urban landscape by engineering two dams that would split the Yongjiang River into 18 smaller waterways and create 80 lakes within the city.

Transparent standards and charges. Our research indicates that cities are more likely to achieve high standards of sustainability if they adopt clear goals, publicize their progress toward meeting them, and hold responsible parties accountable for their performance. For example, superior environmental supervision and strict monitoring of digital information pay off for cities such as Qingdao.

Part of Qingdao's consistent performance in wastewater treatment is the result of pressure from Shandong province officials, who publicly identified the region's 1,000 biggest polluters and set aggressive waste-reduction targets for each of them. By 2008, more than 1,000 companies and 170 wastewater-treatment plants in the province were being monitored. Each company on the list was required to provide digital data on its status regularly. Such policy enforcement at the provincial level in effect places cities in a healthy public competition that encourages improvements.

Indeed, the best-performing cities take one-upmanship to new heights. Shandong, for example, began requiring companies to monitor and report water quality every two hours. Qingdao, wanting to maintain its status as the province's leading city with respect to environmental issues, then mandated monitoring every half hour. In addition, Qingdao sends staff from the environmental-monitoring department to check firsthand the accuracy of the digital data. These inspections occur every 10 to 30 days, depending on a company's place on the list of polluters.

Integrated large-scale recycling. The best-performing cities excel at creating efficient local linkages among industrial producers from

Curitiba's model public-transportation system

Curitiba is Brazil's eighth-largest city, with a population of 1.75 million people. It responded to the population boom of the late 1960s and early 1970s by developing a metropolitan economic strategy that made efficient urban transportation the cornerstone of a program to ensure a high quality of life.

The city established the Institute for Research and Urban Planning in Curitiba (IPPUC) in 1965 to oversee the development and implementation of its mass-transit plan. A major objective was to build two structural roads (subsequently expanded to five) that have two central lanes reserved for express buses. Public transportation consists entirely of buses. Land within two blocks of the transit arteries is zoned for high density, and zoned residential densities taper in proportion to distance from transit ways.

Urbanização de Curitiba (URBS), a state-owned company created in 1980, is charged with maintaining the city's transportation infrastructure and overseeing its bus operations. In 1987, a municipal law designed to reduce congestion required that bus companies be granted licenses and reimbursements based on kilometers traveled rather than number of people carried. Passengers are charged the same rate for service regardless of distance traveled, and the fare is set to ensure that carriers can cover their costs without requiring state subsidies.

The IPPUC and URBS have continued to implement innovations to improve the system, including installing bike paths as an alternative to motorized transportation. The city now has about 100 kilometers of paths that are used by some 30,000 bikers every day. In 1991, they installed elevated tube stations to help passengers board and disembark more quickly and to increase access for the disabled. They also introduced biarticulated buses, which are significantly longer than traditional buses, increasing the carrying capacity per vehicle and the overall efficiency of the fleet.

The popularity of Curitiba's system for bus rapid transit (BRT) has effected a modal shift from automobile to bus travel: 80 percent of travelers use the express or direct bus services, and estimates based on a 1991 traveler's survey indicate that BRT reduced the number of auto trips by 27 million per year, saving approximately 27 million liters of fuel annually. Curitiba uses about 30 percent less fuel per capita than eight other Brazilian cities of its size, and it has one of the lowest rates of ambient air pollution of any city in the country.[1]

[1] "Curitiba experience," *Issues in bus rapid transit*, US Department of Transportation, pp. 10–15 (www.fta.dot.gov).

different sectors. In the next five years, leaders of rapidly industrializing small and midsize cities must find ways to reduce the volume and increase the efficiency of resource consumption. One promising approach in China links manufacturing or utilities plants in a given locale. Tianjin's Binhai New Area, for example, started with two ambitious projects to transform itself into a desalination center. Tianjin officials we interviewed pointed to its power plant near Beijing as an example of resource efficiency: the project links water, power, sea-salt production, waste reuse, and land conservation in an elegant desalination system.

During the project's first phase, launched in 2005, the city invested 1.3 billion renminbi (around $160 million) to construct two 1,000-megawatt generators that would provide 200,000 tons of water a day for city residents as a by-product of power generation. In phase two, which began in 2010, two 1,000-megawatt clean, coal-fired generating units and saltwater-cooling towers will be added. The whole system is expected to provide 400,000 tons of freshwater a day, as well as 11 billion kilowatt-hours of power, 450,000 tons of salt, and 60,000 tons of minerals[4] a year. Fly ash and other waste will be sold cheaply to construction companies for building materials.

In Qingdao, one of China's best-known brands of beer, Tsingtao, has partnered with a local university to explore ways to reuse brewery wastewater and other waste. For example, they have tested a technique called biocontact oxidation, which involves adding live cultures to wastewater to foster clumping of biosolids, thus facilitating the extraction of chemical and biological discharges. Methane generated in the process can be piped to households for cooking, while the remaining waste is used in fertilizers and animal feed. The technique enabled Tsingtao to achieve removal rates of 80 percent for chemical discharges and 90 percent for biological discharges from 2005 to 2008. In light of this success, Hangzhou, Shenyang, and Zhejiang breweries are beginning to use the technique as well.

Cross-departmental coordination. Our interviews with urban officials in China indicate that success in executing sustainable development projects depends on coordination among city agencies and other bodies. For example, successful transit projects typically involve experts in urban planning, construction, and the environment. Efforts to increase environmental transparency involve representatives from industry and information management. And land-renewal projects involve experts in economic planning, land use, urban planning, and multiple industries.

To break down silos and facilitate cooperation, municipalities should establish processes to ensure projects meet coordination requirements before they are approved. In Shenyang, for example, all projects must be approved by a department directly affiliated with the state council, and officials must demonstrate that they have met the city's standards for coordinating with all relevant departments.

Municipal governments should also establish formal channels of communication across departments and set targets indicating how often departments should exchange information. And they should track performance to ensure that departments interact regularly on issues of mutual concern. In Qingdao, the assessments of local officials are tied to project implementation and account for interdepartmental coordination. To ensure its assessments are rigorous, the city has implemented a performance-tracking system, which is maintained by designated administrators.

Every solution should account for contingencies that could jeopardize long-term success. Nanning has managed to continue its tree-planting program despite a succession of four party secretaries and three mayors.

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Our work with the urban sustainability index does not end with these findings. We will continue our efforts, including conducting primary research in emerging countries other than China, and we will refine the index as the analysis evolves. In particular, we intend to identify a larger suite of best practices for emerging-market cities that are committed to sustainable development. We expect to develop a better understanding of the cost and time trade-offs implicit in these measures, explicitly searching for those that can be implemented rapidly with noteworthy results. And we will strive to identify the unique factors—such as intrinsic historical, geographic, or natural advantages—that would make replicating these best practices more difficult.

The challenge facing rapidly growing cities in developing countries is enormous. Leaders in China and other emerging markets have recognized this and are already taking action to develop solutions to these challenges. Our ambition in creating the urban sustainability index is to provide a yardstick that cities can use to measure success and identify initiatives that they can implement to achieve sustainable development.

[1] For the full report on which this article is based, see *The urban sustainability index: A new tool for measuring China's cities*, Urban China Initiative, a joint initiative of Tsinghua University, Columbia University, and McKinsey & Company, November 2010 (www.urbanchinainitiative.typepad.com/files/usi.pdf).

[2] *Urban world: Mapping the economic power of cities*, McKinsey Global Institute, March 2011 (www.mckinsey.com/mgi).

[3] David Blaha and Dan Hoornweg, "The current status of city indicators," 2006 (www.cityindicators.org).

[4] Bromine, potassium chloride, magnesium chloride, and magnesium sulfate.

Shannon Bouton is a consultant in McKinsey's Detroit office. **Molly Lindsay** is a consultant in the Washington, DC, office, and **Jonathan Woetzel** is a director in the Shanghai office. Copyright © 2012 Mckinsey & Company. All rights reserved.

India: Taking on the green-growth challenge

India has the potential to significantly increase its energy security to support continued rapid growth, while securing sustainability that exceeds current expectations.

Rajat Gupta, Sushant Mantry, and Ganesh Srinivasan

Over the next two decades, India is expected to grow at a rate of 7 to 8 percent. And during that same period, it will build approximately 80 percent of the physical assets—including infrastructure, commercial and residential real estate, vehicle stock, and industrial capacity—that will constitute the India of 2030.[1]

Growth of this magnitude will bring tremendous benefits, but it also poses many challenges, particularly regarding sustainability. For example, demand for resources will increase dramatically, raising the country's dependence on imports for commodities such as crude oil and driving commodity prices higher in general. And India will need to expand its capacity to generate electricity to meet increasing industrial and residential demand, which will impel a corresponding increase in greenhouse-gas (GHG) emissions.

India has already taken steps to curb expected increases in GHG emissions, including launching efforts to increase the efficiency with which it uses resources, reduce consumption, and accelerate the adoption of clean technologies. Yet even if most of its planned improvements are implemented, India's GHG emissions will still increase by a multiple of about 3.5 in 2030 compared

with 2005 levels, from 1.6 billion to 5.7 billion metric tons of carbon dioxide equivalent (CO_2e).[2]

Our research indicates that India can do much more to reduce energy consumption and GHG emissions without compromising its prospects for growth. Based on assessments of approximately 200 commercially viable opportunities, we believe the country has the technical potential[3] to shrink its projected energy consumption by 22 percent and lower its consequent GHG emissions by an additional 30 to 50 percent. Specifically, its emission levels would only rise to between 2.8 billion and 3.6 billion metric tons of CO_2e in 2030[4]—more than 2 billion metric tons of CO_2e less than the level that might be achieved under current plans.

These are large figures, and we emphasize that they represent the potential rather than what might necessarily materialize, given the complicated forces at work in India and around the globe. Nevertheless, we believe that understanding what is theoretically possible encourages leaders to strive for—and achieve—more ambitious results than they would when concerned only with what they consider realistic.

What stands in the way of this potential? Briefly put, India will have to develop solutions to long-standing challenges in financing, regulation, skills, and technological and business-model uncertainty. It will also have to navigate the risk that some measures could increase the cost of doing business in some sectors, at least in the short term, which could threaten the country's global competitive positioning.

Despite the challenges, ignoring this potential is far riskier than pursuing it. India is unlikely to be able to maintain its expected rate of growth over the next 20 years unless it takes significant action to reduce its consumption of resources and energy, and capturing even a portion of the technical potential would make a tremendous difference in many areas. In addition to reducing its GHG emissions and increasing its energy security, India could decrease operating costs for many businesses by enabling sustainable process efficiencies and lowering demand for power and resources. Consumers would benefit in the form of lower prices, which would make products and services more widely available, potentially facilitating greater energy inclusion. And by accelerating large-scale adoption of new technologies, India could position itself to become a hub for a number of clean-tech industries.

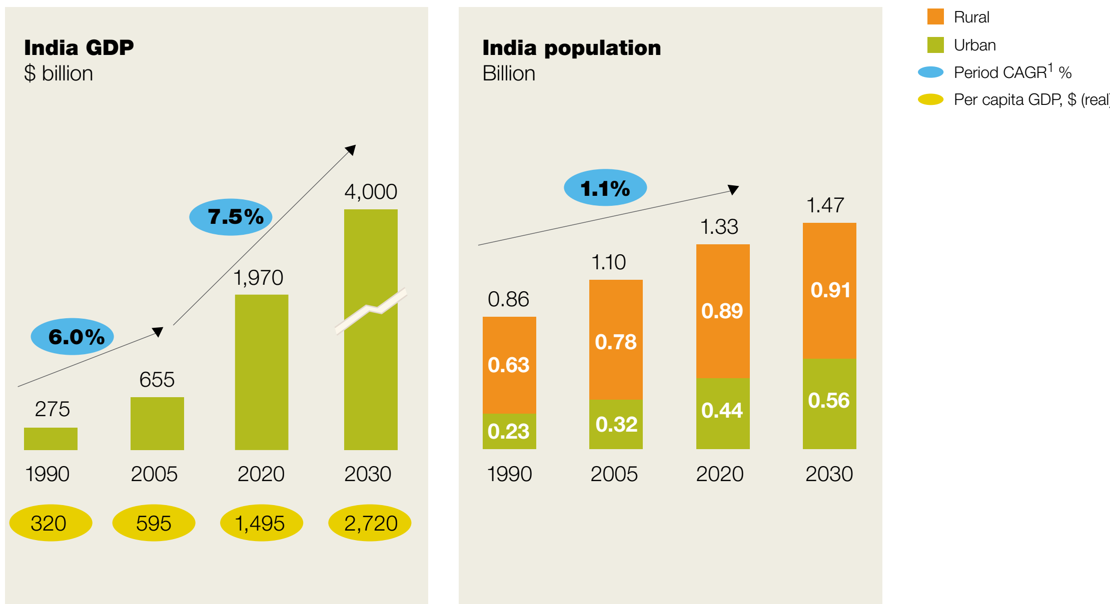
To set a new standard for sustainability, India should focus on four areas that represent almost 75 percent of the technical potential for improvement in its GHG footprint: increasing energy efficiency in industry, vehicles, and appliances; accelerating the transformation of its power sector, promoting the adoption of clean technology; building green infrastructure for urban habitats and transportation; and establishing sustainable agriculture and forestry practices.

The current path

India already ranked as one of the 10 largest economies in the world in 2010, and it is expected to continue to grow rapidly over the next two decades. The country's GDP is projected to rise from $595 billion in 2005 to $2.72 trillion in 2030, and its population is expected to increase from 1.1 billion to 1.47 billion over the same period (Exhibit 1).

Exhibit 1

Economic and population growth continue.



[1]Compound annual growth rate.

Source: McKinsey Global Institute–Oxford Economics model; National Commission on Population, Office of the Registrar General for Census of India; World Market Monitor Global Insight; McKinsey analysis

This is a cause for celebration, but celebration tempered by recognition of the challenges that accompany rapid growth. India will experience dramatic increases in demand for materials and energy, placing serious constraints on natural resources such as land, water, minerals, and fossil fuels, and driving up energy and commodity prices. All things being equal, increasing activity will lead to increasing generation of waste and pollution, particularly in the form of higher GHG emissions. Ultimately, these challenges could curb India's ability to grow, rendering its momentum unsustainable.

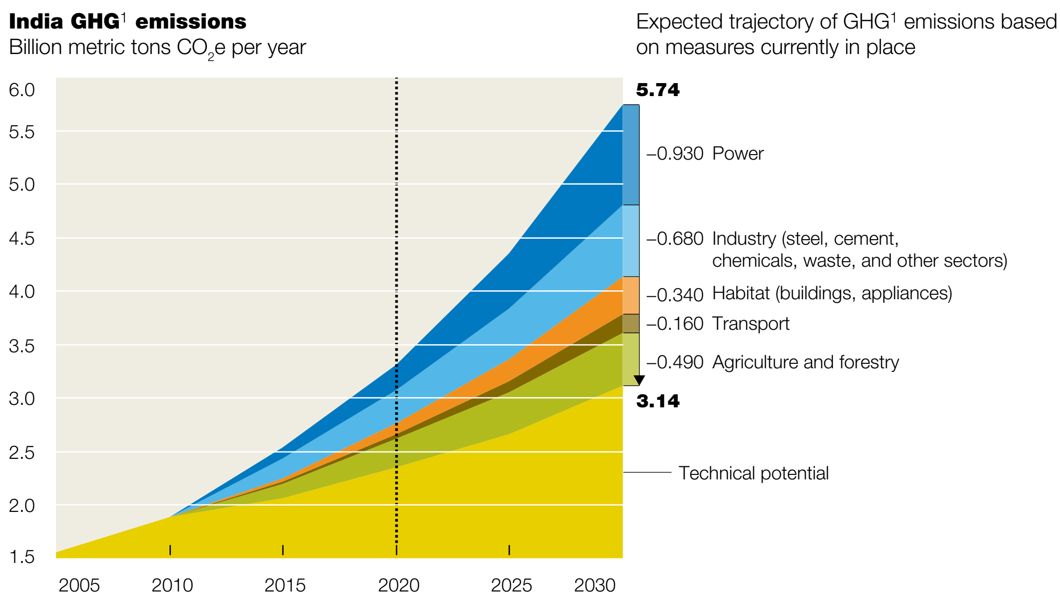
Recognizing the threat, India has already begun to take steps to increase its sustainability, including reducing energy demand and improving energy efficiency. For example, it has launched efforts to upgrade its generation and transmission assets and optimize its power mix by increasing its use of nonfossil fuels. It has taken steps to reduce energy consumption by residential and industrial users, improve fuel efficiency in road transportation, and increase the percentage of forested land in the country, which will increase its CO_2 absorption capacity as well as prevent soil erosion. (See the sidebar, "Summary of key policy measures to reduce emissions," p. 68, for more details about efforts already under way in India.)

The technical potential

India's current efforts are impressive, but even if they were all implemented successfully, the

Exhibit 2

India has the potential to cut its expected 2030 greenhouse-gas emissions almost in half.



In 2020, energy efficiency and agriculture/forestry represent 60% of abatement potential.

Impact from nuclear and renewables starts by 2020 and triples by 2030 as more capacity is added.

[1]Greenhouse gas.
Source: McKinsey India Cost Curve model; McKinsey analysis

country's total energy demand would be likely to increase to 1.8 billion metric tons of oil equivalent (btoe)[5] by 2030, up from 0.5 btoe in 2005. This would make India the third-largest energy consumer in the world, after the United States and China.

Our analysis reveals that India has the technical potential to achieve much greater environmental and energy sustainability than it is on track to accomplish. Expected energy consumption in 2030 could be lowered an additional 22 percent, from 1.8 btoe to 1.4 btoe.[6] And expected GHG emissions in 2030 could be cut almost in half, from 5.7 billion to 3.1 billion metric tons of CO_2e[7] (Exhibit 2).

We estimated this potential by assessing more than 200 opportunities that reduce emissions and increase energy efficiency.[8] We analyzed the emissions abatement potential and the cost of abatement for each measure. The results of this analysis are represented in our India abatement cost curve, which lists each measure in an order that reflects a combined understanding of its impact on emissions and cost through 2030

Summary of key policy measures to reduce emissions

In 2008, Prime Minister Manmohan Singh released India's first National Action Plan on Climate Change (NAPCC), which outlines existing and future policies and programs addressing climate mitigation and adaptation. Several other government and industry initiatives have also been established in India to reduce energy demand and optimize supply. The following summary highlights some of the most important efforts the country has launched to increase its sustainability:

Reduce transmission and distribution losses in the power sector. The Restructured Accelerated Power Development and Reforms Programme was launched in 2007 to reduce aggregate technical and commercial electricity losses from 30 to 15 percent by 2020. The effort is focused on strengthening the country's subtransmission and distribution network and expanding its adoption of state-of-the-art IT solutions.

Increase use of clean-coal technology. The NAPCC recommends that "supercritical boilers" be used in the immediate future for generating power using coal, and it recommends that "ultrasupercritical boilers" be used when we know the technology works commercially in India. The country is also considering adding a ninth mission to the NAPCC on clean coal or clean carbon.

Increase use of nonfossil fuel power. India's National Solar Mission aims to deploy 20 gigawatts of on-grid solar power and 2 gigawatts of off-grid solar power by 2022. At close to 15 gigawatts, wind power is now the largest renewable power source in India with significant untapped potential. India is also considering nuclear power as an alternative to coal-fired plants.

Lower electricity consumption in buildings and appliances. A variety of initiatives were launched by the Bureau of Energy Efficiency (BEE), including the Bachat Lamp Yojana program to promote compact fluorescent lighting, the Star Labeling program to encourage the use of high-efficiency appliances through energy-performance labeling, and the Energy Conservation Building Codes program to prescribe minimum efficiency standards for commercial buildings. Other measures include mandatory labeling of refrigerators, transformers, tube lights, and air conditioners.

Increase fuel efficiency in road transport. BEE has launched a program for labeling cars. Currently the labeling is voluntary, but it is expected to become mandatory in a few years. Additionally, norms are being finalized for fuel efficiency, which vehicle manufacturers will have to achieve by 2015 or 2016.

Improve energy efficiency in energy-intensive industries. BEE is establishing the Perform, Achieve, and Trade scheme, which will require companies in energy-intensive industries such as steel and cement to meet mandated reductions in their energy consumption. The reduction target will be based on companies' current level of energy efficiency.

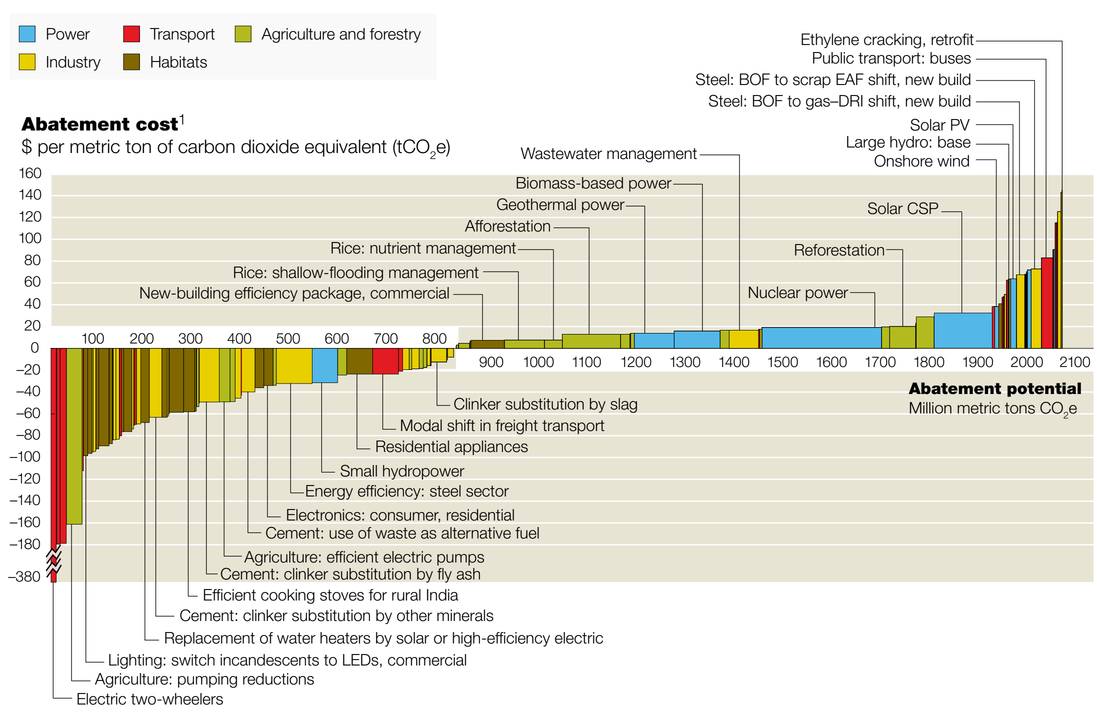
Expand forest cover. The National Mission for a Green India has set a goal to afforest 6 million hectares of degraded lands and expand forests so they cover 23 to 33 percent of India's territory.

(Exhibit 3). Indeed, many of these opportunities would actually reduce costs from current levels. To ensure that our perspective was comprehensive, we also sought the views of more than 100 experts in government, business, academia, and society in India and around the world.

In addition to achieving GHG reductions, India stands to benefit in a variety of ways from seizing the opportunities we considered. By capturing these energy-efficiency opportunities, India could avert the addition of about 120 gigawatts of power capacity. This represents $100 billion in avoided capital expenditures. And reduced use of coal for power generation, steelmaking, and cement production could reduce coal demand by nearly half, thereby doubling the life of the country's coal reserves.

Exhibit 3

Our model shows India's abatement cost curve for 2030 (cost below $145 per metric ton).



[1]This curve estimates 2.1 billion metric tons of CO_2e potential. Additional potential below $145 per metric ton includes reduction in technical-transmission and distribution losses (190 million metric tons (mt) CO_2e), auxiliary consumption (~50 mt), efficiency improvement in other sectors (~200 mt), improved urban planning (~30 mt), and distributed generation using combined heat and power (~15 mt). Levers costing more than $145 per metric ton (not included in the cost curve) have a total abatement potential of 80 mt. Important levers are public-transport infrastructure in metropolitan regions (7 mt), electric vehicles, and full hybrids (6 mt). An 8% discount rate was assumed for the cost-curve analysis, based on benchmark yield for long-term Indian government bonds.

Source: McKinsey India Cost Curve model

Beyond pure economic benefits, these measures would also significantly increase energy inclusion and quality of life in India

Lessening the demand for energy and improving transportation would also increase India's energy security by easing its reliance on imports of coal and oil. The country has the potential to reduce the oil required for transportation by as much as 40 percent, thus reducing its annual import bill by about $60 billion (at an assumed cost of $100 a barrel) in 2030.

India could also take the lead in a few clean-technology industries by leveraging its engineering talent and low-cost manufacturing advantage. It could become a center of intellectual-property creation and a leader in the manufacture of clean-tech products. Areas of opportunity include clean-coal-based power plants, solar, efficient building technologies, smart grids, LED lighting, and electric two-wheelers. The global market potential in these areas is more than $1.5 trillion over the period from 2010 to 2030 and offers a potential global revenue pool of $70 billion to $100 billion annually.

Beyond pure economic benefits, these measures would also significantly increase energy inclusion and quality of life in India, particularly for those living in rural areas. For example, distributed power generation would increase access to electric power. Improved agricultural practices would reduce energy and water consumption as well as increase availability of food and water. Shifting freight transport to rail and coastal shipping would reduce road congestion, making driving safer. Urban citizens would enjoy improved public-transportation infrastructure, reduced road congestion, and lower vehicular pollution. Waste-to-energy technologies would help urban municipalities manage their waste-disposal obligations, and improved agricultural practices would better utilize the nation's supply of water. Moreover, many solutions would bring significant public-health benefits, particularly a reduced risk of respiratory diseases.

Practical constraints

While acknowledging the benefits, however, it would be naive not to identify the challenges that could inhibit India's ability to achieve this full potential.

Abatement opportunities vary widely in cost and ease of implementation (Exhibit 4). Our analysis suggests that only about 10 percent of the abatement potential is readily achievable, mostly from opportunities involving improving energy efficiency in appliances, buildings, industry, and transport. The majority of the clean power, industrial technology, and green transportation opportunities are more difficult to implement.

India would have to incrementally invest from about $850 billion to $1 trillion between 2010 and 2030 to capture the full potential, even after accounting for likely reductions in the cost of emerging technologies. Policies would have to be altered in many areas, including those regu-lating electric power, buildings and construction,

Exhibit 4

Our model evaluates the feasibility of capturing abatement potential.

Abatement potential in million metric tons CO_2e, 2030

- Readily achievable
- Medium difficulty
- Difficult
- [x] Sum of abatement potential

Cost/ metric ton	**Ease of implementation**[1] Moderately challenging	Challenging	Very challenging
Negative <$0	• Energy-efficient equipment and appliances (90) • Mileage standards (30) **120**	• Energy efficiency in steel (90) • Lighting controls (20) • Clinker substitution by other mineral components such as low-grade limestone (25) **135**	• Clinker substitution by fly ash in cement (40) • LED lighting (35) • Clinker substitution by slag in cement (30) • Efficient cook stoves (20) • Pumping reductions (30) **155**
Modest $0–$30	• Small hydro (50) • Hydro run of river[2] (35) • Coal supercritical[2] (200) • Nuclear power: • 30 gigawatts (GW)[2] (215) **50**[3]	• Nuclear power (30–60 GW) (250) • Reduction in transmission and distribution/auxiliary losses (200) • Biomass power (95) • New-building efficiency (70) • Nutrient management for rice (40) **655**	• Afforestation (120) • Efficiency from other sectors (190) • Geothermal power (80) • Wastewater management (60) • Degraded forest reforestation (50) • Organic soil restoration (20) • Rice: shallow flooding (80) **590**
High >$30	• Bus-based public-transport systems (20) **20**	• Shift to scrap-based electric-arc furnace in steel (20) • Shift to gas-based direct reduced iron (20) • Solar photovoltaic (PV) and concentrated solar power (CSP):[2] 30 GW (55) **40**[4]	• Offshore wind energy (20) • Forest management (40) • Large hydro (15) • Solar PV (20) • Solar CSP (90) • Ultrasupercritical coal (15) • Modal shift in transport (40) **240**

[1]Ease of implementation based on financing issues, regulatory support, agency issues, entrenched behavior, supply constraints, and technological readiness; only key levers (covering about 80% of potential) are listed in the matrix.
[2]These levers are assumed to be implemented in the reference case.
[3]Without reference-case additions; 500 million metric tons after accounting for reference-case actions.
[4]Without reference-case additions; 95 million metric tons after accounting for reference-case actions.

Source: McKinsey India Cost Curve model; McKinsey analysis appliances, agriculture, and water use. India would have to develop the capability to leverage new processes and technologies, including developing end-to-end supply chains to implement nuclear and solar-power solutions, and training engineers and designers to develop needed products and infrastructure.

A number of the opportunities we identified depend on technologies that are yet to be proved. In addition, new business models will have to be developed to address market imperfections, such as principal-agent failures that can arise if the interests of different stakeholders are not aligned.

Finally, India must take care to ensure that the steps it takes serve its national interest. It must manage the risk of taking unilateral action on climate policy, which could increase the relative cost of doing business within its borders. For example, requiring power generators to adopt more sustainable but more expensive technologies—renewable-energy technologies could increase costs for companies operating in global industries such as steel and automobiles, which could make Indian businesses less competitive.

Claiming the prize

The challenge is daunting, but as we have pointed out, India is already making significant progress. The government is driving advances through its National Action Plan on Climate Change, as well as through programs launched by entities such as the Bureau of Energy Efficiency (BEE). For example, it has made the solar sector more attractive for companies by making the bidding process for solar opportunities more transparent. India has also made it easier for financial institutions to fund sustainability projects by helping banks manage the risk of default and by establishing mechanisms for fast-track lending.

We believe India has tremendous room for additional improvement. To claim as much of the opportunity as it can, India should prioritize efforts at the intersection of what is feasible and what will yield the greatest results. As noted, four broad areas represent approximately 75 percent of the technical potential available to reduce GHG emissions in India: energy efficiency in industry, vehicles, and appliances represents 40 percent; transforming the power sector, 15 percent; green urban and transport infrastructure, 10 percent; and agriculture and forestry, another 10 percent.

Energy efficiency in industry, vehicles, and appliances

In the steel industry, where India's demand is expected to grow about fourfold in the next 20 years, producers could adopt new technologies, such as top-pressure recovery turbines, and implement processes, such as pulverized coal injection and coke dry quenching, that will reduce the energy required per metric ton of steel. Newer steelmaking technologies such as direct smelt reduction could also decrease energy demand. Cement companies could lessen energy consumption by using higher amounts of fly ash from coal-based power plants in cement production and reduce their GHG emissions by transitioning to alternative fuels such as solid waste and biomass.

India's vehicle fleet is projected to increase sevenfold by 2030. The country could cut its oil consumption by 15 percent by lowering the average weight of vehicles used for transportation. Using biofuels such as ethanol could reduce oil consumption in the sector by another 5 percent.

The BEE has already taken steps to promote the use of clean appliances, but market imperfections currently prevent full realization of the efficiency savings available. The government could take further steps to introduce technical norms and standards for appliances and increase incentives to encourage use of the most efficient appliances available. It could also consider supporting research and development in high-efficiency appliances.

Transforming the power sector

About 30 percent of the power generated in India is lost due to technical and commercial issues in transmission and distribution. Technical losses account for 15 to 19 percent of total leakage, which is more than twice the average in developed countries. To reduce technical leakage, companies must improve transmission and distribution infrastructure—for example, by installing higher-quality transformers. To reduce commercial losses, which are mostly caused by theft, companies must ensure that all power use is metered.

To reduce reliance on more expensive peak-generation capacity, which typically generates more GHG emissions, utilities could implement demand-side management programs, such as time-of-day tariffs that shift power consumption from high- to low-demand periods. India could also shift generation capacity to cleaner technology to reduce emissions and realize efficiency gains (which result from the fact that the technology is newer than that of the installed base). The country is currently trending downward toward generating 60 percent of its power from coal. It could further reduce coal demand by increasing its use of supercritical and ultra-supercritical technologies.

Other clean technologies could also be used to meet base- and peak-load demand. For example, completing all planned greenfield and brownfield nuclear expansion projects would increase base-load capacity by 60 gigawatts by 2030—although India must take care to incorporate lessons from events in Japan to manage nuclear risks.

India could meet a portion of its peak demand[9] by increasing solar capacity as a replacement for oil and gas generation. Solar is already competitive with diesel-based power generation. If current cost trends continue, photovoltaic-based solar technology may become cheaper than power based on liquefied natural gas[10] before the end of 2020. If solar capacity increases at the rate anticipated by the country's National Solar Mission, India could have more than 60 gigawatts of installed solar power capacity by 2030.[11] India could also increase its capacity in reservoir hydropower to serve peak demand with cleaner energy sources.

Green urban and transportation infrastructure

Sustainable building standards would reduce the demand for power by improving efficiency and reducing waste. The government could encourage, if not require, developers to adopt building codes[12] that prescribe sustainability measures such as using fly ash or slag-blended cement, high-efficiency insulation and windows, LED lighting, and energy-efficient air conditioners. Such measures can reduce the energy consumption of a building by 30 to 40 percent.

More broadly, sustainability could be incorporated as a design parameter in urban planning. Planners could design townships to reduce the distances residents need to travel and thus the amount of energy they require for transportation. They could also develop integrated public-transportation plans that would establish metro railways for the country's nine largest cities and bus systems for the 250 largest cities. The plans could establish smart traffic-management systems, such as congestion-charging schemes, that encourage the use of public transportation and reduce congestion and road pollution.

Oil demand in freight transportation could be reduced by about 20 percent by shifting freight from road to rail and coastal shipping. To achieve this goal, India would need an integrated logistics policy that would direct investment to 7 long-distance rail and water corridors, 15 to 20 interchange points or logistic parks, and a large number of 100- to 300-kilometer expressways on road segments that are already in heavy use.[13]

Agriculture and forestry

Agriculture makes up about one-sixth of the Indian economy. The agriculture sector in India accounts for about 23 percent of the electricity and 15 percent of the diesel consumed in the country. Indeed, India has among the highest rates of diesel and electricity consumption per hectare of agricultural land in the world. Some of the agricultural practices used in India call for twice the amount of water that is required by state-of-the art practices that generate the same yields. Wider use of efficient irrigation techniques, such as drip and sprinkler irrigation, and efficient pump sets could reduce the sector's water needs by up to 25 percent and its electricity and diesel consumption by 15 to 20 percent.

Adoption of techniques to improve rice cultivation and reduce tillage could lower GHG emissions by 200 million metric tons of CO_2e. These techniques confer many important benefits in addition to emissions abatement, including improved crop yields and reduced water consumption, which would enable the country to increase its supply of food and water.

Flood irrigation, the most widespread method for growing rice in the country, causes anaerobic decomposition in fields and produces methane exhaust. In 2005, a fifth of India's emissions came from flood irrigation. India could reduce its emissions by 120 million to 150 million metric tons of CO_2e by using shallow flooding and nonnitrogen fertilizers to prevent anaerobic decomposition.

India could also make great strides in forestry. The National Mission for a Green India set a goal to cover a third of the country with forest. This would involve establishing 20 million hectares of additional forest-covered land. Doing so would reduce the country's emissions by about 150 million metric tons of CO_2e.

To increase its forest density, India could introduce fast-growing grass and tree species; apply fertilizers and organic amendments such as chicken manure, sawdust, compost, or leaves to hasten stock growth; and take steps to prevent forest fires. Enhanced forest management, along with reforestation of degraded forests, could increase carbon sequestration—and hence abatement—by 53 million metric tons of CO_2e by 2030.

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Our research indicates that India has a tremendous opportunity to increase its level of sustainability beyond what it expects to achieve through the ambitious programs already inaugurated. Achieving just a portion of this theoretical potential would yield immense economic and social benefits that would not only enable India to maintain its recent rapid rate of growth and increase its energy security but also to increase the quality of life of its citizens by expanding energy inclusion, increasing access to quality food and water, and improving air quality. And by acting quickly, India has the opportunity to establish itself as a hub for a range of clean-tech industries, thus laying the foundations for new avenues of growth.

[1] *Environmental and energy sustainability: An approach for India*, McKinsey & Company, 2009 (www.mckinsey.com).

[2] CO_2e stands for “carbon dioxide equivalent” and is a standardized measure of greenhouse gases. Emissions are measured in metric tons of CO_2e per year, that is, millions of metric tons (megatons) or billions of metric tons (gigatons). Greenhouse gases include carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions from human activity, in our estimate.

[3] Our estimate reflects what could be achieved if India were to capture the full potential available from the 200 opportunities we analyzed, some of which may depend on technological innovations that are likely but are not yet proven to be commercially viable. We estimate feasibility of some of the most effective opportunities in Exhibit 3.

[4] At an annual GDP growth rate of 7.5 percent; range is due to the uncertainty about measures implemented.

[5] Reflecting greenhouse-gas emissions of approximately 5.7 billion metric tons of CO_2e in 2030.

[6] Decreases in energy consumption in sectors discussed in this article. This does not include direct energy savings from opportunities in other industrial sectors (except steel, cement, chemicals, and refining).

[7] Depending on the range of measures implemented, emission levels could be between 2.8 billion and 3.6 billion metric tons of CO_2e; for our analysis, assumed at 3.1 billion metric tons of CO_2e.

[8] There are additional opportunities beyond those outlined that are difficult to quantify but could further reduce emissions. They include encouraging behavioral changes such as carpooling among consumers. These opportunities have not been included in our study.

[9] Generally, only 60 percent of total capacity is required to meet base-load demand. The rest represents nonbase or peak demand and is usually required during particular times of the day such as evening, when lights and appliances are used simultaneously, or during particular seasons such as summer, when more power is needed for cooling. With the continued dominance of services in India’s economy and the country’s increasing urbanization and affluence, peak demand is likely to grow faster than base-load demand, as use of air conditioners and other appliances increases.

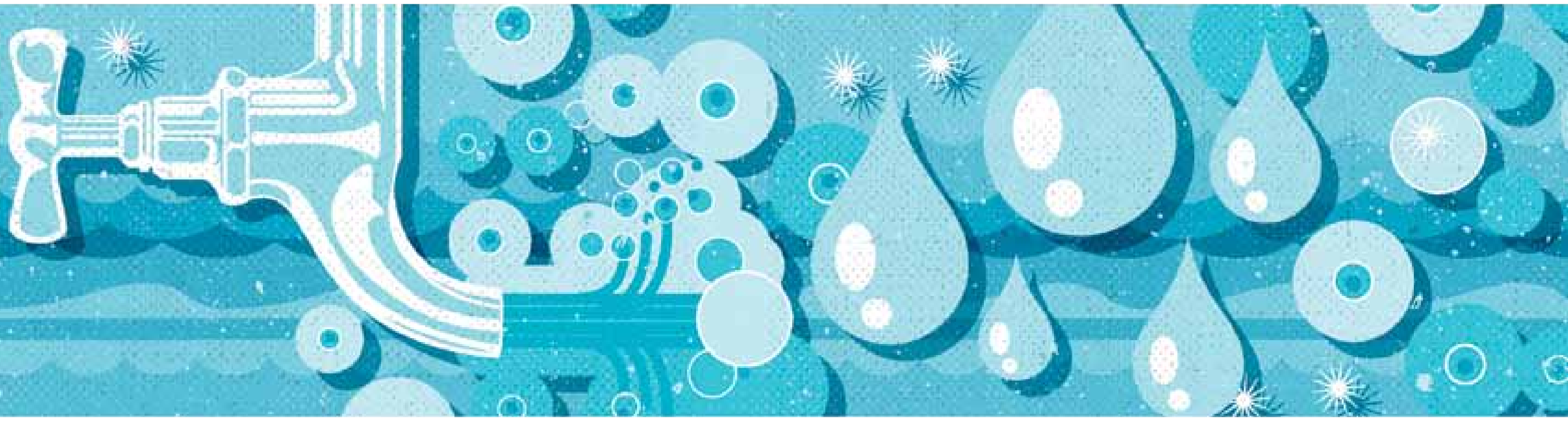
[10] Calculated for closed-cycle gas turbines at landed Japanese Crude Cocktail–linked liquefied-natural-gas prices ($16.5 per one million British thermal units) in India at $100 per barrel of crude.

[11] The National Solar Mission aspires to have 20 gigawatts of grid connected and 2 gigawatts of off-grid solar power by 2022.

[12] The Energy Conservation Building Codes being developed by the government could reduce energy consumption in buildings by over 30 percent. Codes have already been developed in other countries, including the American Society of Heating, Refrigerating, and Air-Conditioning Engineers codes and the Leadership in Energy and Environmental Design codes that are gaining prominence in the United States.

[13] *Building India: Transforming the nation’s logistics infrastructure*, McKinsey & Company, July 2010 (www.mckinsey.com).

Rajat Gupta is a director in McKinsey’s Mumbai office, where **Ganesh Srinivasan** is a consultant. **Sushant Mantry** is a consultant in the Singapore office. Copyright © 2012 McKinsey & Company. All rights reserved.



Transforming water economies

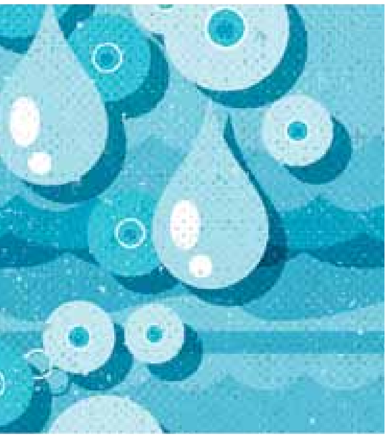
To increase water security, countries must glean insights from information, understand trade-offs among policy choices, and establish institutional mechanisms to support execution.

Giulio Boccaletti, Sudeep Maitra, and Martin Stuchtey

Without action, global water demand could outstrip supply by up to 40 percent by 2030. Rapid population growth and economic development, particularly in emerging markets, will increase the need for food and energy and accelerate industrialization and urbanization, driving a corresponding increase in the need for water. At the same time, many scientists warn that temperatures may rise around the world, which could increase water scarcity. The climate may also become less predictable, which could increase volatility in the water supply, compounding the challenge.

As many countries already know firsthand, limited and uncertain access to water can jeopardize economic growth and social well-being. Given the potential impact of shortfalls, ensuring access to water is rapidly becoming a challenge that could define our times.

Some countries have already developed innovative approaches to managing water under extreme conditions. Australia developed a market-based approach that enables it to minimize the impact of scarcity and volatility of supply without compromising growth. Singapore implemented an approach based on long-term planning and centralized investment in infrastructure and the latest technologies to increase its domestic supply of water. And Israel has leveraged its culture of innovation to establish itself



as an international hub for water-technology development, increasing its water security while establishing a local multibillion-dollar industry.

Economic, political, social, and other conditions may make it difficult for many governments to implement the solutions developed by these pioneers, but virtually every country can benefit from adopting the principles underlying their success.

Drawing on our experience working with governments around the world, we have developed the "ICE framework" for water-sector transformations. This framework organizes the most important principles for success into three categories:

Inform: calculate a dynamic water gap and develop a cost curve to prioritize improvement opportunities by effectiveness and efficiency

Choose: evaluate a set of strategies to close the water gap, accounting for their impact on key economic- and social-development objectives

Execute: establish the institutional mechanisms (national, regional, and local) necessary to guide program and policy implementation

Countries that incorporate these principles into their water strategies can accelerate their progress toward greater water security and improve the economics of water-dependent sectors even in times of drought.

The double threat: Scarcity and unpredictability

Assuming current levels of water efficiency, unconstrained global water demand is likely to grow at a rate of about 2 percent a year until 2030. This expansion in demand will be driven chiefly by population and economic growth, particularly in agricultural and industrial production. The rise of the middle class in emerging economies is also likely to increase water use. Thus, global demand for water in 2030 could prove close to double what it was in 2005—exceeding existing capacity by 40 percent[1] (Exhibit 1).

Higher temperatures would increase demand in many parts of the economy, particularly in irrigation for agriculture, and changes in the frequency and intensity of rainfall and extreme-weather events could reduce the predictability of supply. Indeed, lack of clarity about climate evolution is increasing uncertainty about how to manage water, adding to the risk that countries' investments might prove insufficient or ineffective.

The leading edge

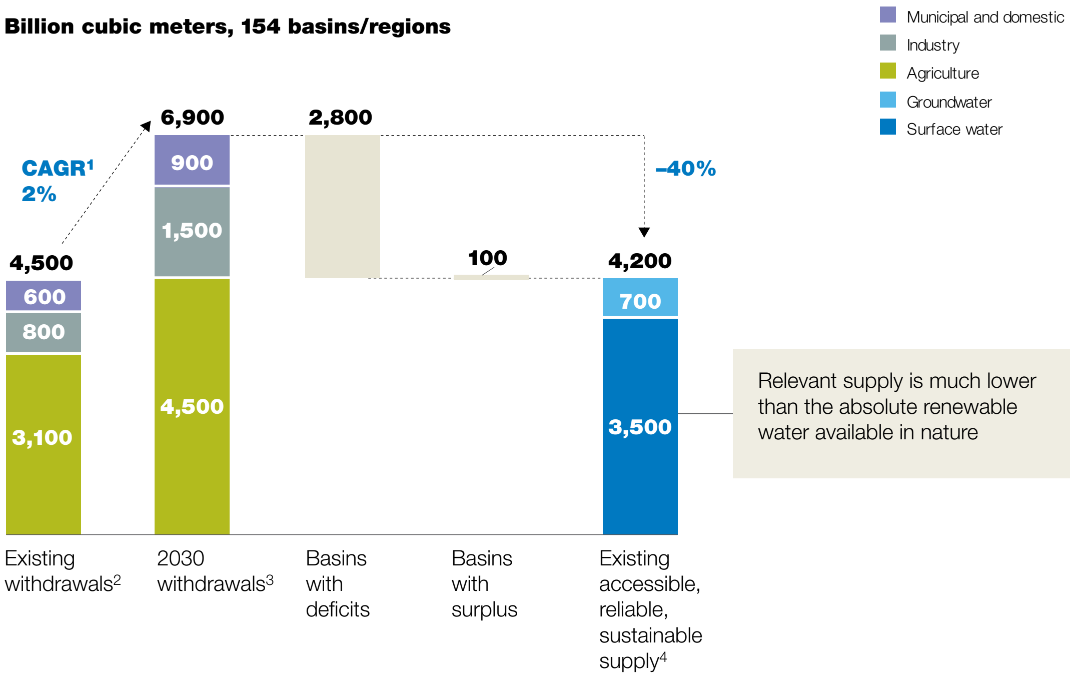
Many countries have been grappling with scarcity for decades, and some have already developed sophisticated solutions to improve water security under extreme conditions. Such nations include Australia, Singapore, and Israel—all of which face significant threats of scarcity and increasing volatility of supply due to factors such as climate, geography, and demographics.

In the 1990s, Australia launched a national agenda to develop market mechanisms to improve its water security. Early steps included redefining property rights to separate water rights from land ownership and disaggregating the water-industry value chain to enable water trading among states and private entities. The country also took steps to manage demand, including charging higher fees for consumption that exceeds levels of basic

Exhibit 1

The global gap between existing accessible, reliable supply and 2030 water withdrawals could reach 40%.

Billion cubic meters, 154 basins/regions



[1]Compound annual growth rate.
[2]Based on 2010 agricultural-production analyses from International Food Policy Research Institute (IFPRI).
[3]Based on GDP, population projections, and agricultural-production projections from IFPRI; considers no water productivity gains between 2005 and 2030.
[4]Existing supply that can be provided at 90% reliability, based on historical hydrology and infrastructure investments scheduled through 2010, net of environmental requirements.

Source: 2030 Water Resources Group; global water supply and demand model; agricultural production based on IFPRI IMPACT-WATER base case

necessity. Australia's current supply of water is significantly lower than it was a decade ago, but its improved water management has helped limit negative impact on economic growth. (See the sidebars "The double threat in Australia" and "Australia's water transformation" for details about the country's water challenge and how it has been addressed.)

Singapore has taken a top-down approach to expanding its domestic supply of water. Its "Four National Taps" policy is designed to reduce its dependence on Malaysian imports by increasing its ability to procure water via local catchments, reclamation, and desalination. The country has classified two-thirds of its land as partially protected catchment areas, and it

The double threat in Australia

Australia's climate has always been extreme. Much of the country is semi-arid or desert—indeed, 40 percent of its landmass is covered by sand. Australia receives less rain than any other continent, barring Antarctica, and it experiences frequent and long-lasting droughts. And due to geographic and other factors, it is only able to capture a small portion of the water that does fall within its borders—less than 10 percent, compared with a world average of 20 percent; some regions, including parts of North America, capture more than 40 percent.

Australia also experiences extraordinary variability in its supply of water. The country's Murray-Darling Basin, its most significant agricultural area, is fed by the Murray and Darling Rivers and drains one-seventh of the Australian landmass. But both of these rivers have highly variable flow volumes. The Murray River's ratio of maximum to minimum annual flows is 15, while the Darling River's ratio is an extraordinary 4,000. In comparison, China's Yangtze River has a ratio of 2.0, and the Amazon River's ratio is a mere 1.3.

Historically, Australia has managed this variability by building storage capacity to compensate for low river flows in times of undersupply. For example, the Murray-Darling Basin has more than 30 cubic kilometers of storage capacity, enabling it to hold a quantity of water equal to about one-and-a-half years of flow from the Murray and Darling Rivers. Thus, Australia ranks among the top-three countries for water-storage capacity in the world.

But Australia's climate has changed dramatically over the past decade, posing serious threats to the country's historical approach to water management. In particular, a prolonged drought, which began in 2003, has dramatically reduced inflows to the country's water reservoirs.

Infrastructure that had been built to contend with historical rates of variability suddenly became inadequate. At the beginning of the millennium, Perth expected to have enough water to meet demand through 2030. But it has since needed to hastily build a number of desalination plants to ensure the city's security of supply.

Such conditions give rise to increasingly fierce competition for resources among a range of stakeholders, including municipalities, agriculture producers, energy companies, and heavy industry. The challenge lies not only in investing to capture the maximum amount of water but also in allocating the water a country captures most productively, ensuring both economic and social well-being.

now has 19 raw-water reservoirs, 9 treatment works, and 17 service reservoirs for treated water. NEWater is the brand name for reclaimed water produced by Singapore's public utilities; the country currently has five factories that generate 50 million gallons of NEWater per day. In 2005, Singapore opened its first desalination plant, one of the largest in the world, capable of producing 135 million liters of water a day. It also launched demand-side-management efforts that have reduced consumption to 160 liters per day per capita in 2005 from 172 liters in 1995.

Historically, Singapore has imported about half its water supply from Malaysia. Today, that figure has fallen to about 40 percent, though the country's population doubled from almost 2.5 million in 1980 to more than 5 million in 2010. The government expects to be self-sufficient in water by 2061, when existing import agreements with Malaysia expire.

Israel is well-known as a water-technology innovator. Netafim, a company formed after its founders invented drip irrigation in 1965, helped to establish a culture of water innovation in the country; today, Netafim ranks among the largest "blue tech" firms in the world. In 1993, Israel's government launched (and later privatized) Kinrot Ventures, the world's only start-up incubator specializing in water technologies. And in 2006, the government launched NewTech to promote the country's domestic water industry globally by supporting research and development, facilitating marketing efforts to increase exports, and bringing companies together to form an international blue-tech hub that drives further innovation. Due in

Australia's water transformation

Australia's transformation is rooted in its effort to optimize the allocation of water by tying water use to economic and market principles. An early enabling step, initiated in the mid-1980s in the state of Victoria, established cost recovery for new irrigation systems to minimize the risk of investment by private companies. This facilitated the expansion and improvement of irrigation networks, greatly increasing the efficiency of water distribution and consumption.

In 1994, the Council of Australian Governments (COAG) endorsed a national framework to overhaul the country's water economy. The framework adapted Victoria's cost-recovery system for national rollout. It implemented tariff reforms that factored opportunity cost into the price of water so that luxury uses, such as watering private gardens, would be more expensive than critical uses, such as irrigating crops.

In 1995, the Standing Committee on Agriculture and Resource Management developed the National Framework for the Implementation of Property Rights in Water, which separated land rights from water rights such that land ownership was no longer a condition of water ownership. Regulators also disaggregated the industry value chain, turning ownership of irrigation infrastructure over to states or private entities. These actions facilitated the creation of markets that enabled water trading among states, which increased the efficiency of water allocation by factoring scarcity into its price. As a result, Australia became one of the most integrated water markets in the world.

In 2003, COAG established the National Water Initiative to promote the economically efficient and sustainable use of water, encourage adoption of "user pays" principles, increase pricing transparency, and facilitate the efficient functioning of water markets.

Australia established the National Water Commission in 2004 to oversee the implementation of the National Water Initiative. The Murray-Darling Basin Authority was established under the Water Act of 2007 to manage issues relating to the drought that began in 2003 and to address potential effects of climate change. More recently, the government has begun to act as a market participant on behalf of the environment, buying water to preserve ecological assets.

Traded water in Australia was valued at almost AU $2 billion (about US $2.06 billion) in 2007 and 2008, with more than 95 percent traded among states in the Murray-Darling Basin. There are a variety of exchanges and brokerages that facilitate trading, but a majority of the trades are done for agricultural purposes.

part to these efforts, the Israeli water sector generated revenues of $1.4 billion from exports in 2010.

The importance of country specificities

Many countries that are facing water challenges are not in a position to implement advanced strategies to transform their water sectors. They can learn much from cases such as Australia, Singapore, and Israel, but their particular success will depend on their ability to develop strategies that work within their unique political, social, and economic contexts.

Such countries face a mix of "hard" barriers related to physical assets, capital, and technology and "soft" barriers related to skills, institutions, and leadership. For example, many lack the basic infrastructure that is a prerequisite to implement some proven strategies; the assets they do have are often outdated or need repair. Utilities often lack access to the capital and capabilities they need to transform their water sectors. Countries frequently lack the institutions necessary to set effective water policies or monitor and enforce rules. And regulators may be weak, either because they lack authority (for instance, to recover costs) or because they are embedded within cumbersome institutional arrangements.

Political conditions may impede action, particularly when stakeholders do not understand the issues at hand. And social conditions can also present powerful barriers to progress. For example, reform can be particularly challenging in countries with significant populations of subsistence farmers who cannot easily adopt more capital-intensive, water-efficient agricultural methods.

The ICE approach to water transformations

Through our research and experience supporting water-sector reform in several countries, we have recognized that successful transformations often hinge on the ability of stakeholders to gather and analyze information about water availability and usage, make choices that account for critical trade-offs, and establish processes and procedures to ensure execution. We developed the ICE framework to highlight core principles in these areas that every country seeking to transform its water economy should consider.

Inform

Countries benefit from aggregating and organizing economic data about water use. In our experience, water cost curves can be useful tools for assessing data to understand the relative effectiveness and cost of the full spectrum of approaches to improving water security. When coupled with realistic assessments of operational risk, cost curves can also help policy makers and investors improve water-sector productivity.

To develop a water cost curve, countries should first understand their current supply and demand dynamics. To identify potential shortfalls, they also need to estimate their future supply and demand for water. This involves accounting not only for demographic and competitive factors that affect demand but also for emerging dynamics that can affect supply, such as the potential for higher temperatures, lower rain volumes, and an increase in the incidence of extreme-weather events.

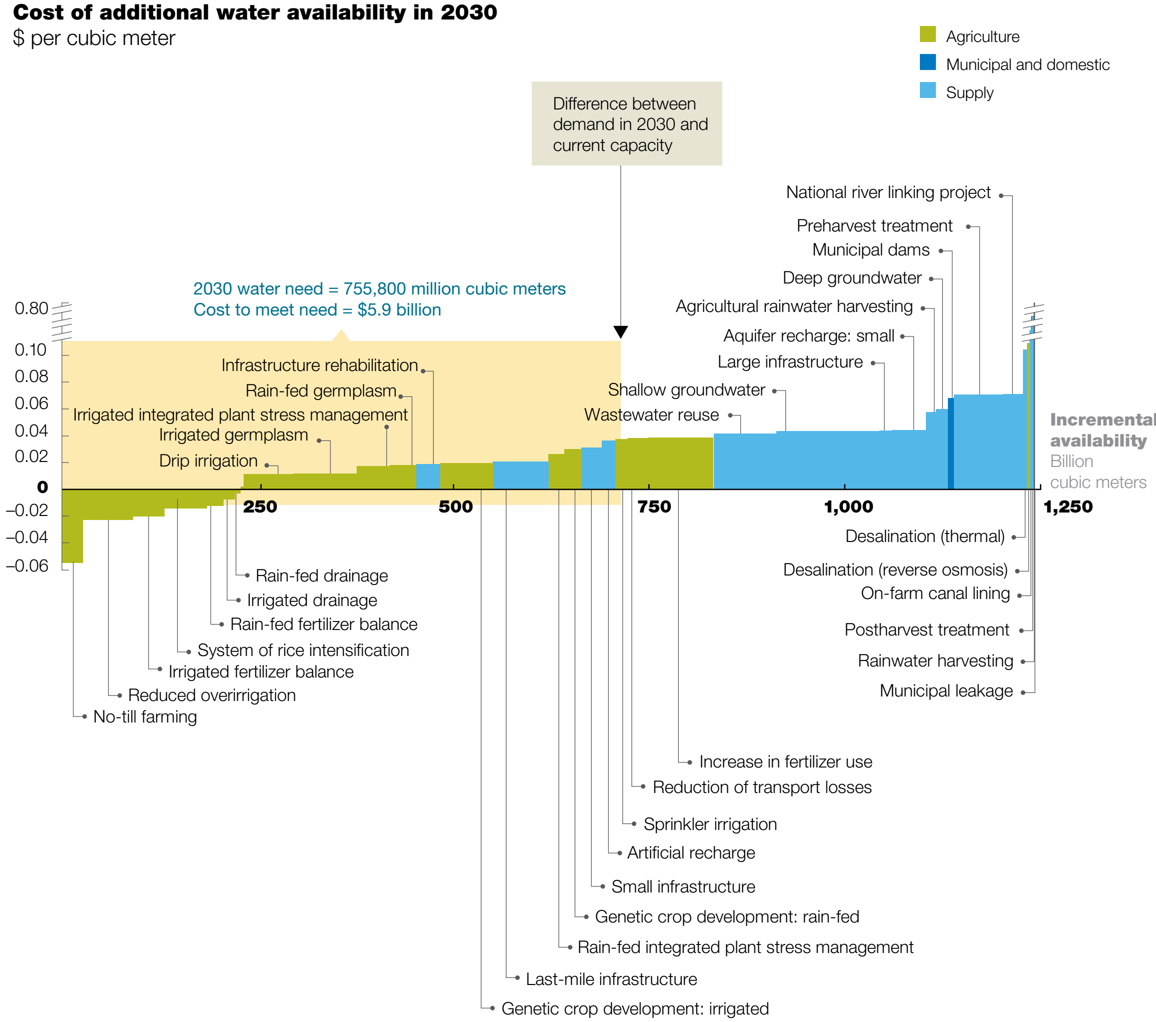
Once a country has estimated its potential water gap (the difference between its projected future demand and its current capacity to supply water),[2] it can conduct an audit to identify all potential improvements that could reduce water consumption; it can also estimate the cost of implementing each of these. The country then arranges the opportunities on a curve—such as the one shown for India in Exhibit 2—enabling it to identify the most cost-effective solutions to meet its estimated needs.

India's water cost curve indicates that if the country focuses on the most cost-effective approaches available, it could meet its 2030 water needs—estimated to be 755,800 million cubic

Exhibit 2

India's water cost curve illustrates a number of available options.

Cost of additional water availability in 2030
$ per cubic meter



Source: 2030 Water Resources Group

meters, or roughly 200 million gallons more than current supply—by investing $5.9 billion (Exhibit 2). The curve lists every approach, arranged from left to right according to increasing cost, that the nation could use to meet its water-consumption needs. In India's case, the approaches listed on the far left actually offer savings, and the vast majority of the most cost-effective approaches involve optimizing agricultural processes and practices.

Each country's cost curve will be unique. For example, China's cost curve points to the potential of measures to improve water use in industrial contexts, which would require significant investment. South Africa's cost curve suggests that the greatest potential could be achieved through roughly equal investment in agriculture, industry, and municipalities.

Choose

To ensure that their water policies are balanced, countries should also account for trade-offs involving areas such as economic development and quality of life. This is critical, as a narrow focus on efficiency and cost can have negative unintended consequences. For example, a country could prioritize approaches that minimize water use only to find that the policy leads to higher unemployment or reduces industrial productivity, which has a negative effect on GDP.

Countries can use scenario planning to account for as many relevant trade-offs as possible. This involves analyzing a range of options that are designed to achieve different policy objectives, each with its own demand profile and set of technical solutions that would enable the country to close its water gap.

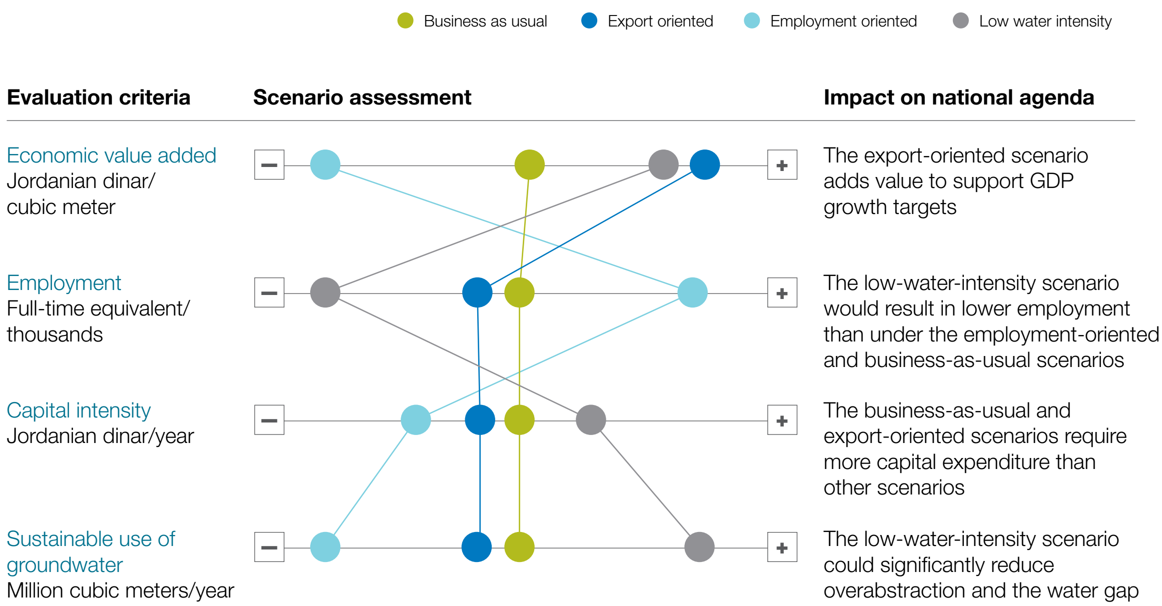
Jordan—leveraging a water-resource diagnostic conducted with support from the Water Resources Group[3]—considered four scenarios when setting its water policy in agriculture. A business-as-usual scenario simply extrapolated current economic activity into the future. An export-oriented scenario emphasized production of crops that could be sold in foreign markets. An employment-oriented scenario prioritized jobs. And a low-water-intensity scenario focused on reducing unsustainable use of groundwater. Each scenario had a different cost structure—the employment-oriented approach was the most expensive—but Jordan had the technological capability to pursue any of them and still close its water gap.

Once a country has identified a range of scenarios, it can use the economic-choices framework we have developed to determine which scenario will enable it to achieve its overall economic and social objectives most effectively. Jordan used the framework to assess each of its four scenarios on four priority measures: economic value added, employment, capital intensity, and sustainable use of groundwater (Exhibit 3). It found that the export-oriented approach would support its target for GDP growth, but both the export-oriented and business-as-usual approaches would require higher capital investments than other approaches. It found that the low-water-intensity approach would reduce not only unsustainable use of groundwater but also employment.

Tailored appropriately, the framework provides countries with a quantified understanding of how each scenario is likely to affect critical components of their national agendas, helping them clarify their purpose and catalyze decision making to improve water productivity.

Exhibit 3

The economic-choices framework allows countries to assess different scenarios.



Source: 2030 Water Resources Group

Execute

Establishing institutional mechanisms to guide and monitor delivery is critical, both to coordinate government-level action and to drive initiative-based rollout.

Governments may need to establish a cross-ministerial “water delivery unit” to make quick decisions about how to allocate water to its most productive use. This may prove particularly important for countries that lack market mechanisms for pricing water. The delivery unit should obtain input from all relevant parts of government, but it should be headed by a secretariat empowered to make decisions that may affect all aspects of the economy. The unit should also have the capability to monitor progress of implementation and manage delivery of reform at a granular level.

A number of countries have established delivery units, often to support implementation of a broad government agenda. For example, the Prime Minister’s Delivery Unit in the United Kingdom helped the government achieve its key priorities in education, health, crime, and transportation from 2001 to 2010. Malaysia’s Performance Management and Delivery Unit was established in 2009 to oversee and support a broad range of transformation efforts. Other nations have established units that are focused on particular areas of the economy.

For example, Ethiopia launched its Agricultural Transformation Agency in 2011 to coordinate and accelerate reform of the country's agricultural system.

Countries can also develop institutional mechanisms that target the execution of particular initiatives, especially those that require public support to finance infrastructure investments. In 2005, for example, India established a National Mission on Micro Irrigation that has enabled the use of drip and sprinkler irrigation systems in 1.8 million hectares of cultivated land in 18 states.

To achieve efficiency targets, governments may need to set policies and incentives that require or encourage the efficient use and conservation of water. For example, Singapore meters virtually all water use within its borders, which enables it to set incentives for use that support its national agenda. It also sets policies to ensure that water equipment installed in new residential buildings meets high standards of efficiency. Singapore sets the price of water so that all residents can meet their basic needs, but it charges higher rates for nonessential consumption. And it encourages water reuse by setting the price for recycled water at one-fifth the price charged for water that has not been recycled.

• • •

Most countries that face water challenges have begun to develop strategies to manage water more effectively, but few have succeeded in establishing approaches equal to the challenges they face. Rapid population and economic growth is likely to drive increasing demand for water in the coming years, and the challenge of meeting this demand could be exacerbated by rising temperatures and growing weather-related unpredictability. But even countries that lack the resources to pursue sophisticated solutions such as those pioneered in Australia, Singapore, and Israel can achieve greater water security by adopting the principles of successful transformations. Countries that develop solid information, clearly understand their economic choices, and establish the necessary institutional mechanisms to execute their policies can accelerate their progress to greater water security at lower cost.

[1] 2030 Water Resources Group, *Charting our water future*, 2009 (www.mckinsey.com). The 2030 Water Resources Group was formed in 2008 to contribute new insights to the issue of water scarcity. Members include McKinsey & Company, the World Bank Group, and a consortium of business partners: The Barilla Group, The Coca-Cola Company, Nestlé SA, New Holland Agriculture, SABMiller PLC, Standard Chartered, and Syngenta AG.

[2] The gap is not a prediction of future water shortage; it is a reflection of the effort required to ensure that future demand is met.

[3] 2030 Water Resources Group, *Charting our water future*, 2009 (www.mckinsey.com).

Giulio Boccaletti is a principal in McKinsey's London office, where **Sudeep Maitra** is an associate principal. **Martin Stuchtey** is a director in the Munich office. Copyright © 2012 McKinsey & Company. All rights reserved.

Reducing deforestation:
The land-use revolution

Adopting a more sustainable approach to managing forest reserves is a complex challenge. But by putting five critical building blocks into place, the international community can help REDD+ advance from concept to reality.

Marco Albani, Jeremy Oppenheim, Jens Riese, and Adam Schwarz

The Intergovernmental Panel on Climate Change estimates that deforestation and forest degradation, along with resulting changes in land use, are responsible for 17 percent of global greenhouse-gas (GHG) emissions.[1] Many observers of climate talks see REDD+,[2] the United Nations–sanctioned program to reduce these GHG emissions, as one of the most promising areas for international efforts to achieve near-term successes. A relatively cost-effective mitigation option, REDD+ may offer significant additional benefits, including the preservation and enhancement of ecosystem services[3] that sustain local communities and the world at large.

By accelerating the transition from net deforestation to net reforestation, REDD+ presents forest countries with an option to more tightly align their national-development choices with the global need for climate action and biodiversity stewardship. But for REDD+ to succeed, it must be understood as more than just a framework focused on forests and the rate of deforestation. Rather, it should be considered within the broader context of economic development.

This is consistent with the program's overall mission, since REDD+ is ultimately an effort by the international community to support

heavily forested poor or middle-income countries in making different economic-development choices than most countries have made in the past. In other words, REDD+ should be understood as a mechanism to empower forest countries to pursue alternative development pathways that are not only environmentally sustainable but also economically, politically, and socially sustainable.

To be sure, the path forward will require enlightened and determined political leadership from both developing- and developed-country leaders. Adopting a more sustainable approach to managing forest reserves and a more climate-compatible development model will inevitably disrupt existing political, institutional, and economic arrangements. New alliances will have to be built to include often-overlooked forest-based communities. Some reshuffling of institutional authority is likely. And to achieve REDD+ success at scale, developed countries will have to contribute ample financial and technical support, underpinned by a spirit of partnership.

The objective of this article is to reflect on some of the key challenges to implementing REDD+ and to share insights from our experience supporting public- and social-sector institutions working to take REDD+ from concept to reality.

REDD+ challenges

REDD+ was initially conceived to enable the international community to allocate economic resources to forest countries in ways that would make standing forests more valuable than cut ones. In fact, most deforestation activities seem to generate limited overall economic benefits for the countries where deforestation happens, particularly when the loss of natural capital from forests is taken into account.[4] Yet developing winning REDD+ strategies has proved challenging. Here we discuss four principal challenges we have encountered while working with countries that have pursued REDD+ solutions: market economics of deforestation; nonmarket drivers of land-use choices; capability, coordination, and information; and international commitment.

Market economics of deforestation

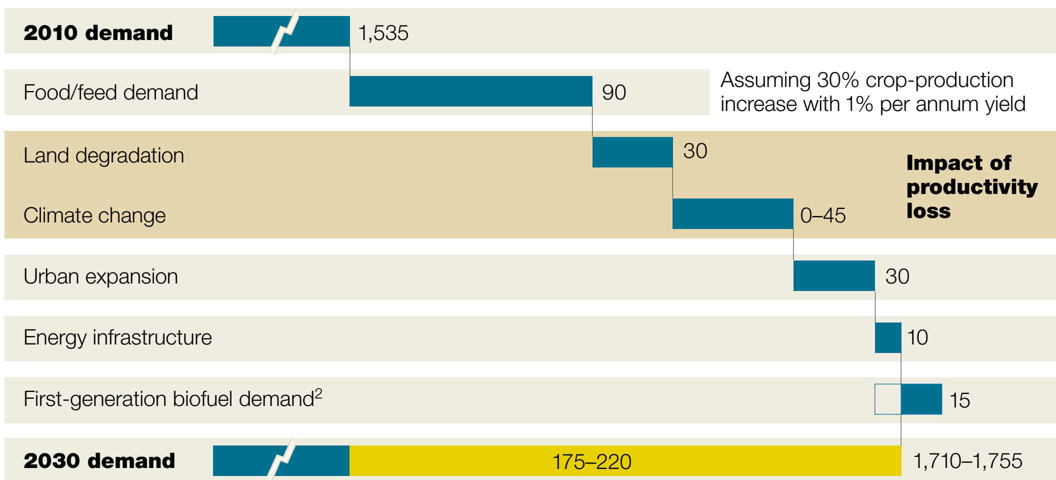
For a number of reasons, countries often have difficulty designing effective incentive systems to prevent the loss of forests. In some cases, deforestation can enable compelling market-based returns, particularly given the opportunities that have emerged for alternative uses of forested land as agricultural commodity prices have skyrocketed. For example, at current prices for crude palm oil, a palm-oil plantation with typical productivity can generate average annual revenues of $4,500 to $5,400 per hectare,[5] which provides a net present value (NPV) of $5,000 to $17,000 per hectare, depending on conversion costs and productivity assumptions.

Compare this with the expected returns from generating revenues from REDD credits on preserved forest. The average reduction in biomass carbon stock between a tropical rainforest and a mature palm-oil plantation on mineral soil is about 150 metric tons of carbon (tC) per hectare or about 550 metric tons of carbon dioxide equivalent (tCO_2e).[6] The NPV of not deforesting a hectare at a price of $5 per tCO_2e (the interim price used in the 2009 Guyana-Norway Agreement)[7] would be about $2,750, which is only about half of the lower range for the

Exhibit

To meet 2030 food, feed, and fuel demand, 175 million to 220 million hectares of additional cropland would be required.

Base-case cropland demand[1] by 2030
Million hectares



[1]Defined as arable land and permanent crops by the Food and Agriculture Organization (FAO) of the United Nations.
[2]As 30–80% of biomass input for biofuel production is fed back to livestock feed, the cropland required to produce feed crops would be reduced by about 10 million hectares.

Source: International Institute for Applied Systems Analysis; FAO; International Food Policy Research Institute; Intergovernmental Panel on Climate Change; Global Land Degradation Assessment; World Bank; McKinsey analysis

NPV of palm-oil conversion. The gap would likely be even wider for the extraction of high-value mineral resources like gold or petroleum. This admittedly simplistic analysis illustrates the difficulties countries may encounter in their efforts to devise simple incentive models that encourage landowners or concession holders to forgo development in exchange for REDD+ payments. It also suggests that approaches based purely on “buying out” deforestation activities may not be realistic in the absence of a sharp and sustained increase in the price of forest-carbon credits.

Unless the world takes action, dynamics such as these are likely to endure. Our recent report indicates[8] that unless crop yields and productivity are substantially improved, an additional 175 million to 220 million hectares of cropland will be needed globally by 2030 to satisfy increasing demand for food, animal feed, and fuel (exhibit). While there are opportunities to bring non-forest land under production, the tendency in the tropics has been to clear primary forests when additional land is needed for agricultural purposes.[9]

Nonmarket drivers of land-use choices

Deforestation and forest-degradation activities can also be compelling for specific interests or population segments, regardless of market returns. For some segments of the rural poor, forests provide access to essential sources of food, energy, or income that cannot be readily obtained elsewhere. This is particularly true in the poorest countries where deforestation rates are highest, such as in Haiti, where trees are cut to produce charcoal, which is then used as primary source of domestic fuel.

In other cases, deforestation has been used as a strategy for acquiring or securing a title to land. This is often the case in Brazil, where ranchers engage in deforestation not only to clear land to raise cattle but also to take possession of land to which they would otherwise have no legal claim. The same is true for the Dayak people of Central Kalimantan in Indonesia, who fell trees and plant rubber as a proxy for land title.

In such cases, REDD+ payments could provide financial flows comparable with or even superior to those generated by land-use activities that are enabled by deforestation or degradation. But payments are unlikely to be effective unless local institutional, political, and economic conditions change to account for other motivating factors such as land ownership. This requires reconciling the competing interests of multiple stakeholders, who often come to the table with a history of mutual distrust and in the context of weak governance. In the cases where it is necessary to navigate competing claims on land tenure among indigenous people, settlers, and governments, the challenge is to develop REDD+ strategies that benefit all stakeholders.

Capability, coordination, and information

The adoption of a more sustainable approach to development in forest-heavy geographies requires a multitude of new skills and capabilities, as well as coordinating mechanisms, which sometimes necessitate new institutions. Governments should develop new ways of thinking and new capabilities for critical functions such as economic strategy, infrastructure planning, fiscal policy, and spatial planning, though they should be mindful that doing so takes time. In many countries, a principal obstacle to the success of REDD+ projects is the knowledge gap between private-sector investors and relevant agencies in local governments.

Progress is further impeded by a lack of clear information about land use, rights, and regulations in many forest countries. In some cases, land ownership may be unclear because countries lack reliable land registries. Rules governing land use may be ambiguous, particularly when different authorities use different maps to delimit land-management units. And information about land cover can be difficult to obtain. A number of new remote-sensing technologies have been developed in recent years, but it remains difficult to obtain information that is sufficiently detailed and precise to be useful at the operational level.

These problems were put in stark relief by the technical challenges that beset last year's Indonesian moratorium on new forestry concessions. The decision also gave rise to extensive discussion about which maps could be used to delimit the moratorium areas. It was subsequently revealed that the Ministry of Forestry, the Ministry of Environment, and the participating nongovernmental organizations use different criteria to define primary and secondary forests, and thus often had different and conflicting ideas about which areas were covered by the moratorium. Similar problems have hindered reviews of special agricultural leases in Papua New Guinea, where a lack of coordination among the different government agencies involved with land affairs makes it difficult for stakeholders to understand the terms of particular leases.

International commitment

Finally, progress is impeded by the apparent absence of international economic support for REDD+ at the scale required for success. The 2010 Oslo Climate and Forest Conference brought forward substantial pledges for interim REDD+ finance, totaling about $4 billion. The Voluntary REDD+ Database[10] reports additional REDD+ financing commitments of $1.6 billion per year from 2012 to 2014. These commitments are important, but they constitute only a small portion of overall financial flows generated by agriculture and commodity markets. Added together, they roughly equal the value of annual revenues generated by the world's top-five tropical-log exporters. To provide further contrast, in 2010, Brazilian beef and soy exporters generated annual revenues of $15 billion and Indonesian and Malaysian palm-oil exporters generated $27 billion.[11]

Many major REDD+ initiatives remain undercapitalized, and many developing-country stakeholders perceive disbursement of international REDD+ public finance as slow and unreliable.[12] For example, recent reports show that two primary REDD-readiness multilateral processes, the Forest Carbon Partnership Facility and the UN-REDD Programme, have so far disbursed only a fraction of their funds to REDD+ countries.

Many developing-country stakeholders also complain that existing REDD+ funding mechanisms are based on traditional models for overseas development assistance (ODA) and as such are unsuitable for meeting the broadly defined REDD+ challenge. These stakeholders argue that criteria for use of donor funds currently earmarked for REDD+ purposes are too narrowly focused, give too little weight to the priorities of host governments, and underemphasize capability building.

The delay in disbursement of funds is compounded by the uncertainty about the emergence of "at scale" funding mechanisms for REDD+. In the United States, efforts to establish a carbon market based on national-level cap-and-trade have been deferred indefinitely, and uncertainty about the nature of the United Nations Framework Convention on Climate Change (UNFCCC) mechanism for REDD+ remains high. These and other variables have so far discouraged serious engagement by the private sector in REDD+

efforts beyond participation in voluntary carbon-market projects.

The international commitment required for REDD+ success is not limited to donor agencies; consumers also need to play a role. Important efforts have been launched to address the demand side, but REDD+ strategies could benefit significantly from initiatives that increase demand for sustainably produced commodities, particularly through expanded use of certification. Since 2000, the world's certified forest area has increased from 32 million hectares to 240 million hectares (although most of these certified forest lands are located in North America and Europe).[13] And the area certified by the Roundtable on Sustainable Palm Oil increased from about 100,000 hectares in 2008 to more than 1.1 million hectares in 2011.[14] Yet certification programs only account for a small portion of total commodities traded. It has been difficult for some certified commodities to capture attractive price premiums, and uptake remains challenging. Progressive companies could be in a position to develop innovative operational and supply-chain practices that reduce costs and increase uptake.

A model for green growth

These are formidable challenges, but they can be met with a high level of commitment and leadership. Of course, there is still much to learn about how to accomplish REDD+ goals, not least to ensure adequate input rights and benefits for indigenous peoples and forest communities. But a number of promising insights are emerging. It seems increasingly clear that defining REDD+ as merely a system of payments for reduced deforestation is unlikely to achieve sustained impact; rather, long-term success will depend on the ability to embed REDD+ within national-development plans that enable robust economic growth from activities that leave behind smaller carbon footprints.

We highlight five building blocks required at national and subnational levels to deliver against the broadly defined REDD+ challenge: green-growth planning, agricultural productivity, data and technology, REDD+ finance, and capacity and institution building.

Green-growth planning

The success of REDD+ will hinge on the ability to create development plans that not only mitigate GHG emissions and protect biodiversity but also expand economic and employment opportunities, increase food security, and improve standards of living (for example, by expanding access to education, safe water, energy, and financial services).

Our experience suggests that some of the most important initiatives within such plans include opportunities that increase adoption of sustainable agricultural practices, divert development of agricultural or other plantations away from forests and onto idle or degraded land, alter conventional logging practices to minimize their impact on forest management, and reduce consumption of wood as fuel. Many of these initiatives are still relatively new, so examples of their implementation at scale may be limited. But several forest countries have begun the process of building REDD+ strategies that prioritize protection of the environment, stakeholder engagement, and economic development.

For example, in Indonesia, the National REDD+ Task Force developed a draft REDD+ strategy

that has been distributed to different stakeholder groups, which were asked to provide comments. Some of the Indonesian provinces with the highest GHG emissions, such as East Kalimantan, Central Kalimantan, Papua, Aceh, and Jambi, have developed or are developing their own green-growth strategies and action plans. And in Guyana, under the leadership of the country's former president and with support from the government of Norway, an ambitious low-carbon development strategy has been developed to drive a cross-sector transition to a green economy; this includes investments in renewable energy, sustainable agriculture, rural energy access, and rural education.

Agricultural productivity

As noted, one critical step to reduce pressure on forests is to improve productivity of land use in areas that are already cultivated. Our research indicates that best-practice applications in commercial farming could increase crop yields by 20 percent over base-case outcomes from 2011 to 2030. Achieving such productivity gains would be equivalent to freeing up more than 150 million hectares of land. Smallholders could make even larger strides, potentially increasing their productivity by 60 to 70 percent by adopting proven techniques.[15] We believe smallholders could free up the equivalent of an additional 75 million to 105 million hectares by pursuing crop-yield improvements, even accounting for the fact that many will not be able to make use of all the available technologies.[16]

An opportunity on a similar scale could be achieved through improved spatial planning[17] and better use of degraded or abandoned land that has already been cleared. While there is considerable debate about the extent of degraded or nonforested land available for agricultural use, the World Bank and the International Institute for Applied Systems Analysis estimate that there are still 450 million hectares of land that is uncultivated, unforested, and potentially productive, and hence potentially available for cultivation.[18]

Building and scaling up livelihood-improvement programs that successfully engage stakeholders—especially smallholders, forest people, and indigenous communities—is clearly a great challenge. But a number of countries have launched promising efforts to improve the agricultural productivity of smallholders. For example, the Moroccan government developed an aggregation program that involves leasing farmland to commercial farmers who are committed to working with local smallholders through an "outgrower" program.[19] An agricultural-development agency encourages and directs these efforts, ensuring equity in the relationship between outgrowers and commercial farmers. More than 30 aggregation partnerships have been launched since the program began.[20]

In Indonesia, a so-called nucleus-and-plasma scheme obliges large-scale producers of commodities such as palm oil to buy a certain percentage of their production from nearby smallholders. This provides an incentive to the larger players to support smallholders with better seeds, improved irrigation techniques, and other capacity-building actions. Such models could be incorporated more broadly in REDD+ strategies to support sustainable intensification of agriculture and yield increases by smallholders; the models could also be incorporated into community forestry and other smallholder agroforestry programs.

Data and technology

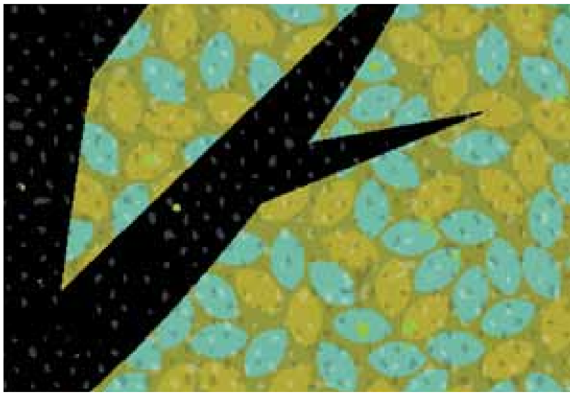
A solid fact base must take into account the economic-development needs that drive deforestation. Once such a fact base is established, stakeholders can begin to quantify the impact of their efforts relative to business-as-usual scenarios and build a shared understanding of the trade-offs implied in shifting to a climate-compatible path to growth. The fact base can also be used to help prioritize given limited strategic and financing capacity, ensuring that resources are focused on the opportunities that hold the greatest promise from the perspective of social and environmental benefits and feasibility.

At the international level, new applications of satellite and aerial remote sensing are emerging that make forest-carbon mapping and monitoring substantially easier. In 2011, NASA's Jet Propulsion Laboratory published a new set of pantropical maps of forest carbon,[21] and another set of maps prepared by the Woods Hole Research Center was published in 2012.[22] Moreover, the Planetary Skin Institute's Automated Land Change Evaluations, Reporting, and Tracking System (ALERTS) platform now enables global tracking of land-use changes in near real time.

REDD+ finance

Prompt and effective deployment of REDD+ public finance remains a challenge, and donor coordination is often more an aspiration than a reality. But there are encouraging instances of national and international commitment and strong leadership driving toward new models of REDD+ finance that could work at scale.

The phased approach that is described in the *REDD options assessment report*,[23] which was further developed by the Informal Working Group on Interim Finance for REDD+ (IWG-IFR), has now been adopted by the UNFCCC as part of the Cancun Agreements. The Amazon Fund in Brazil and the bilateral REDD+ agreements between Norway and Guyana and between Norway and Indonesia are creating living laboratories for the kind of support envisioned by the IWG-IFR. As part of their partnerships with Norway, both Guyana and Indonesia have designed their programs so that they are globally relevant and replicable—and also so that performance can be monitored and codified.



The speed and scale of REDD+ finance is increasing. It is estimated that total forest-directed ODA grew by almost 50 percent from 2000 to 2007, and individual REDD+ initiatives represent a significant fraction of the total ODA to the sector.[24] Moreover, there is considerable hope that the new generation of REDD+ financing models—such as the Green Climate Fund or the REDD+ funding mechanism being developed through the Indonesia-Norway partnership—can improve on traditional ODA models by ensuring adequate host-government ownership and context-specific safeguard regimes.

Capacity and institution building

Capacity is being developed at the national and subnational levels in key REDD+ countries, although much more needs to be done. Green-growth development is by definition a multi-sectoral, multiministry challenge requiring robust policy-coordination mechanisms. The institutional adjustments required for REDD+ success are still in relatively early stages, but some encouraging examples are beginning to emerge.

In Indonesia, the National Council on Climate Change (DNPI) is bringing new rigor to processes for assessing GHG emission levels and abatement potential in different sectors. The DNPI is also coordinating a multisector measurement, reporting, and verification blueprint. In East Kalimantan, the Provincial Council on Climate Change is leading the charge to identify plots of degraded land suitable for large-scale cultivation and to reform spatial-planning procedures. Other provinces in Indonesia have recently established councils for climate-change coordination or are looking to do so.

Papua New Guinea has established an Office of Climate Change and Development that is advancing an ambitious forest-monitoring agenda in collaboration with the country's governmental bodies, other stakeholders, and the UN-REDD program.

• • •

More work is needed to develop effective approaches that incorporate important non-carbon issues, such as the protection of biodiversity and indigenous land rights, into the design and implementation of REDD+ strategies. The international community still lacks a model for international forest financing that is backed by pledges many REDD+ countries will perceive as credible and that is nimble enough to deliver necessary resources in a timely fashion. But it should also be remembered that the international community has made significant progress on many fronts in the past five years—and much more progress can be made when all stakeholders engage in a spirit of partnership. ○

[1] This figure is based on the fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC), which estimated forestry's contribution to global greenhouse-gas emissions at 17 percent (see R. K. Pachauri and A. Reisinger (editors), *Climate change 2007: Synthesis report*, IPCC, 2007 (www.ipcc.ch)). In 2009, the figure was estimated to be 12 to 15 percent, depending on the contribution of tropical peatland forests, according to G. R. van der Werf et al., "CO_2 emissions from forest loss," *Nature Geoscience*, 2009, Volume 2, pp. 737–8.

[2] According to the UN-REDD Programme Web site, "Reducing Emissions from Deforestation and Forest Degradation (REDD) is an effort to create a financial value for the carbon stored in forests, offering incentives for developing countries to reduce emissions from forested lands and invest in low-carbon paths to sustainable development. 'REDD+' goes beyond deforestation and forest degradation, and includes the role of conservation, sustainable management of forests, and enhancement of forest carbon stocks" (www.un-redd.org).

[3] The benefits that natural ecosystems supply to humankind are known as "ecosystem services"; this includes, for example, products such as clean drinking water and processes such as the decomposition of waste.

[4] At the microeconomic level, this point is supported by the low opportunity cost of most drivers of deforestation, as described in our own work and by many others. Similar results are found through empirical analysis of human-development indexes in municipalities that have experienced deforestation, as described in Ana S. L. Rodrigues et al., "Boom-and-bust development patterns across the Amazon deforestation frontier," *Science*, June 12, 2009, Volume 324, Number 5933, pp. 1435–7 (www.sciencemag.org).

[5] These figures are based on a price of $1,100 per metric ton for crude palm oil (CPO), a fresh-fruit-bunch (FFB) average lifetime yield of 21 to 24 metric tons per hectare, and a 20 percent CPO/FFB yield.

[6] The numbers are calculated for a forest on mineral soil. For peatland forests, the carbon-stock difference with a palm-oil plantation would be significantly higher.

[7] Guyana-Norway Agreement, Joint Concept Note, March 31, 2011 (www.lcds.gov.gy).

[8] *Resource revolution: Meeting the world's energy, materials, food, and water needs*, McKinsey Global Institute and McKinsey Sustainability & Resource Productivity practice, November 2011 (www.mckinsey.com).

[9] H. K. Gibbs et al., "Tropical forests were the primary sources of new agricultural land in the 1980s and 1990s," *Proceedings of the National Academy of Sciences*, 2010, Volume 107, Number 38, 16732–7 (www.pnas.org).

[10] According to the Web site for the database, "The Voluntary REDD+ Database was formally launched at the Ministerial Meeting of the REDD+ Partnership in Nagoya, Japan, in October 2010, building on the initial data collection effort by Australia, France, and Papua New Guinea launched during the Paris-Oslo process. It aims to improve transparency around REDD+, support efforts to identify and analyse gaps and overlaps in REDD+ financing, and help share experiences on REDD+" (reddplusdatabase.org).

[11] United Nations Commodity Trade Statistics Database (comtrade.un.org).

[12] *Emergency finance for tropical forests, two years on: Is interim REDD+ finance being delivered as needed?* The Prince's Rainforests Project, October 2011 (www.pcfisu.org).

[13] The Programme for the Endorsement of Forest Certification is the world's largest forest-certification system (www.pefc.org).

[14] The Roundtable on Sustainable Palm Oil was formed in 2004 with the objective of promoting the growth and use of sustainable palm-oil products through credible global standards and engagement of stakeholders (www.rspo.org).

[15] J. N. Pretty et al., "Resource-conserving agriculture increases yields in developing countries," *Environmental Science & Technology*, 2006, Volume 40, pp. 1114–9 (www.pubs.acs.org).

[16] *Resource revolution: Meeting the world's energy, materials, food, and water needs*, McKinsey Global Institute and McKinsey Sustainability & Resource Productivity practice, November 2011 (www.mckinsey.com).

[17] Spatial planning refers to the methods used by the public sector to influence the distribution of people and activities in spaces of various scales. Discrete professional disciplines that involve spatial planning include land-use planning, urban planning, regional planning, transport planning, and environmental planning.

[18] We provide a detailed discussion of the opportunities and challenges presented by expanding agriculture into "available" land in *Resource revolution: Meeting the world's energy, materials, food, and water needs*, McKinsey Global Institute and McKinsey Sustainability & Resource Productivity practice, November 2011 (www.mckinsey.com).

[19] Outgrower programs are contract-farming arrangements whereby small farmers are linked with larger farms or operations that may support production planning, supply input, and provide services such as advice and transportation.

[20] Sunil Sanghvi, Rupert Simons, and Roberto Uchoa, "Four lessons for transforming African agriculture," *McKinsey Quarterly*, April 2011 (www.mckinseyquarterly.com).

[21] Sassan S. Saatchi et al., "Benchmark map of forest carbon stocks in tropical regions across three continents," *Proceedings of the National Academy of Sciences*, 2011, Volume 108, Number. 24, 9899–904 (www.pnas.org).

[22] A. Baccini et al., "Estimated carbon dioxide emissions from tropical deforestation improved by carbon-density maps," *Nature Climate Change*, 2012, Volume 2, pp. 182–5 (www.nature.com).

[23] Arild Angelsn et al., *Reducing emissions from deforestation and forest degradation (REDD): An options assessment report*, 2009 (www.REDD-OAR.org).

[24] Markku Simula, *Financing flows and needs to implement the non-legally binding instrument on all types of forests*, prepared for the Advisory Group on Finance of the Collaborative Partnership on Forests, with the support of the Program on Forests, World Bank, Washington, DC, 2008 (www.un.org).

Marco Albani is a consultant in McKinsey's Rome office, and **Jeremy Oppenheim** is a director in the London office. **Jens Riese** is a director in the Munich office, and **Adam Schwarz** is a consultant in the Singapore office.
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The business of sustainability

More companies are managing sustainability to improve processes, pursue growth, and add value to their companies rather than focusing on reputation alone.

Sheila Bonini

Many companies are actively integrating sustainability principles into their businesses, according to a recent McKinsey survey,[1] and they are doing so by pursuing goals that go far beyond earlier concern for reputation management—for example, saving energy, developing green products, and retaining and motivating employees, all of which help companies capture value through growth and return on capital. In our sixth survey of executives on how their companies understand and manage issues related to sustainability,[2] this year's results show that, since last year, larger shares of executives say sustainability programs make a positive contribution to their companies' short- and long-term value.

This survey explored why and how companies are addressing sustainability and to what extent executives believe it affects their companies' bottom line, now and over the next five years.

On the whole, respondents report a more well-rounded understanding of sustainability and its expected benefits than in prior surveys. As in the past, they see the potential for supporting corporate reputation. But they also expect

operational and growth-oriented benefits in the areas of cutting costs and pursuing opportunities in new markets and products. Furthermore, respondents in certain industries—energy, the extractive industries,[3] and transportation—report that their companies are taking a more active approach than those in other sectors, probably as a result of those industries' potential regulatory and natural-resource constraints.

A more active agenda

There are some noteworthy changes since our 2010 survey[4] in the actions executives report their companies are taking on sustainability, their reasons for doing so, and the extent to which they have integrated sustainability into their business. For instance, the share of respondents saying their companies' top reasons for addressing sustainability include improving operational efficiency and lowering costs jumped 14 percentage points since last year, to 33 percent. This concern for costs replaces corporate reputation as the most frequently chosen reason; at 32 percent, reputation[5] is the second most cited reason, followed by alignment with the company's business goals, mission, or values[6] (31 percent) and new growth opportunities (27 percent), which climbed 10 percentage points since last year.

Therefore, it's not surprising that the areas where most executives say their companies are taking action are reducing energy usage and reducing waste in operations, ahead of reputation management (Exhibit 1). Fewer respondents report that their companies are leveraging the sustainability of existing products to find new growth or committing R&D resources to bring sustainable products to market. Yet both of these are important ways sustainability can drive growth: organizations that act in these areas are the likeliest to say they're more effective than their competitors at managing any other sustainability initiatives. These results suggest that companies may be better able to find a competitive advantage when pursuing growth activities than operational activities.

Companies are also integrating sustainability across many processes, according to respondents: 57 percent say their companies have integrated sustainability into strategic planning (Exhibit 2). The most integrated area is mission and values, followed by external communications, while the least integrated areas are supply-chain management and budgeting. That said, sustainability has stayed at about the same place on CEOs' agendas, and about the same share of respondents say they have formal programs to address it (Exhibit 3). The share of respondents saying their companies effectively manage sustainability has even shrunk somewhat. Starting last year, we used these three characteristics to define a group of "sustainability leaders,"[7] companies that are more adept at capturing value through sustainability along various measures that the survey asked about.

Leading the way with a strategic approach

In general, respondents from companies in the leaders' group say their companies do more on every aspect of sustainability; this is especially true in the areas of growth and risk management that, along with return on capital, are three ways in which sustainability can create value based on McKinsey research[8] (Exhibit 4). For example, 94 percent say their companies have

Exhibit 1

Companies are taking action to move beyond reputation management.

% of respondents,[1] n = 2,956

	Company is currently taking action	Company is more effective than competitors
Reducing energy use in operations	63	47
Reducing waste from operations	61	44
Managing corporate reputation for sustainability	51	57
Responding to regulatory constraints or opportunities	46	50
Reducing emissions from operations	43	48
Managing portfolio to capture trends in sustainability	38	56
Reducing water use in operations	38	46
Committing R&D resources to sustainable products	31	59
Leveraging sustainability of existing products to reach new customers or markets	28	61
Managing impact of products throughout the value chain	28	50
Improving employee retention and/or motivation related to sustainability activities	26	48
Mitigating operational risk related to climate change	22	41
Achieving higher prices or greater market share from sustainable products	18	52

[1] Respondents who answered “don’t know” or “none of the above” are not shown.

Exhibit 2

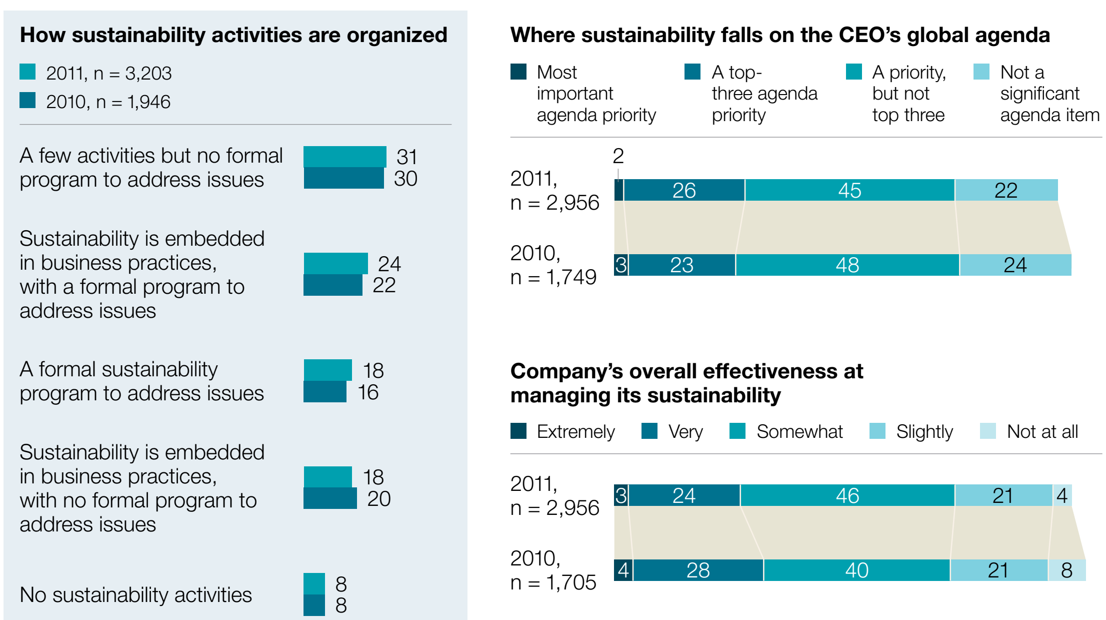
Integration of sustainability is widespread.

% of respondents, n = 2,956

Exhibit 3

There has been little change across leadership criteria.

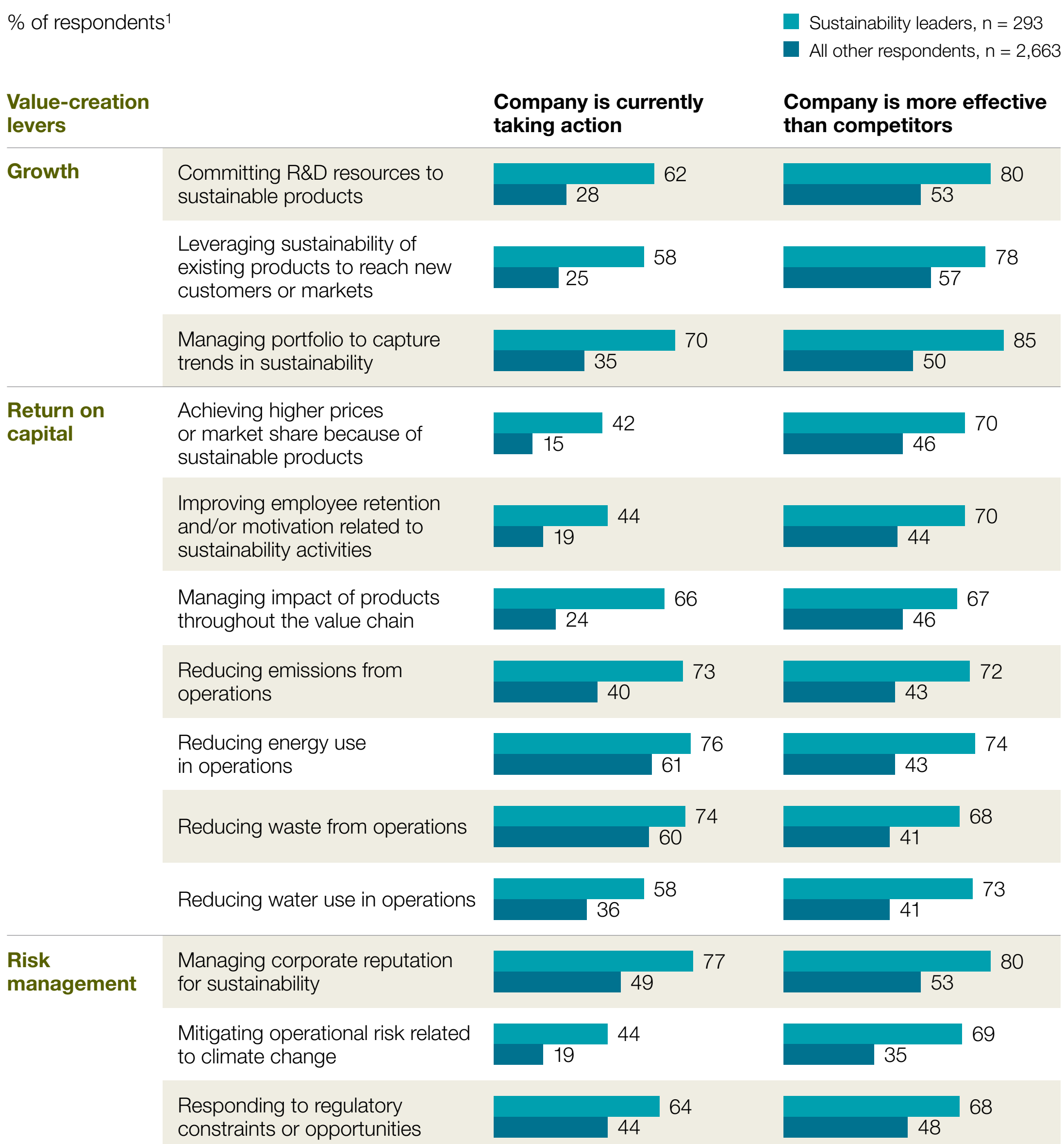
% of respondents[1]



[1] Respondents who answered "don't know" are not shown; in 2010, "don't know" was not given as an answer choice in the overall effectiveness question.

Exhibit 4

Sustainability leaders take action to create value.

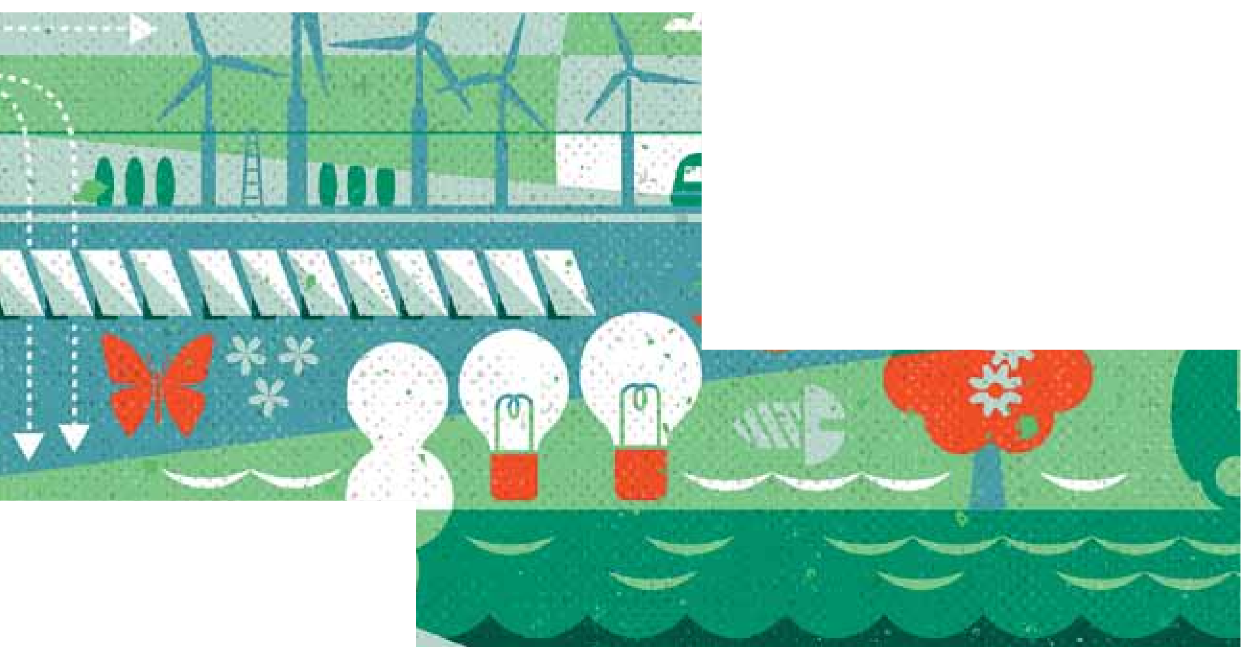


[1] Respondents who answered "don't know" or "none of the above" are not shown.

integrated sustainability into strategic planning, versus 53 percent of all other respondents. Compared with the integration of sustainability into other processes, however, the leaders' supply chains and budgets are less integrated; respondents at other companies report this pattern as well. In addition, respondents in the leaders' group are more likely than other respondents to report that their companies are pursuing each of the 13 actions related to sustainability listed in the survey, and they rate themselves more effective at taking action, relative to competitors, more often than the rest of respondents do.

Executives in the leaders' group are also more likely to say their companies are taking higher-level, more strategic actions: much higher shares of leaders are managing their business portfolios to capture trends in sustainability and committing R&D resources to sustainable products. Furthermore, just 9 percent of respondents at these companies say they have sustainability programs in place to respond to regulatory requirements, compared with 25 percent of all other respondents. Those in the leaders' group are more likely to say instead that sustainability is aligned with their goals, mission, and values (59 percent versus 28 percent of all others) and that it strengthens their competitive position (43 percent versus 24 percent).

It's likely related that executives in the leaders' group are more than twice as likely as all others to say their companies capture value from sustainability opportunities. Indeed, 30 percent say they are capturing all the value they can, versus 9 percent of all others. And while all respondents struggle with the pressure of short-term earnings performance as a barrier to value creation, the leaders struggle less with



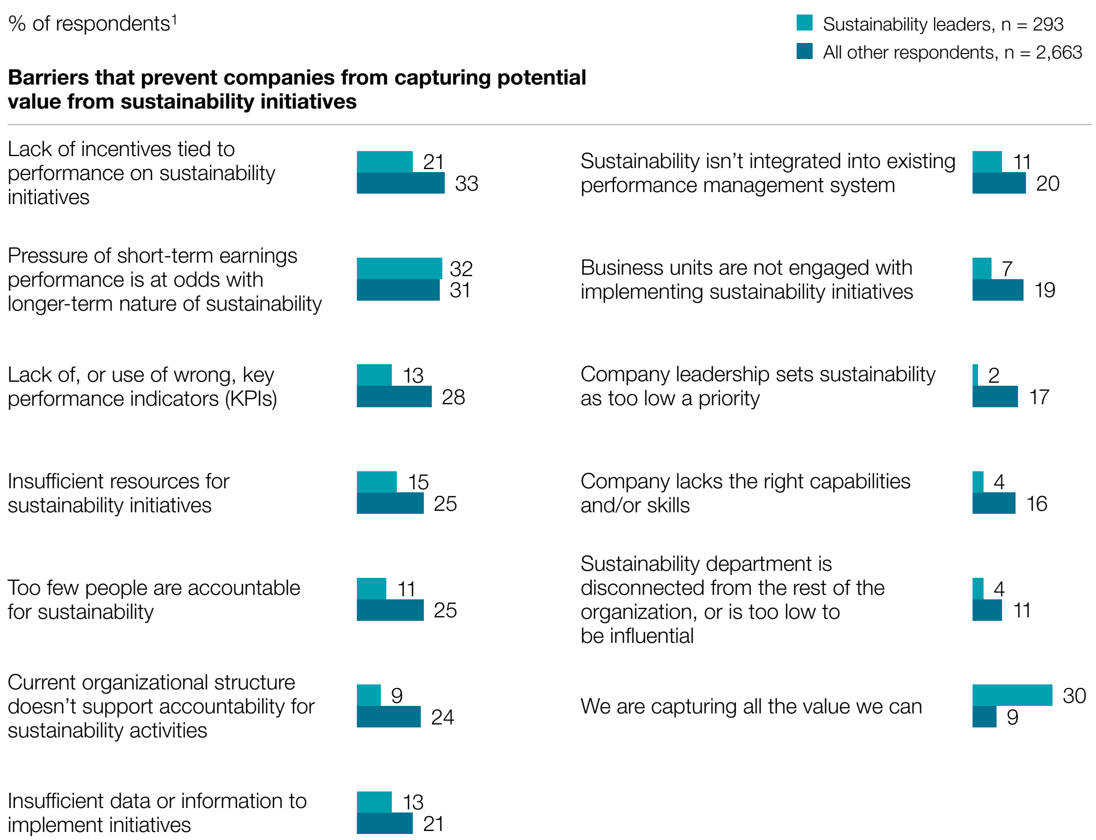
leadership, systems, and processes that enable organizations to drive value through sustainability (Exhibit 5).

Executives whose companies fall into the leaders' group also report that employees at all levels are far more knowledgeable about their companies' sustainability activities—and that sustainability is more important for attracting and retaining employees—than respondents at other companies.[9] This finding suggests that the integration of sustainability extends far beyond business practices at these companies.

It's important to note that the mix of industries represented in the leaders' group differs from the full group of respondents to the survey. A handful of industries—arguably those with a higher impact on environmental issues such as resource use and emissions, whose need to be

Exhibit 5

Leaders see fewer barriers.



[1] Respondents who answered "don't know" or "other" are not shown.

more proactive on sustainability to effectively manage their future business is more urgent—are overrepresented: energy, extractive industries, manufacturing, and transportation. Relatively few respondents from finance, retail, and business, legal, and professional services are in the leaders group.

Value creation and industry

The fact that some industries are overrepresented in the leaders' group highlights differences in emphasis on and effective management of sustainability across industries. This carries over to value creation. Overall, the relationship between sustainability and quantifiable value is still somewhat unclear, executives indicate: about one-third of respondents say they don't know how much sustainability initiatives add to shareholder value at their companies. In addition, the share that rate sustainability's contribution to short-term value as positive has only inched up since last year's survey, to 48 percent.

However, respondents do cite several different levers for value creation over the next five years. Among the top are managing corporate reputation, capturing sustainability trends in the business portfolio, and committing R&D resources to sustainable products; across industries, the relative importance of each effort varies (Exhibit 6).

Respondents at consumer and B2B companies diverge on the levers that could drive longer-term value creation. Respondents in both groups expect reputation to add a similar level of significant value, or more than 11 percent of shareholder value—indeed, it's the most frequently selected action by respondents at consumer companies. Among B2B respondents, however, the highest share (23 percent) say managing their business portfolios to capture sustainability trends adds significant value to companies in their industries, compared with 15 percent of consumer respondents. Achieving higher prices or greater market share through sustainable products, committing R&D resources, and responding to regulations has more value potential for B2B companies, executives say, while those at consumer companies see more potential in managing sustainability through the value chain, water use, and waste.

Across industries, executives also differ in how they view barriers to value creation. Those at extractive firms point to a lack of capabilities (25 percent versus 15 percent of all respondents) and lack of incentives tied to sustainability performance (42 percent versus 32 percent) as being bigger barriers than they are for respondents in other industries. Higher shares of transportation respondents than the average also cite lack of incentives (45 percent), while fewer executives at energy firms select most of the barriers presented, perhaps suggesting that they've been thinking about sustainability and value longer than others. Some in the energy sector do still cite key performance indicators (KPIs) and integrating sustainability into their performance management systems as concerns. Executives at retail firms are more likely to report barriers—except for organizational structure and a disconnected sustainability department—than the average.

Looking ahead

- Companies are not doing as much to integrate sustainability into internal communications or employee engagement as they are into other

Exhibit 6

Value varies by industry.

% of respondents

Value-creation levers		Total, n = 3,203	Industry, top three most cited activities[1] with potential to create significant value over the next 5 years
Growth	Committing R&D resources to sustainable products	17	Energy (2), high tech/telecom (3), manufacturing (1)
	Leveraging sustainability of existing products to reach new customers or markets	15	Health care/pharma (3)
	Managing portfolio to capture trends in sustainability	20	Energy (1), extractive services[2] (3), finance (2), high tech/telecom (1), manufacturing (2), retail (3), transportation (2)
Return on capital	Achieving higher prices or market share because of sustainable products	13	
	Improving employee retention and/or motivation related to sustainability activities	11	Finance (3), health care/pharma (2)
	Managing impact of products throughout the value chain	13	Retail (1)
	Reducing emissions from operations	10	
	Reducing energy use in operations	15	Extractive services (3), retail (3), transportation (1)
	Reducing waste from operations	13	Retail (2), transportation (3)
	Reducing water use in operations	9	
Risk management	Managing corporate reputation for sustainability	20	Energy (3), extractive services (1), finance (1), health care/pharma (1), high tech/telecom (1), manufacturing (2), retail (3), transportation (2)
	Mitigating operational risk related to climate change	8	
	Responding to regulatory constraints or opportunities	13	Energy (3), extractive services (2), health care/pharma (3)

[1]Numbers 1, 2, and 3, in parentheses, indicate the first, second, and third most frequently chosen activities within each industry.
[2]This group includes respondents from the coal, metal, oil and gas extraction, petroleum and natural-gas distribution, petroleum refining, and other mining subindustries.

areas of business, such as strategic planning. With 53 percent of respondents saying company performance on sustainability is at least somewhat important to attracting and retaining employees, companies that take action are more likely to gain an advantage in employee retention. The leaders are better at engaging employees on this issue (and at keeping employees at all levels more informed), suggesting that it's possible to make the most of this opportunity in sustainability.

- Our experience in working with companies in different industries on sustainability aligns with the survey findings that different industries use different levers (growth, return on capital, and risk management) to create significant value. There's no single way to create value from sustainability, so knowing where the biggest opportunities for value creation are in an industry—and where the risks and barriers lie—can serve as a guide for developing sustainability strategies.

- Coupled with the shift in reasons for pursuing sustainability, from reputation management to operational improvements and new growth opportunities, the overall high degree of integration seems to indicate that companies have become more businesslike about their sustainability agenda. Most companies, however, are still struggling to factor sustainability into the "hard" areas of their business, such as supply chain and the budget, so there is still a lot of potential to drive further integration and increased value creation. Where leaders and all others diverge most is around KPIs, organizational structure, and leadership engagement; these may be high-potential areas for companies striving to become sustainability leaders.

[1] The online survey was in the field from July 12 to July 22, 2011, and received responses from 3,203 executives representing the full range of regions, industries, tenures, company sizes, and functional specialties.
[2] Defined as a combination of environmental, social, and governance issues also known as corporate social responsibility (CSR) or corporate responsibility.
[3] In these survey results, this group includes respondents from the coal, metal, oil and gas extraction, petroleum and natural-gas distribution, petroleum refining, and other mining subindustries.
[4] The online survey was in the field in February 2010 and received responses from 1,946 executives representing a wide range of industries and regions.
[5] In 2011, the answer choice was, "building, maintaining, or improving our corporate reputation"; in 2010, the answer choice was, "maintaining or improving corporate reputation."
[6] In 2010, the answer choice was, "alignment with company's business goals."
[7] Respondents in this group say sustainability is either the most important or a top-three priority on their CEOs' agenda, that it is embedded in their companies' business practices, that their companies have a formal program to address related issues, and that their companies manage sustainability very or extremely effectively. This year's analysis is not fully comparable to the 2010 sustainability survey, because "leaders" in the most recent survey include energy industry respondents, whereas the 2010 survey excluded them from the leaders group.
[8] McKinsey's research on sustainability and value creation has allowed us to develop a framework that shows how sustainability creates value for companies with three levers.
[9] Within the leaders' group, 23 percent of respondents say their companies' performance on sustainability issues is one of the most important factors for attracting and retaining employees, while 5 percent of all other respondents say the same.

Sheila Bonini, a contributor to the development and analysis of this survey, is a consultant in McKinsey's Silicon Valley office. Copyright © 2012 McKinsey & Company. All rights reserved.

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