McKinsey on

Sustainability & Resource Productivity

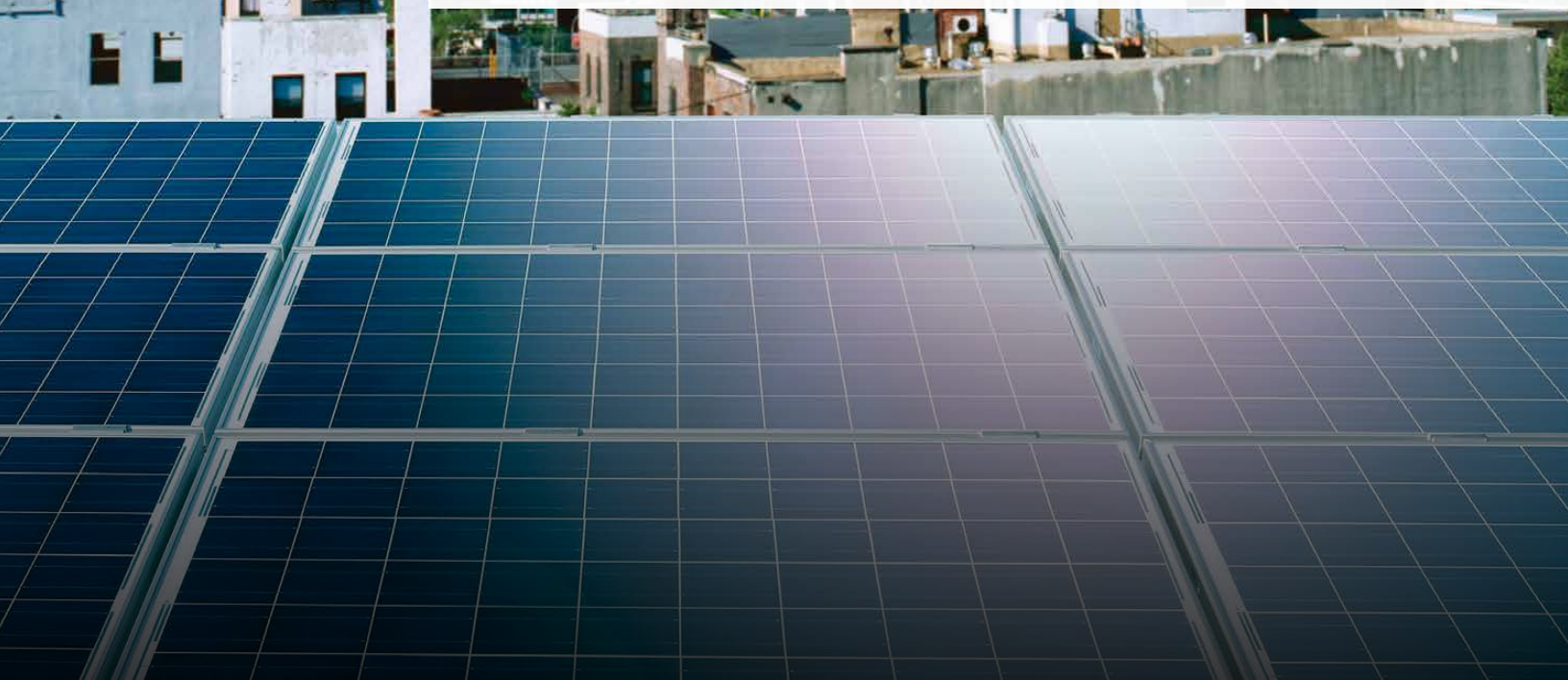
Highlights

Profits with purpose: How organizing for sustainability can benefit the bottom line

Riding the resource wave: How extractive companies can succeed in the new resource era

Brave new world: Myths and realities of clean technologies

Sustainability & Resource Productivity July 2014



McKinsey on Sustainability & Resource Productivity is written by consultants from across sectors and geographies, with expertise in sustainability and resource productivity.

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

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Introduction

Tomas Nauclér, Scott Nyquist, and Jeremy Oppenheim

"Revolution" is an overused term, and sometimes revolutions only become obvious after the fact. That said, we are confident in saying that global business is in the midst of a revolution. It's unfolding in many different ways, particularly in the production, management, and use of energy and natural resources. If this is not immediately clear, it is because the process is gradual. But businesses cannot ignore what is happening: this revolution will bring great challenges, as well as great opportunities, and play a major role in shaping the 21st-century global economy.

In the first edition of *McKinsey on Sustainability & Resource Productivity*, published in Summer 2012, we argued that "if the scale of the resource challenge is unprecedented, so, too, is the know-how available to address it." In this edition, we show how many companies are deploying that knowledge and building new management capabilities. We do not address policy issues in depth, because there is a great deal that business can do without waiting for legal or regulatory action. The opportunities to improve sustainability and resource productivity will continue to build, regardless of what governments do.

It is impossible to say what the ultimate outcome will be: revolutions, by their nature, are unpredictable. But we can say that global currents are running strongly in the direction of rapid improvements in environmental stewardship and resource use. This is not a matter of "greenwashing" to appease critics and activists. It is becoming a critical part of business strategy and operations for two reasons. First, the addition of 2.5 billion people to the middle class, and higher and more volatile resource prices, means that business as usual simply will not be good enough to maintain profitability. Second, there are growth opportunities that smart companies can capture. Sustainability is increasingly just business—big business. Companies and countries are finding they cannot meet their growth and profit objectives without a commitment to resource productivity.

In this second issue of *McKinsey on Sustainability & Resource Productivity*, we seek to establish the value of sustainability and to demonstrate how these opportunities can (and are) being captured in a range of industries. As McKinsey director Matt Rogers and alumnus Stefan Heck put it in their new book, *Resource Revolution: How to Capture the Biggest Business Opportunity in a Century* (New

Harvest, April 2014), "We confront an opportunity that will reframe the world's economy and create opportunities for trillions of dollars in profits."

That sentence informs the content of this compendium. Taken together, the seven articles suggest ways that companies can adapt to global trends, profit from them, and improve human and environmental well-being along the way—what we mean by "sustainability." Is that a utopian idea? Or an implausible one? Not at all.

In our conversations with global executives, these issues come up more and more often. Sustainability is becoming a core principle of how some of the world's leading companies plan for the future and organize their operations. Moreover, the level of sophistication, managerial skill, and knowledge of sustainability is rising fast. Thanks to the integration of digital and industrial technologies and that harsh but invaluable taskmaster—experience—companies simply know more about how to produce and use resources productively. Productivity metrics are increasingly refined; so is the evaluation of risk and returns. And failure has been its own reward, forcing out weaker players and identifying the best, most productive business models.

Inside *McKinsey on Sustainability & Resource Productivity*

We open with a wide-ranging article, "Profits with purpose: How organizing for sustainability can benefit the bottom line," based on interviews with dozens of executives. Sheila Bonini and Steven Swartz look at why leading companies are bringing sustainability principles into practice. The reason, one leader told us, is simple: "Leading on sustainability is driven largely by our desire to grow." The article details how to apply performance-management principles to sustainability and shows how doing so can create value.

That idea is central to *Resource Revolution*. Heck and Rogers note that business leaders require new management skills to compete in markets characterized by tight resource constraints, increasing pollution pressures, and rising customer expectations. It's a perfect storm of circumstance—no wonder many business leaders are feeling beleaguered and more than a little anxious. In an excerpt from the book, the authors address a subtle and often-overlooked aspect of the sustainability journey: human capital. Companies that seek to get and stay ahead need to find the right people with the right skills; conventional practices and talent may not be enough. As the authors put it, "New talent needs to be found in new places." Competing in a world where information technology is reshaping industrial technology may require reaching into adjacent industries and emerging-market universities.

Extractive companies will face specific issues: a growing share of natural resources will need to be drilled or dug out of places with unstable business and legal structures. The risks are extraordinary, as Pablo Ordorica Lenero and Fraser Thompson explain in "Riding the resource wave: How extractive companies can succeed in the new resource era." They estimate that to find new sources of oil, copper, and other commodities, and to replace those that are running out, at least $11 trillion will be required. To protect those investments, the authors argue that companies need to establish a new deal with local communities by putting economic development at the heart of strategy.

Several articles consider energy-related questions. They share a common theme: the future is bright for the energy sector, including renewables.

"Brave new world: Myths and realities of clean technologies" takes on the skeptics and demonstrates

that the cleantech sector is on the verge of the big time. Cleantech is going through a difficult phase, but other emerging technologies—think of the car, the semiconductor, and even the elevator—also had teething problems. It is a natural part of the maturation process. "Cleantech is no passing, unprofitable fad," conclude Sara Hastings-Simon, Dickon Pinner, and Martin Stuchtey. "The sources of underlying demand—a growing middle class around the world, wanting clean air and water, and resource constraints—aren't going away, and cleantech is pivotal in dealing with both."

In "Unconventional wisdom: Fracturing enters a new era," Parker Meeks, Dickon Pinner, and Clint Wood look at the dynamics of a fossil fuel–based form of energy—gas and oil derived from shale resources. Almost all of this is being drilled in the United States, where shale-based production has upended the energy market faster and more profoundly than anyone might have guessed even five years ago. There are, however, environmental concerns about drilling for shale energy. This article explains four technologies that could help to address these concerns and possibly further disrupt global energy markets.

Next, we turn to solar energy, which has hit some rough patches of late, with numerous high-profile closures and bankruptcies. At the same time, however, deployments continue to grow; solar, for example, has grown by 57 percent a year since 2006, due to sharply lower module costs and innovative business models. It will not be long, say David Frankel, Kenneth Ostrowski, and Dickon Pinner, authors of "The disruptive potential of solar power," before solar will be in striking distance, in economic terms, of traditional energy sources such as coal and gas.

Finally, the growth of bioenergy in Europe has not been as fast as expected, but that could change, according to Marco Albani, Anja Bühner-Blaschke, Nicolas Denis, and Anna Granskog in "Bioenergy in Europe: A new beginning—or the end of the road?" Bioenergy offers a promising way to make the transition from coal to renewables, and new technologies such as torrefaction and pelletization could improve efficiency markedly—and thus improve bioenergy's competitive position.

The thread that runs through the contents of this issue is a preference for the down to earth, the empirical, and the rigorous. Sustainability could be a profound force in shaping the future of business—but only if business leaders believe it will also be a profoundly profitable approach. We believe these articles make that case.

We will follow up on these and related ideas in future issues of *McKinsey on Sustainability & Resource Productivity* and on mckinsey.com. And of course, we look forward to continuing our efforts on the ground. This business revolution is a work in progress—but a future of solid and sustainable economic growth is a goal well worth pursuing. ■

Tomas Nauclér is a director in McKinsey's Stockholm office, **Scott Nyquist** is a director in the Houston office, and **Jeremy Oppenheim** is a director in the London office; they serve as global leaders of the sustainability and resource productivity practice.

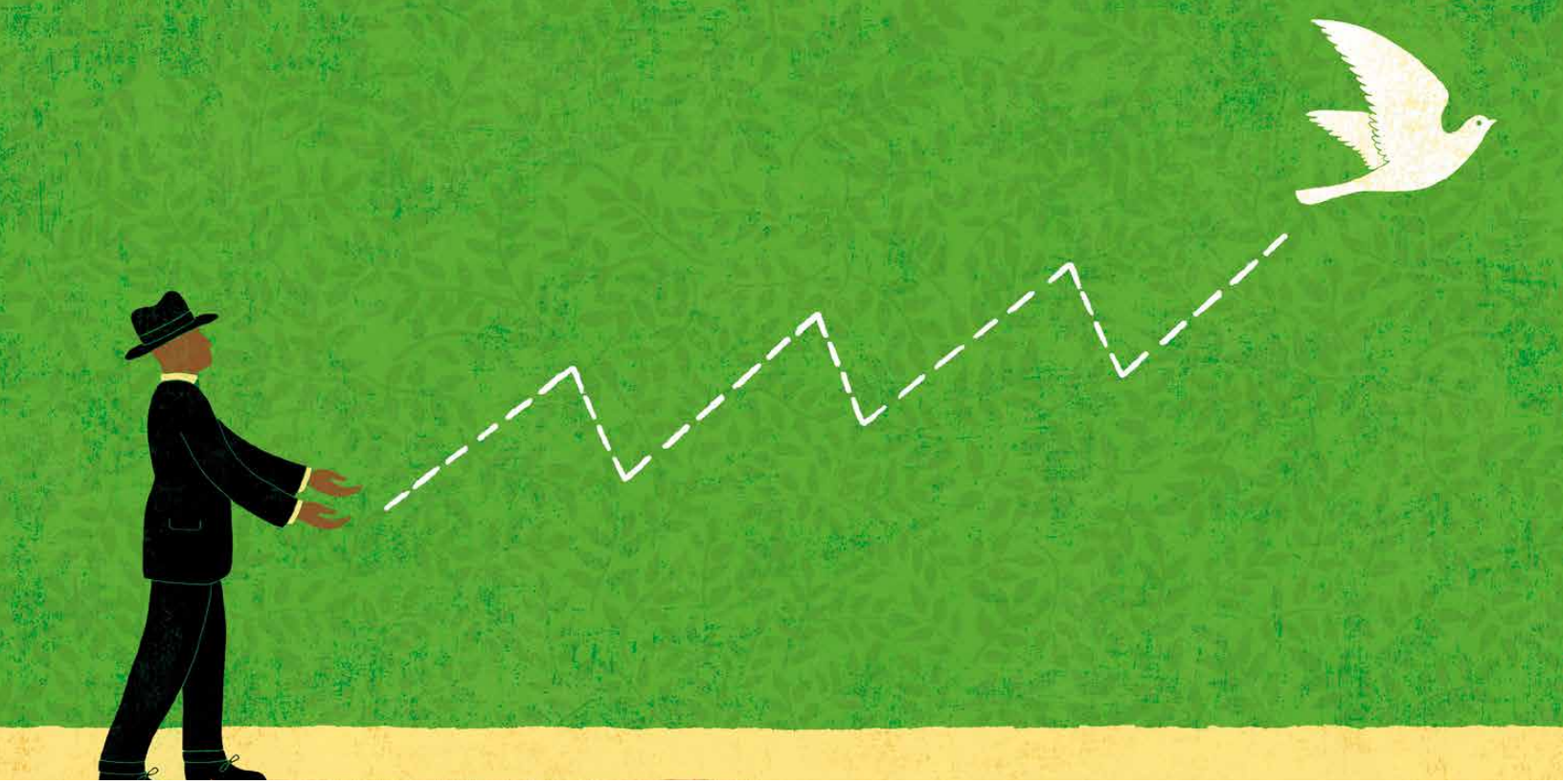


Illustration by James Steinberg

Profits with purpose:
How organizing for sustainability can benefit the bottom line

Becoming a sustainability leader requires big changes, but the effort is worth it—in both environmental and economic terms.

Sheila Bonini and Steven Swartz

Sustainability—a term we use to describe the business programs, products, and practices built around environmental and social considerations—is often seen as a luxury investment or a public-relations device. We think that view is cynical and increasingly untenable. In fact, a growing body of evidence indicates that sustainability initiatives can help to create profits and business opportunities.

McKinsey recently launched a knowledge collaboration with more than 40 companies to understand their sustainability challenges (see sidebar "How we did it"). We sought to develop a set of practical recommendations for companies to capture value from sustainability. In doing so, we found that leading companies pursue sustainability because it has a material financial impact. The value at stake from sustainability-related issues—from rising raw-material prices to new regulations—is substantial. "Leading on sustainability is driven largely by our desire to grow," one technology executive told us. "The industry changes so rapidly that we need flexibility."

Success requires both a structured program to improve performance and a sustainability philosophy. Such efforts often get stuck, especially at the business-unit level, when managers have other priorities. Moreover, given that less than 5 percent of companies do a good job of providing financial incentives or career opportunities for sustainability performance,[1] people may not see the pursuit of sustainability as a way to a build their career.

In this article, we discuss the research about the economic benefits of sustainability. Then we detail the organizational practices businesses need to follow to make this work. Finally, we show how moving in this direction can create value. Sustainability is a long-distance journey; the evidence is growing that it is one worth taking.

Sustainability and value creation

Over the past 20 years, the idea of corporate sustainability has become part of mainstream business discourse. Companies in many industries issue sustainability or corporate-social-responsibility reports; executives everywhere pledge allegiance to the idea. Even so, the concept still carries considerable baggage. In a recent report for the UN Global Compact, 84 percent of the 1,000 global CEOs surveyed agreed that business "should lead efforts to define and deliver new goals on global priority issues." But only a third said "that business is doing enough to address global sustainability challenges."[2]

To understand the role of sustainability initiatives in business, we looked at academic studies, investor strategies, and public data on resource efficiency.

We also surveyed and interviewed companies with successful sustainability programs. Our conclusion: sustainability programs are not only strongly correlated with good financial performance but also play a role in creating it.

According to research by Deutsche Bank, which evaluated 56 academic studies, companies with high ratings for environmental, social, and governance (ESG) factors have a lower cost of debt and equity; 89 percent of the studies they reviewed show that companies with high ESG ratings outperform the market in the medium (three to five years) and long (five to ten years) term.[3] The Carbon Disclosure Project found something similar. Companies in its Carbon Disclosure Leadership Index and Carbon Performance Leadership Index, which are included based on disclosure and performance on greenhouse-gas (GHG) emissions, record superior stock-market returns. Companies in the Carbon Disclosure Leadership Index substantially outperformed the FTSE Global 500[4] between 2005 and 2012. Companies in the other index also did better.[5]

How we did it

To create the factual basis for this article, McKinsey canvassed the extensive literature on the organizational practices and financial effects of corporate-sustainability initiatives. We also did our own analysis of resource-efficiency and financial-performance data.

Then we interviewed executives from 40 companies from various sectors, including oil and mining, sneakers, soup, cosmetics, and telecommunications. Research participants were chosen because they had outperformed their industry average across financial and sustainability-performance metrics. We also interviewed experts from universities, nongovernmental organizations, and the financial sector.

Finally, we conducted a sustainability-assessment survey, the seventh of this kind, of almost 40 companies, exploring why and how companies are addressing sustainability and to what extent executives believe it can and will affect their companies' bottom line. We benchmarked the results of these 340 respondents against McKinsey's global-executive-survey database of more than 4,000 companies.

Even more intriguing is recent research by three economists (two from Harvard and one from the London Business School) suggesting that sustainability initiatives can actually help to improve financial performance. The researchers examined two matched groups of 90 companies. The companies operated in the same sectors, were of similar size, and also had similar capital structures, operating performance, and growth opportunities. The only significant difference: one group had created governance structures related to sustainability and made substantive, long-term investments; the other group had not.

According to the authors' calculations, an investment of $1 at the beginning of 1993 in a value-weighted portfolio of high-sustainability companies would have grown to $22.60 by the end of 2010, compared with $15.40 for the portfolio of low-sustainability companies. The high-sustainability companies also did better with respect to return on assets (34 percent) and return on equity (16 percent).[6] The authors conclude that "developing a corporate culture of sustainability may be a source of competitive advantage for a company in the long run." As careful academics, they note that this research was not done in laboratory conditions, and therefore they cannot claim definitive proof of causality: "confounding factors might exist." But they clearly believe that they are onto something—that it is the sustainability policies themselves that were responsible for the better financial performance of the high-sustainability group.

Additionally, there is evidence that being more efficient at using resources is a strong indicator of superior financial performance overall. We created a metric (the amount of energy, water, and waste used in relation to revenue) to analyze the relative resource efficiency of companies within a sector. On that basis, we found a significant correlation (95 to 99 percent confidence) between resource efficiency and financial performance in sectors as diverse as food products, specialty chemicals, pharmaceuticals, automotive, and semiconductors. In each sector, there were also a small number of companies that did particularly well, and these were the ones that had taken their sustainability strategies the furthest.

No wonder, then, that investors are increasingly comfortable with the idea of putting their money into socially responsible investment. In the United States, such investment grew by 486 percent between 1995 and 2012, outpacing the broader universe of managed US assets, which grew by 376 percent over the same period.[7] In the last three years, socially responsible investment has grown by 22 percent; it now accounts for more than 11 percent of all assets under management in the United States ($3.74 trillion). Globally, more than $13 trillion is invested in assets under management that incorporate ESG metrics.[8]

With trillions of dollars in play, the professionals have taken notice. The quality and availability of sustainability data has improved, for example, as mainstream data providers such as Bloomberg, MSCI, and Thomson Reuters have begun to offer sustainability-performance data in much-improved formats.[9]

As a result, investors are able to go well beyond "negative screening" (not investing in certain kinds of companies or industries). This approach was inherently limited, and did not lead to higher returns. Now, investors are more sophisticated; they are seeking above-market returns by investing in best-in-class sustainable companies.

Osmosis Investment Management, for example, assesses companies using a proprietary methodology based on relative resource productivity; it has built a portfolio of large companies that has outperformed the market over the past eight years. Goldman Sachs's GS Sustain assesses both market

competitiveness and management quality with respect to environmental, social, and governance performance. Generation Investment Management uses a global research platform to integrate sustainability into investing, taking into account key global issues such as climate change and poverty. All three have delivered above-market returns.

Applying performance management to sustainability

Although sustainability is usually somewhere on the corporate agenda, there are often problems with execution, even in the most committed companies. To find and deliver real strategic opportunities, leaders should consider applying four organizational practices. These principles aren't new—they are associated with performance management, in particular—but they are not often used to address sustainability challenges.

Identify issues and set priorities

Two-thirds of companies in a representative sample from the S&P 500 have more than 10 different sustainability focus topics, and some have more than 30. That's too many: it's hard to imagine how a sustainability agenda with this many focus areas can break through and get the necessary buy-in to be successful. While there are several areas that companies need to comply with, it's better to concentrate on a few strategic themes. Coca-Cola, for example, has set for itself a strategy it calls "me, we, the world," which encompasses its approach to improving personal health and wellness, the communities in which it operates, and the environment. Within this strategy, the company reports making material, tangible progress on metrics related to three specific areas of focus: "well-being, women, and water." The company does not ignore other issues such as climate change and packaging, but it has made it clear that this is where it wants to lead.

To develop a clear set of priorities, it is important to start by analyzing what matters most along the entire value chain, through internal analysis and consultations with stakeholders, including customers, regulators, and nongovernmental organizations. This process should enable companies to identify the sustainability issues with the greatest long-term potential and thus to create a systematic agenda—not a laundry list of vague desirables.

After extensive consultations, for example, BASF, the global chemical company, put together a "materiality matrix." As Exhibit 1 shows, the chart maps the importance of 38 sustainability-related issues based on their importance to BASF and its stakeholders. (Other companies use similar matrixes.) Such exercises help companies to recognize the most important issues early and then integrate them into management.

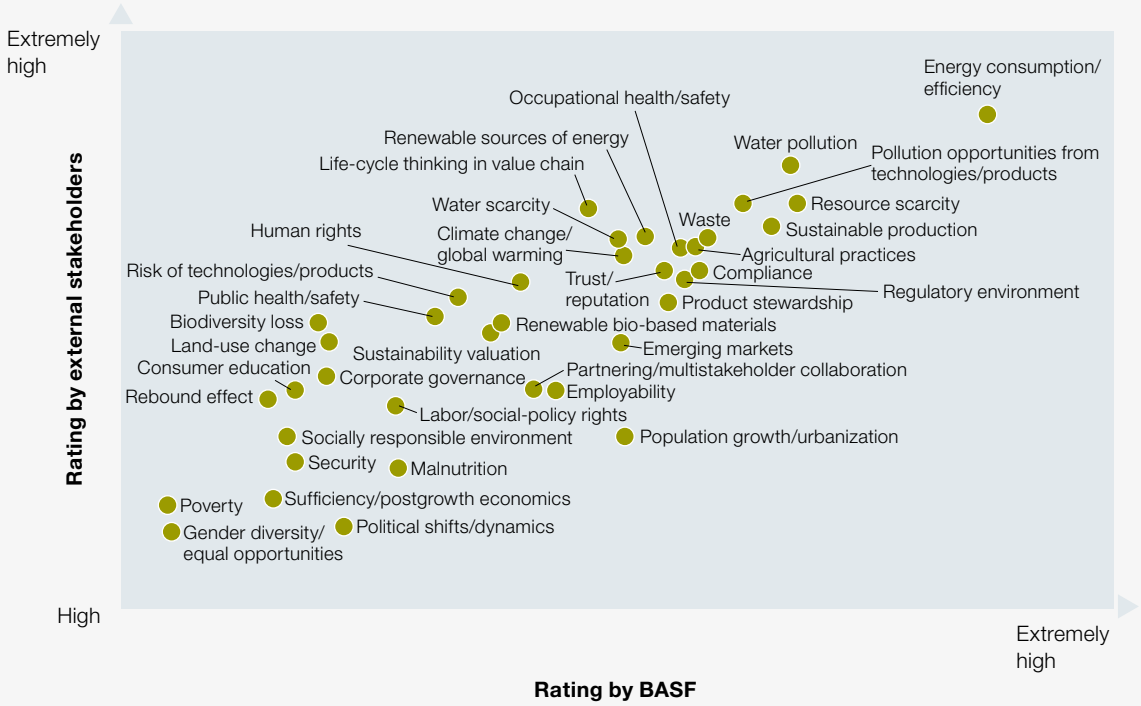
Once the priorities are identified—having no more than three to five is best—the next step is to develop a fact base from which to create a detailed financial and sustainability analysis. Siemens, for example, identified one priority as helping customers to reduce their carbon impact and has created an environmental portfolio of green products and services, including energy efficiency, renewable energy, and environmental technology. In 2013, these generated revenues of €32.3 billion and saved 377 million metric tons of carbon emissions.

Set goals

After completing the initial analysis, translate this information into external goals that can be distilled into business metrics. These goals should be specific, ambitious, and measurable against an established baseline, such as GHG emissions; they should also have a long-term orientation (five years or more) and be integrated into business strategy. And their intent should be unmistakable. One company stated as a goal: "Reduce the impact of our packaging on the environment."

Getting more specific is even better. (Reduce how much? By when? Compared to what?) Here is a

Exhibit 1 **One company maps its sustainability priorities.**



Source: Company website

stronger approach, from a sustainability leader: "Reduce 2005 carbon dioxide emissions by half by 2015." It is important to build internal support to meet these goals. Our analysis found that the companies that excelled at meeting sustainability goals made sure they involved the business leaders responsible for implementing them from the start. One global manufacturer we interviewed announced in 2010 that it would reduce GHG emissions and energy consumption by 20 percent. To do so, it set up energy assessments and energy-management plans, established global programs to optimize procurement and building standards, and began to use renewable energy where possible.

Setting ambitious external goals motivates the organization, forces resources to be allocated, and promotes accountability. An analysis of companies that are part of the Carbon Disclosure Project found that those that set external goals did better on cutting emissions—and also had better financial returns on such investments. Stronger goals, then, seem to encourage innovation; people may feel more motivated to find ways to meet them. Lack of goals is a sustainability killer: "what gets measured gets managed" is as true of sustainability as it is of any other business function. And yet it is not happening. We estimate that only one in five S&P 500 companies sets quantified, long-term sustainability goals; half do not have any.

Show the money

Almost half (48 percent) of survey participants said that the pressure of short-term earnings

performance is at odds with sustainability initiatives. A constructive response is to make the case that sustainability can pay for itself—and more.

Senior leaders will give sustainability lip service, not capital, if they do not see financial benefits. "Sustainability metrics can seem like random numbers and don't do much," one chemical-industry executive told us. "For our businesses, sustainability efforts have to compete directly with other demands, which means that financial impact is key." This needs to be done rigorously, reinforced with fully costed financial data, and delivered in the language of business.

Alcoa, a US-based global metals company, incorporates sustainability into how it does business—and how it talks about the company to stakeholders. In one investor presentation, for example, it detailed how its supply-chain simplification sharply lowered labor and energy costs as well as cut GHG emissions, but it was the financial effects that took front and center.

To emphasize that sustainability is a business issue, boards should review goals at every meeting. For each project, specific executives should be accountable for costs and effectiveness. This is, of course, much easier said than done. At Intel, for example, although business leaders were interested in saving water, they saw little financial justification to do so: water was cheap. Advocates of the initiative were able to calculate that the full cost of water, including infrastructure and treatment, was much higher than the initial estimates. Saving water, they argued, could therefore create value in new and unexpected ways. On that basis, Intel went ahead with a major conservation effort. The company now has a finance analyst who concentrates on computing the financial value of sustainability efforts.

Making the business case for sustainability might sound obvious, but apparently it isn't. Most companies do not communicate the financial performance of sustainability; only a quarter said that the financial benefits of these efforts were well understood.

Sustainability initiatives can be challenging to measure because savings or returns may be divided across different parts of the business, and some benefits, such as an improved reputation, are indirect. It is important, then, not only to quantify what can be quantified but also to communicate other kinds of value. For example, an initiative might improve the perception that important stakeholders, such as consumer groups, nongovernmental organizations, or regulators, have of the company. This can help to build consumer loyalty, nurture relationships, and inform policy discussions.[10]

Create accountability

The top reason that respondents gave for their companies' failure to capture the full value of sustainability is the lack of incentives to do so, whether positive or negative. According to the UN Global Compact, only 1 in 12 companies links executive remuneration to sustainability performance; 1 in 7 rewards suppliers for good sustainability performance. Among the executives we surveyed, 38 percent named lack of incentives and 37 percent named short-term earnings pressure for poor results; about a third said the lack of key performance indicators and not enough people being held accountable were problems.

In this area, a number of companies exhibit good practices from which others can learn, such as tracking data and reporting indicators, including carbon emissions, energy use, water use and waste, and recycling. Even these companies, however, are still working on integrating sustainability-

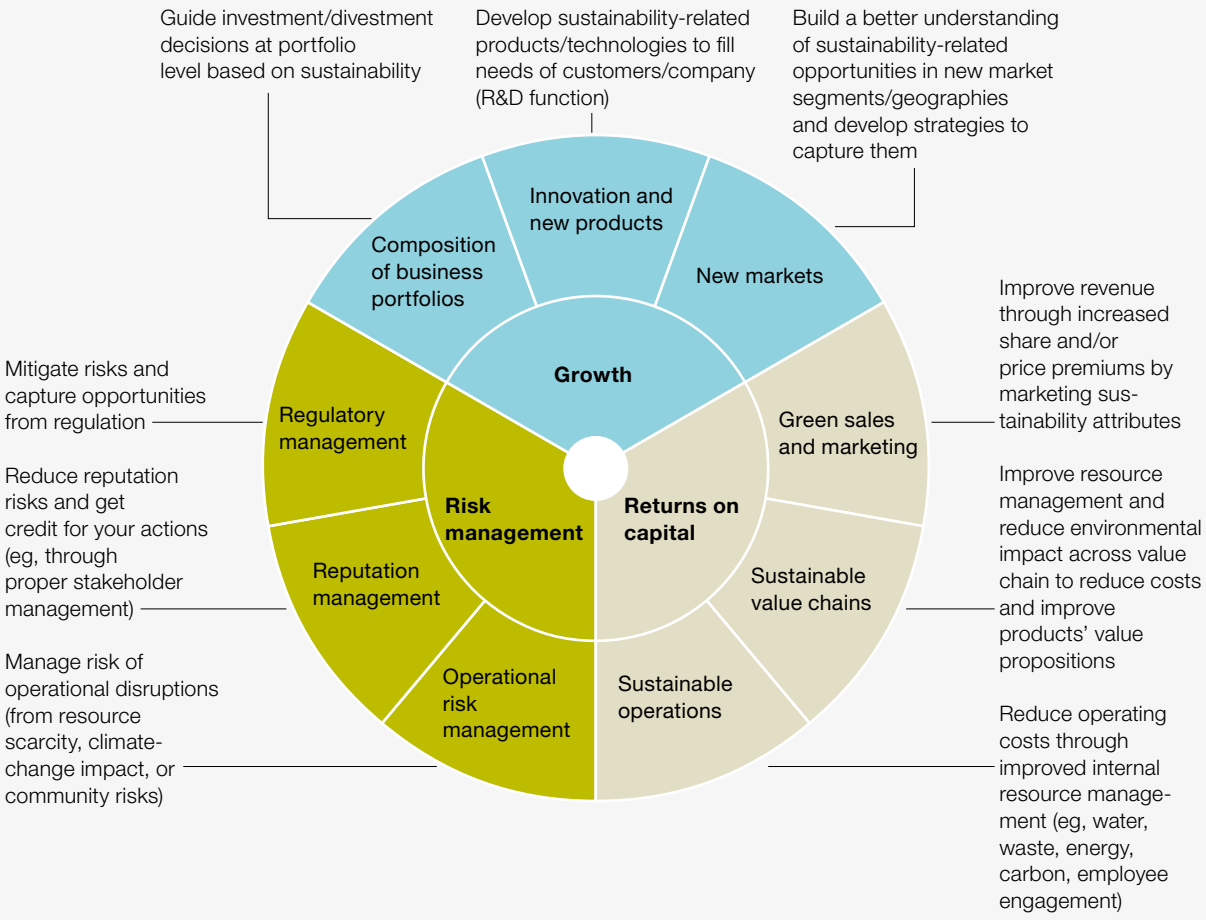
performance indicators into individual incentives; the only area where most have managed this is with regard to worker safety.

Adidas shows one useful approach. The sporting-goods company breaks down its long-term goals into shorter-term milestones. Its suppliers, for example, are given strategic targets three to five years ahead, as well as more immediate goals to encourage them to focus. The beer company MillerCoors does something similar. It tracks and quantifies progress in ten areas, including water, energy, packaging, and human rights, using its own sustainability-assessment matrix. The idea is for MillerCoors to understand its performance, in quantitative terms, in areas that are often difficult to quantify.

How sustainability can create value

All the companies we interviewed are pursuing sustainability agendas, and most are making

Exhibit 2 **Companies are pursuing sustainability in a way that creates value.**



Source: Sheila Bonini and Stephan Görner, "The business of sustainability: McKinsey Global Survey results," Oct 2011, mckinsey.com

aggressive public commitments. Is this just green window dressing? Our analysis says no. Companies are addressing important environmental and social issues in a way that creates value. In previous work, we outlined how leading companies use sustainability initiatives across each of the areas shown in Exhibit 2 to manage risk and to improve growth and returns on capital.[11] In this research, we sought to understand how successful companies did it. What these interviews demonstrated is that companies that built sustainability into their operations saw immediate benefits, and that gave them the momentum to do even more, creating the conditions for long-term success.

These leaders told us that they pursue sustainability because they believe it has a material financial effect. The value at stake from sustainability issues can be as high as 25 to 70 percent of earnings before interest, taxes, depreciation, and amortization (Exhibit 3). Sustainability leaders can and do change their business models to respond to major discontinuities, such as higher natural-resource prices or changes in demand, that create material risks to the business—or opportunities.

Manage risk

More than 90 percent could point to a specific event or "trigger" that got them started, such as consumer pressure or a jump in the price of commodities. More than half cited long-term risks to their business: 26 percent mentioned mitigating reputational risk, and 15 percent each said avoiding regulatory problems and eliminating operational risks.

Two candy giants, for example, are looking to guarantee future supplies of cocoa, an essential ingredient in chocolate, in part by improving the sustainability of their suppliers. Mars is helping smallholder cocoa farmers in the Cote d'Ivoire to increase their productivity by providing access to improved planting materials, fertilizers, and training. It is also investing in research that will help increase the quality and performance of cocoa plants. Hershey's sends out experts to teach

Exhibit 3 **Our research shows that the value at stake from sustainability challenges is substantial.**

Impact	Examples	Potential impact, % of EBITDA[1]
Regulation/ reputation	Restricted license to operate Reputational damage based on perceived misuse of resources	70
Rising operating costs	Raw-material costs driven up by supply/demand True cost of water or carbon reflected in prices	60
Supply-chain disruption	Production delay or cancellation due to lack of access Especially significant for "local" resources—water, power	25

[1]Earnings before interest, taxes, depreciation, and amortization.

Introducing the circular economy

Martin Stuchtey and Helga Vanthournout

In the traditional linear economy, inputs go in and waste comes out. The circular-economy model, by contrast, is based on reusing resources, regenerating natural capital, and decoupling resource use from growth. We have devoted considerable attention to the circular economy; we believe it has tremendous potential for companies, for economies, and for the environment.

The process begins with design, specifically by making a distinction between a product's consumable and durable components. In the circular economy, consumables are designed so that they can safely reenter the biosphere; one way to do this is to use pure materials that can be easily separated and "cascaded" to the next use. H&M, the global apparel retailer, for example, collects old clothes and works with I:CO, a reverse-logistics provider, to sort them. The clothes are then sold into the secondhand-apparel market or substituted for virgin materials in other products, and the remaining textiles become fuel to produce electricity.

For durable components, such as metals, the preferred options are reuse, remanufacturing, or refurbishment. Such practices have long been the norm for engines and building equipment but are now becoming common as well for photocopiers, power tools, mobile phones, and passenger cars. More and more industries are discovering that taking back products can reduce costs and strengthen customer relationships. Doing so, however, requires a fundamental shift in thinking—seeing consumers as users and offering them performance, not products.[1]

This development is well under way. Car-sharing services are an example; they sell mobility, not vehicles, and each car has multiple users, not a single owner. Philips, the Dutch manufacturer, offers another example. Noticing that major customers were reluctant to make large investments in light of the financial crisis and the rapid shifts in technology, the company began to offer lighting as a service, not a product. "Customers only pay us for the light, and we take care of the technology risk and investment," explains CEO Frans van Houten.

Toward a new industrial revolution

Why should businesses move toward a circular-economy model? First, because global economic pressures, such as rising resource prices and a fast-growing global consuming class, are changing the status quo. Second, because it's good for business. The savings in materials alone could top $1 trillion a year. We believe that companies that adopt circular-economy principles will outcompete other actors in a world where scarce resources expose companies to high costs and unforeseeable risks.

The real payoff will come only when multiple players from many sectors come together to figure out how to reconceive manufacturing processes and the flows of products and materials. Capitalizing on these opportunities will require new ways of working. But the benefits, to both business and the environment, are well worth the costs.

[1] For more, see Thomas Fleming and Markus Zils, "Toward a circular economy: Philips CEO Frans van Houten," *McKinsey Quarterly*, February 2014, mckinsey.com.

Martin Stuchtey is a director in McKinsey's Munich office, and **Helga Vanthournout** is a specialist in the Geneva office.

best-practice farming methods; its CocoaLink mobile-phone service offers advice and market information. Hershey's is also addressing child labor and school-attendance rates through local initiatives. Both companies aim to have their entire cocoa supply sustainably sourced by 2020.

Take advantage of new business opportunities

Almost half of those interviewed (44 percent) mentioned business and growth opportunities as a reason to get started on sustainability. A number of different business models that embed sustainability are emerging. Electric utilities, for example, are working on ways to make money by helping consumers cut their energy use.

Sustainability also offers an interesting way to scope out product innovations that use fewer resources or that meet specific social needs. Redesigning products and services around sustainability can drastically increase profits or reduce costs (see sidebar "Introducing the circular economy"). Unilever, for example, changed the shape of a deodorant to use less plastic and created a concentrated laundry product that sharply reduces the use of water—innovations they might not have found had they not been thinking about sustainability. DuPont, a diversified science company, began its sustainability operations more than 20 years ago as a matter of risk reduction, but these have turned into a major profit center. Since 2011, the company has invested $879 million in R&D for products with quantifiable environmental benefits. DuPont has recorded $2 billion in annual revenue from products that reduce GHG emissions and an additional $11.8 billion in revenues from nondepletable resources.

Improve returns on capital

Whether the trigger for commitment to sustainability was risk management or growth, most companies started by improving natural-resource management. In fact, 97 percent of the research participants were taking action on energy efficiency, 91 percent on waste, and 85 percent on water.

For example, Bayer, the German health and agriculture company, developed a resource-efficiency check to improve operations by using by-products and reducing wastewater. The company expects the process to save more than $10 million a year, and this is not unusual; 79 percent of Fortune 500 companies reporting to the Carbon Disclosure Project had higher returns on their carbon investments than their overall portfolio. Paradoxically, taking such actions may be easier to do in companies that have been slow to embrace sustainability. There are almost certainly "quick wins" ripe for the picking that can bring tangible results and create momentum to do more.

An emphasis on sustainability can also reveal opportunities for process innovations. It is not uncommon for companies to complain that different units do not collaborate well. By its cross-functional nature, sustainability brings different divisions together and provides a common motivation; the result can be new, profitable ideas. Lockheed Martin, for example, wanted to reduce wood waste from packing crates. But as it started on this one modest initiative, it found other production improvements that reduced overhead and resulted in more than $7.5 million in savings from a $240,000 investment. Many of the companies interviewed had similar innovation stories but often did not measure the results or attribute them to sustainability. That may help to explain why there is still skepticism about whether sustainability is worth it.

To succeed, sustainability efforts need to be an organizational priority, with clear support from leadership. This is not easy. Fewer than half of the leaders with whom we spoke thought they had a sustainability philosophy that permeates their day-to-day operations, even though their companies considered sustainability one of their top priorities.

Chief sustainability officers have an important role to play in this regard. Although they often do not have the authority to dictate the agenda, they can influence it. This means translating the promise of sustainability into value propositions that make sense to different parts of the company. This takes time and effort. But there is no alternative: for sustainability to spread, business units need to own their part of the agenda.

Becoming a sustainability leader can pay off, but it is not easy. "It's a perception issue," one executive told us. "We need to show that it makes good business sense to get over the hurdle." Fair enough—and the evidence is building that for the best companies, this standard is within reach. ■

[1] In February 2014, McKinsey surveyed 3,344 executives about their companies' sustainability activities. The respondents represented the full range of regions, industries, company sizes, tenures, and functional specialties.

[2] *The UN Global Compact–Accenture CEO Study on Sustainability 2013: Architects of a Better World*, Accenture and United Nations Global Compact, 2013, unglobalcompact.org.

[3] Mark Fulton et al., *Sustainable Investing: Establishing Long-Term Value and Performance*, DB Climate Change Advisors, Deutsche Bank Group, 2012, dbadvisors.com.

[4] FTSE Global Equity Index Series, as of January 1, 2013.

[5] *Sector insights: what is driving climate change action in the world's largest companies—Global 500 Climate Change Report 2013*, Carbon Disclosure Project, 2013, cdp.net.

[6] Robert G. Eccles, Ioannis Ioannou, and George Serafeim, "The impact of a corporate culture of sustainability on corporate behavior and performance," Harvard Business School working paper, HBS Working Knowledge, Number 12-035, November 2011, hbs.edu.

[7] *2012 Report on Sustainable and Responsible Investing Trends in the United States*, US SIF Foundation, Forum for Sustainable and Responsible Investment, 2012, ussif.org.

[8] *2012 Sustainable Investment Review*, Global Sustainable Investment Alliance, 2013, gsi-alliance.org.

[9] For example, to track environmental, social, and governance (ESG) factors, Bloomberg has an ESG valuation tool, MSCI has the ESG Impact Monitor, and Thomson Reuters offers Quantitative Analytics.

[10] Sheila Bonini, Timothy M. Koller, and Philip H. Mirvis, "Valuing social responsibility programs," *McKinsey Quarterly*, July 2009, mckinsey.com.

[11] Sheila Bonini and Stephan Görner, "The business of sustainability: Putting it into practice," October 2011, mckinsey.com.

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Sheila Bonini is a senior expert in McKinsey's sustainability and resource productivity practice and is based in the Silicon Valley office; **Steven Swartz** is a principal in the Southern California office.

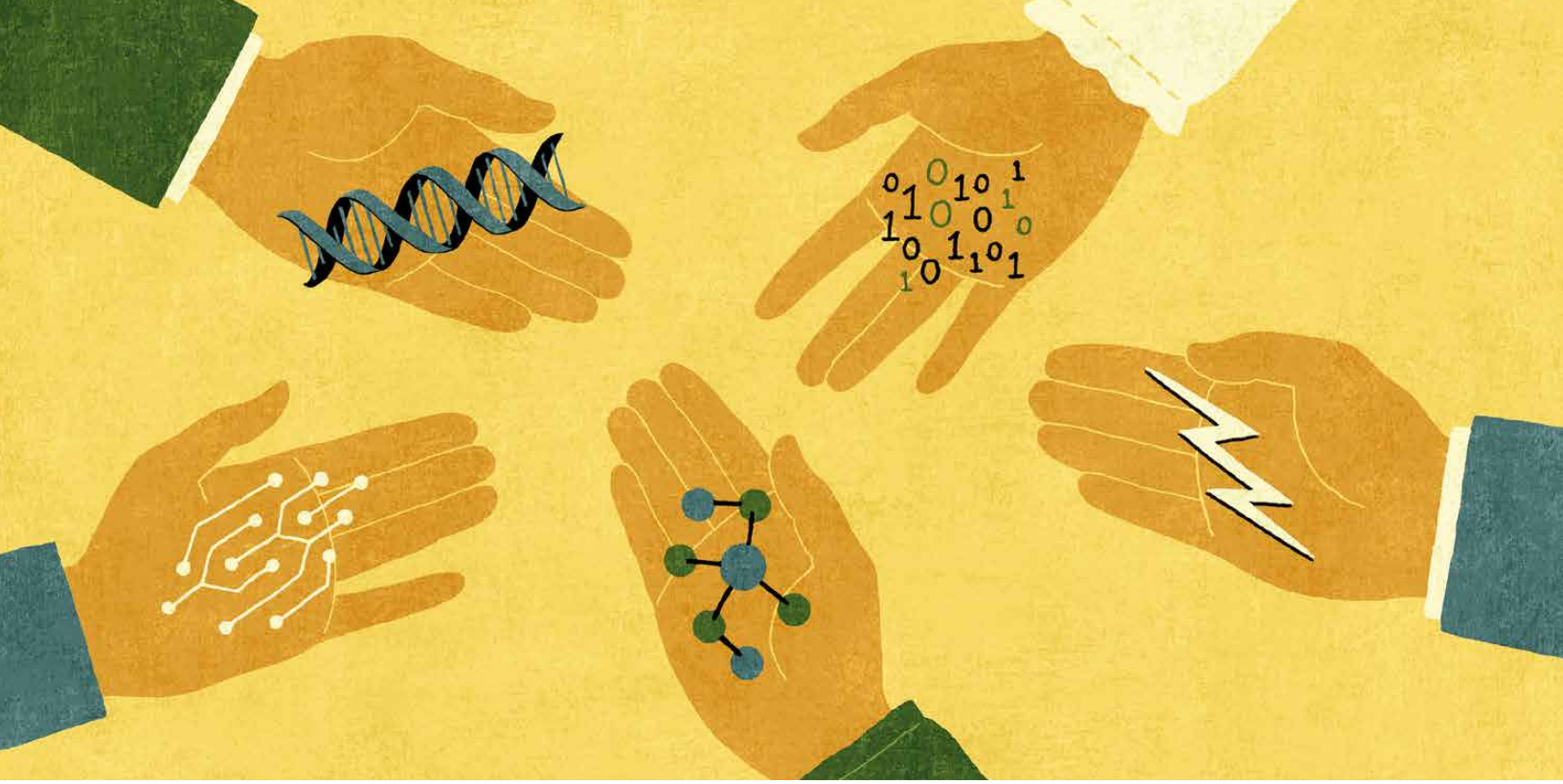


Illustration by James Steinberg

The human factor:
Amassing troops for the 'resource revolution'

Companies on the front lines of the resource revolution need to implement creative talent-management strategies.

Stefan Heck and Matt Rogers

The conventional wisdom is that the world could face a crisis with regard to resource scarcity. In our book, *Resource Revolution: How to Capture the Biggest Business Opportunity in a Century* (New Harvest, April 2014), we argue that this is actually an opportunity to reframe the world economy and create trillions of dollars in value. But doing so will require new organizational models and lots of human capital. In this excerpt from our book, we discuss which skills companies should seek and develop to win.

Looking for talent far afield

In thinking about the people who will be needed in a new organizational model and its operating system, the first thing to do is to begin to map the new skills that will be needed to pursue opportunities in resource productivity. The list will be long.

All companies will need more software talent, because software increasingly provides the operating instructions for our world. IT no longer is solely the business of managing company desktops and networks; information technology is merging with traditional engineering to create the lifeblood of the modern corporation. Those companies that can build the talent to integrate software and industrial hardware faster and more reliably than the market will win. The operating algorithms that identify which pump needs maintenance and which oil well needs more pressure will become the basis for competitive

advantage, just as Amazon's book-recommendation tools and its rapid checkout-management capabilities defined success in book sales. Many companies we think of as building hardware actually have more software than hardware engineers. Airplanes, automobiles, construction equipment, trains, and industrial machinery all ship with millions of lines of software code and are far more complex than the typical iPhone app.

Many companies will need more systems-integration skills because much of the power of the resource revolution will come from combining bits and pieces of disparate ideas, and most companies simply aren't very good at systems integration at the moment. For companies focused on resource use, the need for specialization is high, but the scarce resources are engineers and innovators who can solve the cross-functional problems that networks of technologies create. Success will come from harnessing rapid innovation in software and semiconductors, biotechnologies and nanotechnologies, and ubiquitous sensors and controls, and then integrating them with industrial processes for the first time. While emerging markets such as Brazil and China have some advantages in resource use because they're able to design networks such as electric grids from scratch, developed countries such as the United States have an advantage with the cross-functional aspects of resource productivity. Developed countries have senior architects with 30 years of experience in designing whole systems—the kind of experience that will be needed to integrate all the technologies available.

Beyond the ability to integrate various functions, new specialty skills will come into play for the first time. For example, automotive companies in Germany have found that while they are long on mechanical engineers, they are short on the software and chemical engineers that will be required to build electric, hybrid, and—perhaps one day—hydrogen cars. Entire components, such as transmission systems, could be eliminated with the advent of electric drivetrains, but carmakers will need people who understand how to weave carbon fiber, integrate 4G communication protocols and security with the car's operating system, and deal with battery issues such as heating and optimizing chemistry. Already, the electronics content in cars has hit 40 to 50 percent of their value, and this is before cars are routinely connected to the Internet. Many other industries will, like carmakers, need to increase their understanding of materials science, chemistry, or biology.

Many companies will need skills at super-low-cost manufacturing, too. For years, the goal in product design was to add features and generally improve capabilities. But the ability to build high quality very inexpensively now offers the key advantage. Wal-Mart pioneered the everyday-low-price promise and developed supply chains that could offer high-end products at very low prices. Huawei did the same for telecommunications technology. The market for high-quality, low-price goods is growing rapidly, and all but a few companies will have to look outside their walls to find the capabilities to tap that market.

The upshot? When looking for new talent, it's no longer enough to try to raid competitors for their best people—those competitors don't have the new skills, either. New talent needs to be found in new places.

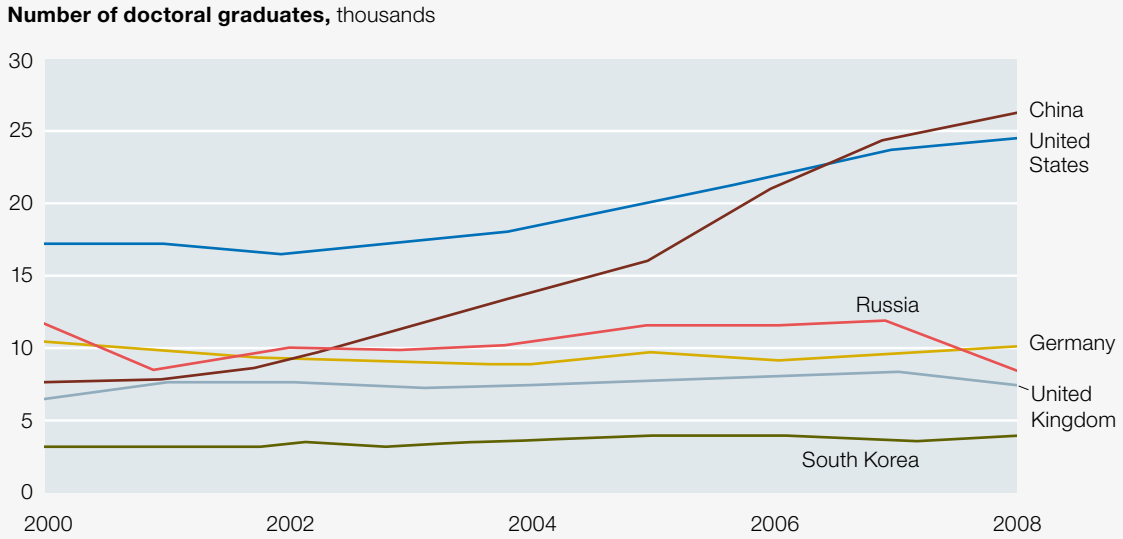
One place to start is in neighboring industries that haven't traditionally overlapped but that have been identified as having capabilities worth borrowing. Consumer electronics will present a big opportunity. So many people have become addicted to their smartphones that they will demand that the rest of the world's interactive devices have a similarly simple, smooth interface, and companies will need to be able to provide one, whatever the industry. Cars, for instance, are already migrating away from levers and buttons and toward iPad-like capabilities—though the switch will have to be negotiated

carefully, both because of familiarity with the old ways and because drivers have to keep their eyes on the road.

The Nest Labs thermostat provides another example. Until Nest came along, thermostat interfaces hadn't changed much since the shift in the early 1970s from the mercury-based mechanical switch to the box with a small liquid-crystal display and a bunch of buttons. Nest now has taken on the attributes of an iPod: the thermostat, which is round again, with an interface like a track wheel, learns users' preferences and communicates with their iPhones and other equipment in their houses over Wi-Fi. Nest, which can adjust to the weather and sense whether anyone is at home, takes another page from Apple in that the company sees the thermostat as just the first app for household-wide automation and convenience. Nest has already announced a smoke detector that gently warns users when it detects small amounts of smoke or when its battery is fading. Because the thermostat and smoke detector can already tell when someone is home, security is a natural extension. The plan is that new applications, software features, and more sensors and controls will one day allow Nest to do everything but deliver breakfast in bed.

Even though companies will need expertise on technologies such as the chips, apps, and batteries that go into consumer electronics, it won't always make sense to hire people from other industries. In some cases, it will make more sense to form partnerships with businesses in those industries that provide access to specialized expertise. For instance, rather than hire all its own experts on materials science, Apple is working with Corning on glass and coatings and with Liquidmetal Technologies on casting and ductility for casing materials. To differentiate its products from competitors with similar inventions, Apple has signed extensive agreements that guarantee exclusivity and supply from its partners.

Exhibit 1 **Finding qualified graduates will require a global search.**



Beyond looking at new industries for talent, it will be important to look in new countries, too. Building the leading workforce in the world requires developing a global talent-sourcing pipeline (Exhibit 1). Where companies might have traditionally recruited from the industrial-engineering core in the United States's Midwest and South—the Big Ten and Southeastern Conference engineering axis that powered the industrial innovations in the United States during the 20th century—the leading companies today need to be winning on the campus of Tsinghua University in Beijing, for example. Companies need to go to Russia to find experts in algorithms, to Israel for electro-optics and water technology, to Finland for leaders in wireless technology, and so on.

Less developed countries will be important sources of talent for low-cost manufacturing because "low cost" has a very different meaning to a street vendor in Delhi than it does to a citizen of the European Union. The lack of an infrastructure such as the one taken for granted in the United States requires that we look at technology and design options that would never even be considered in the United States. An American-made refrigerator needs to make ice cubes, fit in with kitchen decor, and have enough storage space to hold a weekly SUV run of groceries. For a person in the 80 percent of India's population that has no access to ice or refrigeration, there are no such expectations.

That difference is why Godrej's Chotukool, a $70 refrigerator, was developed in India and not the United States. The refrigerator, which looks like an oversize cooler and uses a battery-powered heat exchanger for its cooling technology rather than traditional compressors, comes at a price that wouldn't have even been considered possible in the developed world. Hitting that price may unlock a market for cooling in the developing world that is $108 billion today and is set to increase to $185 billion or more by 2018. Similarly, a low-cost sonogram machine was developed in India and is now being marketed worldwide by General Electric.

It isn't enough to just go looking for new talent, of course. Companies have to be able to win the competition for it. To do so, companies must first realize that they aren't just competing against traditional rivals. Companies have to win against, say, consumer-electronics firms and software companies, too. Likewise, competing for talent in China, India, and Russia requires competing against local national champions and their privileged local networks.

To win, companies not only have to compete on the usual measures of compensation and responsibility but also have to be willing to go where the talent is, whether geographically or virtually. Companies may even need to be willing to set up multiple development centers around the world to tap into those algorithm experts in Russia and the electro-optics geniuses in Israel.

Developing talent

In some cases, people with the skills to help companies thrive throughout the resource revolution simply don't exist, at least not in the numbers that will be needed, so companies will have to develop their own talent.

Much of the need will occur at the top of organizations, among the leaders. The leadership skills required to deliver 10 to 15 percent annual productivity gains for a decade or more are a far cry from the incremental-improvement skills that marked the generation of leaders after World War II. When technologies are largely mature in an industry, the focus on generating incremental improvement is the whole game, and we have developed a group of managers who are great at squeezing the last drop out of the radish. We developed a whole series of tools—lean, Six Sigma, business-process redesign, dispatch linear programs—all with the goal of

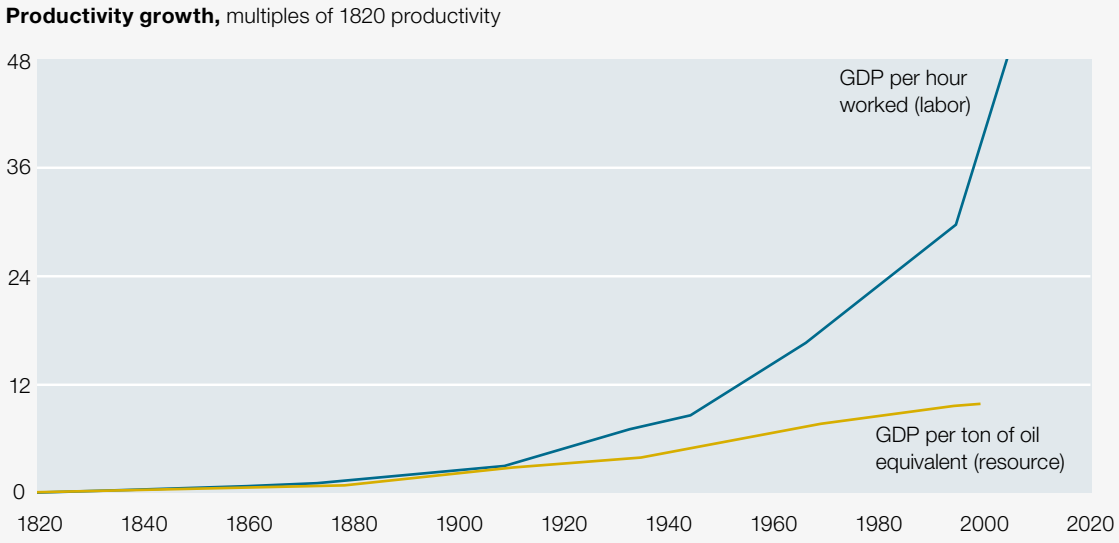
improving productivity by 1 to 2 percent annually. The idea was: keep the process in control, squeeze the next drop out, and the company will win. But not anymore.

Leaders' technology-management skills will also have to improve radically. When technology is changing at a rapid pace, the ability to identify and integrate new tools to improve performance is critical (Exhibit 2).

Everyone is familiar with the difficulties of upgrading their computers to handle new software—performance is always supposed to get better, but most of the time the upgrade takes forever, and there is a great deal of lost productivity in the transition. The same can happen when a business makes a fundamental upgrade in its operating system and supporting technology. So, imagine the pressure when a manager needs to upgrade the base business-technology portfolio every six to nine months and can't afford any downtime.

Even tougher, the challenge won't be just to upgrade a known form of technology; the world of resource revolutions is too cross-functional to be that simple and requires different departments, multiple suppliers, and often a customer willing to try something new. To take a simple example: it might make sense to shift from making trucks that use diesel to making trucks that use natural gas, to take advantage of low-priced, clean-burning methane. That single shift requires changes to the fuel tanks, the engine, pollution-control equipment, driver-information systems, cooling systems, network fueling infrastructure, and maintenance protocols. The results can deliver 37 percent savings in fuel costs and 9 percent savings in the total cost of ownership for the truck, but success requires taking an integrated view of the network problem. Making these integrated decisions in a world where the future differential between natural gas and diesel is highly uncertain makes the decision making even more difficult. Even within the car or truck platform, automotive companies will have to make trade-offs

Exhibit 2 **Factory-productivity growth will continue to improve.**



The good news is that, while the search for new organizational models and new talent in new places will be extraordinarily taxing, just about all the competition will face the same problems.

that cut across software, mechanical engineering, electronics, and chemistry.

Workers will need to be developed, too, whether by schools, by the government, or by employers. The reason is that the nature of work is changing and, in many cases, becoming much more technical. Workers on a solar-panel assembly line, for instance, need to learn how to handle equipment that operates within a tolerance of a fraction of a millimeter. That doesn't require a four-year college degree but does require a great deal of training with digital process-control technologies.

Quality-control supervisors in manufacturing will have to be able to understand advanced statistical techniques and need to be able to make adjustments to process-control technology to deliver extremely tight tolerances.

Resource productivity requires frontline labor such as the delivery-truck drivers employed by UPS to make much more sophisticated decisions based on big data and advanced analytics. They obviously don't have the data-analysis capabilities that UPS does centrally, so UPS pushes as much information out to the drivers as possible. UPS integrates data both on actual traffic and on anticipated traffic to instruct drivers to adjust routes. Now, as drivers make their morning deliveries, UPS dynamically pulls together routes for the pickups they'll make that afternoon.[1]

Developing new talent requires a new education model, much more technically focused than the one the developed world built around German liberal-education principles at the end of the 19th century to help people move from the farm to the city and be able to read, vote, and conduct business. The focus has been driving 90 percent of the population to have at least a high-school degree. The challenge now is that a high-school degree is not enough. Most countries in the developed world show 40 to 50 percent of the population having some college education, but countries will need to reach 80 to 90 percent to remain competitive with the likes of Korea, as "knowledge worker" skills such as communicating, problem solving, analyzing data, setting parameters on machines and algorithms, and collaborating globally become much more important. The German model continued to evolve after World War II to incorporate technical apprenticeships in trades like machining, carpentry, and programming, but much more is needed.

Learning will need to continue postcollege, too, largely through online course work—basically, higher education will undergo its own resource revolution, delivering learning virtually rather than in classrooms and lecture halls, even though the face-to-face model has worked well for millennia. Universities such as Stanford are already experimenting with a "flipped classroom" model enabled by computing technology: students read the book and watch the video of the lectures on their own time

on an iPad or laptop, and come to class (physically or virtually) to discuss, ask questions, and get a deeper understanding of the material. Once physical constraints are removed, the student can even be in a remote part of Western China and have access to the world's best professors on any topic. (A 15-year-old in Mongolia became 1 of 340 students to earn a perfect score in 2012 in MIT's Circuits and Electronics, a sophomore-level class that was the first massive open online course, that MIT offered. More than 150,000 students had enrolled in the course. The boy was accepted as a freshman at MIT at 16.)

The flipped classroom is the brainchild of companies such as Coursera and Udacity, which are trying to make the best courses in the world available to the masses, without requiring students to pay $50,000 a year to go to Harvard.

There also needs to be a stronger alignment between business and education, setting ever-increasing technical standards for each graduate. Students will need at least four years of mathematics plus specific technical training in statistics and data management to remain competitive during the resource revolution. Some companies are working with schools to set up feeder programs. Microsoft, for one, recently began sending engineers to high schools both to teach math skills and to generate enthusiasm that could bring more talent into software design and coding.

Businesses will need to do even more of their own training, too. There will need to be hands-on learning combined with simulations, often using the best graphics to allow hundreds of repeats on major tasks and key decisions. Businesses may want to work with universities to bring some of their experts and proven techniques to the corporate campus.

The good news is that, while the search for new organizational models and new talent in new places will be extraordinarily taxing, just about all the competition will face the same problems. That fact gives each company a bit of a grace period, but the sooner management starts confronting the gaps a company is facing, the sooner it is likely to close them—and gain a big edge on the ones who don't. ■

[1] UPS is on the cutting edge in other ways, too. It is experimenting with trucks that run on natural gas, which now costs a fraction of the price of gasoline because of shale-gas breakthroughs. Liquefied natural gas (LNG) is also much denser than gasoline with respect to the energy it contains. UPS trucks could travel from Texas to Chicago on three tanks of LNG. Eventually, when enough LNG fuel stations get built, the trucks will also be able to cross east to west.

This article is excerpted from *Resource Revolution: How to Capture the Biggest Business Opportunity in a Century,* first edition, New York, NY: New Harvest, April 2014.

Stefan Heck is a consulting professor at Stanford University's Precourt Institute for Energy and an alumnus of McKinsey's Stamford office; **Matt Rogers** is a director in the San Francisco office.

Riding the resource wave: How extractive companies can succeed in the new resource era

With economic and social expectations rising in resource-rich countries, extractive companies must rethink how they do business.

Pablo Ordorica Lenero and Fraser Thompson

The business of extracting resources could be increasingly lucrative in the years ahead, and it is crucial to the economic prospects of many countries. But it is also likely to become riskier and more complex, requiring extractive companies in both mining and oil and gas to rethink their business models. Specifically, that means shifting from an extraction mind-set to a development one in what we call "frontier regions"—places with unstable business and legal environments. Extractive companies must systematically learn the priorities of host governments and local communities, then forge partnerships to deliver on them. Such an approach can defuse tensions before they arise and make for a less volatile operating environment.

Ever since the wave of nationalizations of oil companies in the 1970s, extractive industries have operated in a relatively secure world. Much of production came from legacy assets in economies that are members of the Organisation for Economic Co-operation and Development, where the rules of the game were established, and the focus was largely on operational improvement. This era was characterized by relatively abundant access to critical inputs such as water. Governments earned stable fiscal flows and, given the fairly low profit margins that were standard, companies attracted less external scrutiny. This environment is changing rapidly.

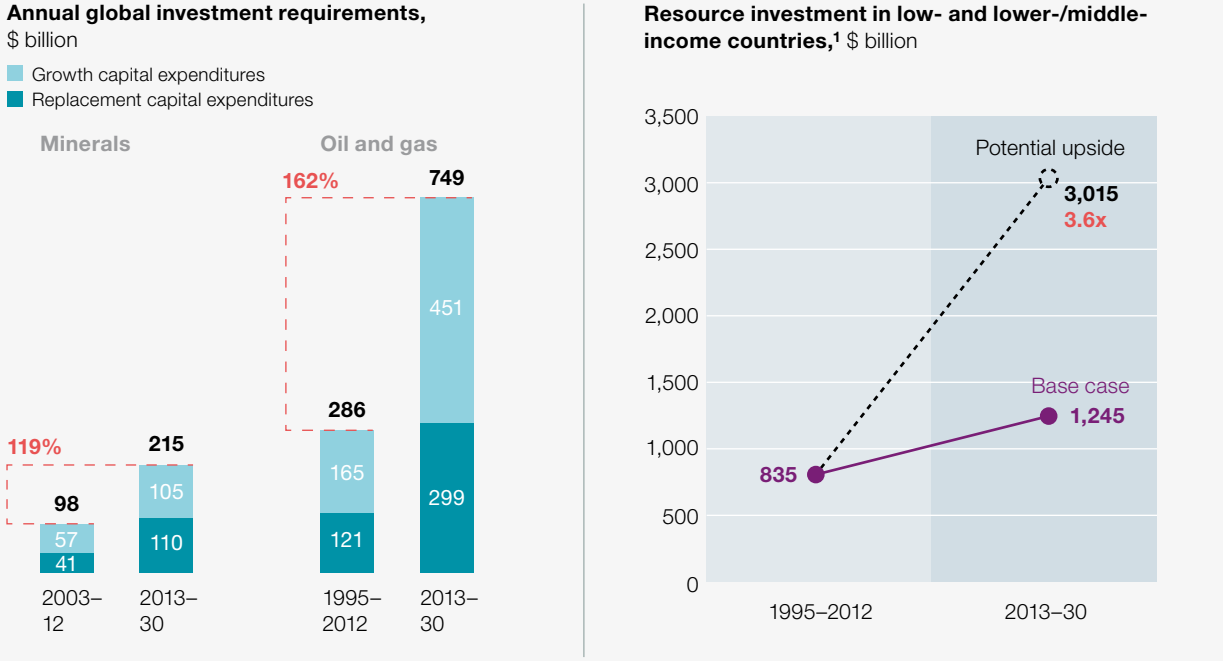
There are several reasons for this.

Higher and more volatile resource prices

Since the turn of the century, average minerals prices have roughly doubled; energy prices have tripled. This has led to a strong increase in the production of energy and minerals, by 14 percent in the case of oil and by more than 100 percent in the case of iron ore since 2000. Despite recent declines in prices for some resources, such as iron ore, commodity prices on average remain roughly where they were in 2008, when the global financial crisis began. They have also risen more sharply than global economic output since 2009.[1] Moreover, the volatility of resource prices is at an all-time high, a state that we think will continue.

Volatility can undermine relationships between extractive companies and host governments. If prices rise sharply from where they were when contracts were signed, governments might feel they are not getting enough and want to renegotiate. Data from the Royal Institute of International Affairs in London indicate that the number of arbitration cases has risen sharply since 2000, when the run-up in oil, metals, and mineral prices began.[2] Between 1990 and 1999, there were five arbitrations in mining and five in oil and

Exhibit 1 **Cumulative investment in mineral and oil and gas projects could be more than $16 trillion in 2030.**



Cumulative total, 2013–30: >$16 trillion (~$3.6 trillion for minerals)

Resource-extraction investment in lower-income countries could triple from historical levels

[1]As defined by the World Bank on the basis of gross national income per capita in 2011. This represents the share of the total global cumulative investment to 2030 that could be focused on low- and lower-/middle-income countries.

Source: Economics & Country Risk; Rystad Energy; Wood Mackenzie; World Bank; McKinsey analysis

gas; from 2000 to 2009, there were 21 and 44 such cases, respectively.

More challenging production locations

Even if the world were able to achieve a step change in resource productivity—the efficiency with which resources are extracted and used—new sources would still be required to replace those that are running out. By 2030, we estimate that between $11 trillion and $17 trillion of new investment will be needed—65 to 150 percent higher than historical levels (Exhibit 1).[3]

Historically, almost 90 percent of resource investment has been in generally stable high- and upper-middle-income countries. In the future, the share of resource investment is likely to be in poorer and often more volatile environments. New projects in many of these frontier regions, however, are environmentally and geologically challenging. Infrastructure is often lacking, and the political dynamics can also be difficult. Almost half of new copper projects, for example, are in countries with high levels of political instability. All this translates into higher costs and greater risks.

Larger and more visible projects

Another challenge is that many projects are huge relative to the size of their host-country economies. Consider Rio Tinto's Simandou iron-ore project in Guinea. This is expected to produce revenue of more than 130 percent of GDP; we know of at least another five projects whose revenues will be half or more of GDP. As a result, operations are highly visible, contributing to public pressure that they be seen to help society, with regard to taxes, jobs, and other contributions. Our analysis of a selection of speeches by policy makers in several resource-driven countries shows that there has been a strong emphasis on issues such as local economic development and social and community benefits. The clear implication is that companies are expected to be not only responsible operators but also positive forces in the country in many dimensions.

Fiscal pressures on governments

There are 42 countries (for which there are data) where resources account for more than 20 percent of government revenue.[4] Many of these countries are under pressure to meet the increased expectations of their citizens while also addressing major issues, such as pensions and cost of living. This can lead to pressure to renegotiate fiscal agreements with extractive companies to increase the government's share of the wealth generated.

Dealing with the 'resource curse'

The number of countries where resources represent a large share of their economic output, fiscal revenues, or exports has increased by 40 percent since 1995.[5] However, the economic track record of many of these countries is far from impressive. Many have struggled to create long-term growth and employment. Almost 80 percent of countries whose economies historically have been driven by resources have below-average levels of per capita income, and more than half of these are not catching up. This economic underperformance, dubbed the "resource curse," can create further pressures on the extractive industry to support broader economic growth and job creation. This is a particular challenge in an industry that tends to employ relatively few people directly.

Pressure for greater transparency

The expectations for extractive-company behavior are higher than ever before. In the European Union, for example, new laws require companies to report payments of more than €100,000 made to the government in any country in which they operate, including taxes levied on their income, production or profits, royalties, and license fees. The United States also has stringent laws governing conduct of US companies overseas. Between them, US law and EU directives cover about 70 percent of the value of the global extractive industries. The rise of social media, the rapid diffusion of technologies such as mobile phones to low-income consumers, and the more active role of nongovern-

mental organizations mean that any extractive companies are subject to strong scrutiny.

Increased environmental concerns

The extractive industry is likely to face increasing pressure to pay for commodities such as carbon and water that are largely under- or unpriced. While carbon is a global concern, water constraints have a large direct impact on relationships with host communities. Pricing water could dramatically raise costs and constrain output, given that 32 percent of copper mines and 39 percent of iron-ore mines are in areas of moderate to high water scarcity. Pricing water to reflect its "shadow cost"—meaning the economic value of the water if put to its best alternative use—could increase iron-ore costs by more than 3 percent.[6] Companies also face having to deal with "stranded resource assets"—those that are subject to unanticipated or premature write-offs, downward revaluations, or conversion to liabilities if there is strong policy action to combat climate change or promote other goals.

Relationships between extractive companies and governments have long been fraught. In a higher-risk, higher-volatility environment, such tensions could increase and lead to a zero-sum game in which companies and governments are constantly at odds. The stakes are too high to let that happen. Therefore, it is in the interest of all parties to adapt their operating models to this new context.

Policy makers in these countries will need to adopt new approaches to ensure that their resource endowments are a blessing for their economies rather than a curse and seek to create real partnerships with extractive companies.[7] For their part, companies will need to rethink their operating model. Right now, the usual practice is to concentrate on extraction, with some additional attention given to corporate responsibility. We think the better long-term approach, and one that will bring a genuine competitive edge, is for companies to put economic development at the heart of their corporate strategy.

One good example of this is the Moroccan phosphates company OCP, which decided to boost the local content in its supply chain. Based on an analysis of spending in around 80 sectors, OCP developed a portfolio of target sectors. It then considered the GDP contribution of each sector and how it might be possible to localize content. OCP supported this effort by engaging in joint ventures with international companies to ensure that Moroccan companies could gain skills and capabilities, establishing volume guarantees to minimize the risk to local suppliers, developing dedicated economic zones, and creating transparency on the demand pipeline to minimize uncertainty. A dedicated office responsible for deal making, program management, local-content auditing, and reporting and communications supported OCP's program.

Another area of opportunity is infrastructure. We estimate that extractive companies are likely to spend on the order of $2 trillion on infrastructure by 2030. We believe companies and governments should look closely at ways of sharing these assets. By doing so, countries can take advantage of private-sector capital and know-how while both sides benefit from building stable, long-term partnerships. Examples include building roads that allow other users to benefit or ensuring that power capacity is sufficient to provide excess power to the grid.

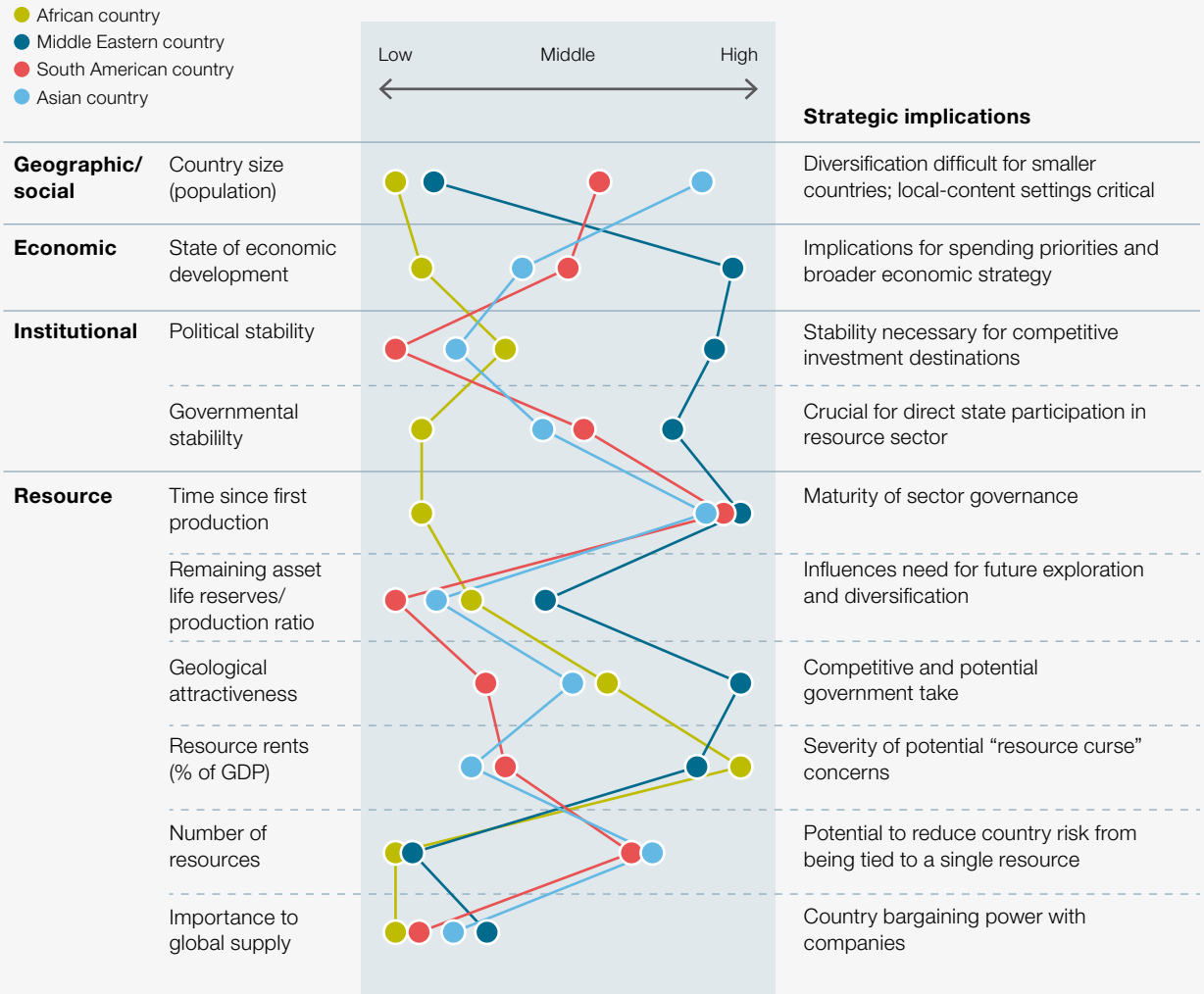
Companies need to develop a deep understanding of the societies where they operate and build relationships with host governments that can endure through inevitable difficulties. That means they must be willing to some extent to accept the country's priorities as their own and to perform against these expectations. This also means that both parties need to create strong incentives to adhere to agreements throughout the lifetime of the project.

There are three major considerations.

Developing a detailed understanding of the country context. Extractive companies spend hundreds of millions of dollars and many years to understand the geological and technical aspects of project development. They spend much less time and money to develop an equally sophisticated view of the political, social, and economic factors that shape the countries in which they operate. This needs to change. There are ten elements that companies need to understand before they start digging or drilling (Exhibit 2).

A few generalities are worth keeping in mind as extractive companies seek to create effective partnerships with local stakeholders. One is that the less developed a country is, the more likely

Exhibit 2 **Companies need to understand ten important dimensions of resource-driven countries.**



Source: *BP Statistical Review of World Energy*; World Bank Worldwide Governance Indicators; McKinsey analysis

its government will have high expectations that extractive companies will build infrastructure and contribute to economic and social development. Companies also need to be prepared to deal with weak institutions and limited government capacity. Another factor to consider is the nature of the resource in its particular context. If the country has a long history of, say, gold production, it is likely to be easier to find local suppliers, skilled personnel, and experienced regulators. The remaining life of an asset is also important. Are the resources there for hundreds of years or for a decade? A longer time horizon encourages both sides to strike long-term stable agreements.

Measuring performance against expectations. Most extractive companies already make substantial contributions to the countries where they work, but we believe companies need to adopt a more sophisticated approach. Specifically, they need to understand stakeholder expectations and develop a business case for such investments. This is the only way to judge whether they offer value. Drawing on a broad-based review of the available literature and interviews with a large number of experts, we have developed a set of more than 90 measures to consider. These fall into five categories: fiscal contribution, job creation and skill building, infrastructure investment, social and community benefits, and environmental preservation (Exhibit 3). Other measures assess the company's performance on managing stakeholders and communications efforts, which are important if the company's contributions are to be appreciated.

Based on our work with extractive companies, we have noticed the following things about the current operations of many extractive companies:

- The priorities of extractive companies often do not match those of local stakeholders. We found a considerable disconnect between what companies do and what governments want them to do. In one instance, a company was doing well in environmental management but far less well on infrastructure and job creation, which were higher priorities for the local government. Priorities for development decided in corporate headquarters can be disconnected from those of local stakeholders. This dynamic is particularly ironic given that one of the main goals of development-focused activities is to foster positive relations with a host government. Specific priorities vary, but we found that local job creation consistently appeared to be valued less by companies than by local stakeholders.

- Priorities and performance can vary significantly within the same company. We found considerable variation among companies on their priorities for economic development and how different business units of the same company performed. This variation did not appear to reflect different priorities among local stakeholders but rather a lack of internal consistency and alignment.

- Local stakeholders often do not adequately value company efforts. As a result, companies may not get enough credit for their contributions. This is sometimes due to the mismatch of priorities mentioned earlier and sometimes due to a failure to communicate, leading to a lack of understanding and support both within government and in local communities.

- Companies often fail to consider the business case for their development activities. Effective corporate performance on economic development and sustainability is not just a matter of money. No matter how copious a resource, the rents can never be sufficient to meet all of the demands of the host country with regard to infrastructure, healthcare, education, and other needs. It is therefore vital to undertake

Exhibit 3 **There are five core elements of a company's local development contributions and one critical enabler.**

The degree to which the company understands stakeholder concerns, tracks its impact against those concerns, communicates effectively with stakeholders, and seeks to create an aligned vision.

1 The degree to which the company meets national tax, royalty, and equity obligations in a transparent manner and seeks to prevent corruption.

2 The degree to which the company contributes to its own workforce development, supply-chain development, resource beneficiation, and labor-market vocational education.

3 The degree to which the company attempts to create broader societal benefits from its infrastructure investment in roads, power, water, and other areas.

4 The degree to which the company contributes to local communities through health, education, safety, site rehabilitation, and economic sustainability.

5 The degree to which the company seeks to minimize associated air, land, and water pollution and to reduce waste and preserve biodiversity.

rigorous economic analysis to determine what benefits might come from additional investment. Companies, however, often fail to make such calculations and thus miss the chance to link investment to activities that will yield direct benefits, perhaps in the form of lower supply-chain costs, increased labor productivity, reduced project risks, or accelerated permitting. Impact is not necessarily a matter of cost, either. One company significantly improved community relations and reduced the threat of operational disruptions by adopting measures as simple as enforcing speed limits for its trucks as they went through local villages.

Exploring strategic moves that foster symbiotic relationships with governments. Oil, mining, and other resource projects can last for decades; governments and businesses therefore need to develop a relationship that can last. That requires goodwill and flexibility on both ends. One common pitfall is to strike a hard-nosed initial contract that maximizes short-term benefits but creates long-term resentment that could lead to pressure to renegotiate or even the withdrawal of the right to operate. A contract—and a relationship—is more likely to prove sustainable if companies ensure that the government is clear about the contribution the company is making

and how it compares internationally so that both sides can see that they are getting a good deal. Conversely, governments need to be aware of the costs of renegotiation or even appropriation of assets. One extractive company operating in Africa shared a series of case studies with the host government that demonstrated how other resource-driven countries were affected when their governments attempted to nationalize assets. The idea is to help host governments realize that they need the extractive company, just as the company needs them.

There are different ways of achieving this kind of partnership. In many cases, the extractive company has a technological edge that the country cannot otherwise access. Some companies cement relationships by developing and operating core infrastructure, such as local railways. Others have become global advocates for the host country on key issues of concern. The fundamental imperative for companies is to show that they are indispensable, or at least worth living with.

The resource landscape is changing radically. In the economies that will dominate future extraction, companies and host governments need to figure out how to work together for the long haul. Now is the time for businesses to reach a true understanding of the development needs of the countries where they will be operating and calibrate their approach to meet those needs. Only by doing so can they be sure that they can maintain their social license to operate—and secure a competitive edge.

[1] For more, see *Resource revolution: Tracking global commodity markets*, McKinsey Global Institute and McKinsey sustainability and resource productivity practice, September 2013, on mckinsey.com.

[2] Bernice Lee et al., *Resources Futures*, Chatham House, December 2012, chathamhouse.org.

[3] For more, see *Reverse the curse: Maximizing the potential of resource-driven economies*, McKinsey Global Institute, December 2013, on mckinsey.com.

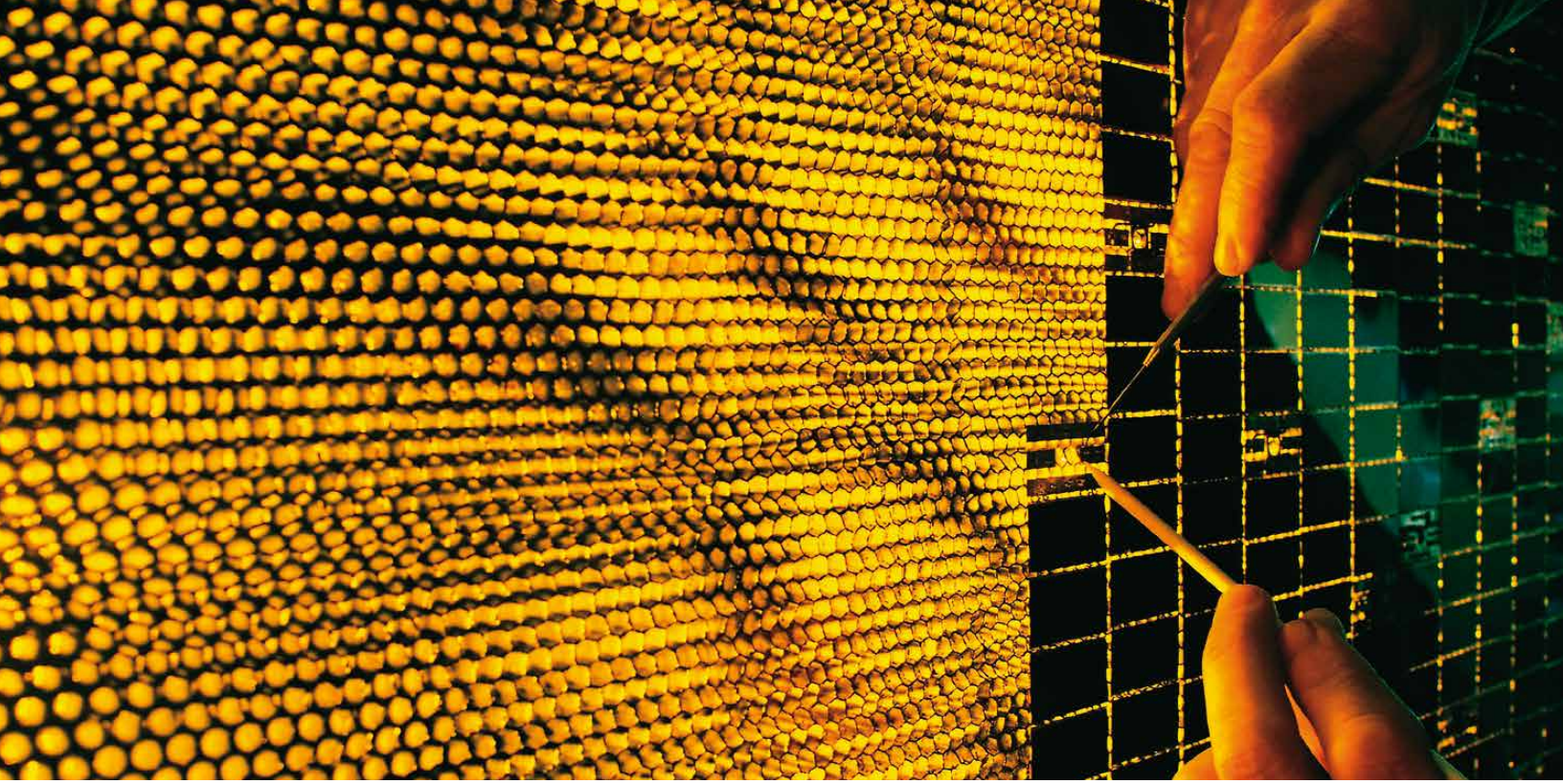
[4] *Macroeconomic Policy Frameworks for Resource-Rich Developing Countries*, International Monetary Fund, August 2012, imf.org.

[5] We use three criteria to identify which economies are driven by resources to a material extent: resources account for more than 20 percent of exports, resources generate more than 20 percent of fiscal revenue, or resource rents are more than 10 percent of economic output. The resources include energy and mineral commodities.

[6] For more, see *Resource revolution: Meeting the world's energy, materials, food, and water needs*, McKinsey Global Institute and McKinsey sustainability and resource productivity practice, November 2011, on mckinsey.com.

[7] For more, see *Reverse the curse*; this report identifies six core elements that policy makers need to address: institutions and governance, infrastructure, fiscal policy and competitiveness, local content, spending the windfall, and broader economic development.

Pablo Ordorica Lenero is a director in McKinsey's Mexico City office, and **Fraser Thompson** is a senior fellow at the McKinsey Global Institute and is based in the Singapore office.



Brave new world:
Myths and realities of clean technologies

Don't be fooled by high-profile setbacks. The cleantech sector is gaining steam—with less and less regulatory assistance.

Sara Hastings-Simon, Dickon Pinner, and Martin Stuchtey

The world is on the cusp of a resource revolution. As Stefan Heck and Matt Rogers argue,[1] advances in information technology, nanotechnology, materials science, and biology will radically increase the productivity of resources. The result will be a new industrial revolution that will enable strong economic growth, at a much lower environmental cost than in the past, thanks to the broad deployment of better, cleaner technologies and the development of more appropriate business models. But how do we reconcile this heartening prediction with recent challenges experienced by cleantech, the general term for products and processes that improve environmental performance in the construction, transport, energy, water, and waste industries? Over the past couple of years, many cleantech equity indexes have performed poorly; in January 2014, the American news program *60 Minutes* ran a highly critical segment on the subject. The former chief investment officer of California's largest public pension fund complained in 2013 that its cleantech investments had not experienced the J-curve: losses followed by steep gains. It's been "an L-curve, for 'lose,'" he said.

So, is cleantech failing? In a word, no. Rather, the sector has experienced a cycle of excitement followed by high (and often inflated) expectations, disillusionment, consolidation, and then stability as survivors pick up the pieces. We've seen this before with other once-emerging technologies such as cars, railroads, elevators, oil, and the Internet. Much of cleantech is just leaving its disillusionment or consolidation phase. For example, in transport,

Tesla Motors is looking good, while Fisker went into bankruptcy in 2013. In energy, SunPower is making healthy margins, and SolarCity raised $450 million in 2013, but more than a hundred other solar companies are now gone. The shakeout is brutal—and typical. It has weeded out weaker players, making the industry as a whole more robust. Despite this rough patch, annual growth is at double-digit rates.

It's also important to look beyond financial statements. Global wind installations, for example, have soared about 25 percent a year since 2006 (exhibit). And global commercial investments in clean energy have more than quintupled, from nearly $30 billion in 2005 to about $160 billion in 2012. Even countries with vast reserves of oil and coal—in the Middle East and Central Asia—recognize that they can't miss out and are developing substantial programs for renewables. Meanwhile, the average real cost per oil well has doubled, and new mining discoveries have been flat, despite high investment. And, clearly, new ways are needed to meet the needs of the 1.3 billion people who lack electricity and the 2.7 billion who rely on traditional biomass, such as wood and dung, for cooking.

Cleantech is no passing, unprofitable fad. The sources of underlying demand—a growing middle class around the world and resource constraints[2]—aren't going away, and cleantech could be pivotal in dealing with both. There are three major myths that undermine confidence in cleantech's future.

Myth 1: Deployment and influence will be marginal

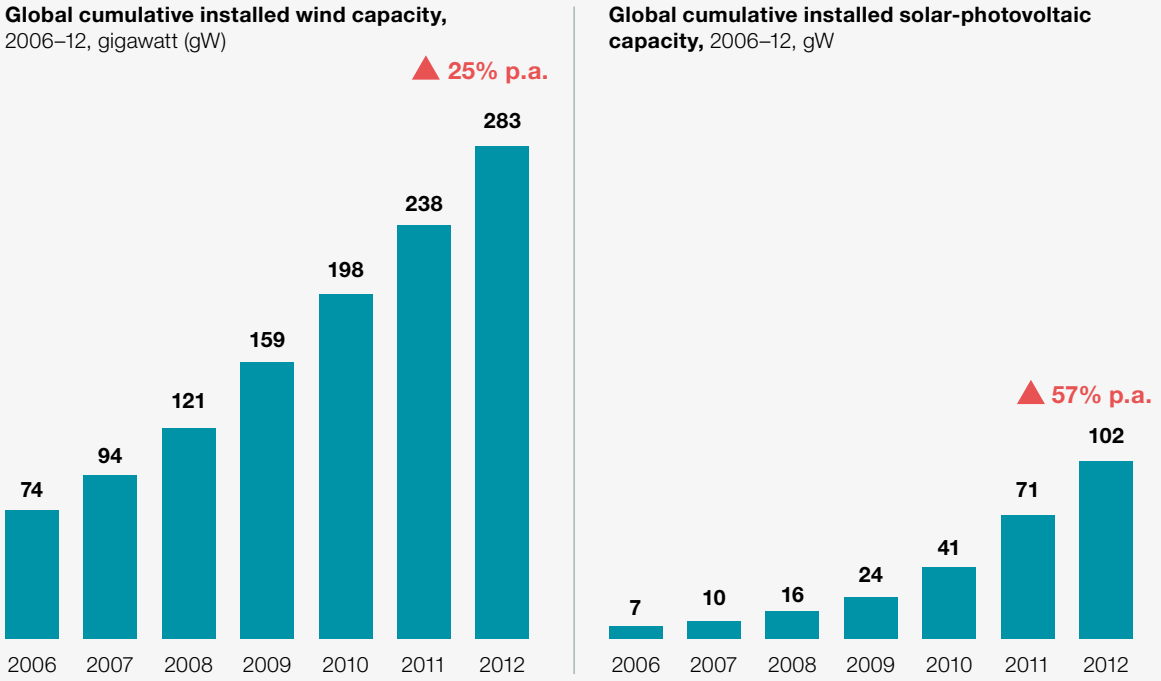
This is not so, and we know that because we see what is actually happening. According to the International Energy Agency, renewables already accounted for 18 percent of global consumption in 2010, and they are growing faster than any other form of energy. Given the radically lower marginal costs of renewables, their position is even more promising over the long term. In fact, the International Energy Agency predicts they will account for more than 60 percent of new power-plant investment to 2035.

The effects of clean technologies will vary significantly by industry and geography. In some cases, they may truly transform markets, as light-emitting-diode (LED) technology is now doing in lighting. In cases where penetration rates are lower, they can still have a dramatic impact on industry structures and market dynamics. Among US electric utilities, for example, the traditional business model relies on putting capital in the ground. But the potential of distributed solar generation to meet the majority of new demand growth can upend that model entirely. As more people install solar panels on their roofs and add new capacity, demand will increase more slowly for utilities. Some utilities are responding to this by trying to get regulators to allow them to include investments in energy efficiency or renewables in their rate base. In addition, shale gas, which already makes up about 40 percent of gas production in the US (largely at the expense of coal-fired generation), has lowered the wholesale price of power, cutting into revenues and profit margins for deregulated utilities.

It's important to remember, too, that the cleantech space is diverse; it cannot be painted with a broad brush. We looked at 16 important clean technologies[3] and found that while every single one has made progress over the past decade, some are moving much faster than others. Just over half of them—advanced building technologies, advanced agriculture, food life-cycle optimization, grid analytics, grid-scale storage, intelligent transport, next-generation vehicles, solar photovoltaics (PVs), unconventional natural gas, and water treatment—could become truly disruptive to the incumbent industries. The others have enormous potential and could well succeed, but without disrupting the status quo.

Exhibit

Many clean technologies have seen a high rate of growth in installed capacity since 2006.



Source: Bloomberg; Dow Jones; *Global Market Outlook for Photovoltaics 2012–2017*, European Photovoltaic Industry Association, May 2013; Factiva; Global Wind Energy Council; Thomson Reuters Datastream

Myth 2: Technologies have underdelivered

Profit margins have certainly been squeezed in some areas. For instance, Chinese production of solar panels has pushed many higher-cost producers in the Europe and United States out of business. In other cases, limited access to capital and decreasing subsidies have slowed deployment. And many big incumbents have scaled back their cleantech investments.

Yet cleantech has far exceeded expectations in many areas; technological innovation and manufacturing improvements have driven prices down. Costs for onshore wind, solar PV, and lithium-ion batteries have all fallen faster than many industry watchers anticipated, for example, and are continuing to drop. The cost of electricity from onshore wind facilities is half what it was 15 years ago, thanks to technological innovation and business-model changes. In the lighting market, LED gained market share as manufacturing costs and prices fell; over the past five years, the cost of superefficient LED lights has fallen by more than 85 percent. We estimate that the cost of electrical storage has fallen by roughly half, from $1,000 per kilowatt-hour to $500 per kilowatt-hour, since 2009. Similar shifts are taking place in less prominent sectors, such as water reuse, waste separation, and anaerobic digestion.

Total installed costs that US residential consumers pay for solar PV have also been falling fast, from nearly $7 per watt of peak system capacity in 2008 to less than $4 in 2013. We think that could be as little as $1.60 by 2020 (see "The disruptive potential

of solar power," on page 42). The bottom line: cleantech is getting more economically competitive.

Myth 3: The sector depends on regulatory support

Four critical elements—cost, access to capital, the go-to-market approach (broadly defined),[4] and regulation—typically must come together to create successful cleantech businesses.

As the industry matures, the relative importance of these factors is changing: regulation is becoming irrelevant in many cases as clean technologies find their competitive footing. LED lighting is one example: in 2013, LED light sources accounted for the majority of the sales of several large lighting manufacturers, even in markets where incandescent bulbs are still widely available. That figure could rise to more than 80 percent by 2015.

Solar provides evidence both for and against the need for continued regulation. Given budget concerns, a number of countries have canceled or reduced subsidies, and growth has slowed. But the larger point is that solar is still growing. For example, Germany has cut its feed-in tariffs to encourage renewables production, and its strategy of *Energiewende*—a long-term effort to deploy renewables, move away from fossil fuels, and phase out nuclear power—has had some troubles. But the use of renewables continues to grow. Globally, solar installations have risen by 57 percent a year, on average, since 2006. One lesson is that sudden changes in regulation can create peaks and valleys in demand, and that isn't helpful to establish an industry on a sound footing. But the point is that while regulation can be and has been helpful to launch clean technologies, it is no longer critical in many sectors.

The reason isn't only that these technologies continue to advance, although that is the case. What's more interesting is the increased sophistication of business models, financing, and management practices. There are, for example, significant innovations in how cleantech companies are getting access to lower-cost sources of capital, such as cleantech bonds and third-party financing.

And business-model innovations are all over the cleantech map. Water-treatment companies are creating leasing options that reduce capital outlays for filtration technology to encourage its faster deployment. Car-sharing services save millions of tons of carbon in Europe and the United States by making auto ownership more efficient. There are initiatives to use waste products from one industry as feedstock for another; some brewers, for example, are using spent grain as a fuel source for their steam boilers. So far, every company involved has reported increased profits and decreased carbon emissions. A whole new industry has been created around using IT to reduce energy consumption. Some companies, such as C3 Energy, sell electric-utilities software as a service, which analyzes the data generated across their electrical networks to help improve grid operations and asset utilization, thereby increasing profits. Green businesses, in short, are benefiting from better, more creative management practices.

Partnerships and progress

The big guns are taking note. For example, there are power-train partnerships, like Daimler and Tesla's, between the biggest global car giants and small but rapidly growing electric-car companies. The US Department of Defense is working with renewable producers on off-site energy production, and the European oil major Total has taken a controlling investment in SunPower. Such partnerships should help get offerings to market much faster, while giving the smaller firms access to lower-cost capital.

Advanced building technologies, having proved their economic worth and utility, are proliferating—and they are standard for new construction in some markets. So are smart water sensors. The price and energy requirements of water-treatment

technologies have fallen, and investment is strong. Smart-grid hardware has been deployed widely in the past decade, and as users figure out how to use big data and analytic tools, it will become much more important, as witnessed by Google's recent acquisition of Nest Labs for $3.2 billion. For the first time, next-generation vehicles show signs of becoming this-generation vehicles.

We are witnessing the maturation of an industry and the adoption of proven management practices. Successful cleantech companies are making their offerings competitive by focusing on excellence in operations, marketing, sales, and distribution. The principles that apply to any manufacturing business, such as reducing procurement costs and improving productivity through lean manufacturing, are increasingly important for clean technologies as well. The same can be said for practices such as customer segmentation, channel access, and pricing. As these businesses continue to scale up, there will be additional opportunities for improvement.

■ ■ ■

Trends can accelerate, slow down, or even reverse. But it's unlikely that all these technologies will fail, and many are now at the stage where management practices, and not regulation or subsidies, are the defining factor for success. Those that do succeed could be highly disruptive to incumbents, even (or especially) entrenched ones. Big changes in resource use and business models are just around the corner.

To be sure, some cleantech companies will go bust, and some technologies will not make the cut. But these ups and downs are simply the nature of business—part of progress. Notwithstanding the failures of individual companies, cleantech is not going away, either on the ground or as an investment opportunity. And that's no myth. ■

[1] For more on this argument, see Stefan Heck and Matt Rogers, "Are you ready for the resource revolution?," *McKinsey Quarterly*, March 2014, mckinsey.com. This summarizes some of the ideas in Heck and Rogers's new book, *Resource Revolution: How to Capture the Biggest Business Opportunity in a Century*, first edition, New York, NY: New Harvest, April 2014.

[2] See Richard Dobbs, Jeremy Oppenheim, and Fraser Thompson, "Mobilizing for a resource revolution," *McKinsey Quarterly*, January 2012, and *Resource Revolution: Meeting the world's energy, materials, food, and water needs*, McKinsey Global Institute, November 2011, both available on mckinsey.com.

[3] Advanced building technologies, agriculture (seeds, pesticides, drought resistance), biopower, grid analytics, next-generation vehicles, solar photovoltaics, unconventional natural gas, waste recycling, wind, advanced biofuels and bio-based chemicals, carbon capture and storage, food life-cycle optimization, grid-scale storage, intelligent transport, smart water sensors, and water treatment.

[4] The broad go-to-market approaches encompass the wide range of activities (such as marketing, sales, distribution, pricing, and channel management) needed to get products and services to customers and also include the business models companies use, partnerships with established players, and the set of product offerings available.

The authors wish to thank Jason Baum, Stefan Heck, and Sean Kane for their contributions to this article.

Sara Hastings-Simon is a specialist in McKinsey's Calgary office, **Dickon Pinner** is a director in the San Francisco office, and **Martin Stuchtey** is a director in the Munich office.

Unconventional wisdom: Fracturing enters a new era

Faced with change on a scale not seen in decades, companies must alter their business plans to accommodate unconventionals or else risk irrelevance.

Parker Meeks, Dickon Pinner, and Clint Wood

The emergence of shale gas and light tight oil (collectively called "unconventionals") is the biggest change the oil and gas industry has seen in decades. Indeed, the rise of these resources is one of today's biggest economic stories—and hardly anyone saw the scale of what was coming. The shale revolution is, in short, a classic story of disruption. From next to nothing in 2000, unconventional resources already account for 40 percent of US natural-gas production and 29 percent of oil. And their contribution is likely to grow bigger still.

A combination of innovations and technological breakthroughs allowed the oil and gas industry to extract hydrocarbon resources previously considered uneconomical. However, this is only the beginning, not the end, of the need for innovation. The danger for exploration and production companies or oilfield-service companies—whether they are independent wildcatters or global majors—is that they are so stretched to keep up the pace of development that they keep putting off larger questions.

Among them: What is the next big innovation? Are we ready for it? Where are the opportunities for improvement? What are the biggest risks? How can we address or avoid them?

The potential for technological improvements on the horizon is so significant, and so comprehensive, that it could redefine the industry. Companies that want to succeed in the next generation of unconventionals need to start thinking about these things now and incorporate them into their business

strategies. Those that do not will face the biggest risk of all: irrelevance.

Three phases

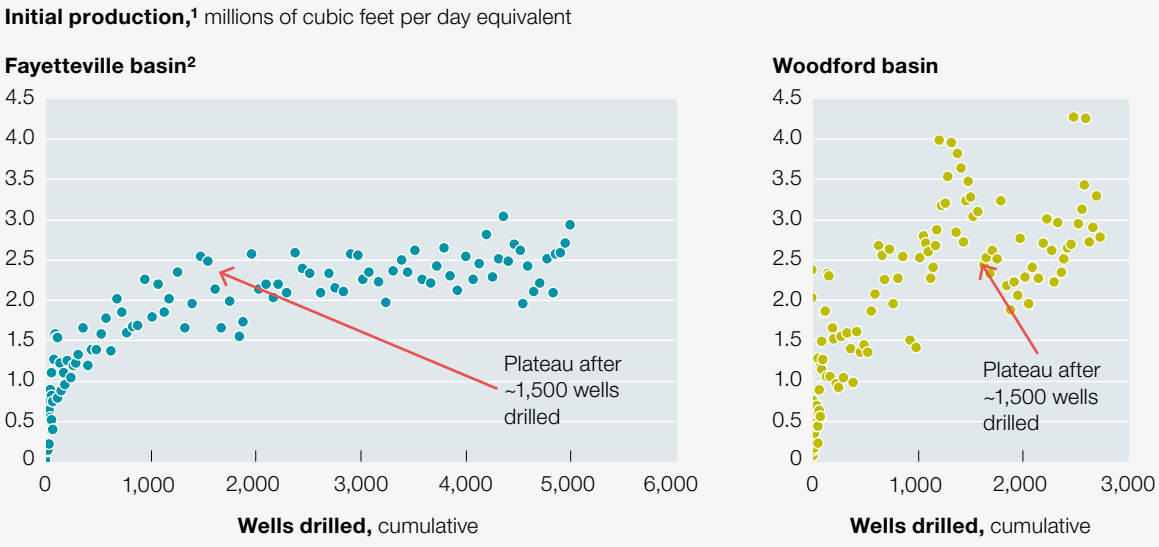
The evolution of unconventional hydrocarbon extraction could be viewed in three phases. In phase one of the shale era, the industry learned how to combine horizontal drilling and hydraulic fracturing (or "fracking") to unlock previously inaccessible supplies. The pioneers were independent energy producers, many of them small. The second phase began as more companies, including some of the majors, started investing significant capital to acquire and develop large positions. Much of the early activity was directed toward shale gas, but investment shifted rapidly to light tight oil, where the same technologies and techniques were applied.

Despite the scale of production, and though the industry has continued to improve production techniques, the fracturing process remains by and large a matter of trial and error. Each new basin has a different geology, requiring a long and expensive learning period to determine how to operate (Exhibit 1). Even in mature basins, there is little consensus on how wells should be spaced or the optimal number of wells per pad.

That is the context for phase three, which we believe the industry is about to enter. In this phase, companies will continually optimize best practices; these will spread. Technology and improved operations will address major pain points, including cost and environmental concerns. If unconventionals follow the path of other industries that have been able to tap new markets thanks to innovation breakthroughs,

Exhibit 1

Learning curves for new basins show that about 1,500 wells must be drilled before initial production from the wells plateaus.



[1]Based on reported initial production rates for first 2 calendar months of production.
[2]Includes both East and West Fayetteville.

Source: HPDI; McKinsey analysis

then production from individual wells will rise and be more systematic and predictable for new basins. Costs will fall. And those who are late to the party will be shut out.

The potential of unmet needs

Making operations cheaper, cleaner, and more efficient will require technological advances along every link of the value chain. There is considerable value waiting to be unlocked, as technology begins to address outstanding issues in the production cycle. Among the possibilities are identifying attractive basins at lower cost, improving recovery rates from each well, improving logistics and supply-chain management, and reducing environmental effects.

We have identified four promising technologies that in the next five to ten years could address these needs and deliver another dose of disruption. The value of additional light-tight-oil production alone, based on greater production and lower capital costs, could reach $55 billion a year by 2020, according to our research (Exhibit 2). This does not take into account the value of improved environmental performance, such as reduced water use, improved energy efficiency, or less truck traffic.

Technology 1: Improved geophysical data collection and integration with real-time fracture modeling

The industry's understanding of subsurface fracture behavior has significant room for improvement. Hydrocarbons trapped in shale do not flow like those in conventional reservoirs. Changes in geology over small distances (even as little as ten feet) could influence a drilling- or completion-design decision. The difficulty of understanding fluid-flow mechanisms and fracture productivity is reflected in the fact that 60 percent of all fracture stages are ineffective and 70 percent do not reach their production targets. One big opportunity, then, is to use technology to make more stages more productive and to identify stages that will not bring a good return on investment. A better understanding of fracture behavior, in combination with new proppant technology (that is, technology involving the materials that keep the fracture open), could

Exhibit 2 **New technologies could unlock an additional $55 billion in light-tight-oil production in 2020.**

also boost the productive life of wells and improve access to the resource in the source rock.

This is challenging, due to the nature of unconventional production. Disaggregating geological effects from well-design decisions is an uncertain process. Moreover, the data to judge well performance is often based on the scale of initial production, which is only a proxy for total recovery over the lifetime of the well. As a result, systematic optimization and comparisons are difficult—but not impossible.

To address these issues, the industry needs to have better information and to utilize the information it can access in a more timely manner. One emerging technology that companies are working on for real-time fracture monitoring is microseismic analysis, in which geophone arrays measure seismic activity in real time. These arrays can detect the spatial location of fracture events as well as frack size.

The industry is also working on developing predictive algorithms to provide insights about fracture behavior and help determine where to place stages and how to set fracturing-stage design parameters. Ideally, models would process and combine downhole and microseismic data, building this into their predictive algorithms and thus optimizing conditions in real time.

Improved modeling could also reduce the number of wells required to prove a basin, cutting both costs and environmental impact. This could be particularly important outside the United States, where the industry is not as well developed, not as many existing wells have been drilled, and the cost for developing a basin is split among only a few players or state-owned companies.

Technology 2: Water treatment

Large volumes of chemically treated water—two million to seven million gallons per well—are used to create fractures in the rock. Much of this water is being used in regions that are experiencing extended drought conditions, such as the Eagle Ford in South Texas. The water that flows back is typically disposed of, rather than treated for reuse. Although reuse is preferable because it reduces the use of freshwater, disposal historically has been more common. A big reduction in water usage, however, could help the industry to open new markets in countries where water is scarce and infrastructure undeveloped and address one of the key environmental challenges of hydraulic fracturing.

Freshwater use can be reduced by using flow-back water—the fracturing water recovered at the surface—to fracture other wells. To be reused, however, the flow-back water must be treated to remove larger suspended solids and other contaminants. The flow-back period can last for weeks or even months. During this time, there can be changes in the rate of flow of water, the amount, and the type of suspended solids in the water. This makes treatment difficult. Advances in the effectiveness of fracturing chemicals have reduced treatment requirements, but there is considerable room for technological and logistical improvement.

Widespread reuse is within reach, and treatment technologies can be borrowed from other applications and industries. Mature technologies such as membrane and filtration, distillation and flash distillation, and crystallization produce clean water but come with higher costs and energy usage. Emerging technologies include flocculants, centrifuges, electroprecipitation, and the use of ultraviolet lights and ultrasonics. It may be necessary to use a combination of these technologies to meet treatment needs. Further out and still unproved are technologies such as electrodialysis, ion exchange, and algae.

Technology 3: IT-enabled supply-chain management

IT and analytic tools can address a number of the unmet needs, from exploration and production

Reducing greenhouse-gas emissions and the amount of land required for each well site will be critical in many geographies, particularly in Europe.

to transportation, refining, distribution, and retail sales. These tools can range from individual point solutions to fully integrated enterprise-class data-analytics platforms.

Information management can help operators to identify and solve problems earlier. For example, GPS-enabled trucks and tracking programs make it possible to identify when a shipment will be delayed. As a result, operators can begin to find solutions before the truck is late, reducing the amount of down-time for staff and equipment.

Integrated platforms can aggregate data from across the value chain and develop insights that can generate billions of dollars in annual value for large companies. For example, upstream asset-analytics applications can reduce costs and increase production by tracking, ranking, and predicting the performance of individual wells; this data can then be used to predict the performance of other wells with similar characteristics. It can also help to shift an industry that thinks about well maintenance as "interventions" to one that leverages the best in predictive analytics.

Technology 4: Nonwater fracturing

The benefits of breaking into the source rock by using something other than water could be enormous, reducing environmental impact and opening up new areas for exploration that are off limits now because of lack of water.

The nonwater technologies in use today are similar to hydraulic fracturing in that they use pressurized-fluid mixtures to break the rock. Vapor fracturing uses a foam of high-pressure nitrogen or carbon dioxide gas. This commercialized technology is offered by major oil-field-service and equipment providers but is often limited to reservoirs with lower-pressure volumes. Liquid-petroleum-gas fracturing uses a cooled gel to pump the proppant and has the benefit of lower surface tension but the material risk of being highly flammable.

All these technologies have safety, cost, technical, and logistical concerns. There may be specific places, such as those where water is short or where hydraulic infrastructure is less developed, where these technologies could compete. However, a truly new approach to accessing the source rock without using pressurized fluids would be a game changer. This type of technology is the furthest from development but could generate the most value and disruption.

Capturing the value

The potential to boost shale-energy production to a new level raises several issues for industry participants—producers, oil-service companies, and equipment manufacturers.

There are three important considerations.

Diversity of needs. The need for and value of different technologies will vary by region, depending on geology, environment, and policy. Reducing greenhouse-gas emissions and the amount of land required for each well site will be critical in many geographies, particularly in Europe. In China, key

challenges are water scarcity and geology. The most pressing needs may evolve over time, as they have in North America.

Technology as the price to play. In many countries with national oil companies, such as Indonesia and Saudi Arabia, foreign companies cannot own the land or drilling rights, but they can partner with local players if they bring technology. For many of these global unconventional basins, having a technology offering may be the price to enter.

Who captures the value? Industry participants need to understand how the industry structure is changing and what the half-life is for new innovations. We have already seen more vertical integration in unconventional oil and gas production, but oilfield-service companies are investing more in R&D focused on unconventionals. Reconciling who will develop the new technologies, who will pilot them, and how value will be split among value-stream participants will be critical as unconventionals mature in North America and potentially grow globally.

■ ■ ■

Most energy-industry participants recognize that the unconventional revolution has not yet reached its full potential. But we think the opportunity for technological innovation could be bigger, with respect to both scale and geographic reach, than acknowledged in many current conversations in the industry.

There are immediate operational improvements to be made, and these matter. But players must not get so lost in these day-to-day concerns that they miss the much bigger opportunities associated with longer-term technological development. And that brings us to one final challenge: to manage innovation at the industry level, different players—even competitors—must work together to solve technological issues and seek appropriate regulation. That may cut against the grain. But the alternative is to leave tens of billions of dollars in profits untapped and underground. ■

The authors wish to thank Vanessa Chan and Sara Hastings-Simon for their contributions to this article.

Parker Meeks is a principal in McKinsey's Houston office, where **Clint Wood** is an associate principal, and **Dickon Pinner** is a director in the San Francisco office.

The disruptive potential of solar power

As costs fall, the importance of solar power to senior executives is rising.

David Frankel, Kenneth Ostrowski, and Dickon Pinner

The economics of solar power are improving. It is a far more cost-competitive power source today than it was in the mid-2000s, when installations and manufacturing were taking off, subsidies were generous, and investors were piling in. Consumption continued rising even as the MAC Global Solar Energy Index fell by 50 percent between 2011 and the end of 2013, a period when dozens of solar companies went bankrupt, shut down, or changed hands at fire-sale prices.

The bottom line: the financial crisis, cheap natural gas, subsidy cuts by cash-strapped governments, and a flood of imports from Chinese solar-panel manufacturers have profoundly challenged the industry's short-term performance. But they haven't undermined its potential; indeed, global installations have continued to rise—by over 50 percent a year, on average, since 2006. The industry is poised to assume a bigger role in global energy markets; as it evolves, its impact on businesses and consumers will be significant and widespread. Utilities will probably be the first, but far from the only, major sector to feel solar's disruptive potential.

Economic fundamentals

Sharply declining costs are the key to this potential. The price US residential consumers pay to install rooftop solar-photovoltaic systems has plummeted from nearly $7 per watt peak of best-in-class system capacity in 2008 to $4 or less in 2013.[1] Most of this decline has been the result of steep

reductions in upstream (or "hard") costs, chiefly equipment. Module costs, for example, fell by nearly 30 percent a year between 2008 and 2013, while cumulative installations soared from 1.7 gigawatts in 2009 to an estimated 11 gigawatts by the end of 2013, according to GTM Research.

While module costs should continue to fall, even bigger opportunities lurk in the downstream (or "soft") costs associated with installation and service. Financing, customer acquisition, regulatory incentives, and approvals collectively represent about half the expense of installing residential systems in the United States. Our research suggests that as they become cheaper, the overall costs to consumers are poised to fall to $2.30 by 2015 and to $1.60 by 2020.

These cost reductions will put solar within striking distance, in economic terms, of new construction for traditional power-generation technologies, such as coal, natural gas, and nuclear energy. That's true not just for residential and commercial segments, where it is already cost competitive in many (though not all) geographies, but also, eventually, for industrial and wholesale markets. Exhibit 1 highlights the progress solar already has made toward "grid parity" in the residential segment and the remaining market opportunities as it comes further down the curve. China is investing serious money in renewables. Japan's government is seeking to replace a significant portion of its nuclear capacity with solar in the wake of the Fukushima nuclear accident. And in Europe and the United States, solar adoption rates have more than quadrupled since 2009.

While these economic powerhouses represent the biggest prizes, they aren't the only stories. Sun-drenched Saudi Arabia, for example, now considers solar sufficiently attractive to install substantial capacity by 2032,[2] with an eye toward creating local jobs. And in Africa and India, where electric grids are patchy and unreliable, distributed generation is increasingly replacing diesel and electrifying areas previously without power. Economic fundamentals (and in some cases, such as Saudi Arabia, the desire to create local jobs) are creating a brighter future for solar.

Business consumption and investment

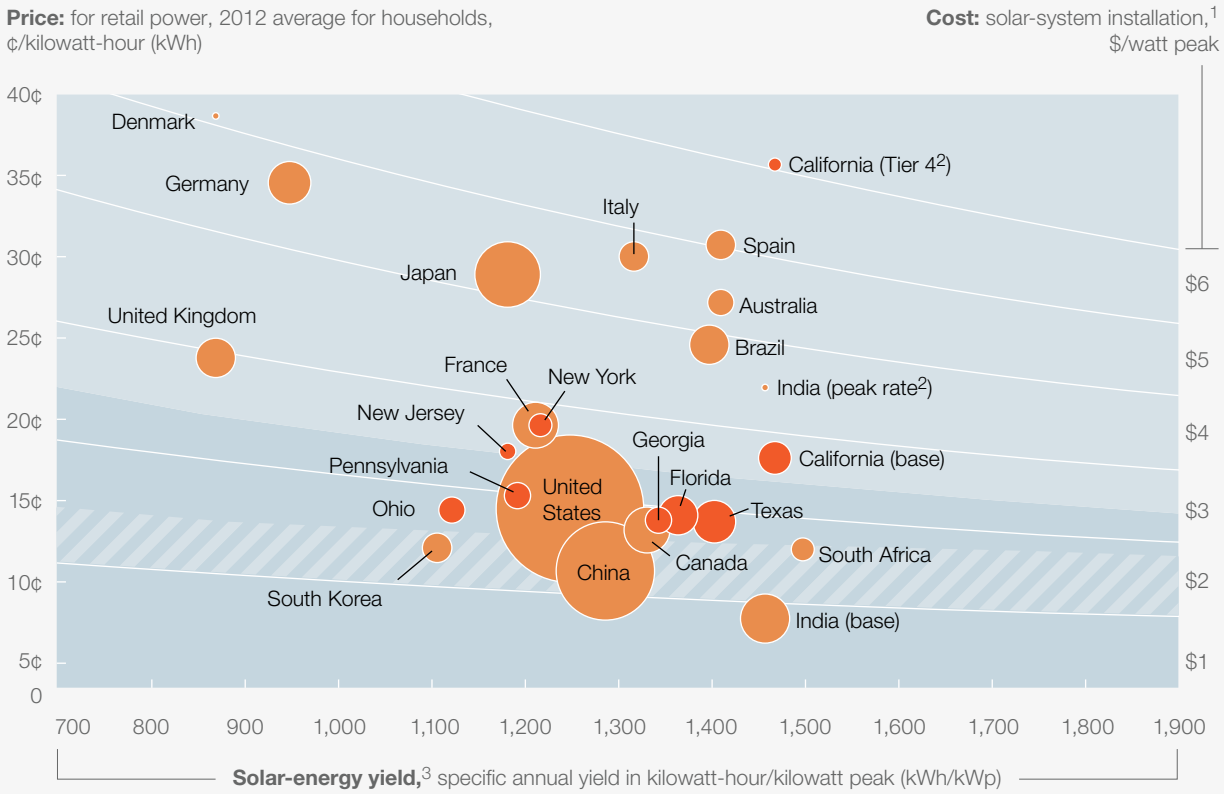
Solar's changing economics are already influencing business consumption and investment. In consumption, a number of companies with large physical footprints and high power costs are installing commercial-scale rooftop solar systems, often at less than the current price of buying power from a utility. For example, Wal-Mart Stores has stated that it will switch to 100 percent renewable power by 2020, up from around 20 percent today. Mining and defense companies are looking to solar in remote and demanding environments. In the hospitality sector, Starwood Hotels and Resorts has partnered with NRG Solar to begin installing solar at its hotels. Verizon is spending $100 million on solar and fuel-cell technology to power its facilities and cell-network infrastructure. Why are companies doing such things? To diversify their energy supply, save money, and appeal to consumers. These steps are preliminary, but if they work, solar initiatives could scale up fast.

As for investment, solar's long-term contracts and relative insulation from fuel-price fluctuations are proving increasingly attractive. The cost of capital also is falling. Institutional investors, insurance companies, and major banks are becoming more comfortable with the risks (such as weather uncertainty and the reliability of components) associated with long-term ownership of solar assets. Accordingly, investors are more and more willing to underwrite long-term debt positions for solar, often at costs of capital lower than those of traditional project finance.

Major players also are creating advanced financial products to meet solar's investment profile. The best example of this to date is NRG Yield, and we

Exhibit 1 **A sharp decline in installation costs for solar-photovoltaic systems has boosted the competitiveness of solar power.**

Grid-parity potential of solar-photovoltaic (PV) power in major markets, residential-segment example



[1]Full cost estimated, based on residential 5-kilowatt c-Si system; levelized cost of energy accounts for solar insulation and assumes 5% weighted average cost of capital, 25-year lifetime, 0.3% annual degradation, and fixed 1% operating and maintenance costs.
[2]California's rate structure charges more for higher consumption; the highest rate ranges from 31–37¢/kWh, depending on the utility. For India, peak rate refers to the rate without an artificial cap, which is imposed to close the peak-power deficit filled by diesel-generated power. Only 2008 data available.
[3]Amount generated by a south-facing 1 kWp module in 1 year (a function of solar intensity).

Source: Enerdata; India Central Electricity Authority; International Energy Agency; Solar Energy Research Center at Lawrence Berkeley National Labs; US Energy Information Administration; US National Renewable Energy Laboratory's PVWatts calculator; McKinsey analysis

expect other companies to unveil similar securities that pool renewable operating assets into packages for investors. Google has been an active tax-equity investor in renewable projects, deploying more than $1 billion since 2010. It also will be interesting to track the emergence of solar projects financed online via crowd-sourcing (the best example is Solar Mosaic, which brings investors and solar-energy projects together). This approach could widen the pool of investors while reducing the cost of capital for smaller installations, in particular.

Disruptive potential

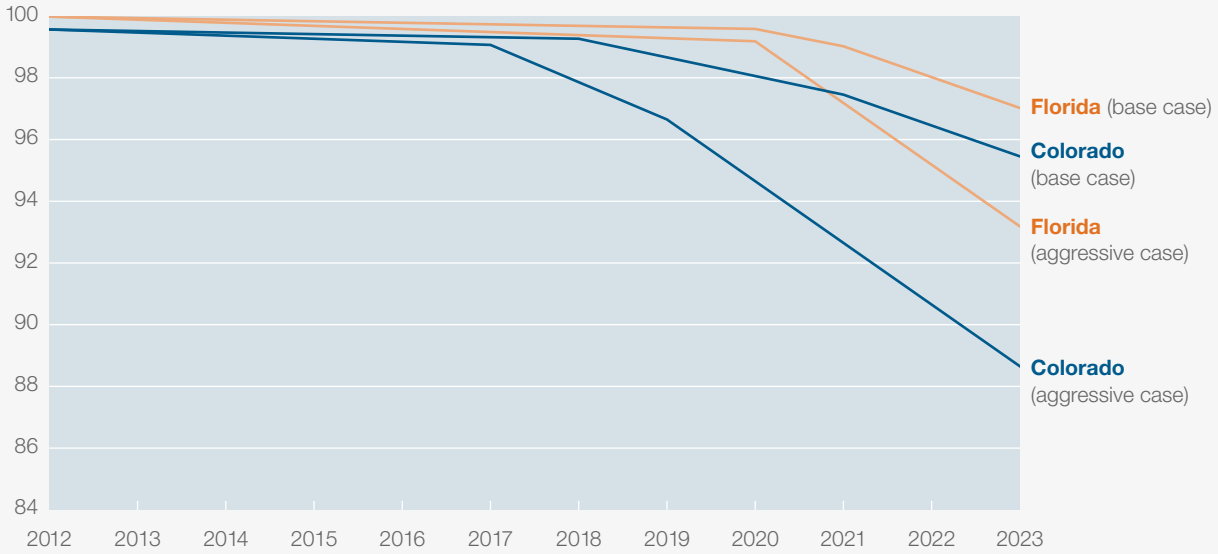
The utility sector represents a fascinating example of the potential for significant disruption as costs fall, even as solar's scale remains relatively small. Although solar accounts for only less than half a percent of US electricity generation, the business model for utilities depends not so much on the current generation base as on installations of new capacity. Solar could seriously threaten the latter because its growth undermines the utilities' ability to count on capturing all new demand, which historically has fueled a large share of annual revenue growth. (Price increases have accounted for the rest.)

Depending on the market, new solar installations could now account for up to half of new consumption (in the first ten months of 2013, more than 20 percent of new US installed capacity was solar). By altering the demand side of the equation,

Exhibit 2

Although solar power will continue to account for a small share of the overall US energy supply, it could well have an outsize effect on the economics of utilities.

Remaining electricity consumption from utilities after solar-photovoltaic (PV) adoption, both residential and commercial,[1] % of megawatt-hours



[1]Assumes 8% discount rate, $0.02/watt year in operations and manufacturing costs, 25-year system life; US solar investment tax credit expires post-2016 (10% thereafter), Colorado incentive of $0.04/kilowatt-hour (kWh) for residential, $0.07/kWh for commercial customers through 2018. Base case assumes 0.05% annual solar PV adoption when levelized cost of electricity is above retail grid electricity prices, and 1% when below. Aggressive case assumes 0.1% and 2%, respectively.

Source: US Energy Information Administration; McKinsey analysis

solar directly affects the amount of new capital that utilities can deploy at their predetermined return on equity. In effect, though solar will continue to generate a small share of the overall US energy supply, it could well have an outsize effect on the economics of utilities—and therefore on the industry's structure and future (Exhibit 2).

That's already happening in Europe. Over the last several years, the demand for power has fallen while the supply of renewables (including solar) has risen, driven down power prices, and depressed the penetration of conventional power sources. US utilities can learn many lessons from their European counterparts, which for the most part stood by while smaller, more nimble players led the way. Each US utility will have to manage the risks of solar differently. All of them, however, will have to do something.

Broader management implications

As solar becomes more economic, it will create new battlegrounds for business and new opportunities for consumers. When a solar panel goes up on a homeowner's roof, the installer instantly develops a potentially sticky relationship with that customer. Since the solar installation often puts money in the homeowner's pocket from day one, it is a relationship that can generate goodwill. But, most important, since solar panels are long-lived assets, often with power-purchase agreements lasting 15 or 20 years, the relationship also should be enduring.

That combination may make solar installers natural focal points for the provision of many products and services, from security systems to mortgages to data storage, thermostats, smoke detectors, energy-information services, and other in-home products. As a result, companies in a wide range of industries may benefit from innovative partnerships built on the deep customer relationships that solar players are likely to own. Tesla Motors already has a relationship with SolarCity, for example, to develop battery storage coupled with solar. It is easy to imagine future relationships between many other complementary players. These possibilities suggest a broader point: the solar story is no longer just about technology and regulation. Rather, business-model innovation and strong management practices will play an increasingly important role in the sector's evolution and in the way it engages with a range of players from other industries. Segmenting customers, refining pricing strategies, driving down costs, and optimizing channel relationships all will figure prominently in the solar-energy ecosystem, as they do elsewhere.

As solar becomes integrated with energy-efficiency solutions, data analytics, and other technologies (such as storage), it will become an increasingly important element in the next generation of resource-related services and of the world's coming resource revolution. In the not too distant future, a growing number of industries will have to take note of the promise, and sometimes the threat, of solar to business models based on traditional energy economics. But, in the meantime, the battle for the customer is taking place today, with long-term ramifications for existing industry structures. ■

[1] Based on the 90th percentile of 2012–13 installed costs in California, as reported to the California Solar Initiative.
[2] Both solar photovoltaic and concentrated solar power are included in the Saudi government's request for proposals.

The authors would like to thank Stefan Heck, Sean Kane, and Farah Mandich for their contributions to this article.

David Frankel is an associate principal in McKinsey's San Francisco office, where **Dickon Pinner** is a director, and **Ken Ostrowski** is a director in the Atlanta office.

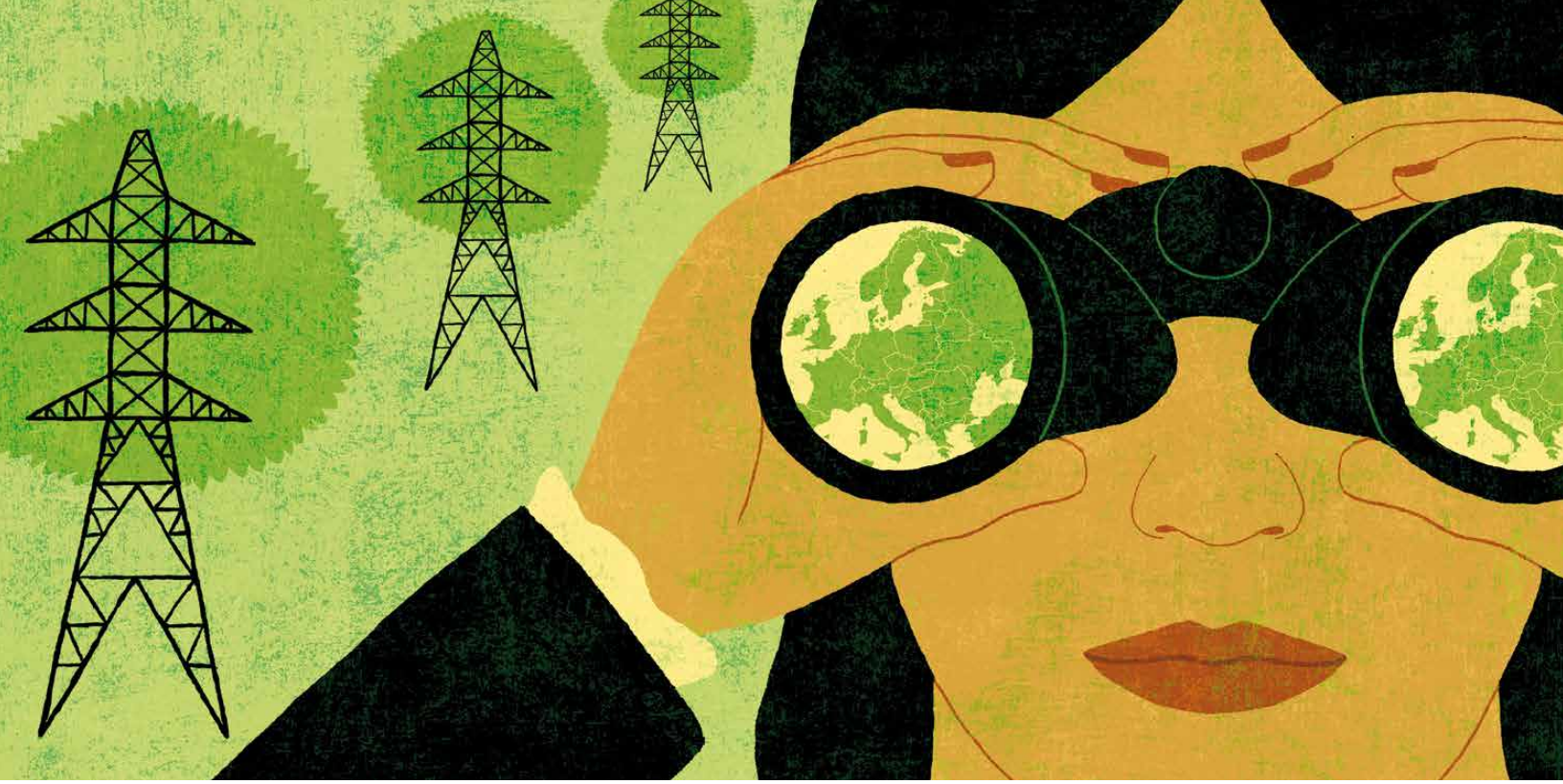


Illustration by James Steinberg

Bioenergy in Europe:
A new beginning—or the end of the road?

Bioenergy faces challenges in Europe, but there is reason to believe it can make a comeback.

Marco Albani, Anja Bühner-Blaschke, Nicolas Denis, and Anna Granskog

When the European Commission announced its long-term climate-change strategy in January 2014, it called for a higher target for the use of renewable-energy sources: 27 percent by 2030. This goal, combined with recent developments in the industry, could open a new and promising chapter for bioenergy in Europe.

In broad terms, the new plan is the natural follow-up to the "20-20-20" program of 2007 and the 2010 National Renewable Action Plans (NREAPs). The 20-20-20 plan called for a 20 percent reduction in greenhouse-gas emissions (compared with 1990), thereby increasing renewable energy to 20 percent of the power supply and improving energy efficiency by 20 percent. The NREAPs helped governments figure out the renewable-energy part of the puzzle.

At the time, the outlook was for the volume of biomass-based electricity—that is, power derived from wood and other organic materials, such as crops and agricultural residues—to double from 114 terawatt-hours[1] in 2010 to 232 terawatt-hours in 2020 (out of a total 3,346 terawatt-hours). As for heat, the goal was for biomass to grow from 685 terawatt-hours to just over 1,000 terawatt-hours. In both cases, biomass has fallen short; the European Union estimated it will reach only 83 percent of its target by 2020.[2]

What happened? Why has biomass-based energy been growing less than planned? Is there still a place for it in the European energy mix?

Like all renewable energy in the European Union, bioenergy has suffered from low-priced coal imports (a side effect of the rise of shale gas in the United States), low carbon dioxide (CO_2) prices in the emissions-trading system, and the economic and regulatory backlash against renewable-energy policies, including substantial cuts in government support. It has not delivered on declining unit costs and is often not competitive with wind and solar in the renewables sector.

In addition, biomass has to overcome hurdles of its own making, including the lack of industrialized fuel supply chains and continued skepticism over whether bioenergy is sustainable. Most important, because of the slow growth, biomass has not reached critical mass in the European energy mix. Given these issues, it is fair to question the future of bioenergy in Europe, even as the European Union prepares to increase its use of renewables.

However, there are two reasons to be optimistic. First, bioenergy offers one of the most capital-efficient transitions from coal to renewables. In 2011, the European Union produced about 850 terawatt-hours of electricity from coal and lignite; that accounted for about a quarter of energy production. Reducing the share of coal-fired power generation is an essential part of any decarbonization strategy. Biomass cofiring and coal-to-biomass conversions enable generators to use existing coal assets and infrastructure to produce renewable energy. This cannot be said of other renewable-energy sources.

Second, bioenergy offers a scalable opportunity for European utilities to take part in the second wave of renewable-energy-source growth. To date, European utilities have captured a limited share of these investments, mostly onshore wind and rooftop solar. Biomass has the significant advantages of being able to serve as a source of baseload power, which wind and solar cannot, and requires no major investments in the grid. With carbon capture and storage still far from happening, bioenergy offers a way for big utilities to comply with renewable targets while using their existing assets.

Drax, a UK generator, shows it can be done. In part because moving away from coal is a prerequisite for its license to operate, the company has begun an €800 million program to convert three of its six coal units, with a combined capacity of about 2,000 megawatts (enough to power up to 3.5 million British homes), to run on biomass.

Three challenges

A bioenergy comeback, however, will require specific barriers to growth to be addressed. There are three major challenges: affordability, efficiency, and acceptance.

Affordability: Making biomass-based energy cost competitive

Historically, biomass-based power has been generated from low-cost, low-grade waste-fuel streams, such as crop residues and wood chips. These have often been used in small-scale combined-heat-and-power plants that serve industrial sites or municipal-district heating networks.

The development of solar and onshore wind, however, followed a different trajectory. Both industries have seen an influx of Chinese and other non-European equipment makers; the ensuing competition sharply cut the price of the levelized cost of energy, or the cost per kilowatt-hour, in real terms, of building and operating a power plant. Lower costs in turn fueled more growth.

Bioenergy technology providers have not been exposed to similar competitive forces in their own segment, and they have so far not fully embraced the competition from other renewable energy technologies. Bioenergy trails onshore wind on cost

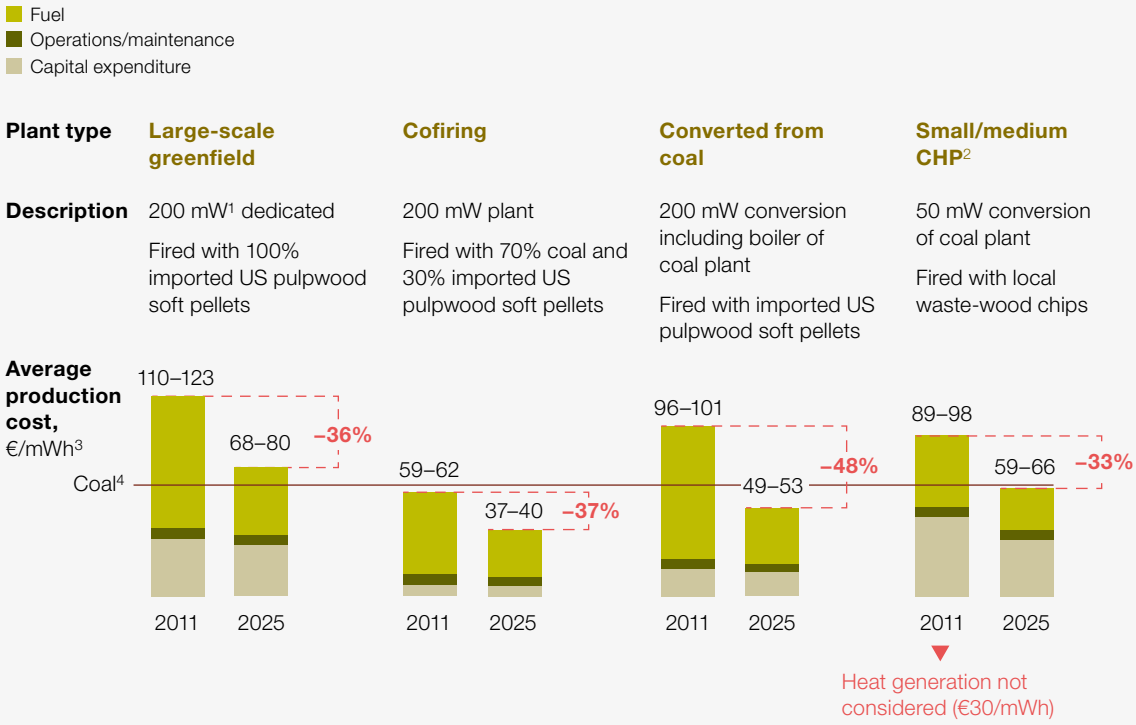
competitiveness; in addition, the costs for most other renewable technologies are projected to keep falling faster.

Where does biomass fit in? Our analysis suggests that there is an opportunity to reduce the levelized cost of energy for bioenergy by almost half by 2025. This would require significant efforts but no new technology breakthroughs. For instance, boiler efficiency in biomass plants today is often as little as 30 percent. Improvements, such as increasing steam parameters,[3] would reduce the volume of feedstock required and lower costs. The standardization of bioenergy-plant designs, boiler and plant modularization, and application of design to value could also push costs down. Finally, fuel costs could be lowered by applying lean techniques to remove unnecessary supply-chain costs. As suggested in Exhibit 1, getting this right could bring down the cost of bio-based electricity to levels that are competitive with coal.

Efficiency: Industrializing the biomass supply chain

Bioenergy feedstocks are abundant, but their potential has not been maximized.[4] The use of biomass for energy is therefore well below the sustainable annual cut volumes of forests.

Exhibit 1 **Depending on the type of plant, biomass could make levelized-cost-of-energy improvements of up to 48 percent by 2025, making it close to competitive with coal.**



[1]Megawatts.
[2]Combined heat and power.
[3]Megawatt-hour.
[4]Estimated cost of coal (€64/mWh, with carbon dioxide at €20/ton), which remains stable throughout 2025.

One reason is that the value chains of wood pellets and wood chips (the most common feedstocks) are not well established. Feedstock contracts today are done on a bilateral basis; there is no biomass market to provide price transparency or liquidity for buyers and sellers.

There is potential to develop more efficient, industrialized supply chains for biomass. To make this happen, there are two requirements: the use of long-term contracts and a breakthrough in fuel-treatment technology.

Long-term contracts with a duration of five to ten years would provide a basis for increasing supply investments, because they give investors a sense of security that this use of capital will pay off. Such contracts would also provide an incentive for removing waste along the supply chain. The much-needed operational improvements along the biomass supply chain include raising the utilization of pellet plants, optimizing inventories, improving the energy efficiency of pelletization, and maximizing shipload sizes.

Generators' largest concern with regard to long-term contracts has been regulatory uncertainty. If government policies change, so might their revenue streams. That is one reason that generators have not been willing to commit to contracts that fix their feedstock costs on a long-term basis.

On the supplier side, some providers have held back on long-term contracts, believing that increased demand for biomass could lead to higher prices; they therefore wanted to avoid getting locked in at lower ones. Our analysis suggests that this is not a valid assumption: increased demand does not necessarily lead to higher prices, as long as supply keeps up (Exhibit 2).

The cost competition between bioenergy and other renewable-energy sources limits biomass buyers' willingness to pay more; the cost pressure is downward. Thus, buyers and sellers need to find ways to make biomass a cost-competitive fuel. At this stage of development, long-term contracts are needed as a bridge before a transparent, liquid, and efficient biomass market can emerge.

Second, breakthroughs in fuel treatment, like pelletization and torrefaction, could markedly improve efficiency and also simplify transportation and storage. Recently, there has been significant progress in torrefaction, which is the removal of moisture and volatiles from the feedstock, leaving biocoal. Torrefied pellets not only have higher energy content but also have physical properties similar to coal, making them relatively simple to cofire with the same infrastructure. In late 2013, Topell Energy, a Dutch cleantech company, announced that it would produce torrefied pellets at commercial scale (six tons an hour). Valmet, a Finnish technology company, has developed a different method (steam explosion) for producing biocoal that is also ready for commercial-scale application.

Acceptance: Defining 'sustainable bioenergy'

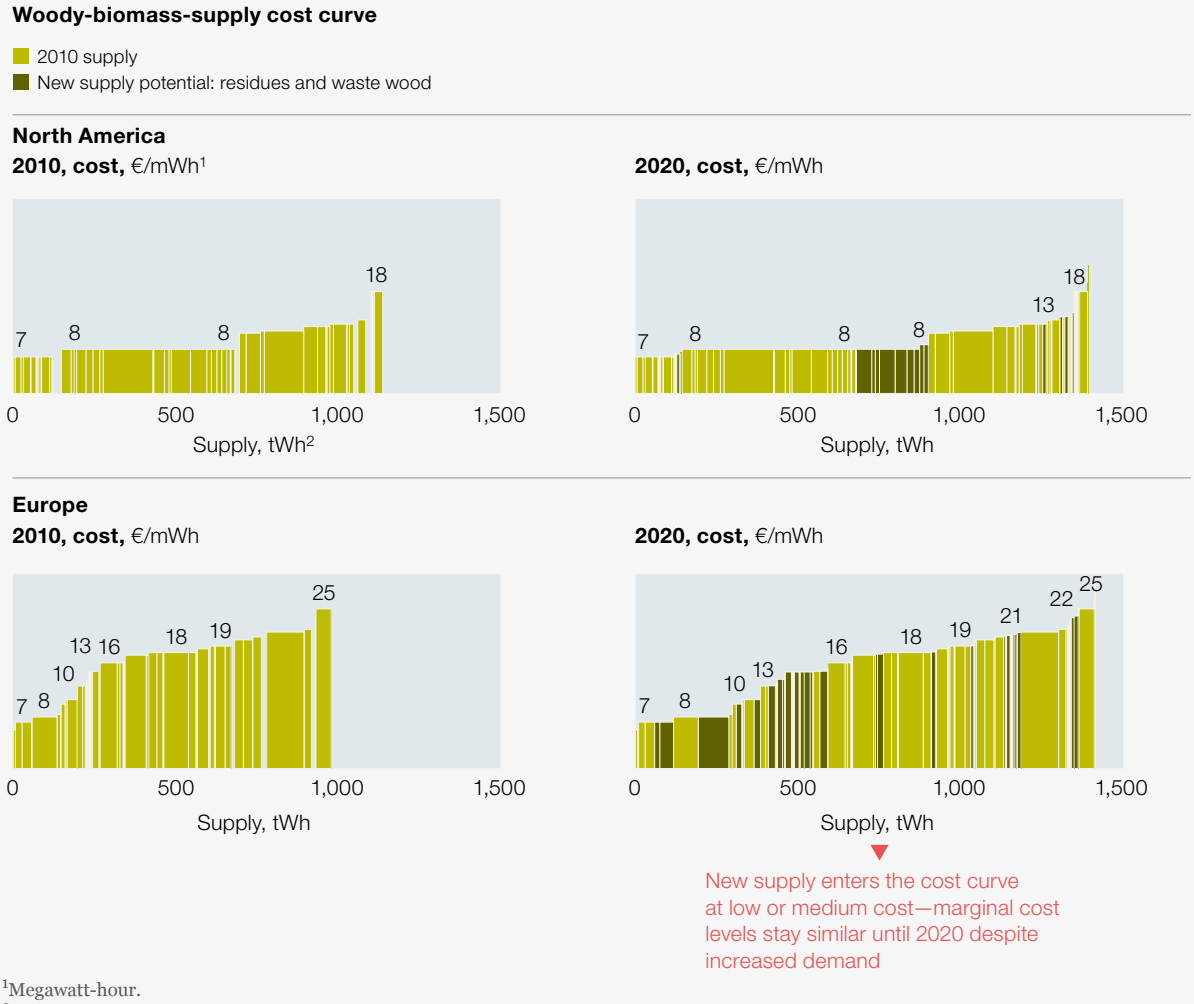
Opinions on the benefits of bioenergy vary widely. The main issues are the environmental standards of non-European biomass imports, and to what extent biomass leads to lower CO_2 emissions.

The lack of clear standards makes it difficult for market participants to trust that the biomass they source will be considered sustainable in the long term. This uncertainty inhibits growth. There are high-level discussions about how to create EU-wide sustainability criteria but no official conclusions yet.

The question of how much actual CO_2 reduction can be achieved through biomass cannot be answered in a straightforward manner. According to the broadest definition, bioenergy should be considered sustainable from a greenhouse-gas perspective as

Exhibit 2

The marginal cost of biomass does not necessarily increase significantly when demand increases, assuming residues and waste wood can be captured.



[1]Megawatt-hour.
[2]Terawatt-hour.

Source: US Department of Energy

long as its fossil CO_2 emissions are lower than if the same amount of energy was generated with fossil fuels. At the time of combustion, bioenergy-related carbon emissions may be higher than comparable emissions from burning fossil fuels because of the lower energy density of biomass. But, unlike fossil fuels, the recultivation of the area from which biomass is removed can return it to its former carbon-stock level and thus offset the emissions. In the case of wood or crops cultivated specifically for energy use, the CO_2 has already been absorbed in advance. Hence, in a steady state, net emissions from fossil fuels will always exceed those of bioenergy.

A stricter approach—the closed-CO_2-loop perspective—considers bioenergy carbon neutral

as long as its emissions (including those from harvesting, transport, and replanting) are offset by new biomass growth. As such, the growth of new biomass must always surpass harvest to cover these additional emissions. In the United States, for example, harvest rates have been lower than carbon-stock growth in recent years. It is important to note that the speed at which forests sequester carbon varies significantly depending on climate conditions. For example, Brazilian eucalyptus plantations close their CO_2 loop faster than Nordic softwood forests.

A much stricter school of thought considers bioenergy sustainable only if it is close to 100 percent carbon neutral at any time. That is, bioenergy emissions should never be higher than the emissions that would have occurred had the biomass not been burned, including the foregone carbon sequestration from the land where biomass fuels have been produced. This approach, however, is complex to put into practice. It requires assumptions about the biomass-fuel mix that will be used—for example, what fraction of biomass will come from harvest residues (tops and branches of trees cut for use by the forest industry), instead of whole trees that would have not been otherwise cut.

It also requires understanding how bioenergy demand will affect the land-management decisions of a dispersed base of biomass suppliers. More active management, if done well, can improve the economic and ecological services of many forested landscapes without reducing the carbon they store. Finally, even unmanaged forests are at risk of carbon loss from unforeseen insect infestation or large fires. These risks need to be taken into account.

The industry would benefit from a clear definition of sustainability so that participants can understand what is expected of them.

Europe's climate goals provide a new opportunity to revive the bioenergy industry, with great potential to step up as a fast and capital-efficient replacement for coal. But while these policies might be helpful, the industry itself must act to make the case for its existence—something it has failed to do in the past. A comeback requires that the industry lower total costs, create more efficient value chains, and define a credible sustainability story. Without a renewed sense of urgency to deliver improvements in both cost and performance, there will be no place for bioenergy in Europe's future energy mix. ■

[1] A terawatt-hour is a unit of energy equivalent to a million megawatt-hours, or 588,440 barrels of oil.
[2] *Renewable Energy Progress Report*, Commission to the European Parliament, the Council, the European Economic and Social Committee, and the Committee of the Regions, March 2013, ec.europa.eu.
[3] For example, pressure, temperature, and energy efficiency.
[4] Bill Caesar et al.,"Biomass: Mobilizing a sustainable resource," *Sustainable Bioenergy*, Environmental Finance Publications, 2010.

Marco Albani is a senior expert in McKinsey's Rome office, **Anja Bühner-Blaschke** is a specialist in the Singapore office, **Nicolas Denis** is a principal in the Brussels office, and **Anna Granskog** is a principal in the Helsinki office.

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