McKinsey&Company

McKinsey on Sustainability & Resource Productivity

Highlights

Sustainability & Resource Productivity Number 4, 2016

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, email us: Sustainability@McKinsey.com.

Editorial Board:
Shannon Bouton, Anne-Titia Bové, Dorothée D´Herde, Pablo Ordorica Lenero, Scott Nyquist, Matt Rogers, Sunil Sanghvi, Steven Swartz, Jonathan Woetzel

Editors: Cait Murphy, Josh Rosenfield

Art Direction and Design:
Leff Communications

Managing Editors:
Michael T. Borruso, Venetia Simcock

Editorial Production:
Runa Arora , Elizabeth Brown, Heather Byer, Roger Draper, Torea Frey, Heather Hanselman, Gwyn Herbein, Katya Petriwsky, John C. Sanchez, Dana Sand, Sneha Vats, Belinda Yu

Cover photo:
© Stevanovicigor/ Getty Images

McKinsey & Company Practice Publications
Editor in Chief:
Lucia Rahilly

Executive Editors:
Michael T. Borruso, Allan Gold, Bill Javetski, Mark Staples

Table of contents

© Stevanovicigor/Getty Images

Introduction

Scott Nyquist and Matt Rogers

Welcome to the fourth issue of *McKinsey on Sustainability & Resource Productivity*.

Sustainable growth, in both economic and environmental terms, is a global priority. Economically, more than a billion people lack access to electricity. Even more lack access to clean water. Almost 200 countries agreed in 2015 to work on limiting the overall rise in the Earth's temperature to less than two degrees Celsius, and there is growing attention to issues related to energy, food, water, and clean air.

The world is not standing still as policy makers and business executives figure these issues out. Technology innovation continues to cut the cost of solar, wind, and natural gas, reshaping the global power mix. The combination of ride sharing, vehicle electrification, autonomous operations, and lightweighting is changing transportation, even as more and more people are migrating to cities. By 2050, according to the United Nations, two-thirds of the world's people will live in urban areas. And there will be an additional 2.5 billion people by then—all of whom will need light and food, putting further pressure on the environment.

Can society improve human lives while addressing climate concerns and preserving natural resources? We think it can, if business and political leaders commit to doing so and make good use of emerging innovations, technologies, and practices. To make that case, this collection considers three broad sectors: energy, mobility, and consumer products. In each, we see progress—and the chance for more.

When it comes to energy, for example, the analysis in "Energy 2050: Insights from the ground up" finds that while fossil fuels such as oil, gas, and coal will continue to be a mainstay of the global energy system for the near future, the momentum is shifting toward renewables. Specifically, the price of solar continues to drop steeply, accelerating adoption. The industry's task, argue the authors of "How solar energy can (finally) create value," is to make a more compelling economic case to investors. Government policies can play a helpful role by providing incentives to the market. However, lower costs and more attractive customer propositions have proved

more important than policy in driving broad-based adoption. The next generation of biofuels faces a steeper climb (see "The future of second-generation biomass"). Biofuels have not lived up to expectations so far, but the potential is real, particularly in applications to the chemical industry. Better management, execution, and incentives can take them to the next level.

Affordable and reliable energy storage could play a critical role in the development of renewables, enabling wind and solar power to be dispatched on demand. Storage also plays a role in ensuring efficient dispatch of baseload coal and nuclear. Already, this technology makes economic sense for certain applications (see "The new economics of energy storage"). To reach its global potential—estimated at 1,000 gigawatts in the next 20 years—energy storage needs to improve efficiency and reduce system costs.

When it comes to transportation, our contributors see the same combination of challenges and change. In "Rethinking the rules for transport in cities," the authors detail the new business models and technologies, including connectivity and sharing, that are emerging worldwide to make getting around cleaner, cheaper, more flexible, and even more enjoyable. They also provide a framework to help cities figure out the best way to improve mobility in an environmentally sound and efficient manner. In an interview ("Rolling along: Bicycles, mobility, and the future of cities"), Jay Walder, a mass-transit expert who heads New York City's bike-sharing program, notes that these systems are new and still small. But he sees a much bigger future: "I think bike sharing fits not just with our desire for mobility but also with our values. It fits with what we want to be as a society."

Finally, the way that consumer-product companies make and sell their goods will be crucial to creating a sustainable future. In the past, few consumer companies paid attention to whether their suppliers managed the social and environmental impact of their business activities. That is beginning to change. In an interview ("Toward a circular economy in food"), Danone CEO Emmanuel Faber discusses the business and environmental case for embedding sustainability principles into corporate thinking. "We need a comprehensive response to tackle growing resource scarcity," he argues, "which both drives the efficient use of those resources through the supply chain and brings healthy food to as many people as possible."

In "Starting at the source: Sustainability in supply chains," the authors describe three tactics that leading consumer businesses are using to help their suppliers lessen their environmental impact—and position themselves for growth as the global consumer class expands.

Of course, none of this can be done without money. In many areas, business models matter as much as technology and policy. Governments have an important role, not only with regard to their own spending but also in creating incentives so that the private sector will want to participate. Project developers, too, need to play a role in attracting more private investment. In "Taking conservation finance to scale," the authors explain the new financing models and risk-management techniques that fund managers and conservation experts can use to increase the flow of private capital to conservation projects. For the infrastructure sector, the authors discuss six public policies, spanning the entire project-development cycle, that can help mobilize large-scale investment in sustainable projects (see "Mobilizing private-sector financing for sustainable infrastructure").

Boosting global living standards while preserving and even improving the environment is not impossible. Nor is it inevitable. But we know it can be done because, in many instances, it is already being

done. Indeed, the rate of change has been faster than most forecasters expected. Many improvements require little in the way of new expertise. The consistent application of well-known principles of good business judgment and practices can go a long way toward making this transformation real.

Consumer-product companies, for example, do not have to reinvent supply-chain management. Rather, they must work with their suppliers to embed sustainability throughout their processes. For clean-energy companies, the priorities are to improve operations as they scale up, while working with investors to demonstrate that the innovations and technologies that will be crucial to meeting the two-degree target can also provide a healthy rate of return. That means designing projects well and improving cash management and capital efficiency—priorities that matter to businesses of all kinds. In turn, governments can learn from one another, adopting successful policies that have worked elsewhere (and jettisoning poor ones).

In last year's issue of *McKinsey on Sustainability & Resource Productivity* (June 2015), we stated that "the real question is whether the global economy can be nudged decisively enough onto a lower-carbon, less resource-intensive path." That was the right question. In this edition, we offer some answers. ■

Scott Nyquist is a senior partner in McKinsey's Houston office, and **Matt Rogers** is a senior partner in the San Francisco office.

Energy 2050:
Insights from the ground up

How will the world satisfy its need for energy? McKinsey research offers a perspective.

Scott Nyquist

When it comes to energy, there is one matter everyone agrees on. For the near future, at least, the world will need more of it—and how it is produced and used will be a critical factor in the future of the global economy, geopolitics, and the environment. With that in mind, McKinsey took a hard look at the data, modeling energy demand from the bottom up, by country, sector, and fuel mix, with an analysis of current conditions, historical data, and country-level assessments. On this basis, McKinsey's Global Energy Insights team has put together a description of the global energy landscape to 2050.

It is important to remember that this is a business-as-usual scenario. That is, it does not anticipate big disruptions in either the production or use of energy. And, of course, predicting the future of anything is perilous. With those caveats in mind, here are four of the most interesting insights from this research.

Global energy demand will continue to grow. But growth will be slower—an average of about 0.7 percent a year through 2050 (versus an average of more than 2 percent from 2000 to 2015). The decline in the rate of growth is due to digitization, slower population and economic growth, greater efficiency, a decline in European and North American demand, and the global economic shift toward services, which use less energy than the production of goods. For example, in India, the percentage of GDP derived from services is expected to rise from 54 to 64 percent by 2035. And efficiency is a forthright good-news story. By 2035, McKinsey research expects that it will take

Given that global energy demand will grow, it is likely that prices will continue to be volatile. Better energy efficiency, then, is an important way to reduce related risks.

almost 40 percent less fuel to propel a fossil-fueled car a mile than it does now. By 2050, global "energy intensity"—that is, how much energy is used to produce each unit of GDP—will be half what it was in 2013. That may sound optimistic, but it is based on recent history. From 1990 to 2015, global energy intensity improved by almost a third, and it is reasonable to expect the rate of progress to accelerate.

Demand for electricity will grow twice as fast as that for transport. China and India will account for 71 percent of new capacity. By 2050, electricity will account for a quarter of all energy demand, compared with 18 percent now. How will that additional power be generated? More than three-quarters of new capacity (77 percent), according to the McKinsey research, will come from wind and solar, 13 percent from natural gas, and the rest from everything else. The share of nuclear and hydro is also expected to grow, albeit modestly.

What that means is that by 2050, nonhydro renewables will account for more than a third of global power generation—a huge increase from the 2014 level of 6 percent. To put it another way, between now and 2050, wind and solar are expected to grow four to five times faster than every other source of power.

Fossil fuels will dominate energy use through 2050. This is because of the massive investments that have already been made and because of the superior energy intensity and reliability of fossil fuels. The mix, however, will change. Gas will continue to grow quickly, but the global demand for coal will likely peak around 2025. Growth in the use of oil, which is predominantly used for transport, will slow down as vehicles get more efficient and more electric; here, peak demand could come as soon as 2030. By 2050, the research estimates that coal will be down to just 16 percent of global power generation (from 41 percent now) and fossil fuels to 38 percent (from 66 percent now). Overall, though, coal, oil, and, gas will continue to be 74 percent of primary energy demand, down from 82 percent now. After that, the rate of decline is likely to accelerate.

Energy-related greenhouse-gas emissions will rise 14 percent in the next 20 years. That is not what needs to happen to keep the planet from warming another two degrees, the goal of the 2015 Paris climate conference. Around 2035, though, emissions will flatten and then fall, for two main reasons. First, cars and trucks will be cleaner, due to more efficient engines and the deployment of electric vehicles. Second, there is the shift in the power industry toward gas and renewables discussed above. The countervailing trends are that there are likely to be some 1.5 billion more people by 2035, and global GDP will rise by about half over that period. All those people will need to eat and work, and that means more energy.

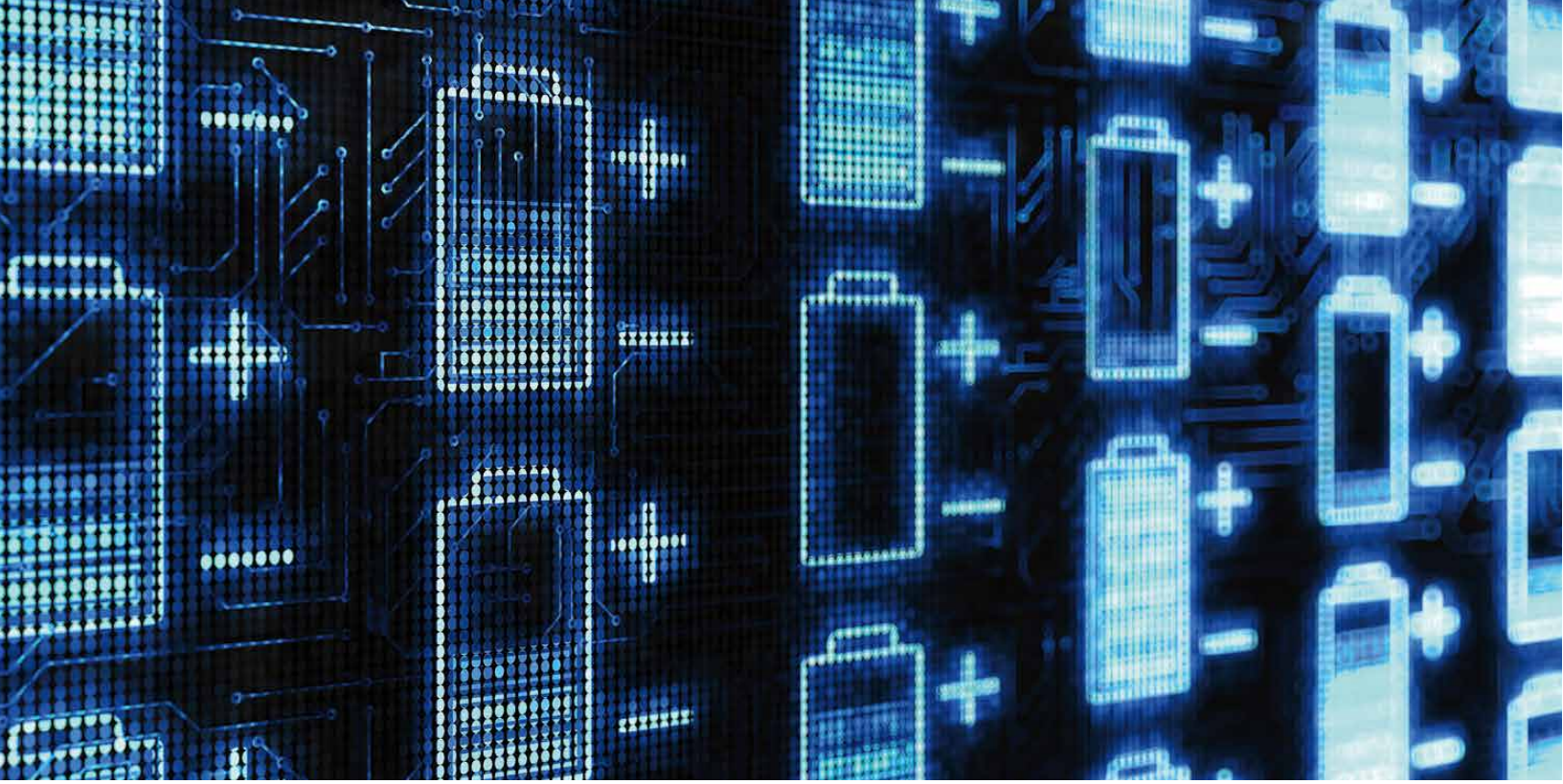
The world is full of unpredictable and sometimes wonderful surprises, so I accept that these numbers

are unlikely to be perfect. As with any forecast, they are based on assumptions—about China and India, for example—as well as about oil prices and economic growth. Other sources see different outlooks. Concerted global action to reduce greenhouse-gas emissions, for example, could change the arc of these trends. Technological disruptions could also bend the curve.

For business and political leaders, though, the implications are clear. Given that global energy demand will grow, it is likely that prices will continue to be volatile. Better energy efficiency, then, is an important way to reduce related risks. Technology development is critical to ensuring that the world gets the energy it needs while mitigating environmental harm. This will require substantial new investments. Finally, to encourage the creation of the clean and reliable energy infrastructure that the world needs, energy producers will need to work with local, regional, national, and international regulators. Getting things right the first time is essential; there is extensive evidence to show that dramatic changes in policy act as a powerful deterrent to energy investments by producers. Given the scale of the new investments needed, this will be a factor of growing importance. ■

This article is adapted from a previously published LinkedIn post.

Scott Nyquist is a senior partner in McKinsey's Houston office.



The new economics of energy storage

Energy storage can make money right now. Finding the opportunities requires digging into real-world data.

Paolo D'Aprile, John Newman, and Dickon Pinner

Energy storage is a favorite technology of the future—for good reasons.

Many people see affordable storage as the missing link between intermittent renewable power, such as solar and wind, and 24/7 reliability. Utilities are intrigued by the potential for storage to meet other needs, such as relieving congestion and smoothing out the variations in power that occur independent of renewable-energy generation. Major industrial companies consider storage a technology that could transform cars, turbines, and consumer electronics (see sidebar, "What is energy storage?").

Others, however, take a dimmer view, believing that storage will not be economical any time soon. That pessimism cannot be dismissed. The transformative future of energy storage has been just around the corner for some time, and at the moment, storage constitutes a very small drop in a very large ocean.[1] In 2015, a record 221 megawatts of storage capacity was installed in the United States,[2] more than three times as much as in 2014—65 megawatts, which was itself a big jump over the previous year. But more than 160 megawatts of the 2015 total was deployed by a single regional transmission organization, PJM Interconnection.[3] And 221 megawatts is not much in the context of a total US generation capacity of more than a million megawatts.

Our research shows considerable near-term potential for stationary energy storage. One reason for this is that costs are falling and could be $200 per

kilowatt-hour in 2020, half today's price, and $160 per kilowatt-hour or less in 2025. Another is that identifying the most economical projects and highest-potential customers for storage has become a priority for a diverse set of companies, including power providers, grid operators, battery manufacturers, energy-storage integrators, and businesses with established relationships with prospective customers such as solar developers and energy-service companies.

In this article, we describe how to find profitable possibilities for energy storage. We also highlight some policy limitations and how these might be addressed to accelerate market expansion. These insights could help forward-thinking companies win an early toehold in a market that in the United States could reach $2.5 billion by 2020—six times as much as in 2015.[4] The ultimate prize, of course, is much bigger. As the technology matures, we estimate that the global opportunity for storage could reach 1,000 gigawatts in the next 20 years.

Where to compete: Model insights

Identifying and prioritizing projects and customers is complicated. It means looking at how electricity is used and how much it costs, as well as the price of storage.

Too often, though, entities that have access to data on electricity use have an incomplete understanding of how to evaluate the economics of storage; those that understand these economics have limited access to real-world data on electricity use. Moreover, there has been a tendency to average the data when doing analyses. Aggregating numbers, however, is not useful when evaluating prospects for energy storage because identical buildings next door to each other could have entirely different patterns of electricity use. Conclusions drawn based on averages therefore do not have the precision needed to identify which customers would be profitable to serve.

What is energy storage?

Energy storage absorbs and then releases power so it can be generated at one time and used at another. Major forms of energy storage include lithium-ion, lead-acid, and molten-salt batteries, as well as flow cells. There are four major benefits to energy storage. First, it can be used to smooth the flow of power, which can increase or decrease in unpredictable ways. Second, storage can be integrated into electricity systems so that if a main source of power fails, it provides a backup service, improving reliability. Third, storage can increase the utilization of power-generation or transmission-and-distribution assets, for example, by absorbing power that exceeds current demand. Fourth, in some markets, the cost of generating power is significantly cheaper at one point in time than another; storage can help smooth out the costs. Historically, companies, grid operators, independent power providers, and utilities have invested in energy-storage devices to provide a specific benefit, either for themselves or for the grid. As storage costs fall, ownership will broaden and many new business models will emerge.

In our research, we were able to access data from both utility and battery companies. On this basis, we found that it is quarter-hour-by-quarter-hour or even minute-by-minute use that reveals where the opportunities are.

To identify today's desirable customers, we built a proprietary energy-storage-dispatch model that considers three kinds of real-world data:

- electricity production and consumption ("load profiles"), at intervals of seconds or minutes for at least a year
- battery characteristics, including price and performance
- electricity prices and tariffs

Using both public and private sources, we accessed data for more than a thousand different load profiles, dozens of batteries (including lithium ion, lead acid, sodium sulfur, and flow cell), and dozens of electricity tariff and pricing tables.

Our model, shown in the exhibit, identifies the size and type of energy storage needed to meet goals such as mitigating demand charges, providing frequency-regulation services, shifting or improving the control of renewable power at grid scale, and storing energy from residential solar installations.

The model shows that it is already profitable to provide energy-storage solutions to a subset of commercial customers in each of the four most important applications—demand-charge management, grid-scale renewable power, small-scale solar-plus storage, and frequency regulation.

Demand-charge management

Some customers are charged for using power during peak times (a practice known as a demand charge). Energy storage can be used to lower peak consumption (the highest amount of power a customer draws from the grid), thus reducing the amount customers pay for demand charges. Our model calculates that in North America, the break-even point for most customers paying a demand charge is about $9 per kilowatt. Based on our prior work looking at the reduction in costs of lithium-ion batteries, this could fall to $4 to $5 per kilowatt by 2020. Importantly, the profitability of serving prospective energy-storage customers even within the same geography and paying a similar tariff can vary by $90 per kilowatt of energy storage installed per year because of customer-specific behaviors. Another interesting insight from our model is that as storage costs fall, not only does it make economic sense to serve more customers, but the optimum size of energy storage increases for existing customers.

Grid-scale renewable power

Energy storage can smooth out or firm wind- and solar-farm output; that is, it can reduce the variability of power produced at a given moment. The incremental price for firming wind power can be as low as two to three cents per kilowatt-hour. Solar-power firming generally costs as much as ten cents per kilowatt-hour because solar farms typically operate for fewer hours per day than wind farms.

Small-scale solar-plus storage

At a residential level, the combination of solar and storage is only worthwhile when specific market and regulatory conditions are in place to make the value of storage greater than the cost of installing it. This can happen, for example, when excess production can be stored for later consumption; in that case, consumers need to buy less power from the grid and thus cut their costs.

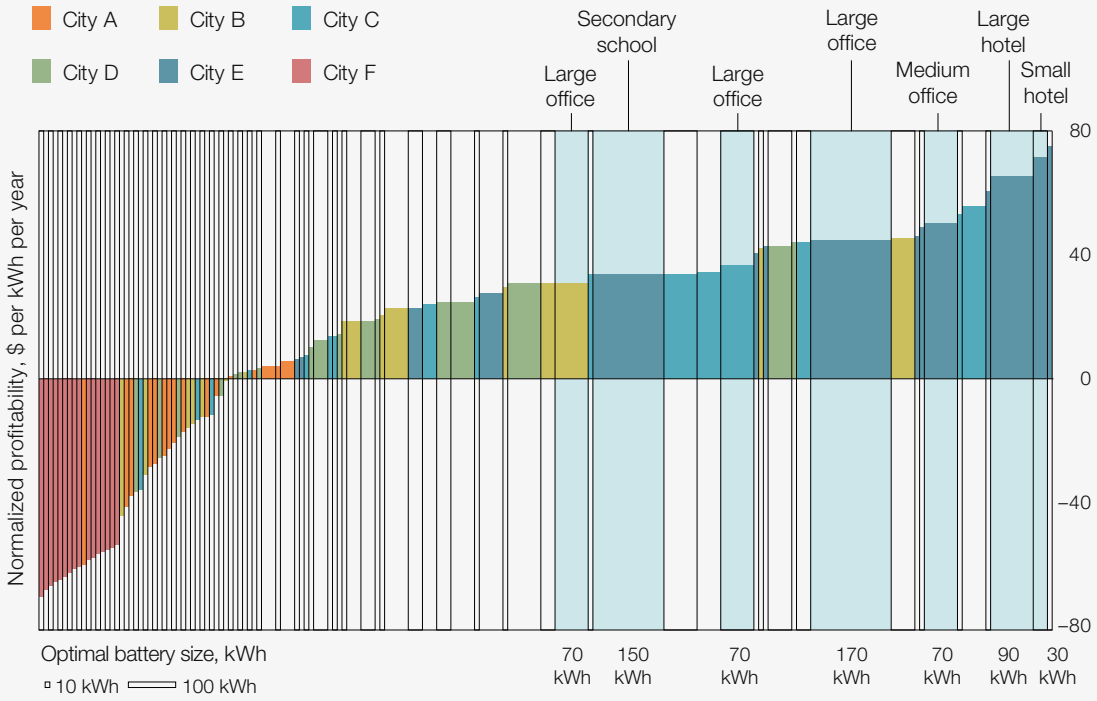
Frequency regulation

Electricity grids experience continuous imbalances between power generation and consumption because millions of devices are turned on and off in an uncorrelated way. These imbalances cause electricity

Exhibit

Customer-by-customer analysis of energy-storage economics shows significantly different profitability even within cities.

Lithium-ion-battery storage, 4% weighted average cost of capital, 2015
Normalized profitability, $ per kilowatt-hour (kWh) per year, **based on optimal battery size,** kWh



- **58% of profitable buildings represent 71% of total demand**
- **Average optimal battery size of 31 kWh for profitable buildings**

Source: McKinsey analysis

frequencies to deviate, which can hurt sensitive equipment and, if left unchecked and allowed to become too large, even affect the stability of the grid. Storage systems are particularly well suited to frequency regulation because of their rapid response time and ability to charge and discharge efficiently.

Our model confirms that storage can be profitable in select frequency-regulation markets. The economics depend on the context. Ideally, batteries hover around a specific state of charge to minimize the amount of storage required.

How to compete: The state of batteries

Battery technology, particularly in the form of lithium ion, is getting the most attention and has progressed the furthest. Lithium-ion technologies accounted for more than 95 percent of new energy-storage deployments in 2015.[5] They are also widely used in consumer electronics and have

shown promise in automotive applications, such as plug-in hybrids and electric vehicles. Prices for lithium-ion batteries have been falling and safety has improved; moreover, they can work both in applications that require a lot of energy for a short period (known as power applications) and those requiring lower amounts of energy for longer periods (energy applications). Collectively, these characteristics make lithium-ion batteries suitable for stationary energy storage across the grid, from large utility-scale installations to transmission-and-distribution infrastructure, as well as to individual commercial, industrial, and residential systems.

Our model confirms the centrality of lithium-ion batteries to utility-scale energy storage, but with two important caveats. First, it is critical to match the performance characteristics of different types of lithium-ion batteries to the application. For example, we looked at two major lithium-ion-battery providers that were competing to serve a specific industrial application. The model found that one company's products were more economic than the other's in 86 percent of the sites because of the product's ability to charge and discharge more quickly, with an average increased profitability of almost $25 per kilowatt-hour of energy storage installed per year.

Second, in some specific applications, nonlithium-ion technologies appear to work better. For demand-charge management and residential solar-plus storage, certain lead-acid products are more profitable than lithium-ion cells. For large-scale firming of wind power, our model shows that flow cells can be more economic than lithium-ion cells for all but the shortest periods (less than an hour) and are projected to continue to lead on cost through 2020.

Policy and market limits

Our model suggests that there is money to be made from energy storage even today; the introduction of supportive policies could make the market much bigger, faster. In markets that do provide regulatory support, such as the PJM and California markets in the United States, energy storage is more likely to be adopted than in those that do not. In most markets, policies and incentives fail to optimize energy-storage deployment. For example, the output from intermittent renewable-energy sources can change by megawatts per minute, but there are few significant incentives to pair renewable energy with storage to smooth power output.

Another issue is that tariffs are varied and not consistently applied in a way that encourages energy-storage deployment. Thus, customers with similar load profiles are often billed differently; some of these tariffs provide incentive for the adoption of storage to the benefit of the electrical-power system, while others do not. Pairing load profiles with appropriate tariffs and ensuring that tariffs are stable could help build the economic business case for energy storage.

Finally, the inability to bring together detailed modeling, customer data, and battery performance (due in part to policy choices and rules limiting data access) makes it difficult to identify and capture existing opportunities.

What the future may hold

Our work points to several important findings.

First, energy storage already makes economic sense for certain applications. This point is sometimes overlooked given the emphasis on mandates, subsidies for some storage projects, and noneconomic or tough-to-measure economic rationales for storage (such as resilience and insurance against power outages).

Second, market participants need to access the detailed data that could allow them to identify and prioritize those customers for whom storage is profitable. Given the complexity of energy storage,

deployment is more likely to follow a push versus a pull sales model, favoring entrepreneurial companies that find creative ways to access and use these data.

Third, storage providers must be open-minded in their design of energy-storage systems, deciding whether lithium-ion, lead-acid, flow-cell, or some other technology will provide the best value. A strategy that employs multiple technologies may carry incremental costs, but it may also protect against sudden price rises.

Fourth, healthy margins are likely to accrue to companies that make use of battery and load-profile data. The unique characteristics of individual customers will favor tailored approaches, including the development of algorithms that find and extract the greatest value. Strong customer relationships are required to access relevant data and to deliver the most economical solution as regulations and technologies evolve.

Fifth, how to use storage to reduce system-wide costs will require some thought. Examples might include price signals that are correlated with significant deviations in power generation and consumption, rules that reward the provision of storage to serve multiple sites in close proximity, and tariffs that favor self consumption (or load shifting) of renewable electricity.

The most important implication is this: the large-scale deployment of energy storage could overturn business as usual for many electricity markets. In developed countries, for example, central or bulk generation traditionally has been used to satisfy instantaneous demand, with ancillary services helping to smooth out discrepancies between generation and load. Energy storage is well suited to provide such ancillary services. Eventually, as costs fall, it could move beyond that role, providing more and more power to the grid, displacing plants. That moment is not imminent. But it is important to recognize that energy storage has the potential to upend the industry structures, both physical and economic, that have defined power markets for the last century or more. And it is even more important to be ready. ■

[1] This article does not consider pumped storage, the most common type of storage. It is used for hydro projects.
[2] Peter Maloney, "After record year, U.S. energy storage forecasted to break 1 GW capacity mark in 2019," *Utility Dive*, March 7, 2016, utilitydive.com.
[3] PJM serves all or part of Delaware; Illinois; Indiana; Kentucky; Maryland; Michigan; New Jersey; North Carolina; Ohio; Pennsylvania; Tennessee; Virginia; Washington, DC; and West Virginia.
[4] "The 2015 year-in-review executive summary," GTM Research, March 2016, greentechmedia.com.
[5] Ibid.

Paolo D'Aprile is an associate partner in McKinsey's Rome office, and **John Newman** is an alumnus of the San Francisco office, where **Dickon Pinner** is a senior partner.

The authors wish to thank Hussein Abdelhalim and Benedikt Battke for their contributions to this article.

How solar energy can (finally) create value

The market for solar power is growing faster than ever, but profitability has been lagging. The keys to improvement are better capital and operational efficiency.

David Frankel, Aaron Perrine, and Dickon Pinner

Solar energy is becoming a force to be reckoned with.

Last year, China and the United States installed a record 15 and 7.5 gigawatts (GW) of solar, respectively. This year, the world could install as much as 66 GW.[1] In 2015, investors poured $161 billion of capital into solar, the largest amount for any single power source.[2] In China, 43 GW of capacity have been installed, more than in any other nation; India aspires to build 100 GW of solar capacity by 2017. Across the sun-drenched Middle East, investment rose from $160 million in 2010 to about $3.5 billion in 2015.[3]

The world is building more solar-power plants because they are getting cheaper. Since 2009, the total installed costs of solar have fallen by as much as 70 percent around the world. New power-purchase agreements frequently fall below $100 per megawatt-hour, with some reaching less than $30.[4] That price puts solar at or below the cost of a new natural-gas plant.

Regulatory measures, such as the Investment Tax Credit in the United States, further support the economics of solar. In many instances, solar is often "in the money"—that is, less costly than the next cheapest alternative. A number of leading multinationals are signing solar deals not only to gain green credentials but also to lower their energy costs and diversify their sources of supply.

Given these trends, we believe that 2,000 to 3,000 GW of solar capacity—or almost half of

total electric-power capacity in the world today—will be economic by 2025. Of course, solar can't fully meet the need for electricity on its own because (among other reasons) the sun doesn't always shine, so not all of this will be built. But a significant portion will. And that growth will transform energy markets around the world.[5]

Although the future is bright, many solar companies are struggling. Downstream providers—the developers and builders of solar-power plants—have pursued growth and market share but struggled to deliver profits. In the United States, valuations of some companies fell drastically in 2015 and 2016, and there have been a number of high-profile restructurings and bankruptcies, possibly with more to come.

Macro factors also play a role. Low oil and gas prices have tested solar's competitive position. The threat—though perhaps now more distant—of higher interest rates is another negative factor because the economics of solar projects are sensitive to the cost of capital.

In spite of these issues, we believe opportunities for growth and profit exist throughout the solar value chain. To survive the current market conditions and prosper in the longer term, downstream businesses in particular need to overcome two major challenges.[6]

The challenge of project margins

As more companies enter the market for solar projects, competition intensifies—and profits narrow. The solar industry is relatively young, so construction costs vary widely, with some firms experiencing severe overruns. To maintain attractive margins, the best players will drive down the cost of building a plant faster than the industry average, allowing them to grow and take market share. To do so, they must address system design and construction execution.

System design. Systems for solar are typically designed from the bottom up. Each power plant or roof gets the perfect answer, a process that translates into high costs for labor and production. It doesn't help that the solar supply chain is immature, and the technology itself is still evolving rapidly. Many of the sector's engineering, procurement, and construction (EPC) companies are small, with limited solar-specific capabilities.

As the industry scales up, players should develop systems based on prefabricated components that are a very good, but not perfect, fit for a wide range of sites and that will integrate easily in the field—an approach known as "design for constructability." In addition, automation and aerial site assessments can speed up design prototyping and help firms make more accurate estimates before they put boots on the ground (or the roof).

In the case of large utility-scale projects, better up-front assessments of ground conditions can minimize rework for pile driving or trenching. Developers could prefabricate off-the-shelf units, making it possible to install them in hours rather than days for rooftops, or in weeks instead of months for large ground-mounted systems. To achieve this goal, firms will have to overhaul their supply chains to ensure that components can work with one another and should collaborate closely with EPC companies to create and deploy cost-saving ideas. The automotive industry, which uses standard designs over and over for different models, is a helpful analogy. Similarly, big-box retailers often use a handful of standard designs for their stores.

Construction execution. Traditionally, construction performance has taken a back seat to project development. But from now on, as the industry scales up and the number of projects grows, solar companies must pay more attention to execution.

Many of them struggle to finish projects on time and on budget; the resulting delays and cost overruns damage profitability and capital management. Ultimately, projects are at risk if they miss deadlines for operations and for connections to the power grid.

Photovoltaic (PV) solar plants are not nearly as complex to build as other types of power plants. Even so, firms need contracting strategies that align their own incentives with those of their construction partners across the life of each project and that standardize execution in the field. Owners should be able to monitor progress and capture performance data to learn alongside their EPC partners. Larger players also need to implement lean-construction techniques to increase productivity and decrease labor costs.

Solar players need to bring these pieces together and aggressively manage costs in each area. A detailed cost road map can help to reduce costs and develop a realistic forward cost curve against which developers and sales teams can bid for future projects. An effective cost analysis begins with setting goals, based on the levelized cost of energy for each market. Then, each cost component should be mapped, targets set, and a portfolio of improvement initiatives developed and tracked.

The challenge of capital flows and balance-sheet strength

It's a Catch-22: prudent solar companies cannot afford to scale up beyond the strength of their balance sheets, but most have relatively weak ones. Only by getting bigger, and thus having more collateral in the form of projects, can they bolster their financial positions and scale up. Solar companies must therefore find new ways to attract long-term capital from institutional investors (either through public markets or private placements), to improve capital efficiency, and to forge prudent growth strategies.

Unlock long-term capital markets. Completed solar projects are attractive for investors seeking dependable long-term cash flows. The challenge is how to resolve the lower cost of capital (less equity, more debt) for an operating plant with the higher cost of capital (more equity, little debt) for developers. One approach has been the use of "YieldCos"—entities that purchase completed projects and have balance sheets separate from the development company. Assuming they are focused on delivering low-risk, stable cash flows, these entities should enjoy a much lower cost of capital and higher levels of leverage, and thus could provide the liquidity developers need to grow. Similarly, solar-development companies, or "DevCos," should be equity focused, with low levels of debt.

But for various reasons, YieldCos have not met the needs of institutional investors. There have been issues related to transparency and governance; those owned by developers sometimes presented conflicts of interest. Also, the marketing of YieldCos as growth vehicles—that is, entities meant to provide long-term stable cash flows, not growth—and the quality of underlying assets have been problematic. As a result, many are valued well below their initial-public-offering levels. Similarly, when DevCos take on significant levels of debt, problems can occur, because the cash flows associated with project sales are inherently less predictable.

Institutional investors want a healthy yield at low risk; solar developers want a dependable way to liquidate higher-cost equity capital to reinvest it in the next project. A "YieldCo 2.0" should be developed to meet the needs of both parties, with a transparent, simple governance structure that provides both an attractive home for long-term capital and sufficient flexibility to project developers. Similarly, a pure-play "DevCo 2.0" should be focused on equity, without a great deal of debt.

Several new ideas, including private "PoolCos" that invest on an asset-by-asset basis, look promising but have yet to be fully tested. Such innovative solutions to the industry's financing challenges could bring substantial rewards. We believe markets will test and scale new ways to meet the industry's capital needs.

Improve capital efficiency. Working capital turns matter: every dollar deployed needs to achieve maximum impact. Companies that hope to succeed must carefully choose the parts of the value chain and the customer segments and geographies they want to play in, so that capital doesn't get locked up in low-margin uses for long periods. They should

Key questions for the US distributed solar industry

The distributed solar market in the United States is challenging. The industry must answer several key questions to ensure continued growth.

What regulatory model will prove sustainable?
Net energy metering, which allows solar owners to sell back power to the grid at the retail rate, is proving expensive and does not reflect the full value the grid provides. Market structures must be developed that ensure everyone pays an amount commensurate with the value of the specific services they use, including grid access, energy, reliability, and interconnection. In turn, this will drive sustainable capital formation for distributed solar.

What will it take to cut customer-acquisition costs to sustainable levels?
Lowering customer-acquisition costs requires better knowledge and more efficient go-to-market models for targeting and acquiring customers. It may also involve forming partnerships with utilities and communities to increase installation density.

Will 'tax equity' finance continue to be the US standard?
The system of tax-equity finance creates market inefficiencies, especially since neither solar players nor utilities have a lot of tax capacity. Capital structures that are more transparent to customers and simpler to execute must be developed.

How can distributed solar players shorten the cash cycle?
The lag time from order to installation to grid connection to cash can be six months or more for a job that takes a day for residential customers and, at most, a few weeks for commercial or industrial ones. Project-delivery models, built on standard designs and construction excellence, must be developed and then scaled up.

How can incentives be improved to install solar where it will be most valuable?
The market is building most residential solar in high-income zip codes. The value of solar to the grid is much higher, however, in resource-constrained areas and areas needing grid upgrades. Incentives for new installations must begin to reflect these locational (or "nodal") values.[1]

If the industry does not address these questions, the business models of both solar installers and utilities are likely to come under pressure, with possible restructurings and regulatory disallowances.

[1] Solar is not always the most appropriate type of distributed-energy resource. Depending on the situation and load shape, storage, demand response, and energy efficiency should also be considered to capture "nodal" value.

also pursue forms of low-cost financing, such as project debt and trade credit (for example, from module manufacturers) to leverage equity returns.

At the same time, solar developers must manage their cash and overall cash-to-cash cycle—a task not for the faint of heart. For example, companies should track expected cash inflows and outflows at a very detailed level and resist the temptation to push out payment dates, particularly if smaller vendors may not be able to cope with stretched-out payments.

Finally, it's important to have a systematic yet flexible approach. For example, utility-scale developers may find that some projects earmarked for long-term ownership should be sold earlier to fund equity checks needed to complete other projects.

Build sustainable growth strategies. Solar firms must figure out how to scale up without becoming overextended. Possible strategies include using small, local teams to focus on higher-margin geographies; exploring capital-light strategies for market entry, such as partnerships and joint ventures; becoming an independent power producer over time by retaining stakes in projects once they go into operation; and managing currency exposure and the risk of trapped cash.

Getting back to fundamentals

Meeting these challenges will not be easy. Developers with middling balance sheets or management teams that have focused more on growth than on profitability may now need to pay greater attention to managing liquidity and, in some cases, to avoiding bankruptcy.

In 2015 and 2016, the solar industry has seen significant value erosion, and matters could get worse before they get better. But the sector has proved its resilience before, recovering from both the 2008 financial crisis and the 2011 shakeout. Moreover, the trends that favor the continued growth of solar power—falling costs, improving technology, and regulatory support—are gaining strength. The fundamentals of solar projects are attractive. Over time, solar PV will become one of the cheapest sources of power and possibly the cheapest of all. Developers, however, will capture value only if they return to fundamentals to bring down the total cost of installed systems, manage the cost of capital, and improve operations.

The next critical step for the solar industry, then, is not so much technical as economic: it is time for companies to figure out how to generate not just clean energy but also good financial returns. For those that do, the rewards could be tremendous. Those that don't may not survive. ■

[1] "Led by China, the United States, and Japan, global solar installations to reach approximately 66.7 GW, reports Mercom Capital Group," Mercom Capital Group, April 2016, mercomcapital.com.

[2] *Global trends in renewable energy investment 2016*, Frankfurt School–United Nations Environment Programme (UNEP) Collaborating Centre for Climate & Sustainable Energy Finance, March 2016, fs-unep-centre.org.

[3] Raed Bkayrat, *Middle East solar outlook for 2016*, Middle East Solar Association, May 2016, mesia.com.

[4] "Follow the sun," *Economist*, April 16, 2016, economist.com.

[5] Compared with nuclear or fossil-fuel plants, solar has a much lower capacity factor—the ratio of actual to potential output—of 15 to 34 percent. Solar therefore generates fewer units of energy for every unit of capacity.

[6] We recognize that there also are challenges related to integrating solar with the electric-power grid in a cost-effective, fair, and technically efficient way. These topics are outside the scope of this article.

David Frankel is a partner in McKinsey's Southern California office, **Aaron Perrine** is an alumnus of the Philadelphia and Seattle offices, and **Dickon Pinner** is a senior partner in the San Francisco office.

The authors wish to thank Matt Rogers and Humayun Tai for their contributions to this article.

The future of second-generation biomass

To make bioconversion commercially competitive, the industry needs swift advances.

Simon Alfano, Federico Berruti, Nicolas Denis, and Alberto Santagostino

The promise of the second-generation (2G) bioconversion industry is that it will transform cellulose-based, nonedible biomass and agricultural waste into clean and affordable high-value fuels or chemicals. (The first-generation, or 1G, technology converts edible biomass.) In this way, 2G could offer an alternative source both of energy and of chemical-industry inputs, which other renewable technologies cannot provide.

That is 2G's potential, but the industry failed to deliver on this promise for almost a decade. However, there has been progress in recent years. Since the inauguration of the first commercial-scale 2G plant, in 2013, eight more have opened around the world, of which some, not surprisingly, are failing, while others are progressing. Most are in North America, two are in Brazil, and one is in Europe—all markets with mature 1G biomass industries and governments that support cellulosic ethanol.

Second-generation projects have also begun attracting interest in China, India, Indonesia, and Malaysia in the form of government initiatives to coordinate action and to facilitate the establishment of a 2G ethanol market. As these trends suggest, the technology could be approaching the acceleration phase that marked the development trajectory of other industries, such as wind power, solar energy, and shale gas. In each case, growth was modest at first and then took off (exhibit).

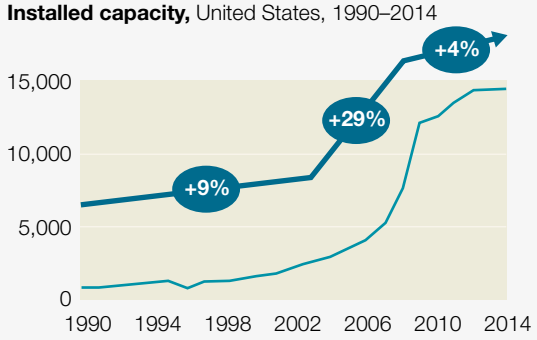
Drawing on more than 100 interviews with executives and experts and on our work with key industry players, we have identified seven critical enablers in three challenging areas—resources,

Exhibit

A new industry can take more than 15 years to reach a sizable commercial scale.

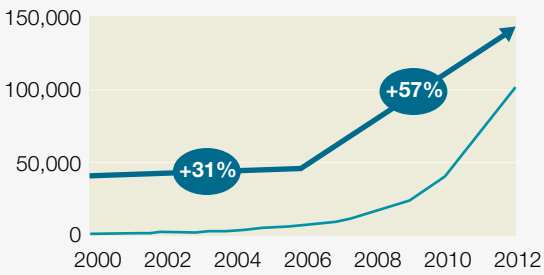
1G ethanol,
million gallons per year

Installed capacity, United States, 1990–2014



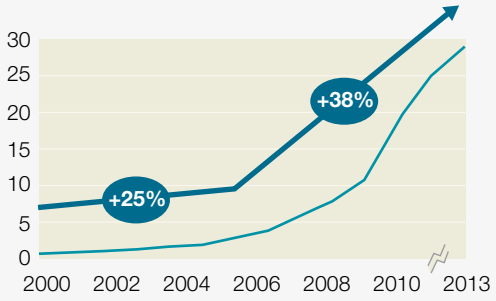
Solar power,
megawatts per year

Installed capacity, global PV,[1] 2000–12



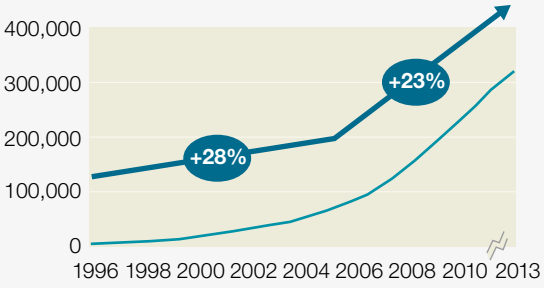
Shale gas,
billion cubic feet per day

Shale-gas production, United States, 2000–13



Wind power,
megawatts per year

Installed capacity, global, 1996–2013



[1]Photovoltaic.

Source: Industry reports; US Renewable Fuels Association: annual capacities after 1999 and sustainable responsible impact from 1990; McKinsey analysis

management, and the market—that the 2G industry must address to ensure continued progress.

Resources

Every business needs money, inputs, and processes that work. The second-generation biofuels industry faces challenges on each count—but these can all be addressed.

Reliable, commercial-scale conversion technology

Commercial 2G plants must demonstrate that they can deliver high-yield products at a competitive price, but conversion technology is taking longer than hoped to reach the necessary scale. One problem is that these plants must process the equivalent of up to 400 truckloads[1] of biomass a day. The semisolid nature of (wet) biomass, which is often mixed with dirt and other impurities, complicates the processing. Biomass must be mechanically pretreated—for example, by extrusion, milling, or grinding—and fed continuously in preparation for hydrolysis.

What's next. The design, reliability, and processes of 2G equipment are all improving. Meanwhile, engineering is rightsizing specifications, increasing levels of process automation, and eliminating costly process aids. The race is on to become the first player to operate a stable, cost-competitive commercial-scale plant. For front-running facilities, the question is not whether their processes work but rather the strength of their operational performance—uptime, throughput, yield, and cost—and how quickly they will cut costs while improving their operations.

Access to affordable feedstock

Second-generation feedstock is abundant, but prices on the biomass cost curve vary. Some forms of feedstock, such as municipal solid waste or cellulosic trimmings from harvests, can be sourced at little or no expense. Other kinds, such as sugarcane residues (known as "bagasse"), have an opportunity cost.

There are also outlays associated with collection and transport, so it is helpful to locate 2G plants near dependable, long-term sources of biomass. The cost of sourcing (the price asked by the producer, plus aggregation and logistics) is another key factor in 2G economics. Like oil, which can cost as little as a handful of dollars to produce but often several times more, biofeedstock should be seen in the light of a cost curve: some supplies will be cheap, others expensive.

What's next. Bagasse, available mostly in Brazil, China, India, and Thailand, is one of the cheapest sources of biomass: as a by-product of sugarcane processing, it is already aggregated at production plants and often burned to produce electricity. But 2G can be an alternative to drive value. American corn leaves and stalks cost about twice as much as bagasse, in part because this "stover" (as it is called) must be collected. Investors should seek long-term agreements to ensure security of supply in areas where the cost of sourcing is lowest.

Capital

At the moment, 2G does not fit the usual risk profile for investors. Those that are willing to take risks, such as venture-capital funds, tend to see 2G as too capital intensive. Investors with abundant capital but less appetite for risk, such as pension funds, view it as too uncertain. Mainstream investors, believing that they have more attractive and less risky alternatives, have resisted 2G investments. Development to date has been driven largely by entrepreneurs, such as the Ghisolfi family of Italy and Bernardo Gradin (with Brazil's GranBio), and by forward-looking companies that want to develop new markets for biorefineries or to find new carbon routes for chemicals. These 2G developments have often received public-sector investment backing, particularly in Brazil and the United States.

What's next. At feedstock costs of $30 to $50 a ton and validated levels of technology performance, 2G production economics can compete on cost with 1G bioethanol and certain more expensive oil sources,[2] particularly at locations where 2G operations can piggyback on existing 1G infrastructure, such as sugarcane bagasse feedstock or corn stover at 1G plants that already process sugarcane and corn, respectively. On a marginal-cost basis, 2G is already structurally more attractive than 1G because its running costs[3] are lower.

However, there are two important risks: feedstock security (which can be addressed through forward contracts) and technology. Building new commercial-scale plants will encourage simplification and standardization, while also leading to scale efficiencies that reduce capital expenditures. As with the development of wind farms, leading players should eventually be able to offer investors turnkey operations. Government support could improve the business case substantially for some 2G plants, and there are precedents for this: Germany helped build initial capacity for solar power, as the United States did for the 1G industry.

Management

The biofuels industry is not all that young; it is time for it to improve the way it is managed, in several ways.

Capabilities for industrialization

Small companies have been at the industry's forefront over the past decade, but they lack the capabilities, infrastructure, and capital for industrial-scale 2G. Attracted by its potential, bigger firms began to get involved, but some have left in recent years for strategic reasons. There's a case that firms should collaborate to maximize their chances of success, but a handful of players will probably take the lead to create competitive technical solutions. The challenge will then be significant because although these companies could own a viable technical solution within a piece of the value chain, they may lack the competencies, people, infrastructure, and capital to scale up a worldwide industry deploying 50 to 100 projects a year. New types of players will have to engage.

What's next. To build the industry, big players, such as contractors or downstream specialists, should create partnerships or acquire firms with specialized value-chain expertise to scale up project deployments. For an analogy, consider how the oil industry creates complex, project-centered value chains in its exploration and extraction projects.

Value-chain integration

Critical gaps persist in the industry's value chain—whose players now have fragmented capabilities—so that each 2G capital project gets a unique, inefficient, and expensive solution. Furthermore, the downstream distribution network is not yet geared for takeoff, because of technological and logistical barriers. Distribution pumps at fuel retailers, for example, are not equipped for flexible blending.

What's next. To establish a bankable turnkey solution, leading players should create and coordinate teams comprising feedstock suppliers, government agencies, technology owners, and investors. By collaborating, these partners can structure complex 2G projects from beginning to end and collectively assemble all the capabilities needed to complete them.

One such project is in the works in the Malaysian province of Sarawak. A consortium of local companies, international partners, and the government plans to invest in a new biomass hub, and a 2G plant is scheduled to open in coming years—the first in Southeast Asia. The Hock Lee Group, based in Malaysia, will grant access to the biomass and operates a local network of petrol stations. Biochemtex (based in Italy) will provide expertise in running large capital-investment projects; its subsidiary, Beta Renewables, will contribute conversion know-how. Another firm will offer enzyme technology. The hope is that by using by-products from the area's palm-oil plantations and other feedstock, these efforts will create new, high-value industries in the region.

Market

The major issues here have to do with getting some breathing space while the market matures.

Demand

In the medium term, as installed 2G capacities increase, producers of 2G biofuels or biochemicals may not find buyers for all their output. In the short term, if oil prices stay low, 2G will have difficulty competing on price; that, in turn, affects the industry's long-term prospects by discouraging sustained commitment. It's also important to remember that competing renewable-energy paths to ethanol, such as gasification, are being developed.

What's next. One possibility is that 2G biofuels could move down the cost curve and eventually compete with fossil fuels on price at the gas station. Other emerging industries have overcome similar cost disadvantages; for example, Germany instituted public policies to give consumers incentives to adopt solar power.

One area of significant potential 2G demand that isn't fuel related would be providing building-block inputs for both bulk and higher-value chemicals, such as butadiene, butanol, and lactic acid. Global chemical companies investing in the sector hope to create opportunities for biorefineries that could produce an array of biobased chemicals providing diversification to adapt at the changing price points that the spot market would offer.

This is already happening with 1G technologies: BioAmber and Mitsui, for example, have invested in a 30,000-ton-a-year Ontario plant to produce succinic acid through bioroutes. Many companies are becoming serious about making their products and processes sustainable and renewable. Initiatives to source plastic more sustainably in the consumer industry, for example, have created an uptick in demand on the biobased-chemical side.

Stable and supportive regulation

Government support—blending mandates and outlays on industry R&D,[4] especially in the United States—has started to create a market for 2G products. But progress has been halting. In part, this is a result of the sluggish buildup of 2G biofuels production; the US Energy Policy Act, in 2005, created mandates, but the industry failed to deliver. No government has taken a bold position promoting 2G fuels or biomass conversion. While the United States has created mandates in the form of Renewable Fuel Standards, these are not binding on ethanol blenders.

What's next. Without stable regulatory support, investors do not see a prospect of strong medium-term demand. That discourages them from committing funds, and without such investments 2G will be hard pressed to scale up. Industry players need to speak with a clear and united voice to explain why public support would be worthwhile.

Given the need for energy and chemicals that are not derived from fossil fuels, as well as the benefits of renewables—reducing pollution and diversifying domestic energy sources—there's a case for developing 2G bioconversion into a full-fledged industry.

How big a piece of the renewables pie is 2G likely to capture? This will depend on two things: the speed of adoption and whether 2G can address the seven enablers discussed above and improve relative to alternative fuels. The future is unknown. What is clear, however, is that even after the problems of the past decade, the 2G industry now has an opportunity to industrialize its technology—and thus to improve its chances of success. ■

[1] This estimate is based on a second-generation (2G) plant with a nominal 2,000-ton biomass-processing capacity. In the United States, a standard round bale of stover weighs about 600 kilograms (1,322 pounds). Thus, 8 bales fit on a standard five-ton flatbed truck or up to 36 bales on a trailer—90 to 400 truck movements a day, depending on the size of the vehicle.

[2] This estimate is based on McKinsey modeling and best estimates for respective conversion costs by input parameter and the estimated evolution of input-factor costs.

[3] Running costs refer to the cost per gallon once an investment is made. Depreciation, for example, is not included.

[4] A blending mandate defines the required share of first- and second-generation bioethanol in a fuel.

Simon Alfano is a consultant in McKinsey's Stuttgart office, **Federico Berruti** is a consultant in the Toronto office, **Nicolas Denis** is a partner in the Brussels office, and **Alberto Santagostino** is a partner in the Copenhagen office.

The authors wish to thank Vitaly Negulayev, Mark Patel, and Marta Wlodarz for their contributions to this article.

© Yun Ya Lu/EyeEm/Getty Images

Rethinking the rules for transport in cities

As more of the world's urban areas become congested and polluted, new business models and technologies are emerging to address mobility challenges.

Shannon Bouton, Stefan M. Knupfer, and Steven Swartz

Cities face urgent challenges in a fundamental aspect of urban life: getting around. Traffic congestion—now close to unbearable in many cities—can cost as much as 2 to 4 percent of a nation's GDP. What's more, transport creates emissions of greenhouse gases; smog damages health.

And these problems could easily get worse. By 2030, 60 percent of the world's population will live in cities, up from about 50 percent today.[1] Over the same period, more than two billion people are likely to enter the middle class. The majority of them will live in cities in emerging markets, and many will want to buy cars. Given the problems associated with urban mobility today, that increase would probably make existing urban infrastructures unmanageable.

These trends, which have been building for years, are now converging with other forces. Mobile communications have not only allowed on-demand mobility services (such as Uber and Didi Chuxing) to achieve significant scale but have also set the stage for self-driving cars. Cities have mounted ambitious efforts to mitigate traffic congestion and expand public transit. With more mobility options, people—especially young people—in some markets are less inclined to buy cars. Together, these factors are bringing urban mobility to a tipping point.

Bold, coordinated action from the private and public sectors will be needed to ensure that urban mobility changes for the better: technological advances, funding, intelligent policies, and business-

model innovation can raise productivity and make cities more sustainable. While many of the technologies and business models we describe are being introduced in more affluent countries, they are also relevant for emerging ones, which can do things differently—and well.

In this article, we describe the evolution of urban mobility and suggest how it is now changing. A mobility revolution is on the way for much of the world. We feel optimistic that this transformation will help to avoid a future of gridlock and to improve the lives of city residents everywhere.

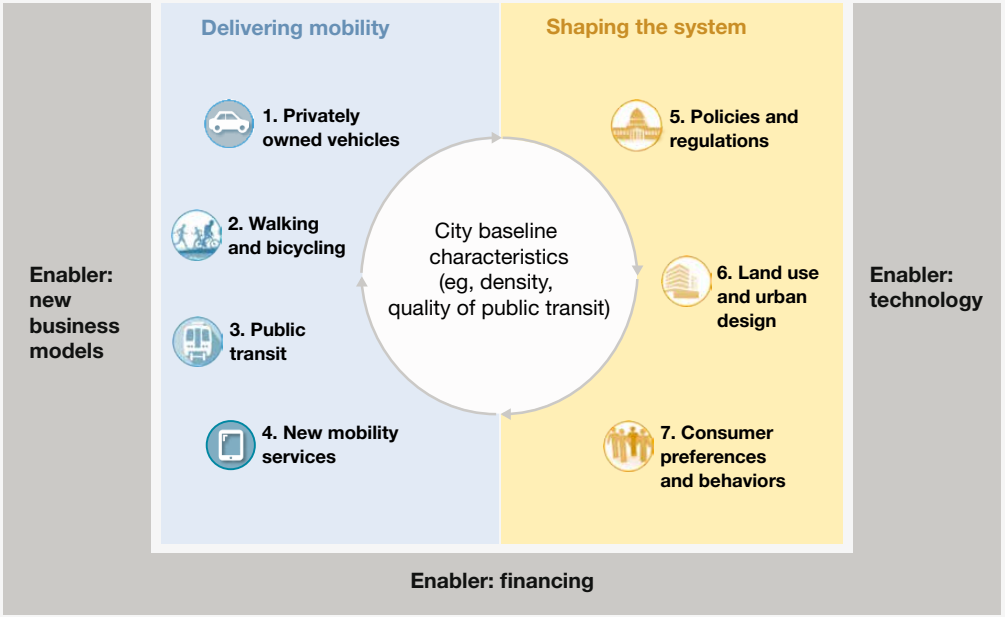
Approaching the tipping point

Today, many cities make decisions about infrastructure investment, regulatory strategies, urban planning, and other mobility-related matters without thinking about the far-reaching effects these choices can have on entire mobility systems. To help stakeholders think through the underlying forces and how they interact—and thus design and implement appropriate interventions—we have developed a framework for understanding urban mobility (Exhibit 1). In this section, we delve into each of the seven parts of this framework. All of them are essential to keep cities moving cleanly and efficiently.

1. Privately owned vehicles

Four major technological trends are converging, and cities that can make them work together could become substantially more mobile and productive. The growing demand for shared, connected modes of mobility will create opportunities for car manufacturers to work with suppliers and

Exhibit 1 **A seven-part framework helps stakeholders understand urban mobility.**



Source: McKinsey analysis

technology providers on new products and services. Even though new mobility services seem likely to slow the growth of private-vehicle sales, the expanding market for shared vehicles could offset this decline to some extent.[2]

In-vehicle connectivity. The broad adoption of in-vehicle connectivity through mobile apps or embedded systems is opening up possibilities; for example, real-time analytics and data on traffic conditions can be used to reroute drivers and avoid congestion. Eventually, vehicle-to-vehicle and vehicle-to-infrastructure communication could reduce the number of accidents and anticipate traffic congestion.

Electrification. The energy efficiency of cars can rise significantly if they have electric power trains. Should cleaner sources of electricity come online, electric vehicles (EVs) will also reduce emissions per mile driven more than conventional cars could. In addition, battery costs are falling fast. As the cost of battery-powered EVs comes down and their quality improves, they could capture a larger share of the global market. Bloomberg New Energy Finance predicts that electric-vehicle sales could rise from an estimated 462,000 in 2015 to 41 million in 2040. That would account for 35 percent of all new light-duty-vehicle sales.

Car sharing. Most cars sit idle 90 percent or more of the time. Car-sharing and other services could make it possible to use all of these vehicles more intensively and perhaps reduce the number of them on the roads at any one time. Shared, fully autonomous vehicles (AVs) could make personal mobility 30 to 60 percent less expensive than private auto ownership.

Autonomous driving. By reducing the human factor behind the wheel, AVs could cut the number of accidents as much as 90 percent, improve traffic flow, make better use of existing roads, diminish the need to widen them or build new ones, and free passengers to perform other tasks. These are exciting prospects, but without car sharing, a significant deployment of EVs, and supportive regulations, the advent of AVs will not, by itself, solve the problems of urban air pollution and traffic congestion.

2. Walking and bicycling

Pedestrian zones are not new. Motorized vehicles have never been allowed in the centers of some cities—for instance, Venice. More recently, cities such as London, New York, Paris, and Singapore have closed areas to traffic and otherwise made themselves more pedestrian friendly.

In addition, many cities are trying to make bicycling safer, easier, and more popular (see "Rolling along: Bicycles, mobility, and the future," on page 33). Bike sharing in particular has hit the mainstream. In 2015, more than 850 cities had such programs, up from 68 in 2007. Some of the largest cities are setting aside more of their roadways for cyclists: London is building 12 extrawide lanes solely for bicycles; New York expects to have 1,800 miles of bike lanes by 2030; and cities as diverse as Delhi, Moscow, and San Francisco are expanding their bike-lane systems.

Elsewhere, the trends for bicycling run in the other direction. In a number of Asian cities, bicycling has declined as newly affluent consumers have bought motorbikes and, eventually, cars. In Beijing, bicycles accounted for 63 percent of all trips in 1986 but for only 14 percent by 2012.

3. Public transit

Cities around the world are investing heavily in public transit. Bogotá, for instance, is well known for the TransMilenio bus rapid-transit (BRT) system, with its dedicated bus lanes, elevated stations, smart-card payments, and red coaches. The TransMilenio BRT, which had 70 miles of service in 2012, is aiming for 241 miles by 2016.[3] Meanwhile,

Beijing has added more than 230 miles of subways in the past seven years.[4] Cities in the developed world are also improving and expanding their public transit; for example, light rail is making a comeback in some parts of the United States.

At the same time, public transit is starting to face competition from new private-transit models. To preserve options for city dwellers and prevent more vehicles from taking to already-clogged streets, cities should consider how to make public transit more convenient and cost competitive. One possible approach is to digitize public-transit systems to coordinate travel by buses and trains with mobility-on-demand services; Los Angeles and Xerox, for example, have launched a single app that consolidates all modes of transport, including public transit. Helsinki is one of several cities developing an on-demand mobility program to let residents get around easily and economically without having their own cars.[5] Helsinki's plan, among other things, would involve giving people mobile apps to summon minivans for shared rides. The city is working with the private sector to develop the technology and pay for the transition.

4. New mobility services

A wide range of emerging mobility services offer transport alternatives (Exhibit 2) that could profoundly change both public and private transit. Even if some start-ups fail, the collective efforts of all these new enterprises will probably improve the technology, business models, and user experiences associated with urban mobility.

We are confident that this will happen: consumers have proved receptive to new mobility models, and investment is pouring into the sector—more than $9 billion of venture capital globally in 2015. Shared mobility and data-connectivity services could

Exhibit 2 **New mobility services offer transportation alternatives.**

	Traditional mobility solutions	New mobility services	
Individual-based mobility	Private-car ownership	Car sharing: peer to peer	A peer-to-peer platform where individuals can rent out their private vehicles when they are not in use
	Taxi	E-hailing	Process of ordering a car or taxi via on-demand app, which matches rider with driver and handles payment
	Rental car	Car sharing: fleet operator	On-demand short-term car rentals with vehicle owned and managed by fleet operator
Group-based mobility	Car pooling	Shared e-hailing	Allows riders going in same direction to share car, thereby splitting fare and lowering cost
	Public transit	On-demand private shuttle	App- and technology-enabled shuttle service; cheaper than a taxi and more convenient than public transit
		Private bus	Shared and Wi-Fi-enabled commuter buses available to the public or to employees of select companies; used to free riders from driving to work

Source: McKinsey analysis

The economics of personal transport

For people living in cities today, is it more economical to own a car or to get around using a mix of different transport modes? How might the economics change as more sophisticated transport options become available? To answer these questions, we used data from the US National Household Travel Survey to calculate the time and costs associated with walking, bicycling, driving, using public transit, e-hailing, and sharing cars in the San Francisco Bay Area.

Not owning a car is already convenient and cost-effective for Bay Area residents who travel 5,000 miles a year, about half the regional average. For them, using an optimized multimodal system could cut costs by almost a quarter compared with running a new car, and it would not add travel time. Multimodal transport is also only a little more expensive than owning a used car. People who travel the regional average of about 10,000 miles a year will pay less to get around by car than by using the best available combination of transportation—using e-hailing services all the time is expensive, and other options, such as public transit, tend to be cheaper but slower.

Innovation in mobility is happening quickly, so we ran the comparative analysis again, this time assuming that autonomous vehicles would be available. By some estimates, these could halve the cost of e-hailing and shared e-hailing by eliminating the expense of the driver. Multimodal travel could cost almost a third less than financing a new car, without any sacrifice of time (exhibit).

This scenario is, admittedly, both optimistic and speculative. The widespread use of driverless cars is not imminent. In aviation, for example, many planes could theoretically fly without pilots. The universal preference, however, has been to require them so that human judgment is available. For similar reasons, and also because of legal issues related to liability, autonomous cars might require human drivers.

expand automotive revenue pools by about 30 percent, adding as much as $1.5 trillion by 2030, compared with $5.2 trillion from sales of traditional cars and aftermarket products.[6] AVs could help make such services more appealing by eliminating the cost of the driver.

Software companies are also getting involved in improving transport by increasing consumer choice and convenience and by making entire transportation systems more efficient. Apps like Moovit help consumers to save time and money by stringing several trips together into an efficient multileg journey rather than making them separately. The firm Urban Engines uses real-time travel data to help visualize, analyze, and improve public transit's performance. And players like RideCell and TransLoc are developing technology platforms to help transportation agencies integrate flexible, on-demand services that supplement traditional high-occupancy, fixed-route fleets.

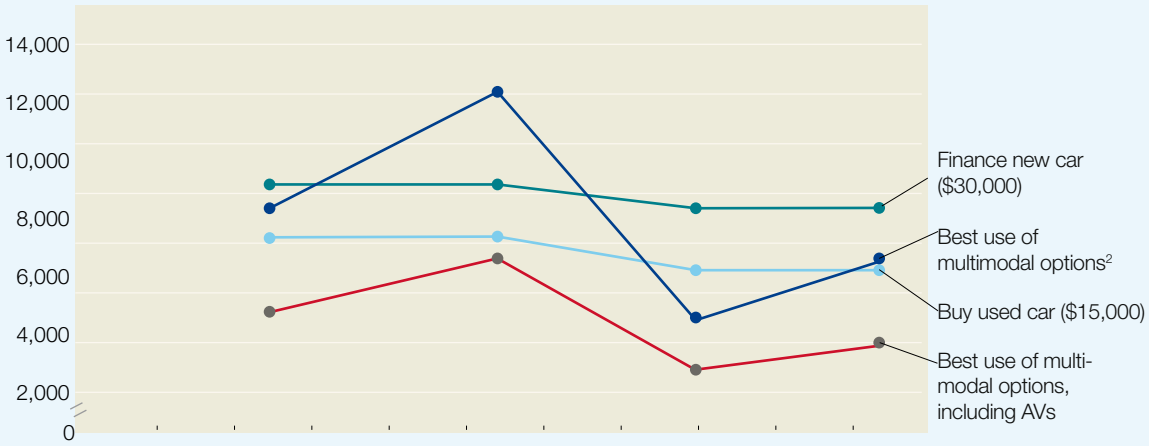
5. Policies and regulations

Urban-policy decisions made today will determine how mobility and car usage evolve in the next 10 to 20 years. After reviewing the long-term transportation plans of more than 25 major cities, we see a trend toward making public-transit, biking, and shared-transportation options more available and attractive.

Exhibit

With autonomous vehicles on the road, mobility could become as cheap and convenient as individual car ownership.

Annual cost of mobility in San Francisco Bay Area,[1]
$ per year



	10,000 miles, 30% time premium[3]	10,000 miles, 0% time premium	5,000 miles, 30% time premium	5,000 miles, 0% time premium
Cost of multimodal transport with AVs, % difference compared with new car	–50	–29	–72	–61
Cost of multimodal transport with AVs, % difference compared with used car	–36	–10	–62	–46

[1]We assumed that autonomous vehicles (AVs) would lower the price of mobility to consumers by half relative to today's e-hailing rate because there is no driver to pay.
[2]Multimodal refers to all different methods people can use to get from point A to point B, apart from using a privately owned car.
[3]Time premium is calculated as total annual travel time using multimodal options compared with time spent traveling in a privately owned car. A 30% time premium, then, means travelers are willing to spend 30% more time than they would driving their own car. A 0% premium means they are not willing to spend any additional time.

Source: McKinsey analysis

In the short term, some cities are considering limits on the number of cars by restricting parking or creating car-free zones. In the long term, however, new technologies could allow more cars on the roads, with less congestion and pollution. Carmakers that invest in EVs and AVs may be in a position to take advantage of that shift.

New players might not have an easy time getting into the game. E-hailing firms face regulatory challenges to their business model. Car-sharing operators must negotiate with cities for permits to operate and to use public parking spaces. And the biggest hurdles AVs must surmount to be adopted at scale may be regulatory, not technological. City officials should think about issues such as data sharing and ownership, equitable access to transportation, competition and licensing, and the use of infrastructure. That will help them make way for new mobility services without triggering disputes such as those between e-hailing companies and established taxicab businesses.

6. Land use and urban design

The way land is used and cities are designed helps to determine what kind of transport they rely on. Single-family homes on large lots increase the need for cars; compact layouts of residential and commercial buildings, with limited parking, create the right conditions for subways, buses, and taxis.

Urban planners are taking these factors into consideration. In many emerging economies, where the urban landscape is still evolving, they can champion transit-oriented development (TOD)—the building of high-density, mixed-use urban areas with easy access to mass transit. Such places have environmental benefits, too: lower levels of greenhouse-gas emissions and of air and noise pollution. They also have less congestion and therefore fewer traffic accidents and can be remarkably livable and attractive for residents of all ages.

Older cities can adopt TOD principles as well. In the decade after Boston added four stations to the train line between the central business district and the city's southern outskirts, communities along the route have seen new life: 1,500 rebuilt housing units, the development of 780,000 square feet (72,500 square meters) of commercial space, and 1,300 additional jobs.[7]

As new mobility services become more popular, city officials will need to think beyond conventional TOD principles in planning how to use land. Many of these services make life more convenient for city dwellers by sending vehicles directly to them instead of forcing passengers to head for parking lots and transit stations. How might this behavior affect the flow of traffic and the need for parking spaces? City planners must not only come up with urban designs that allow traffic to flow and keep residents safe but also find new uses for excess parking areas—uses such as bike lanes and places where mobility-on-demand vehicles can pull over to pick up or drop off passengers.

7. Consumer preferences and behaviors

Evaluating the costs, convenience, service, environmental impact, and time requirements of various transit options is forcing consumers to make trade-offs, just as new technologies are helping to change their transport behavior. The spread of smartphones has enabled companies like Uber and Didi Chuxing to offer on-demand mobility through apps. Other apps help travelers plan, in real time, how best to get from point A to point B.

In developed countries, subtle hints suggest that long-standing consumer preferences are changing. Even in the United States, where the love of cars runs deep, ownership rates have declined in recent years.[8] In Germany, they have dropped sharply among 18- to 29-year-olds: from 420 cars per 1,000 people in 2000 to 240 in 2010.[9] Further research will

be needed to determine whether millennials in the West are merely delaying car ownership or have adopted attitudes that represent the new normal.

There are also countervailing trends. In many developing countries, the desire to own cars is strong, and ownership continues to grow. Without new policies and priorities, these countries will probably follow the same path that much of the developed world went down in the 20th century, with similar pollution and traffic challenges. To cope with them, these countries can benefit from the experience of developed ones and tap into new services and technologies.

For new models to help solve today's urban-mobility problems, two shifts in consumer attitudes and behavior will need to take place.

First, city dwellers will have to learn that cars, whether private or shared, are not necessarily the most economical and convenient mode of urban transit. Our analysis suggests that multimodal transport—the use of various methods of getting around, not just privately owned cars—already costs less than car ownership in some places under certain conditions. It will cost even less once autonomous vehicles are widely deployed (see sidebar, "The economics of personal transport").

Second, public-transit authorities and private firms will need to make their services seamless and simple, as well as economical. Helsinki's plan to create apps that let consumers plan and pay for trips that combine different modes of transportation could prove to be a pioneering example.

Keeping pace

The biggest winners in the mobility revolution are going to be consumers, who will have many more ways to get around. These modes of transport could be cheaper and faster, with customized service and convenience.

Incumbents, including public-transit agencies, should watch for significant shifts in their profit pools as new technologies and business models gain share—witness e-hailing's impact on the taxi industry in some cities. Private on-demand shuttles, for instance, could compete with public transportation, eroding its ridership and making these transit systems less economical. Incumbents need to anticipate such threats and to craft effective strategies sooner rather than later.

Collaboration is an essential element of any strategy for the new mobility economy. Mobility services will need partners to provide technologies to power their businesses. Manufacturers will have to work with insurance companies to develop new products for autonomous vehicles. And competitors might find it advantageous to collaborate, as Lyft and Uber do when dealing with regulators.

City officials can consider how to use new technologies to broaden consumer choice and improve urban environments, especially by reducing traffic and pollution. That may require rethinking rules written for a different era and redeploying city spending that has historically tended to favor roads and highways.

The road ahead

Given rising incomes and aspirations, demand for mobility will increase. Unless cities can adapt across the seven elements of the urban-mobility framework, that demand will stress both the world's infrastructure and its nerves. There is a better way: on-demand urban transit systems that tap into the sharing economy and provide a broader spectrum of services. For certain kinds of trips, autonomous vehicles may become feasible from a technical and regulatory standpoint sooner than many people expect. Urban mobility will probably be more affordable, faster, and safer, and the lines between private and public transport will blur.

Regulators in many parts of the world are working on policies that support such massive changes. Innovation in connectivity, autonomy, lightweight materials, EVs, and AVs will continue to accelerate. The attitudes of citizens and cities around the world are evolving. Put all this together, and urban mobility will probably look very different in the future. ■

---

[1] Shannon Bouton, David Cis, Lenny Mendonca, Herbert Pohl, Jaana Remes, Henry Ritchie, and Jonathan Woetzel, *How to make a city great*, September 2013, McKinsey.com.
[2] Paul Gao, Hans-Werner Kaas, Detlev Mohr, and Dominik Wee, *Disruptive trends that will transform the auto industry*, January 2016, McKinsey.com.
[3] "TransMilenio in Bogotá: Case-study of PPP in BRT," *Global Mass Transit*, August 1, 2011, globalmasstransit.net.
[4] *Gordon's View*, "The growing squeeze on autos in China," blog entry by Gordon Orr, January 20, 2015, McKinseyChina.com.
[5] Adam Greenfield, "Helsinki's ambitious plan to make car ownership pointless in 10 years," *Guardian*, July 10, 2014, theguardian.com.
[6] Gao et al., *Disruptive trends*.
[7] Bouton et al., *How to*.
[8] Michael Sivak, *Has motorization in the U.S. peaked?*, University of Michigan Transportation Research Institute, January 2014, umich.edu.
[9] Kraftfahrt-Bundesamt, kba.de; World Market Monitor, IHS, ihsglobalinsight.com.

Download the full report on which this article is based, *Urban mobility at a tipping point*, published by the McKinsey Center for Business and Environment in September 2015, on McKinsey.com.

Shannon Bouton, the global manager of the McKinsey Center for Business and Environment, is based in McKinsey's Detroit office; **Stefan M. Knupfer** is a senior partner in the Stamford office, and **Steven Swartz** is a partner in the Southern California office.

The authors wish to thank Stefan Heck of Stanford University's Precourt Institute for Energy, as well as Hans-Werner Kaas, Ivan Mihov, Detlev Mohr, Vadim Pokotilo, Yakov Sergienko, Martin Stuchtey, and Jonathan Woetzel, for their contributions to this article.

© Renacal1/Getty Images

Rolling along: Bicycles, mobility, and the future of cities

In an interview, Jay Walder of Motivate discusses how new services and technology are changing how city residents are getting around.

Jay Walder is the president and CEO of Motivate, a bike-sharing company with operations in 11 locations. Before starting Motivate, Walder was CEO of Hong Kong's Mass Transit Railway Corporation, as well as chairman and CEO of New York's Metropolitan Transportation Authority (MTA). He has also worked with Transport for London. He spoke with Simon London, McKinsey's director of digital communications.

McKinsey: *What are the big trends in urban mobility?*

Jay Walder: You have to start by asking, "What's happening in cities?" They're denser and more complex than ever before. Traditional travel patterns are being blown away, and that's pushing us away from some traditional models. In New York, for example, we've seen a phenomenal shift downtown since 9/11, with the area becoming as residential as business. The far west side of Manhattan is becoming a combination of residential and office space. We're seeing the development of technology hubs across the river in Brooklyn and Queens. You see such changes in many, many other cities as well. It's not the same consolidation and centralization we saw before.

McKinsey: *So what does that mean for planners, builders, and infrastructure?*

Jay Walder: It's harder. The traditional model of public transit is to get a lot of people into a vehicle that's going to one place at one time, on a set schedule, and according to a pattern. Today, though, we're used to things being on demand. So developing around the traditional urban infrastructure are

a whole variety of nontraditional means of mobility, such as car sharing and bike sharing. In what I'll call the *Mad Men* days of commuting, you commuted to work one way, and you went back the same way, and the pattern was very symmetrical. Now travel is becoming asymmetrical. You take a whole series of different modes across the day—a train, a bus, an Uber ride, bike share, walking, a ferry.

McKinsey: *Which emerging technologies are most likely to be transformative?*

Jay Walder: Bike sharing is actually one of the most revolutionary changes that we've seen within the urban-transportation space. It's redefined our idea of what public transit should be. Bike sharing creates a system for personal mobility. It is personalized mass transit. You distance yourself from the idea of stations and routes and schedules. Uber and Lyft in many ways reflect that, too, and there is great potential for autonomous vehicles. There are many challenges associated with this shift—technological, social, regulatory. But you can see them as the enablers of tremendous change in the city.

In the 20th century, the development of cities was led by infrastructure—consider the way different rail lines opened up areas of London. It was, in effect, a case of "If you build it, they will come." In the 21st century, cities are not going to be defined by that infrastructure anymore. They're going to be defined by technology and the ways in which technology is brought into the city space. I'm not saying that large-scale infrastructure projects will not have a place. They will. But I think they will be surrounded by a whole set of other things that are going to be increasingly important.

McKinsey: *What is the potential of urban bike sharing?*

Jay Walder: I don't think we've even begun to see the full potential. Fifteen years ago there were 4 modern bike-share systems in the world; now

Jay Walder

Vital statistics

Born 1959, in Indianapolis, Indiana

Married, with 3 children

Education

Received a bachelor's degree from Harpur College at Binghamton University

Holds a master's degree in public policy from John F. Kennedy School of Government, Harvard University

Career highlights

Motivate
(October 2014–present)
CEO

MTR Corporation, Hong Kong
(January 2012–August 2014)
CEO

Metropolitan Transportation Authority, New York
(2009–11)
Chairman and CEO

McKinsey & Company
(2007–09)
Partner

Transport for London
(2001–07)
Managing director for finance and planning

John F. Kennedy School of Government, Harvard University
(1995–2001)
Lecturer in public policy

there are almost 900. Think about what an impact this is having in an incredibly short period of time. In Chicago, rides have increased by 70 percent from March 2015 to March 2016, in New York by 110 percent, in Columbus, Ohio, by 66 percent. We're doubling the size of Citi Bike and growing Bay Area Bike Share tenfold. And we are fielding calls and requests and ideas all the time. Why is this happening? I think bike sharing fits not just with our desire for mobility but also with our values. It fits with what we want to be as a society. We want to be healthier. We want to be fit. And it just makes us feel good.

McKinsey: *How big is bike sharing?*

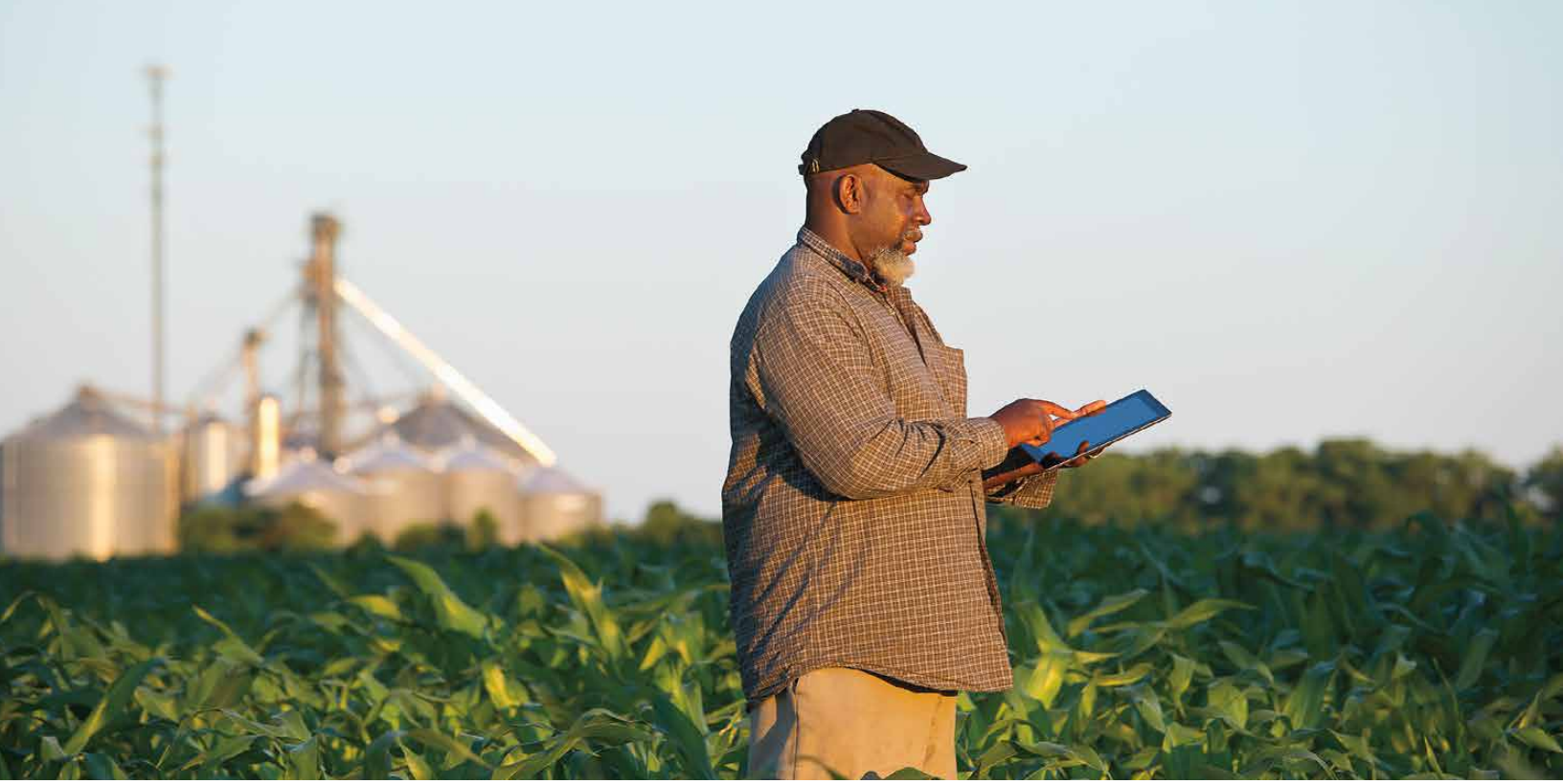
Jay Walder: It's tiny. In New York, the MTA carries 5.7 million people every weekday on the subway, and another 2.5 million people on the bus. In April 2016, our bike-share system carried about 34,000. But I don't think that's the way to look at it. One of the things that you learn as you look at these types of challenges is that the impact is on the margin. I remember walking home one night at about 6 PM and stopped at the streetlight. As I waited, seven people went by on Citi Bikes. And I thought, "This is pretty neat."

McKinsey: *How different could cities be in 30 or 50 years?*

Jay Walder: They could be almost unrecognizable. So much of the way in which we've defined the nature of the city has been about the way in which we get around—from horse-drawn carriages to automobiles and to larger vehicles. What we're looking at today fundamentally reshapes that. In the horizon of 50 years or so, I would be tremendously surprised if we haven't redefined our cities in fundamental ways.

There are physical constraints to cities, so they are going to be in the business of reallocating and rethinking their physical space. That's going to open up opportunities for us to think about what we really want. That's going to be unusually exciting. We went through that process 100 years ago and reallocated the physical space to the automobile. That is already changing.

I am a big believer in the city. Despite all the technology that exists, what is most exciting about the city is the interaction of people within its space. If we had been having this conversation in the mid-1960s, for example, we might have had a hard time making that argument. That's the beauty of what's happened. Many people argued that these changes would be the demise of cities. Actually, it has ended up strengthening them. ■



Starting at the source: Sustainability in supply chains

By working closely with their suppliers, consumer companies can lessen their environmental and social impact and position themselves for strong growth.

Anne-Titia Bové and Steven Swartz

The next 10 to 15 years will present major opportunities for consumer companies. Some 1.8 billion people are expected to join the global consuming class by 2025, a 75 percent increase over 2010.[1] Consumer spending should rise even more than the number of consumers as household incomes swell and people use bigger shares of their budgets to buy consumer goods. China, for example, is on track to gain 100 million working-age consumers by 2030, and it is expected that their spending on personal products will be double the current rate.[2]

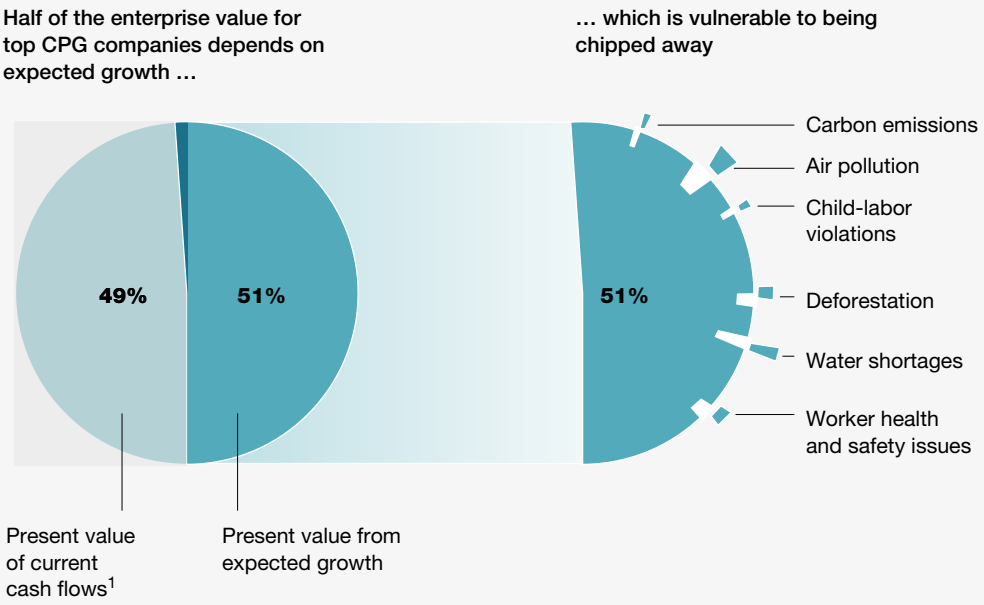
These trends contribute to a strong growth projection for the consumer sector: 5 percent a year for the next two decades. For investors, this level of expected growth should be good news. The worth of a company can be expressed as the sum of two values: the present value of the company's current cash flows extended into the future, and the present value of the expected growth in its cash flows. When we studied the enterprise value of the top 50 publicly traded consumer-packaged-goods (CPG) companies, we found that their expected cash-flow growth makes up roughly half of their current value. Because of this, factors that alter these companies' growth projections will also have a major effect on their total returns to shareholders (Exhibit 1).

One condition that can slow a company's growth is poor sustainability performance, as measured in environmental and social impact. To make and sell goods, consumer businesses need affordable, reliable supplies of energy and natural resources, as well as permission from consumers, investors, and regulators to do business. But companies can no longer take those enabling factors for granted.

Exhibit 1

Sustainability factors could alter the growth projections for consumer-packaged-goods companies, seriously affecting their total returns to shareholders.

Average for top 50 publicly traded consumer-packaged-goods (CPG) companies



[1]Current net operating profit less adjusted tax (NOPLAT) estimated for latest reported fiscal year held flat through perpetuity (NOPLAT divided by weighted average cost of capital). Value ranges from 18% to 88% across the 50 largest global CPG companies, whose combined market capitalization is $2.68 trillion.

Source: Bloomberg; Capital IQ; McKinsey analysis

Indeed, scientific consensus, along with pledges by governments and business leaders—including the leaders of some of the largest consumer companies—calls for dramatic improvements in sustainability performance.

For example, the Paris Agreement, reached by 195 countries at the United Nations climate-change summit in December 2015, aims for reducing global greenhouse-gas emissions enough to prevent the planet from warming by more than two degrees Celsius. To cut their emissions in line with the Paris target while increasing sales at the projected rate of 5.3 percent a year, CPG companies would have to lower their carbon intensity—the amount of greenhouse gas emitted per unit of output—by more than 90 percent between 2015 and 2050 (Exhibit 2).

This figure suggests that consumer companies will have to greatly reduce the natural and social costs of their products and services in order to capitalize on rising demand for them without taxing the environment or human welfare. To that end, some companies will benefit from innovations that allow products to be made using less energy and material and to be reused or recycled with ease (see "Toward a circular economy in food," on page 44). As we explore in the rest of this article, consumer

businesses are likely to find that their supply chains hold the biggest opportunities for breakthroughs in sustainability performance.

Supply chains: A missing link for sustainability

A high-functioning supply chain—the entire hierarchy of organizations, including energy providers, involved in making and distributing goods—can allow a consumer company to manage two types of sustainability-related risks. One type of risk has to do with the sustainability impact of providing goods and services to customers. The typical consumer company's supply chain creates far greater social and environmental costs than its own operations, accounting for more than 80 percent of greenhouse-gas emissions and more than 90 percent of the impact on air, land, water, biodiversity, and geological resources (Exhibit 3). Consumer companies can thus reduce those costs significantly by focusing on their supply chains.

Exhibit 2

To achieve global climate goals while meeting growing demand, consumer-packaged-goods companies would have to significantly cut their greenhouse-gas emissions.

A

Globally, the CPG[1] market is expected to grow at an average of 5.3% annually

B

In 2015, greenhouse-gas (GHG) emissions from CPG companies were approximately 33 GT CO_2e[2]

C

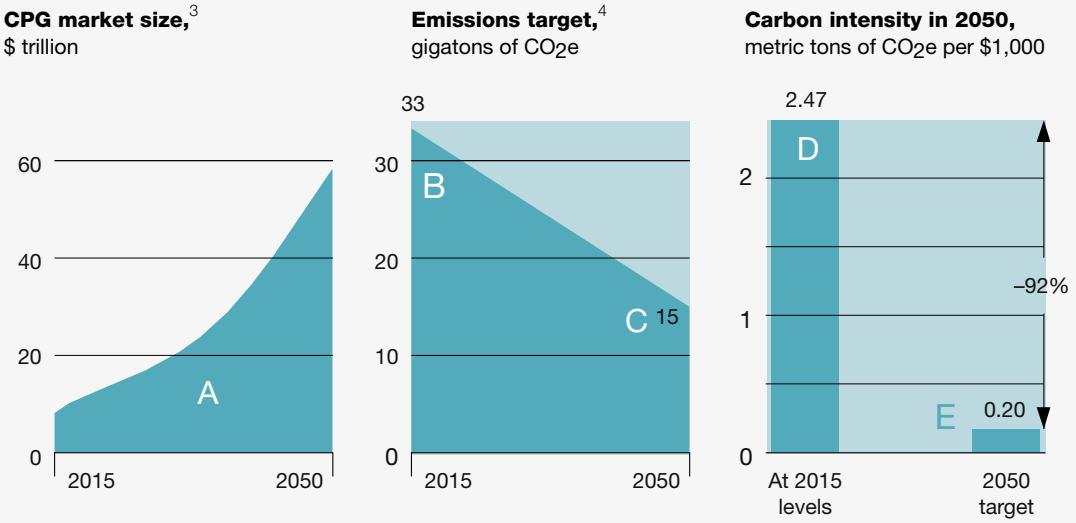
The CPG industry must reduce its GHG emissions by more than half to meet 2050 targets

D

A massive reduction of CPG resource intensity, measured in metric tons of CO_2e per $1,000 of revenue, is required

E

By 2050, CPG companies must reduce their GHG emissions 92%, relative to revenues

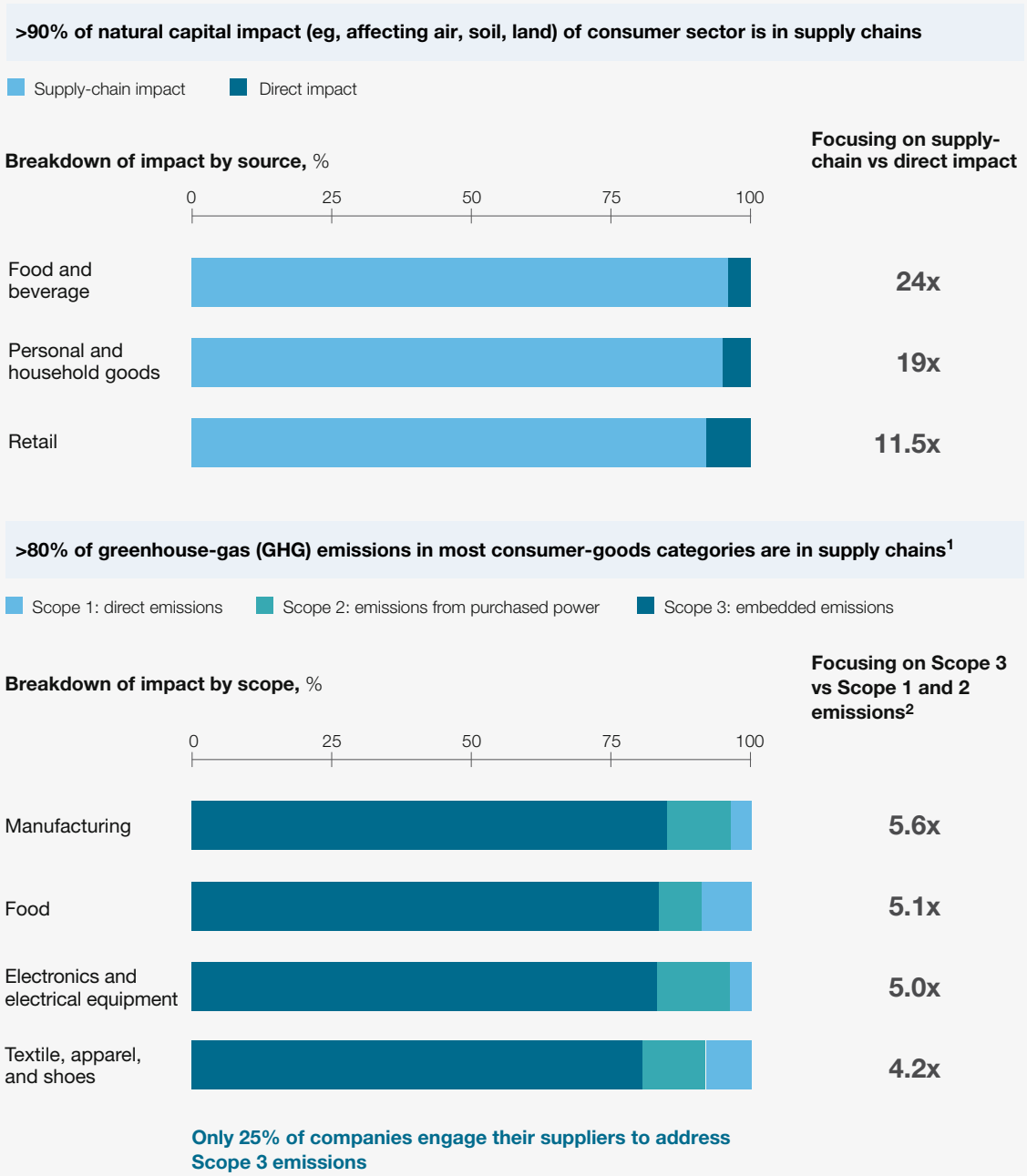


[1]Consumer packaged goods.
[2]Gigatons of CO_2 equivalent.
[3]Based on estimated 5.3% annual growth of global CPG market from 2013 to 2025 ($7.5 trillion in 2013).
[4]Based on 41–72% reduction in GHG emissions by 2050 required to maintain warming at below 2°C (2.1% annual reduction). Estimated consumer goods–related GHG emissions, from sourcing raw materials through disposal, were ~33 GT CO_2e in 2015.

Source: Intergovernmental Panel on Climate Change; McKinsey analysis

Exhibit 3

Most of the environmental impact associated with the consumer sector is embedded in supply chains.



Note: Supply chains are defined here as all organizations, including energy providers, involved in producing and distributing consumer goods.

[1]Supply-chain impact multiples are lower for GHG emissions than for natural capital because GHG multiples consider Scope 1 and Scope 2 emissions jointly.

[2]Among companies that disclose to CDP.

Source: Carnegie Mellon University; CDP; GreenBiz; McKinsey analysis

A second type of risk occurs because sustainability impact can interfere with consumer companies' supply chains. GrainCorp, a large Australian agriculture business, reported that a drought cut its grain deliveries by 23 percent, leading to a 64 percent drop in 2014 profits.[3] Unilever estimates that it loses some €300 million per year as worsening water scarcity and declining agricultural productivity lead to higher food costs.[4] In 2014, a ranking of the world's 100 most reputable companies included 8 apparel companies. Of those, 2 were dropped from the ranking in 2015, following the deadly collapse of the Rana Plaza factory in Bangladesh, which had been making goods for them, and they were left off the list in 2016.[5]

Notwithstanding the sustainability risks that lie in supply chains, relatively few companies are working with their suppliers to manage these risks. As an example, consider how businesses are addressing the climate impact of their supply chains. Of the companies that report their greenhouse-gas emissions to CDP, a nonprofit organization that promotes the disclosure of environmental impact data, only 25 percent say they engage their suppliers in efforts to reduce emissions.[6]

Even when companies attempt to influence their suppliers, they are likely to run into challenges. The biggest one may be that consumer companies do not deal directly with all the firms in their supply chains. Primary suppliers routinely subcontract portions of large orders to other firms, or they rely on purchasing agents to place orders with other firms. Subcontracting is especially common in the apparel industry; the fast-fashion business in particular requires large volumes of garments to be made in short time frames. Subcontractors can be managed loosely, with little oversight regarding workers' health and safety.

Conditions such as these prevent consumer companies from knowing what sustainability impact occurs in segments of the supply chain where the impact is likely to be worst. In a recent survey by The Sustainability Consortium (TSC), a nonprofit organization dedicated to improving the sustainability of consumer products, less than one-fifth of the 1,700 respondents said they have a comprehensive view of their supply chains' sustainability performance. More than half reported being unable to determine sustainability issues in their supply chains.[7] Until consumer companies identify the sustainability problems in their supply chains, they cannot begin to work with their suppliers on solving those problems.

Three approaches to improving sustainability in supply chains

In the eyes of shoppers and investors who are concerned about the sustainability of the goods they buy and the companies they own stakes in, consumer businesses are responsible for ensuring that their supply chains are managed well. These companies are also in a strong position to influence their suppliers. We believe three approaches can help consumer companies make their supply chains more sustainable. These include identifying critical issues across the whole supply chain, linking the company's supply-chain sustainability goals to the global sustainability agenda, and helping suppliers manage their impact.

Locate critical issues across the whole supply chain

To understand the impact of making consumer goods, companies must determine how natural and human resources are used at every step of the production process, whether in the supply chain or in direct operations. Companies must also consider a wide range of environmental, social, and economic issues. The tremendous variety of consumer products means that these issues can differ significantly from one product to another. For example, manufacturing LCDs causes the emission of fluorinated greenhouse gases, while coffee plantations are prone to hire underage workers to cultivate and harvest coffee beans.

Several organizations offer measurement frameworks and instruments that can help companies find the most critical sustainability issues in their supply chains:

- TSC has built a set of performance indicators and a reporting system that highlights sustainability hot spots for more than 110 consumer-product categories, covering 80 to 90 percent of the impact of consumer products. TSC identified the hot spots and developed the performance indicators for them by reviewing scientific research and consulting with more than 100 stakeholder organizations.

- World Wildlife Fund (WWF) offers more than 50 performance indicators for measuring the supply-chain risks associated with the production of a range of commodities, as well as the probability and severity of those risks.

- The Sustainability Accounting Standards Board has developed standards that help public companies across ten sectors, including consumer goods, to give investors material information about corporate sustainability performance along the value chain.

- CDP and the Global Reporting Initiative have created standards and metrics for comparing different types of sustainability impact.

Link supply-chain sustainability goals to the global sustainability agenda

Once companies know where their supply-chain issues are, they can set goals for lessening the resulting impact. Ideally, they will base their goals on scientists' recommendations for bringing various types of sustainability impact under thresholds that will maintain or improve human well-being.

For example, the Intergovernmental Panel on Climate Change, a scientific body established by the United Nations, has defined global targets for reducing greenhouse-gas emissions. Based on these recommendations, CDP and WWF have calculated that the consumer-staple and consumer-discretionary sectors in the United States should cut their greenhouse-gas emissions by 16 to 17 percent and 35 to 44 percent, respectively, to produce their fair share of global reductions between 2010 and 2020. Reaching those targets would also allow the consumer-staples sector to save $15 billion and the consumer-discretionary sector to save $38 billion in costs. The same report suggests that setting aggressive reduction targets makes it more likely that companies will achieve these goals and realize greater returns on their investments in reducing carbon emissions.[8]

General Mills used this approach to set an emissions-reduction goal for its entire value chain that corresponds to the internationally agreed-upon target of lessening emissions by 41 to 72 percent, from 2010 levels, by 2050. With more than two-thirds of its total greenhouse-gas emissions occurring in its supply chain, General Mills announced in late 2015 that it would endeavor to cut emissions "from farm to fork to landfill" by 28 percent within ten years. To reach these goals, the company is encouraging its agricultural suppliers to follow sustainable practices and has pledged to obtain 100 percent of ten priority ingredients from sustainable sources by no later than 2020.

Some suppliers have set sustainability targets of their own, ahead of receiving mandates from their customers. For example, Cargill has committed to creating a transparent, traceable, and sustainable palm-oil supply chain by 2020.

Assist suppliers with managing impact—and make sure they follow through

The purchasing power held by consumer companies and retailers gives them significant influence over their suppliers' business practices. Relatively

few companies in the consumer and other sectors use that influence to get their suppliers to reduce sustainability impact, though that is changing. Between 2010 and 2015, membership in CDP's supply-chain program rose 30 percent but still stands at fewer than 100 companies, including 19 consumer companies. The number of suppliers reporting through the program increased fourfold, from 1,000 to more than 4,000. The supply-chain collaboration has led to a reduction in carbon emissions of more than 3.5 million tons, with suppliers saving an average of $1.3 million per emissions-reduction initiative.[9]

In recent years, consumer companies and others have adopted more sophisticated and effective methods for changing their suppliers' practices. They have gone from disseminating codes of conduct, performing audits, and fielding questionnaires to helping suppliers design and implement sustainability programs that directly support the companies' own goals. Campbell Soup Company, in collaboration with the Environmental Defense Fund, offers farmers technologies, guidelines, and products to help them optimize their fertilizer use and improve soil conservation.

Digital technology has also increased companies' ability to assist large numbers of suppliers. In 2014, Walmart launched a program to help thousands of its Chinese suppliers make their factories more energy efficient through the use of an online tool. The program has enabled the average supplier to reduce its energy consumption by an average of 10 percent. Unilever uses a software tool, developed with the University of Aberdeen, to collect data on whether farmers in its supply chain are using sustainable practices. Unilever offers them the tool for free, with the aim of procuring 100 percent of its agricultural content from sustainable sources by 2020.

To reinforce efforts like these, companies should monitor suppliers' sustainability performance and hold them accountable for it. Ultimately, consumer companies can only achieve ambitious sustainability goals if they set high standards for their suppliers' performance and stop doing business with suppliers that fall short—just as they do with other considerations, such as the cost and quality of goods and the timeliness of shipments.

Consumer companies can also offer their suppliers incentives for improving sustainability performance. Walmart has pledged that by the end of 2017, 70 percent of the goods it sells will come from suppliers that use the company's Sustainability Index, a supplier-sustainability scorecard that employs TSC's supply-chain performance indicators and reporting system. On Walmart's e-commerce site, companies with the highest Sustainability Index scores have their products tagged as "made by Sustainability Leaders," giving them an incentive to participate. Likewise, with the International Finance Corporation, Levi Strauss established its $500 million Global Trade Supplier Finance program to provide low-interest short-term financing to those that rate highly on Levi's own sustainability scorecard for suppliers.

Because supply chains overlap in many consumer sectors, companies have recognized the benefit of collective action and have begun working together to involve their supplier networks in sustainability efforts. For example, the Consumer Goods Forum (CGF), a global network of more than 400 retailers, manufacturers, and other companies, made a collective commitment in 2010 to achieve zero net deforestation by 2020. CGF members are pursuing that goal through the responsible sourcing of four key commodities: beef, palm oil, pulp and paper, and soy.

Another example is the Accord on Fire and Building Safety in Bangladesh, which was set up after the collapse of the Rana Plaza factory. The accord aims to improve safety at factories by supporting

independent inspections, remedial action, training, and disclosure of inspection reports. More than 200 apparel companies have pledged to inspect all of the 1,600 factories they work with. By December 2015, they had completed some 1,380 inspections.[10]

For years, most consumer companies paid relatively scant attention to whether their suppliers managed the social and environmental impact of their business activities. This is beginning to change, as consumer companies have come to appreciate the extent to which their supply chains contribute to global sustainability challenges, as well as the effects that poor sustainability management can have on their growth and profitability. A few leading consumer businesses, along with civil-society institutions, have created a widening array of practices and tools for working with their suppliers to lessen sustainability impact and have begun to realize the benefits of their efforts. Their experiences illustrate the possibilities for many more companies to initiate similar activities. Companies that manage their supply-chain impact may well be best positioned to gain from the boom in consumer spending that is expected to take place over the next decade and beyond.

[1] For more, see "Urban world: Cities and the rise of the consuming class," McKinsey Global Institute, June 2012, on McKinsey.com.
[2] For more, see "Urban world: The global consumers to watch," McKinsey Global Institute, March 2016, on McKinsey.com.
[3] Trevor Chappell, "Drought shrinks GrainCorp profit," *Sydney Morning Herald*, November 13, 2014, smh.com.au.
[4] "Unilever CEO calls for decisive action to tackle climate change," Unilever, August 4, 2014, unilever.com.
[5] *2015 Global RepTrak 100*, Reputation Institute, April 2015, reputationinstitute.com; and *2014 Global RepTrak 100*, Reputation Institute, April 2014, reputationinstitute.com.
[6] *Committing to climate action in the supply chain*, CDP, December 2015, cdp.net.
[7] *Greening global supply chains: From blind spots to hot spots to action*, The Sustainability Consortium, 2016, sustainabilityconsortium.org.
[8] *The 3% solution*, World Wildlife Fund and CDP, 2013, thethreepercentsolution.org.
[9] *From agreement to action: Mobilizing suppliers toward a climate resilient world*, CDP, 2016, cdp.net.
[10] *Quarterly aggregate report*, Accord on Fire and Building Safety in Bangladesh, February 25, 2016, bangladeshaccord.org.

Anne-Titia Bové is a specialist in McKinsey's São Paulo office, and **Steven Swartz** is a partner in the Southern California office.

The authors wish to thank Sheila Bonini, Shannon Bouton, and Nicolas Lefèvre-Marton for their contributions to this article.

Toward a circular economy in food

Danone CEO Emmanuel Faber shares how his company manages resources with an eye on sustainability.

The French food and water company Danone has a history of environmental awareness. In this interview with McKinsey partner Clarisse Magnin, CEO Emmanuel Faber discusses his commitment to resource efficiency.

McKinsey: *What inspired Danone's current thinking?*

Emmanuel Faber: Three things. My own upbringing and convictions, the culture and history of Danone, and the overwhelming case for change.

I grew up in the Alps, where the beauty of the natural cycles seeded in me the underlying importance of something that we as managers can often lose sight of—namely, that life is more than ideas, mathematical models, and software. I later spent three years in Asia, including Indonesia and China, where I saw firsthand how fast resources were being depleted in emerging markets.

Danone's commitment to tackling these problems is not new, so it was always fitting that I should join such a company. More than 40 years ago, in Marseille, Antoine Riboud, our founding CEO, made a speech in which he pointed out that we only have one Earth, that it's our responsibility to look after it, and that as a business we would pursue a dual economic and social agenda.

Last, the world is changing. Cheap, low-quality calories have dominated the industrial-food business for nearly 100 years, but we are reaching the end of this era. Consumer tastes and behaviors are evolving, and as part of this evolution, consumers expect us to act differently.

McKinsey: *Can you say more about these changes?*

Emmanuel Faber: Supply chains are increasingly global, which means there are systemic risks that

we don't see. While we've been able to improve food security in many regions, this has also led to other issues, such as declining soil fertility and threats to the biodiversity of our planet. At the same time, we cannot continue to reduce the costs of agricultural production. The volatility of input prices is much greater than it used to be, and food inflation is rising. The price of milk, our major raw material, was near an all-time low in 2009 but has gone up three times since and 18 months ago almost hit an all-time high.

On top of that, we need to address the needs of a growing population, new regulatory requirements in the area of public health, and the increasing impact of diseases such as obesity and diabetes. Some companies are turning to big data management and ERP[1] to meet these challenges. But I believe this is the wrong approach. We need a comprehensive response to tackle growing resource scarcity, which both drives the efficient use of those resources through the supply chain and brings healthy food to as many people as possible. Danone's approach rests on what we call consumption ecosystems, taking into account every stage in the life of products, from the production of raw material to the "second life" of packaging.

McKinsey: *What does that mean in practice for the way you make products and source materials?*

Emmanuel Faber: To embed the principles of the circular economy in our operations, we have started managing our three key resources—water, milk, and plastic—as cycles rather than as conventional linear supply chains.

Emmanuel Faber

Vital statistics
Born January 22, 1964, in Grenoble, France

Married, with 3 children

Education
Graduated with bachelor's degree in business administration from HEC Paris

Career highlights
Danone Group
(1997–present)

CEO (2014–present)

Vice chairman, board of directors (2011–present)

Deputy general manager (2008–14)

Vice president, Asia–Pacific region (2005–08)

Head of finance, strategies, and information systems (1997–2005)

Legris Industries
(1993–97)

CEO (1996–97)

Chief administrative and financial officer (1993–96)

Fast facts

Director, danone .communities mutual-investment fund (SICAV)

Member, steering committee, Danone Ecosystem Fund

Member, steering committee, Livelihoods Fund

One example of this is what we are doing in yogurt. To make Greek yogurt, you use a "strained" technology with a membrane, extracting a lot of acid whey. Instead of just seeing this acid whey as an effluent, we are testing technology solutions in five or six countries and working with different partners to find ways to use whey as a resource. We are already using whey protein, for instance, in our Early Life Nutrition business, and we will soon be able to use it for animal feed, fertilizers, and energy. What we're doing is turning something that is a challenge today into something that will have value tomorrow.

Under a new partnership with Veolia, a global waste-management company, we are working together on building a circular economy around water and packaging waste, testing new ideas and investigating new technology. One project, for example, aims to optimize recycling techniques so we can build plants with zero liquid discharge.

McKinsey: *What are you doing with plastic waste?*

Emmanuel Faber: At the moment, nearly 30 percent of our total packaging comes from recycled materials, and as much as 80 percent in the case of cartons, but we continue to make progress. For plastics, the endgame could be the creation of a net-positive cycle in partnership with other large companies, which would mean recycling more plastics than we put on the market in the first place.

Plastics are interesting because they highlight an important challenge of a circular economy, namely managing the "hierarchy of degradation." If, say, we allow virgin PET[2] to go into landfills, its reusability potential ends up being low. But if we save it in a closed-loop system, it will continue to be of food-grade quality, good enough to reuse in food packaging. This means it stays at a high level in the hierarchy of degradation. Our ambition is to create a second life for all the plastic packaging we put on the market, so that we move toward 100 percent recycling in this respect. Part of the plan is also to launch a 100 percent biosourced second-generation plastic.

McKinsey: *What changes have you made to Danone's organization to reflect the new ways of working?*

Emmanuel Faber: We have created a position in the executive committee in charge of our Strategic Resources Cycles unit. This person oversees separate internal units for the milk cycle, the water cycle, and the plastic cycle. This organizational change has already started to transform the way we work, because it is cross-divisional and cross-functional.

We have also created a Milk Technology Center that reports to the Milk Cycle Organization—part of the Strategic Resources Cycles unit—not to R&D or to the dairy business, as it might under a conventional structure. The aim here is to achieve a step change in our ability to maximize the value of milk and limit the waste from milk production.

McKinsey: *How do you change Danone's culture to embrace circular-economy thinking?*

Emmanuel Faber: Danone has circular-economy principles in its DNA, and people join Danone because of its unique culture and heritage. We do, however, need to continue to create the conditions for new generations to embrace our founding principles of business success and social progress.

The time horizon is critical. You won't start anything if you only think of the next three months; it's got to be something for the next 30 years. At the same time, you need breakthrough objectives. We would never have made as much progress with our CO_2 reduction program in 2008 if we had just gone for a 2 percent reduction per year rather than 30 percent over five years, which we set ourselves. We actually achieved 42 percent.

If you know at the outset how you are going to achieve an objective, you're not aiming high enough to get the organization to start working differently. You have to come up with an objective which is aspirational—something that is too far away to know how it will be reached. That was our intent when we announced, in December last year, that we would target zero net carbon emissions on our full scope of responsibility by 2050.

You also need an investment-payback period that is longer than it is in today's traditional model—five years instead of three; seven years instead of five. For our CO_2 reduction program, we created a special green capital-expenditure category with this in mind. Some bets may have no payback at all. It's about getting a balance between the short, the medium, and the long term.

Incentives are also an important part of the culture because they really show that the leadership team means what it says. A few years ago, the annual incentive program for the 1,500 top managers at Danone encompassed the CO_2 reduction objective, to the point where, broadly speaking, the yearly bonus attached to CO_2 reduction was equivalent to the yearly bonus attached to profit generation. This is just one example of how we're using incentives to embed our vision across the business.

On top of this, and in order to foster change with Danone's 100,000 employees, the company launched a manifesto to underpin the way we intend to deliver on our mission. This manifesto aims at deepening and enriching Danone's mission, to bring it to the next level of impact, through a series of initiatives across the company and outside it. For instance, a dedicated internal website has been created where people can post ideas and thoughts related to the manifesto and contribute to Danone's journey. To support and coordinate the establishment of the manifesto across Danone's teams and local communities worldwide, the role of chief manifesto catalyst has been created to maximize the potential of this process and catalyze bottom-up innovation.

McKinsey: *How do you think this approach will ultimately benefit Danone, as well as society and the environment?*

Emmanuel Faber: Consumers are interested in what is at work in the products they eat, how these products were produced and delivered, and what their effect is on the body. I believe there is a ladder of brand equity in food. There is a lot attached to the values and culture. Ultimately, the brand should be the link with the consumer and tell the story. ■

[1] Enterprise resource planning.
[2] Polyethylene terephthalate.

Taking conservation finance to scale

Environmental projects are woefully underfunded. Improving their risk-return profiles and structuring larger investment products could unlock private capital to narrow the gap.

Ryan Davies, Hauke Engel, Jürg Käppeli, and Todd Wintner

Environmental-conservation projects face a dramatic shortage of funds. Estimates indicate that $300 billion to $400 billion is needed each year to preserve and restore ecosystems but that conservation projects receive just $52 billion, mostly from public and philanthropic sources.[1] Some asset managers and conservation experts have suggested that private investors could close more than half the gap by profitably funding enterprises or projects in areas such as sustainable food and fiber production, habitat protection, and water quality and conservation.[2]

This is an attractive prospect—except that conservation can be a slow and risky business. It can take decades to realize, verify, and capitalize on conservation benefits; only the most patient investors will wait that long. Some projects are derived from compelling but unproven concepts that investors are understandably reluctant to back. Many more are based on proven concepts yet still operate in challenging circumstances and generate unreliable revenues. We routinely hear about conservation projects for which the investment risks and expected returns are misaligned: imagine an equity investment for which the level of risk is comparable to venture capital but the returns are closer to those of a stake in a successful, established company.

These conditions make it hard for project developers and fund managers to attract private capital. The good news, though, is that developers and fund managers have techniques at their disposal for creating projects with the size, stability, and potential that mainstream investors seek. Here we look at some problems that discourage private investment

in conservation and offer our ideas for how to overcome them.

Acknowledging the challenges in conservation

Conservation finance faces certain problems that affect the wider impact-investing market, of which it is a segment. These problems include a lack of widely accepted standards for measuring impact, a shortage of financial-management experience among project developers, the high transaction costs of investing in small projects, and an abundance of early-stage project concepts that are too speculative to interest all but the most risk-tolerant investors.

Three big challenges have more to do with the specific traits of conservation. The first of these challenges is generating sizable cash flows shortly after a project begins. Some projects only start producing cash flows after years of investment. Others have benefits that are hard to monetize, such as the economic gains that come from preserving biodiversity or from mitigating the risk of future losses. Preserving and rebuilding coastal wetlands, barrier islands, and oyster reefs, for example, can reduce damage from storms. When many parties benefit from a restoration project, though, it can be hard to get some of them to fund the project up front or to pay for the services it provides.

The second challenge is the inherent complexity and unpredictability of natural systems. Even with sophisticated scientific knowledge, it can be difficult to predict the conservation outcomes from managing a natural system in a particular way. This matters because natural systems impose variability on business activities, such as food and fiber production, that depend on those systems. As a result, revenues from conservation projects can be uncertain, whether those revenues are linked to conservation outcomes or to sales of goods and services.

The third challenge is the multifaceted nature of many questions related to land use, particularly its objectives and its governance. Settling these questions requires relevant specialists—ecologists, project managers, lawyers, public-policy analysts, government officials—to agree on the conservation principles for a project. This can be difficult. Most conservation projects depend on certain uses of land or water, which are scarce resources that might be used in multiple ways. Pursuing optimal conservation outcomes can be politically unpopular, preclude other socially beneficial uses of the land, or generate less profit than other uses (for instance, agriculture, resource extraction, or real-estate development practiced with conservation as a low priority).

Many projects are subject to further risks because many stakeholders (government at multiple levels, local communities, and private-land owners, to name a few) impose constraints that can overlap or even conflict. In some countries, national, regional, and local authorities each have jurisdiction over different aspects of how a piece of land is used. And if a project depends on policy mechanisms such as carbon prices to generate income, the possibility that those policy mechanisms will change creates more risk.

How conservation can attract more private investment

Project developers and fund managers can take the lead on several actions that will help attract private capital for conservation projects, first from impact-oriented investors and then, increasingly, from mainstream investors as well. Impact-oriented investors can also support the conservation-finance sector using their knowledge, relationships, and resources other than capital.

Elevate the dialogue on project risk and return to be more open, objective, and structured.

Because many risks can affect conservation projects, developers must start by identifying risks

comprehensively. This often requires consultation with a range of stakeholders. The Water Funder Initiative, for example, has collected ideas from policy makers, scientists, industry executives, conservationists, and others about the risks and opportunities associated with investing in water solutions.[3]

Developers should also approach investors with a realistic and well-structured assessment of risks and returns and how these translate to financial measures. We often see conservation projects that have commercially unattractive risk-return profiles because their risks are high relative to their expected cash flows. Sometimes such projects are pitched as market-rate investments, which diminishes their credibility. Fund managers and financial intermediaries can help developers structure multiple options for investing in a project, including options that are more likely to interest investors who seek market-level returns in addition to conservation impact. Financial professionals can also help identify investors who are qualified to evaluate the risks and returns associated with complicated investments such as conservation projects.

Mitigate risks and boost returns. Project developers and fund managers can use various methods to improve a project's expected risk-adjusted returns (exhibit). Management and operational risks, for instance, can be mitigated by assembling a team with all the necessary skills in science, business, regulatory policy, cultural affairs, and other areas.

Exhibit

Common risk-mitigation strategies can reduce the default rates and investment costs of conservation investment products.

Risk-mitigation strategy		Key aspects
Operational assistance		Assistance with technical, legal, and financial matters can improve project quality and success rates Typically provided by development finance institutions (DFIs) or foundations
Staged risk tranches	Debt	Fungible, liquid collateral can mitigate credit risk Underlying problems (eg, uncertain land rights) can sometimes be addressed
	Equity	Demonstrating stable, predictable cash flows can mitigate risk Works especially well in established sectors such as forestry
Insurance/hedging	Private insurance	Insurance against catastrophic losses can be expensive for new projects or those without established risk models
	Futures/ forward trades	Can be used to hedge against volatile commodity prices in liquid markets Can be expensive or challenging if timing of cash flows is unclear
Guarantees		Can take the form of loss guarantees that assure investors they will receive a percentage of their principal in cases of default Can be provided by DFIs, foundations, or governments

Source: Credit Suisse; McKinsey analysis

One nascent but promising concept for improving risk-return profiles to suit private investors is blended finance. This involves carving out investment tranches with less favorable risk-return profiles so they can be funded by so-called concessional capital from public or philanthropic sources. Other tranches can then have risk-return profiles that fit private investors' expectations, making it possible to raise funding for projects whose overall risk-return profiles might otherwise hold little appeal.

Fund managers continue to explore old and new models for blended finance.[4] Examples include the following:

- *Early-stage grant making* by nongovernmental organizations can fund the development of conservation projects. This not only reduces the amount of capital needed from subsequent investors but also lowers the investment risk. Grants from NatureVest, for instance, were essential to the development of the Stormwater Retention Credit Trading Program in Washington, DC.

- *Donor-funded guarantees* are an established mechanism exemplified by the US Agency for International Development's commitment to guarantee 50 percent of the losses on up to $133.8 million of loans by Althelia Ecosphere's Althelia Climate Fund.

- *Junior debt or equity* has a lower-priority claim to assets and earnings than other loans or securities. With this model, the Global Environment Facility used $175 million to mobilize more than $1 billion of private capital for climate- and environment-related projects.

Structure lower-cost, large-scale investment products. High financing and project costs cut into the returns from conservation enterprises, making them less attractive to private investors. But fund managers and project developers can lower their costs in several ways. One is establishing routine processes. A good due-diligence checklist for evaluating projects can help fund managers remove impractical ones from their pipelines early on so they can devote more time and money to better ones. Project templates, such as Encourage Capital's blueprints for investing in sustainable fisheries or California's conservation-easement template, can accelerate the process of developing and structuring projects while helping investors avoid high-risk concepts.[5]

Structuring larger investment products could also help fund managers tap more private capital while spreading out the costs of creating, marketing, and distributing a fund. One approach is to bundle relatively small projects of a similar type into an ordinary investment vehicle, using a common deal template to bring down costs. The Forestland Group, for example, has set up several real-estate investment trusts for sustainably managed timberland. Fund managers might also aggregate different but related projects—such as forestry, agriculture, and ecotourism projects in the same national park—into a single diversified product.

Another scaling approach is to create investment products with familiar, widely used structures. For example, a private equity–style conservation fund could direct as much as $200 million toward 10 to 20 projects in established markets such as sustainable agriculture, ecotourism, and sustainable forestry. Sovereign institutions could issue bonds covering a large ecosystem, use the proceeds to finance conservation there, and repay the debt with revenues from park-access fees and other sources.

Incubate new conservation concepts. As proven conservation models are being standardized and applied on a large scale, project developers also need to create new models that will generate investment opportunities in the future. Entrepreneurs

working on novel conservation approaches often need more than money to get projects up and running. Assistance with technical and operational matters can be at least as valuable. To support innovative work in conservation, foundations, non-governmental organizations, and investors could establish incubators to help start-ups get both the financing and the knowledge they need.

Incubators could perform a matchmaking role as well, connecting investors with projects that suit their appetites for risk and their expectations for financial returns and environmental impact. Such incubators could also serve as a proving ground for new financing ideas such as conservation-impact bonds, which are analogous to social-impact bonds, or insurance products that monetize the risk-mitigation benefits of conservation projects.

■ ■ ■

Factors such as low interest rates, falling returns on equity investments, and burgeoning demand for environmentally friendly goods and services favor an increase in conservation finance. Conservation experts and fund managers must now win the confidence of mainstream investors by enhancing their management and financing methods. Their success could catalyze significant growth in conservation finance, allowing investors to improve their returns and mobilizing more private capital to protect ecosystems around the world. ■

[1] Fabian Huwyler et al., *Conservation finance: Moving beyond donor funding toward an investor-driven approach*, a joint report from Credit Suisse, World Wildlife Fund, and McKinsey & Company, 2014.

[2] *Investing in conservation—A landscape assessment of an emerging market*, a joint report from EKO Asset Management Partners and NatureVest, November 2014, naturevesttnc.org.

[3] *Toward water sustainability: A blueprint for philanthropy*, Water Funder Initiative, March 2016, waterfunder.org.

[4] *Blended finance vol. 1: A primer for development finance and philanthropic funders*, a joint report from the Organisation for Economic Co-operation and Development and World Economic Forum, September 2015, weforum.org; and *GEF innovations in blended finance: A summary,* Global Environment Facility, 2015, thegef.org.

[5] Alex Markham, Trip O'Shea, and Kelly Wachowicz, *Investing for sustainable global fisheries*, Encourage Capital, January 2016, investinvibrantoceans.org.

This article is adapted from *Conservation finance—From niche to mainstream: The building of an institutional asset class*, published by Credit Suisse and the McKinsey Center for Business and Environment in January 2016.

Ryan Davies is a partner in McKinsey's New York office, **Hauke Engel** is a consultant in the Frankfurt office, **Jürg Käppeli** is an alumnus of the Zurich office, and **Todd Wintner** is a consultant in the Washington, DC, office.

The authors wish to thank Sam DeFabrizio and Fabian Huwyler for their contributions to this article.

© Macenzo/Getty Images

Mobilizing private-sector financing for sustainable infrastructure

The world is only spending half as much as it needs to on infrastructure. Private-sector investment can help to close the gap.

Aaron Bielenberg, Mike Kerlin, Jeremy Oppenheim, and Melissa Roberts

Current public infrastructure spending of $2.5 trillion to $3 trillion a year is only about half the amount needed to keep up with global economic growth over the next 15 years. Given the size of this financing gap, and the urgency to address it, the private sector must be part of the answer.

In addition to capital, the private sector can bring other benefits. For example, private investors can help to ensure that deadlines are met and cost overruns are minimized. They are more likely to develop projects with commercial potential and workable economic structures. Private-sector participation can also provide a signaling effect, helping to bring in more investment.

All of that is particularly important when it comes to building "sustainable infrastructure"—meaning projects that are socially inclusive, low carbon, and climate resilient. For countries to deliver on their commitments to reduce emissions related to climate-change initiatives, how they build and operate infrastructure will be a major factor. The up-front capital costs for sustainable-infrastructure projects typically run 6 percent higher or more compared with conventional ones. Over a project's life cycle, however, sustainable infrastructure can save money and generate healthy economic returns while reducing risks and curbing negative side effects. The question is how to convince the private sector to get involved.

Sustainable-infrastructure investments can be attractive. Such projects often feature long-term returns (roads, bridges, and tunnels last about 50 years), steady cash flows, and safe portfolio diversification. So why is there still such a large gap between what is needed and what is available?

One reason is that there simply are not enough viable projects. Governments often fail to develop long-term plans, and even when they do, many do not appear likely to deliver high enough risk-adjusted returns to attract private-sector equity or debt. Another is that inefficient bidding and procurement processes discourage private investment. Many transactions have to be tailored to individual projects, and there can be diverse and inconsistent standards. Having to create unique financing structures for each project and jurisdiction increases transaction time and costs. A third is that even when sustainable infrastructure's net present value (NPV) is positive over its lifetime, such projects can incur higher up-front costs to the builder, while the savings accrue to the operator or owner. For example, developers pay more to make buildings energy efficient, but it is the homeowner or business that benefits from lower energy bills. Finally, building sustainable infrastructure can mean working with a more diverse and decentralized set of infrastructure owners. For example, renewable-energy development is often off-grid and financed by individual businesses, communities, or even households. New financing models will doubtless evolve to push down transaction costs and create attractive risk-adjusted returns for investing in small distributed assets, but right now these models are limited. South Africa, however, shows that it can be done. It has created an innovative competitive bidding process to bring private finance into renewable energy. Since the first round of bidding in 2011, average tariffs for solar photovoltaic have decreased by 68 percent and for wind by 42 percent. Banks and pension and insurance funds are getting very interested. In three rounds of bidding, more than 60 projects have been awarded, worth $14 billion in private-sector investment.

How to improve financing for sustainable infrastructure

Capital markets exist to mobilize large-scale investment. Investors are, however, naturally skeptical about sectors and asset classes that they are unfamiliar with or where they perceive high political risks or project failure. Sustainable infrastructure falls into this category. But there are ways to overcome this skepticism. Indeed, the six policies described here are already in use; the opportunity, and the difficulty, is to make them more widespread.

Scale up investment in project preparation and pipeline development. Better project preparation, in the form of facilities that can take care of early-stage functions—from conception through financing—can help to make the case that sustainable-infrastructure projects are bankable. Such facilities can perform feasibility studies and structure transactions to make them attractive to investors; they can bring technical and financial expertise to projects and create standards and legal frameworks that reduce transaction costs. On a broader level, they can help governments to create a realistic pipeline.

Preparation facilities are typically oriented "midstream"—that is, on projects that are already part of the government's overall plan. The better approach is to get involved "upstream," in the design and feasibility stages, so that sustainability is baked into the strategy from the start. Early-stage involvement can also encourage thinking on how to meet demand more sustainably. For example, if a government wants more transit, a project-preparation facility could suggest whether a bus rapid-transit system might do the job instead of a road program. Funds like InfraCo, a publicly funded, privately managed early-stage financier of projects in developing countries, have succeeded in such challenging markets as Kenya, Uganda, and Zambia.

Improving project preparation requires both scaling up and improving mechanisms already in place. One challenge will be in establishing and maintaining standard practices, as contractual terms vary widely, even within countries. It's also important

to keep the larger goal in mind. Better project preparation will only contribute to sustainability if efforts are concentrated on sustainable infrastructure. The potential is huge: $150 billion to $450 billion by 2030.

Use development capital to finance sustainability premiums. Development capital includes capital from national, bilateral, and multilateral development banks (MDBs) as well as from climate-finance organizations. This can be repaid over time as total cost of ownership (TCO) savings are captured. The use of development capital can help address the fact that few business models have generated sufficient revenue to allow full cost recovery. The business models that have been successful are typically in countries with favorable policy environments. Colombia, for example, established the Financiera de Desarrollo Nacional (FDN), a state development bank whose purpose is to promote private-sector participation in the infrastructure sector and to provide financial assistance for larger projects. FDN has worked with the finance ministry to provide senior and subordinated loans to complement commercial bank loans and capital-market offerings, and will also guarantee liquidity. These measures help to mitigate risk and improve the provision of project financing.

Development capital could be used to pilot the business case for sustainable-infrastructure investment, especially in middle-income countries (defined as those with per capita incomes between $1,045 and $12,745), and thus demonstrate to the private sector that there are profitable opportunities. This model can work in a variety of sectors, but it is most advanced on energy efficiency. If development banks, bilateral-aid organizations, and climate-finance groups dedicated $10 billion to $15 billion a year to finance sustainability premiums for energy efficiency, that could increase the value of energy-efficient infrastructure by up to $176 billion a year. Over 15 years, that adds up to $2.6 trillion in efficiency projects that would have not otherwise been built. Even if the financial returns are not high, this approach delivers significant social impact for relatively little money.

The use of development capital in this way requires minimal policy changes; even so, putting all the different pieces together will be complex. This investment, however, would be NPV positive and recovered through TCO payback.

Improve the capital markets for sustainable infrastructure by encouraging the use of guarantees. Guarantees are well suited to sustainable infrastructure because they can be precisely targeted and adapted to policy risks. They are also an effective way to bring in private finance and can leverage multiples of private capital for every dollar spent. But they are underused, accounting for only 5 percent of climate finance from MDBs in 2014, or $1.4 billion.

Increasing the use of guarantees can be done in a number of ways. Banks could set aside a certain percentage of existing guarantees for projects that meet sustainability criteria. Or they could adapt guarantees to fill gaps in the market for specific types of risks or phases of the life cycle, such as guaranteeing power-purchase agreements or insuring against changes in feed-in tariffs for renewable-power projects.

Guarantees can generate a number of helpful ripple effects, particularly in middle- and low-income countries. One is that these guarantees signal the importance of sustainability to other investors, providing an incentive for traditional projects to incorporate sustainability principles. Another is that worthwhile projects are completed that otherwise would be considered too risky. Finally, when sustainable-infrastructure projects in middle- and low-income countries succeed, that improves perceptions of risk, generates data, and builds capacity for future efforts.

Encourage the use of sustainability criteria in procurement. Adopting a TCO approach rather than a low-cost bid process could generate long-term savings and shift selection toward sustainable projects that are NPV positive but have higher up-front costs. For sustainable infrastructure that does not have a lower TCO in the current policy environment, sustainability criteria such as emissions and water use could be added to requests for proposals (RFPs). This can be achieved in two ways.

First, governments could incorporate sustainability criteria into public-private-partnership (PPP) RFPs. Second, they could embed sustainability requirements into non-PPP design-bid-build projects. Going in this direction would signal to investors that there is demand for sustainable infrastructure and that contractors, architects, and project managers should develop sustainability-related capabilities to win public contracts.

Increase the use of loan syndication. Syndication can help to raise private-sector capital while reducing balance-sheet exposure for development banks. Increasing loan syndication also allows development banks or other primary lenders to recycle their capital, thus increasing the number of projects financed. By providing a lower-risk, lower-cost way to participate, syndication gets the private sector involved, building its confidence and willingness to invest. For instance, an MDB loan to finance a $200 million bridge project might be syndicated across 20 or more secondary investors. Or MDBs could pool a selection of smaller loans, thus offering secondary financers more diversified exposure. If MDBs increased their loan-syndication portfolio to the levels of the leading lenders, such as the World Bank and the European Bank for Reconstruction and Development, an additional $35 billion to $75 billion could be mobilized over a 15-year period.

Adapt financial instruments to channel investment and enhance liquidity. The right financial instruments can make sustainable-infrastructure investments more attractive to the private sector by reducing transaction costs or due-diligence requirements; mitigating risks to provide steadier, more certain cash flows; and providing additional liquidity.

No financial instrument can compensate for unsound economics. For projects that do make economic sense, however, the right tools can help boost investment from previously restricted investors, increase investor confidence, and address differences in the type and duration of financing required for sustainable infrastructure.

Instruments such as green bonds and "YieldCos" use familiar financial instruments to enhance capital flows to sustainable infrastructure. Green bonds have had a favorable reception from investors, who see them as a good way to achieve market-competitive returns while incorporating climate-change considerations. The value of green-bond issues reached $36.6 billion in 2014. YieldCos

Instruments such as green bonds and 'YieldCos' use familiar financial instruments to enhance capital flows to sustainable infrastructure.

are publicly traded companies created by a parent company; they bundle operating infrastructure assets to generate predictable cash flows that are then paid out in dividends to shareholders. In the United States and the United Kingdom, YieldCos raised $4.5 billion in 2014; their share prices, however, have been volatile.

Building sustainable infrastructure offers great potential to improve quality of life while addressing the public's concerns over climate change and other environmental matters. With the right policies and incentives, investors can make a profit financing the infrastructure needed to make these goals a reality. ■

Download the full report on which this article is based, *Financing change: How to mobilize private-sector financing for sustainable infrastructure*, published by the McKinsey Center for Business and Environment in January 2016, on McKinsey.com.

Aaron Bielenberg is an associate partner in McKinsey's Washington, DC, office, where **Melissa Roberts** is a consultant; **Mike Kerlin** is a partner in the Philadelphia office; and **Jeremy Oppenheim** is an alumnus of the London office.

The authors wish to thank the following people for their contributions to this article: Jonathan Bailey, Jackie Bass, Ryan Davies, Tyler Duvall, Alastair Green, Shelbi Hendricks, Danielle Imperato, Jan Mischke, Rob Palter, and Ishanaa Rambachan.

The authors are also grateful to Amar Bhattacharya, Joshua Meltzer, Helen Mountford, Shilpa Patel, James Rydge, and Lord Nicholas Stern.

The ACRE approach to agricultural sustainability

How farmers can improve agricultural decision making with big data.

Nicolas Denis, David Fiocco, Ryan McCullough, and Viroopa Volla

By 2050, the world will be home to some 9.7 billion people—and they will all need to eat.[1] However, growing more food carries the risk of land degradation, deforestation, and greenhouse-gas emissions from crop and livestock production. Better decision making that leads to higher yields and more precise targets for fertilizer and other inputs can play a critical role in meeting human needs while limiting environmental harm.

But improving farm productivity is complicated. In addition to such inputs as better seeds and fertilizer use, other areas, such as farmer training, infrastructure development, and finance, must also come together. This productivity-improvement potential is greatest in developing markets—but these are also the areas that have had the greatest difficulty attracting resources. This stems in part from a lack of data about distribution, where growers are, and market potential.

Over the past decade, farmers in the United States and other mature economies have applied data and advanced analytics to production decisions. Field sensors, geospatial imagery, and improved analytical processing techniques can also help to boost harvests.

For example, instead of seeing crop-yield performance for an entire farm, growers can now measure this down to "microfields" of 14 square meters or less. Such precision helps them manage their farming practices much more accurately. For example, they can provide irrigation and fertilizer to the right plant, at the right time. Satellite imagery and climate modeling can predict midseason yields to forecast where food supplies will be short—information that has obvious pertinence to commodity traders and agricultural-input companies.

Given the fragmentation of the agriculture sector, with production in every corner of the globe, collecting the insights that matter is challenging, which is one of the reasons the sector is far from fulfilling its potential. With that in mind, McKinsey created the Agricultural Commodity Research Engine (ACRE). By bringing together in one place a vast range of proprietary data, including farm-production costs, yield performance, and local market characteristics, this virtual tool can help improve decision making and performance in an industry that is central to economic growth and sustainability.

ACRE can provide insights in many areas, but it is particularly strong in three.

Sourcing. Where are the lowest-cost locations for sourcing, say, wheat for fast-growing markets in Asia? How would this change if oil prices hit $100 a barrel or more? ACRE can answer these

and related questions by providing a global perspective on the highest-potential sources for agricultural commodities. ACRE can generate these insights because it combines data on yield and production volume with proprietary farm-production cost data collected directly from farmers. For example, ACRE can show the comparative costs of producing a ton of wheat in Iowa, Australia, Ukraine, and hundreds of other locations. Grain traders, consumer-packaged-goods companies, and investors can use these data to target the most promising markets, as well as to help diagnose and address performance gaps.

Crop selection. Crop prices are volatile. Weather is unpredictable. Technology is changing fast. All these factors make it difficult to figure out how to prioritize agriculture investment. Which crops will offer a grower a competitive advantage in commercial markets? Where could investments improve competitiveness? What will returns be under different weather scenarios? ACRE brings economic and agronomic data together in one place, helping investors and landowners make informed choices on what to plant, and where.

To do this, ACRE begins by selecting the most environmentally suitable crops—those that can thrive under local soil and weather conditions—for each region, based on a global database of crop-yield performance. On that basis, ACRE can evaluate the global export potential, to offer clear guidance on which products are best suited, both environmentally and economically, for any location.

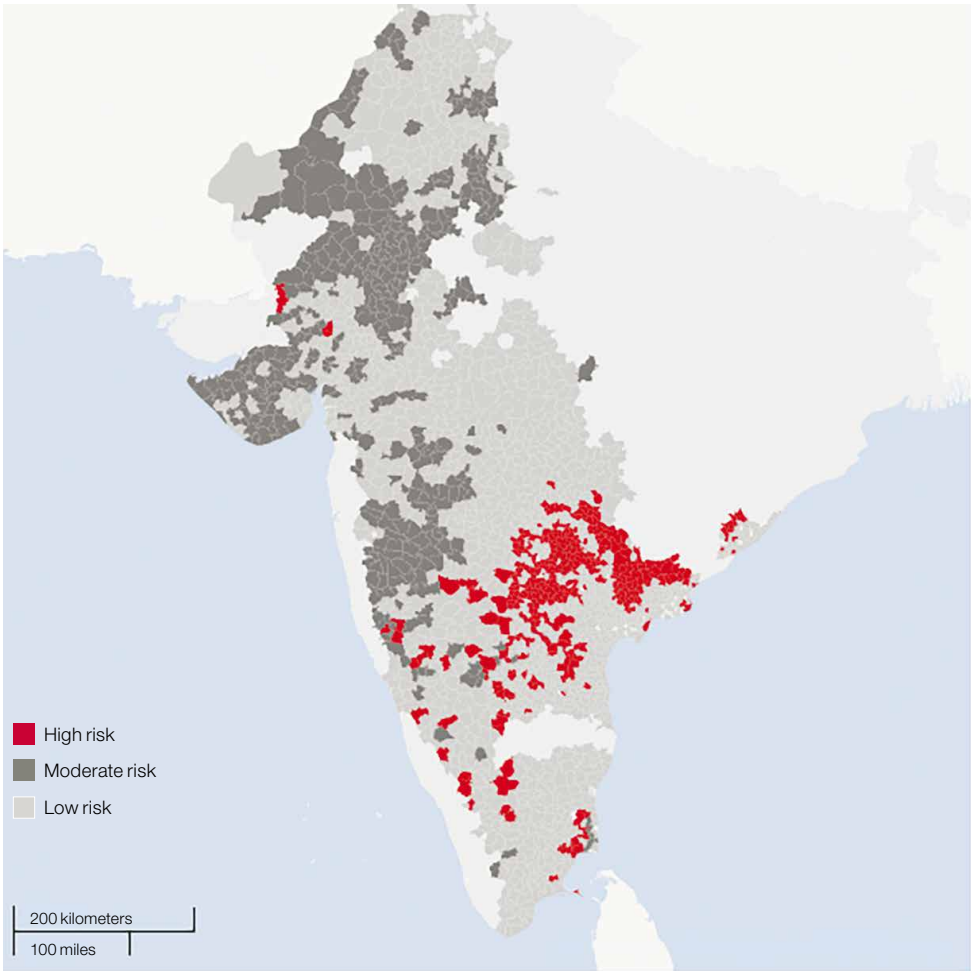
Micromarket analysis. If the world is to feed more than nine billion people, millions of hectares that are under informal or subsistence cultivation will need to become more productive. Identifying and understanding growers' needs in these markets, such as for seeds and fertilizer, can be a challenge. ACRE offers micromarket insights—down to the municipal level—to reach these farmers. That can help companies to build efficient sales-force teams and position inventory in high-potential areas. More than 20 market factors, including farm size, infrastructure access, weather volatility, crop plantings, and current distribution networks are combined to help companies make better decisions on where to expand production or market farm inputs. Each individual factor is helpful, but the larger value is that ACRE makes it possible to visualize multiple layers of data through a web interface. Users can explore different markets and make complex trade-offs across regions and crops.

In India, for example, when the monsoon fails, hundreds of millions of people suffer. Some farmers can see their incomes drop by as much as 70 percent because of drought-induced poor yields. No tool can bring the monsoon, but better information can provide an early-warning signal and thus help deal with the effects. ACRE's micromarket tool combines detailed market data on farm-production zones with weather data and crop-growth models to predict end-of-season crop yields. This can be used to understand which areas are most likely to succeed (or fail), long before the harvests are in.

As the red areas in the exhibit show, the cotton crop—one of India's most important—has many high-risk production areas. Knowing the microgeographies where crops are most vulnerable can help governments, agencies, and businesses take effective action, whether that is providing income subsidies, sending food aid, or selling crop insurance and fertilizer.

Exhibit

How the ACRE tool forecast India's midseason cotton-crop yield (2015).



Source: Agricultural Commodity Research Engine

Improving agricultural resilience and productivity requires doing many things well, including analyzing what to plant and where, improving farm practices, using higher-quality inputs, and building infrastructure to get products to market. Advanced analytics can improve the efficiency and effectiveness of all these decisions and more, helping farmers, investors, businesses, and governments. To feed 9.7 billion people, the world needs all the help—and information—it can get. ■

[1] *World population prospects: The 2015 revision*, UN Department of Economic and Social Affairs, Population Division, 2015, p. 18, esa.un.org.

Nicolas Denis is a partner in McKinsey's Brussels office; **David Fiocco** is an associate partner in the Minneapolis office, where **Viroopa Volla** is a consultant; and **Ryan McCullough,** the manager of ACRE, is a senior expert in the Denver office.

The authors wish to thank Shriram Bhutada for his contributions to this article.

October 2016
Designed by Global Editorial Services

This McKinsey Practice Publication meets the Forest Stewardship Council® (FSC®) chain-of-custody standards. The paper used in this publication is certified as being produced in an environmentally responsible, socially beneficial, and economically viable way.

Printed in the United States of America.

FSC Logo here
63% BLACK