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McKinsey on Sustainability & Resource Productivity

Highlights

Pathways and obstacles to a low-carbon economy

Urban commercial transport and the future of mobility

From 'why' to 'why not': Sustainable investing as the new normal

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Introduction

Dickon Pinner

Death, taxes, and change—these are life's constants. And when it comes to issues related to energy and sustainability, the pace of change is accelerating. That is the theme of this fifth edition of *McKinsey on Sustainability & Resource Productivity*.

Much of daily life still runs on 19th- and 20th-century technologies, such as the internal combustion engine and big, centralized power plants. But when it comes to energy and sustainability, change is happening—indeed, accelerating—in ways that will make the 21st century look and feel very different. We think there is particular promise in practices and technologies that are marginal at the moment but that will, we believe, prove to be important before long. These practices and technologies pertain to three broad transitions covered in this collection: energy, mobility, and sustainable enterprise. There is no longer a question of what is happening; all of these transitions are undeniably taking place. It is a matter of how fast and what businesses and governments should be doing about them.

Energy transitions

In an interview on page 6, Lord Adair Turner, head of the Energy Transitions Commission, argues that while fossil fuels have been essential to the enormous prosperity wrought by 200 years of industrialization, limiting climate change and pollution will require the world to "move away from fossil fuels, while still delivering in many countries even more energy use than there is today." McKinsey partner Arnout de Pee cautions, however, that energy and other kinds of infrastructure often have "very long lifetimes of over 30 and 40 years." So, in many instances, change will have to be gradual.

Accelerating the journey toward a cleaner energy system, then, will require all kinds of efforts, including some that have been too expensive or laborious in the past. Consider offshore wind, which has been a technology of the future for decades (see "Winds of change? Why offshore wind might be the next big thing," on page 13). Now it looks like a technology of the near future: in recent auctions, the

winning bid for offshore wind projects has been less than the wholesale electricity price, meaning that no subsidy is needed. Lower costs, greater competition, better technology—and yes, a little government and regulatory support, particularly in Europe—are allowing more projects to be built at a lower price point than anyone believed possible as little as five years ago.

Another technology that is coming on surprisingly fast is battery storage (see "Battery storage: The next disruptive technology in the power sector," on page 18). Renewables are increasingly popular, but they cannot provide energy around the clock because the sun sets and the wind doesn't always blow. But if power from these intermittent sources could be stored and used later, that would make renewables even more attractive. Battery-storage prices have dropped by more than 75 percent since 2010 (from more than $1,000 to $230 per kilowatt-hour). Storage already makes economic sense for some uses and will be an essential part of the future energy system.

Industrial decarbonization remains one of the hardest nuts to crack, because industry depends on energy, which is often a large part of its costs. A recent look at Dutch industry (see "Energy transition: Mission (im)possible for industry?," on page 24) examines the economics of decarbonizing fast (95 percent lower emissions by 2050) or less fast (60 percent by 2040). According to the research, the faster option is just about possible—but it would cost more than twice as much (some €50 billion) as the slower one. A wide range of actions, such as increasing energy efficiency and recycling, changing feedstocks, and switching to different steel-production processes, will be required, and certain realities, such as the price of carbon and commodities, will also be critical. These factors will impact the pace of decarbonization, but the transition itself is not in doubt.

Reducing emissions is one approach to industrial decarbonization. Another is to repurpose captured carbon dioxide as a feedstock (see "Why commercial use could be the future of carbon capture," on page 29). Three early-stage applications for captured carbon dioxide—fuel production, concrete enrichment, and power generation—could reduce greenhouse-gas emissions by as much as one billion metric tons a year in 2030. Developing the necessary technologies won't be easy, but the authors argue that all three applications could become profitable in the medium to long term.

Mobility transitions

More than half of the world's population lives in cities, up from a third in 1960. By 2050, it will be closer to two-thirds, and there will be at least a billion more urban residents. Cities are wonderful places, with manifold economic, environmental, and social benefits. But they can be stressful, with many people jostling for limited space. In this series of articles, we explore mobility transitions in cities.

Industrial decarbonization remains one of the hardest nuts to crack, because industry depends on energy, which is often a large part of its costs.

Next-generation mobility stands out as a powerful opportunity to enable cities to reduce emissions while increasing GDP (see "A strategic approach to climate action in cities: Focused acceleration," on page 55). Estimates that McKinsey developed with C40 Cities suggest that accelerating the adoption of next-generation mobility, along with changes in other areas—decarbonizing the power grid, optimizing energy efficiency in buildings, and improving waste management—would put cities on track to achieve their emissions targets.

Lower emissions are just one benefit of bringing advanced mobility to more cities. Attractive, affordable mobility options can also maintain and even improve the quality of urban life, by giving people the means to get around quickly and cleanly. In this regard, too, change is coming, in the form of autonomous vehicles, electric power trains, and vehicle-sharing services (see "The future(s) of mobility: How cities can benefit," on page 33). Transportation in the not-too-distant future is likely to be safer and more flexible. Looking at 50 cities around the world, McKinsey estimates that a future of integrated mobility could bring $600 billion of gains, including cleaner air, fewer traffic deaths, smoother flow of business, and less wasted time.

Getting there will be expensive, however, and many cities are already dealing with tight budgets and aging infrastructure. Working with the private sector therefore makes sense (see "Public–private collaborations for transforming urban mobility," on page 49). Such partnerships are already happening. Many bike-sharing programs, for example, have a private sponsor; shared mobility, in the form of ride hailing and rentals, has been driven by entrepreneurs. The authors note that 71 cities have partnerships with private companies to improve urban mobility and expand options. The article estimates that new mobility applications, such as on-demand minibuses or first- and last-mile ridesharing, could not only be profitable but could also help to make entire urban transportation systems better.

One factor contributing to transportation-related anguish in cities is the effect of commercial vehicles. In the United States, for example, trucks account for 7 percent of urban travel but 18 percent of traffic congestion. This isn't just annoying, it's surprisingly costly—congestion can cost as much as 2 to 4 percent of city GDP (see "Urban commercial transport and the future of mobility," on page 44). Some relief will come from autonomous and electric vehicles. What may be more interesting is how comparatively small changes, such as using parcel lockers and encouraging night deliveries, could deliver big benefits with respect to cost, congestion, and pollution.

Examining the usefulness of small changes helped Richard Thaler of the University of Chicago win the Nobel Prize for economics in 2017. In "How nudges can help the environment," on page 85, McKinsey senior partner Scott Nyquist draws on Thaler's work and offers several examples of how "nudges"—such as painting footprints to direct people to litter bins—can bring measurable environmental improvements.

Sustainable-enterprise transitions

Businesses could have much to gain—and possibly to lose—by changing how they operate to respond to these transitions. Brand, supply-chain resilience, regulatory compliance, stranded assets, activist investors, and the ability to attract capital are but a few of the issues companies must deal with. In the final section of this compendium, "Toward sustainability," we look at two intriguing trends.

Sustainable investing has moved far from its origins as a boutique, feel-good strategy (see "From 'why' to 'why not': Sustainable investing as the new normal," on page 61). Globally, the authors note, investments based on the "premise that environmental, social, and governance factors can materially affect a

company's performance and market value" account for at least $23 trillion, or more than a quarter of assets under management. No longer is sustainable investment just a matter of screening out companies that are considered undesirable. Leading institutional investors have begun to integrate sustainable investment practices more closely with their core operations.

Design is another area where the idea of sustainability is increasingly influencing day-to-day practices. In "Creating value through sustainable design," on page 70, the authors offer several examples of sustainable design in action, such as their work for a Swedish airport on an air-traffic system, which sorts traffic more efficiently. That has significant consequences because "a reduction of just one minute in queue per departure results in reduced fuel consumption of at least 1.5 million tons of fuel per year"—savings worth millions of tons of avoided greenhouse-gas emissions a year. This is a classic example of that elusive goal: a "win–win solution."

Perhaps the biggest change regarding the business environment is the idea that the effort to find such win–wins should be part of the core strategy. "Sustainability's deepening imprint," on page 75, reports the results of McKinsey's newest survey on sustainability in business, which received responses from 2,422 people. Six in ten said their company was more engaged with sustainability than it was two years ago. In every industry, a majority of respondents said they believed there was positive economic benefit from managing sustainability. And integrating sustainability into one or more core business functions appears to be economically advantageous: the practice doubles the likelihood that a company will report capturing financial value from its sustainability program.

Predicting the future is a perilous undertaking, so I am going to resist the temptation to do so. But the articles in this compendium strongly suggest that business and society are approaching a tipping point on these three environmental transitions—and that the momentum is powerful. Sustainability practices and new technologies are already mainstream; it may not be long before they are dominant. ■

Dickon Pinner is a senior partner in McKinsey's San Francisco office and serves as the global leader of the Sustainability & Resource Productivity Practice.

Pathways and obstacles to a low-carbon economy

The energy transition is happening. But the pace of change depends on a range of technical, business, and societal factors.

Arnout de Pee, Cait Murphy, and Lord Adair Turner

Technological advances and falling prices are building toward more low-carbon energy production across the globe. In this transcript of a McKinsey Podcast, Lord Adair Turner, chair of the Energy Transitions Commission and the Institute for New Economic Thinking, and McKinsey partner Arnout de Pee speak with McKinsey Publishing's Cait Murphy about the shift toward renewable resources and the future of sustainable development.

Cait Murphy: *What is meant by the term "the energy transition," and why is such a transition necessary?*

Lord Adair Turner: The term "energy transition" describes the fact that over the next several decades, we are going to have to achieve a really dramatic transition in the world away from reliance on fossil fuels. Fossil fuels have been absolutely essential to the original industrial revolution, to the growth of prosperity that we've achieved in an increasing number of countries over the last 200 years.

To limit global warming to below two degrees centigrade above preindustrial levels, we will have to really very significantly move away from fossil fuels, while still delivering in many countries even more energy use than there is today.

And that's what we mean by the energy transition. How do we build economies using enough energy to deliver prosperity for everybody, but with much reduced carbon emissions?

Arnout de Pee: One word to stress here is also the economic implication. So, for many nations, it is no longer only an energy transition, but also an industrial or an economic transition away from the activities and the way energy is being produced, the way goods are being produced, the way goods are being transported, and people are being transported.

Cait Murphy: *How will the energy transition look across different regions such as Africa, Asia, Europe, North and South America?*

Lord Adair Turner: Probably to have a reasonable standard of living, you need to consume maybe 80 to 100 of what are called gigajoules of energy per capita per annum. The European Union's average is now about 130. We could get more efficient and still have our standard of living.

America uses about 200. They could get much more efficient. A country like India is still only consuming about 25 gigajoules per capita, so even if it gets much, much more efficient, if it's going to have a prosperous lifestyle, they're going to consume a lot more energy. So, first of all, we have some countries where the challenge is actually reducing energy use, others where it is growing, but not growing energy use as much as you grow in prosperity. That's one big difference.

Arnout de Pee: I think the dimension to add is also the composition of the economy. There is a large difference between being a service economy versus being heavily industrialized. Given that, for instance, China is moving more and more to a service economy, their pathway toward decarbonization is going to be very different from those countries that are going to be building up industrial activity. So, I think that that's another angle to the problem that makes China different from India, makes it different from Malaysia.

Cait Murphy: *If the goal then is to change the way that goods are moved and produced and how people get around, how do we get there?*

Lord Adair Turner: So, we've just got to get much more efficient at how we get prosperity out of the energy we use. But whatever the energy we use, we've got to increase the extent to which that comes from zero-carbon sources.

And it's those two things, use energy more efficiently and decarbonize, as we call it, the sources of energy; put those two together and we can drive CO_2 emissions down to the level which is required to stay well below two degrees. It is, however, a very big challenge upon both of those dimensions.

Cait Murphy: *How do we get there in terms of specific technologies?*

Lord Adair Turner: We know how to take the carbon out of electricity production.

We know that there is a collapsing price now of renewable energy from solar photovoltaics or from wind. And that means that if you combine that with batteries, which are also collapsing in cost, or with gas turbines as backup, we are very confident that we will be able within 15 years to build energy systems—electricity-production systems that rely almost entirely on renewables and that produce all the electricity that we eventually need—at a price of only seven US cents per kilowatt-hour.

And that's completely competitive with fossil-fuel production. We can start having cars or automobiles which run on electricity. We can get more domestic heat from electricity. We can electrify more of the economy, and that's a very, very attractive thing also in terms of local air pollution. The challenge then becomes that there's a whole set of functions in the economy, things like producing steel, producing cement, making airplanes fly, where it's not clear that we can electrify it, so that even if we've got low-carbon electricity, we don't have the solution.

Arnout de Pee: We're now moving to looking more at the demand side of the energy system, just like Adair

said. What do you do with industry? What do you do with heavy-duty transport? What do you do with building heating, where electrification is not the economic solution?

Plus, these are systems with very long lifetimes of over 30 and 40 years. So, even if you would have a greenfield, new-build solution that will be able to produce steel or chemicals at zero carbon, then you would still be left with an enormous amount of brownfield capacity, where changing the process, moving to an electric furnace or a hydrogen furnace, comes at additional capex cost.

Lord Adair Turner: One of the things that we should be looking at in these industrial-materials areas is how we recycle much more, how we get more of a circular economy so that we don't need to produce as much new raw steel. One vision is that the steel industry eventually will be essentially recycling steel that we've already made.

Now, recycling steel that you've already made, you can electrify with electric-arc furnaces, whereas producing more steel in the first place is pretty difficult to electrify, and we may have to find other routes. We need to be thinking about how we move to a more recycled economy where we're not adding to the stock of these materials in future.

So, the different dimensions tend to overlap in practice, but the key message is the bit which we think unsolvable is solvable here, and that is: Are you going to be able to heat and light your house from clean energy? Yes, because there's going to be clean electricity. Are we going to be able to produce steel, cement in a clean way? We've really got to work out the details of how we do that.

Cait Murphy: *What about the business and investment community? What can they be doing to be part of this transition? And why would they want to?*

Lord Adair Turner: Some businesses absolutely want to be part of it. I mean, there are now huge businesses in the solar space, the wind space, the electric-car space, the battery space. These are huge businesses making very, very big investment commitments. I think for investors the challenge is they've got to think through both how much they want to be invested in these new technology sectors and also what is their approach to investment in the fossil-fuel sectors.

We will need fossil fuels for some time. Some of them have got to go into decline very quickly. I would say coal, particularly in the developed economies. Oil will reach a peak and come down. Gas has to flatten out. But if oil reaches a peak and comes down, there is still a need for investment in some of the existing fields to meet even a declining level of total oil production. So, you can't have a simplistic point of view that says, "All oil investment has got to stop tomorrow."

On the other hand, investors in oil and gas and certainly coal companies have got to make sure that they don't end up investing in assets which are too high cost to make sense in the world where the total demand for fossil fuels is going to come down.

Arnout de Pee: I think for a lot of companies, it is also getting a better understanding of what an orderly transition could look like, instead of having an unorderly transition. What I mean by that is regardless of which industry you are in, as long as you have a sensible outlook of how policy will develop, what's going happen to commodity prices and therefore the state of your industry, the easier it is to make your decisions.

Most of the energy companies I talk to, what they need is a longer-term outlook of how policy will develop in order for them to make the investment choices that meet that future outlook. As long as we don't have that, it becomes very challenging for energy companies to make proper investment decisions here.

As Adair puts it, the energy transition is not a radical shift to only renewables and no more fossil fuels. There is going be a long period ahead of us where these two will have to go hand in hand, where we will be still reliant on the ramp-up of fossil fuels in some sectors to allow for economic prosperity. So, the two will have to go hand in hand.

Cait Murphy: *What are the biggest challenges in technical, political, and social terms?*

Lord Adair Turner: These are difficult transitions economically; they're difficult transitions to get people to agree with. So, yeah, that's a challenge. There's also a challenge, I think, about timing, and about the speed at which we progress.

Am I confident that the world can have an economy with the prosperity levels of the rich developed world for everybody in the world on a low-carbon economy, eventually? I am absolutely, 100 percent confident.

Am I confident that we can get there fast enough to avoid putting so much stock of CO_2 into the atmosphere that we have excessive warming? I believe we can do it, but we have to try hard to meet that challenge. So, the challenge is not whether the end point is possible; it's the pace at which we've got to get there.

Arnout de Pee: One big challenge we've talked a lot about is electricity. Electricity is currently less than a fifth of the total amount of energy that we're consuming, and also the way that our energy infrastructure is set up, the way energy flows between nations, the way energy is stored in countries, is all on the basis typically of fossil fuels.

That entire energy system, the backbone, will have to change alongside everything that we've already been mentioning on energy demand and supply. But also between seasons, there will be flows of energy that will be very different than we have today. I think there is still an enormous challenge. I see it as a positive challenge for technology innovation to solve the energy-systems issues of the future.

Lord Adair Turner: We need to get some changes in behaviors, and we need to incentivize them and encourage them. But here's the interesting point about the electric car, which in theory enables us to shift electricity use around the day. But unless we work out how to make that happen with price incentives and software and mechanisms of management that make it easy for people to leave their car, their automobile on the driveway and have it switch on the charger at 2:00 in the morning, unless we do that, electric cars could make some of the problems of electricity-management systems worse.

The energy transition is not a radical shift to only renewables and no more fossil fuels.

If everybody who drives an electric car comes back home at 6:30 in the evening and all plug it in simultaneously, then we've got a bigger problem of managing electricity supply and demand than we have at the moment.

It's very technologically exciting. It's an area where the application of information and communications technology can achieve some wonderful things for the world. But there's a lot of new business ideas, implementation, and in some cases, appropriate regulation has got to be got right to unleash that potential.

Cait Murphy: *What are some policies and approaches that governments have used that you find interesting and useful? Either to decarbonize or to increase efficiency?*

Lord Adair Turner: Well, we know two things that work, one on the decarbonizing side and one on the sort of energy-efficiency side. On decarbonizing electricity, we began with a set of experiments about how to encourage renewable-energy takeoff, direct subsidies, et cetera.

And increasingly, what we've migrated to is a system of fixed-price auctions, which simply says to the solar farm or the wind farm, "How cheap can you get the delivery of kilowatt-hours of electricity?" What the contract's essentially saying is, "If you get it really cheap, the system will take that electricity whenever you produce it, and then we'll sort out the backup problems," sometimes called a "take or pay" contract. These are very efficient ways of derisking, and they're what have driven these dramatic reductions that we've seen recently in the prices at auction for renewable-energy provision.

And then when I think you switch around to the energy-productivity side, the appliance regulation, the process of saying that regulators are going to go through a series of generations—with light bulbs, for instance—you're creating an environment where there's a year beyond which you can't use an incandescent light bulb, and then a year beyond which you can't use, you know, a halogen light bulb, and a year beyond which you can't use compact fluorescent.

And you drive a certainty for the LED producers that there's going to be a big market for them, and because of that certainty, they invest at scale, and because of that certainty, by the time you get to that regulatory date, the price has come thumping down. Those sorts of pull-through regulations, they work well.

Arnout de Pee: Yes, I think another one too is the emission standards that have been set for cars, for industries, for insulation of homes. Especially when they are given a longer-term trajectory, they're going get a clarity for investment, and it gives clarity for producers or the OEMs of the equipment and the appliances to start investing in this supply chain in a way that they will understand how they can make a return in five or ten years from now.

If I talk to players, for instance, in the wind industry, what they're also asking for is, "Give us a longer-term ambition that we can work toward," because whether we're moving in a market that is 5 or 50 gigawatts in size for a certain region has enormous implication on the type of supply chain that you ramp up.

The better you are in at least understanding what that risk is, the easier it gets to get proper financing and also to place that risk there in the value chain where it can be best managed.

Lord Adair Turner: I think that's absolutely right. So it's a very sort of self-reinforcing circular process that scale commitment drives cost reduction, which makes the scale commitment cheap when you actually get it. I think actually the Netherlands has been doing this pretty well recently, with its offshore developments,

where we've seen the latest in the course of the last year; we've seen some incredibly aggressive bids offshore of the Netherlands, for offshore wind, coming down to $54 per megawatt-hour.

Cait Murphy: *Two big ideas are getting a lot of attention: cap and trade and a carbon tax. Do you think these are useful ways of addressing the decarbonization side of the equation?*

Lord Adair Turner: Look, on the carbon-tax idea, it's absolutely clear that it would be extremely useful in different segments of the economy, if we had significant carbon prices and commitments to rising carbon prices.

What I would be very wary of, and you sometimes get this with a sort of an ideology, which is, "Well, a carbon price can be an answer to everything. And if we had a good carbon price, you could just get rid of all other regulation."

Carbon prices work best where you've got business managers making decisions, looking at future costs. Ask yourself this: Would you persuade the ordinary householder to switch from an incandescent light bulb to an LED light bulb by the expectation of a future carbon price? Most normal, sensible human beings just don't run their life like that. And given that they don't run their life like that, that is an area where regulation is more powerful than price.

Switch over to some of the industrial sectors and the need to search out precisely how we're going to decarbonize chemicals, refining. There, a carbon price would be important, and I think it's actually essential to help drive some of the change that we want.

Arnout de Pee: What's important to look at in that regard, especially for those industrial sectors that act on a global market, is that you need to have a global price-setting mechanism. Take refining, take chemicals, where many of the producing assets only produce maybe for 10 or 20 percent, for their regional market.

Then the rest is all traded on an international market, where the price difference can be as small as a few percentage points. So, penalizing a region with a CO_2 price might stifle a certain part of the industry that's acting in the global marketplace.

Lord Adair Turner: The other thing to comment on is the difference between a tax and a cap-and-trade system. I mean, in absolute theory, you set the total amount of emissions, and you have that on a declining path, as there is within the emissions-trading scheme. And then the price process with the market decides the price, and that's an efficient way to do it.

It depends crucially on having a tight enough set of emissions permits that are in the auction. And the problem that the flagship emissions-trading scheme of the world has had, which is the European emissions-trading scheme, is due to a set of political decisions, frankly; there were just far too many emission permits out there. Tons of emissions allowed, and that meant that the price was very low and also very fluctuating, and really wasn't a powerful indicator. I think we sort of realized that there may be advantages in progressing through a tax side.

Cait Murphy: *Most people are familiar with major renewables, such as wind, solar, and biomass. What are some other technologies that you find interesting or promising?*

Lord Adair Turner: The whole technology suite of batteries and other forms of energy storage is hugely important. We have these amazingly strong and plentiful energy sources, in particular, solar. Every day, the sun radiates on earth about five thousand times as much energy as the entire human race needs to support a prosperous lifestyle.

But one of the big problems is storage. Now, batteries are a very important technology, and it is going to go through a whole series of waves. And it's not just a matter of the cost. It's also a matter of the weight;

how many kilowatt-hours of energy can you get in a kilogram of batteries?

I think that's going to be a hugely important technological development, but there are also other ways of storing energy. You can store energy by pumping water uphill, by compressing air. One of the biggest problems we have in the world is not where does energy come from, but the ability to generate it at one hour and use it at another. And anything that solves that is hugely valuable.

Arnout de Pee: For me, number two is everything around hybridization, and this is more technology deployment rather than development.

Can you imagine what would happen if you would be able to switch on and switch off or hybridize 30 or 40 percent of energy demand for an industry, because you have a system of electric boilers combined with hydrogen or gas boilers? I find that hugely stimulating also because there's a high-tech component to it.

The third thing I would mention is carbon capture and storage and then also usage. When you look at the difficult-to-abate sectors in industry, there is still a wealth of opportunity to capture that CO_2, and to either store it or use it in products, either through circularity or through another process, which for now are still expensive.

Cait Murphy: *You have both been engaged in the climate-change and energy debate for many years. What's changed?*

Lord Adair Turner: Well, I have been interested in the whole issue of climate change for 20 years, but I first got sort of significantly involved in it, in terms of commitment of my time, when in early 2008, I was made the first chair of the UK Climate Change Committee, which is charged with driving UK emissions down by our legal commitment to 80 percent below 1990 levels by 2050.

I suspect if I was to dig out the reports that we produced in the first year of my committee about what we thought was going to happen to the price of wind, the price of solar, or the price of batteries, I would just be embarrassed by how we failed to see the pace at which the costs were going to come down.

And that is hugely optimistic and one of the things that should make us feel that public policy sometimes gets things right by driving the early development of a technology in a way that it then gets onto a self-reinforcing path, where the private sector takes over and drives the price down.

Arnout de Pee: The way I would say it, ten years ago, we were still thinking in linear terms, when we looked at price projections and the speed at which things could change. I think we've grown a little bit more used to it, that some of these cost curves actually follow a very different path [from a linear one], that is, being exponential.

And for me, that's hugely exciting, because that also tells us that there might be lots of different areas where we're also applying a linear way of projecting how quickly costs can go down or how quickly the penetration can increase. Well, actually, we have it all wrong. It can go a lot quicker. ■

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Winds of change? Why offshore wind might be the next big thing

Falling costs and rising acceptance are promising signs, but the industry needs to keep improving.

Arnout de Pee, Florian Küster, and Andreas Schlosser

The landscapes of Rembrandt glow with the great painter's rendering of light. And they are distinctive for another reason: windmills are everywhere. As far back as the 13th century, the Dutch used windmills to drain their land and power their economy. And now, 800 years later, the Netherlands is again in the vanguard of what could be the next big thing, not only in wind power but also in the global energy system as a whole: offshore wind.

In December, the Netherlands approved a bid for its cheapest offshore project yet—€54.50 per megawatt-hour, for a site about 15 miles off the coast. Just five months before, the winning bid for the same site was €72.70. Denmark has gone even further, with an auction in November 2016 seeing a then record-winning bid of €49.90 per megawatt-hour, half the level of 2014.

Europe, which has provided considerable economic and regulatory support, accounts for more than 90 percent of global capacity. As a result, Europe now has a maturing supply chain, a high level of expertise, and strong competition; it is possible that offshore wind could be competitive with other sources within a decade. By 2026, the Dutch government expects that its offshore auctions will feature no subsidies at all. But it might be even sooner: in the April 2017 German auction, the average winning bid for the projects was far below expectations, and even less than the Danish record set only six months before. Some of the bids were

won at the wholesale electricity price, meaning no subsidy is required.

Prices and costs

The industry still has a way to go compared with current costs: the levelized cost of electricity (or LCOE, a metric that incorporates total lifetime costs and expected production) for an offshore park installed in 2016 is expected to be €120 to €130 per megawatt-hour, about 40 percent more than onshore wind in comparable regions and 20 percent more than solar photovoltaics (PVs). Conventional sources, such as coal and gas, are currently even cheaper in many locations.

The technology thus still comes at a premium. Costs are higher because building at sea requires more materials for foundations and piles, while rough weather conditions make installation and maintenance expensive. Offshore wind parks also require expensive connectors to the inland transmission network.

While prices for all renewables will continue to drop, offshore wind is at an earlier stage of development, so its prices can be expected to fall further, faster, thus improving its competitive position. According to McKinsey research, when different wind farms are made comparable by normalizing for water depth, site preparation, subsidies, and other factors, this is already happening.

One caveat: these are prices, not actual costs. Until the parks are actually built and running, it is impossible to know if they can be profitable at these prices. But companies would not be competing so fiercely—the Dutch auction saw 38 bids—if they didn't think they could be.

Offshore wind has a number of advantages that can help to compensate for its higher costs. Specifically, it can be sited near densely populated coastal areas, where land can be costly, and its higher wind speeds produce more power per unit of capacity. Offshore also complements solar PV, because it produces well in winter when load is highest, creating a stable production profile, day in and day out, throughout the year. Offshore wind produces at 35 to 55 percent of capacity, versus 10 to 20 percent in the Northern Hemisphere for solar PV. Finally, the not-in-my-backyard (NIMBY) effect is considerably less when the nearest turbine is miles away at sea. However, when offshore parks are not placed far enough offshore, NIMBY can become an issue, with complaints of visual or horizon pollution.

Factors outside the industry's control, including low interest rates and low steel prices, have played a major role in cutting costs. But so has better technology, especially the trends toward larger turbines and greater durability (exhibit). Larger turbines harvest more of the wind, which make them more efficient. For many years, 3- to 4-megawatt turbines were standard; now 8- to 10-megawatt models are common, and by 2024, 13- to 15-megawatt models will likely hit the market. This reduces the cost per megawatt. Even as turbines have become larger, they have also become better. In the 1990s, the expected lifetime of offshore wind parks was only 15 years; now it is closer to 25 years, and new sites project an operational lifetime of 30 years.

One final piece of good news: as investors get more comfortable with offshore wind, financing risk premiums will come down.

Room for improvement

The offshore wind industry is still in the process of growing up and becoming more professional. There are a limited number of fit-for-purpose suppliers and vessels, for example, and owners, contractors, and subcontractors are still learning how to work together. There aren't that many industry professionals who are experienced at completing offshore wind projects, and as parks get bigger, the need for such expertise is greater.

Scale itself will help. With more offshore farms being built, the economics of scale are beginning to emerge, in both logistics and along the supply chain, including such things as sharing crew transfer vessels, helicopters, and coordinating jack-up barges across assets and operators for major component replacements.

For offshore wind to fulfill its considerable potential, it needs to raise its game everywhere. The most promising opportunities are in design, procurement, and execution; operations; and innovative financing.

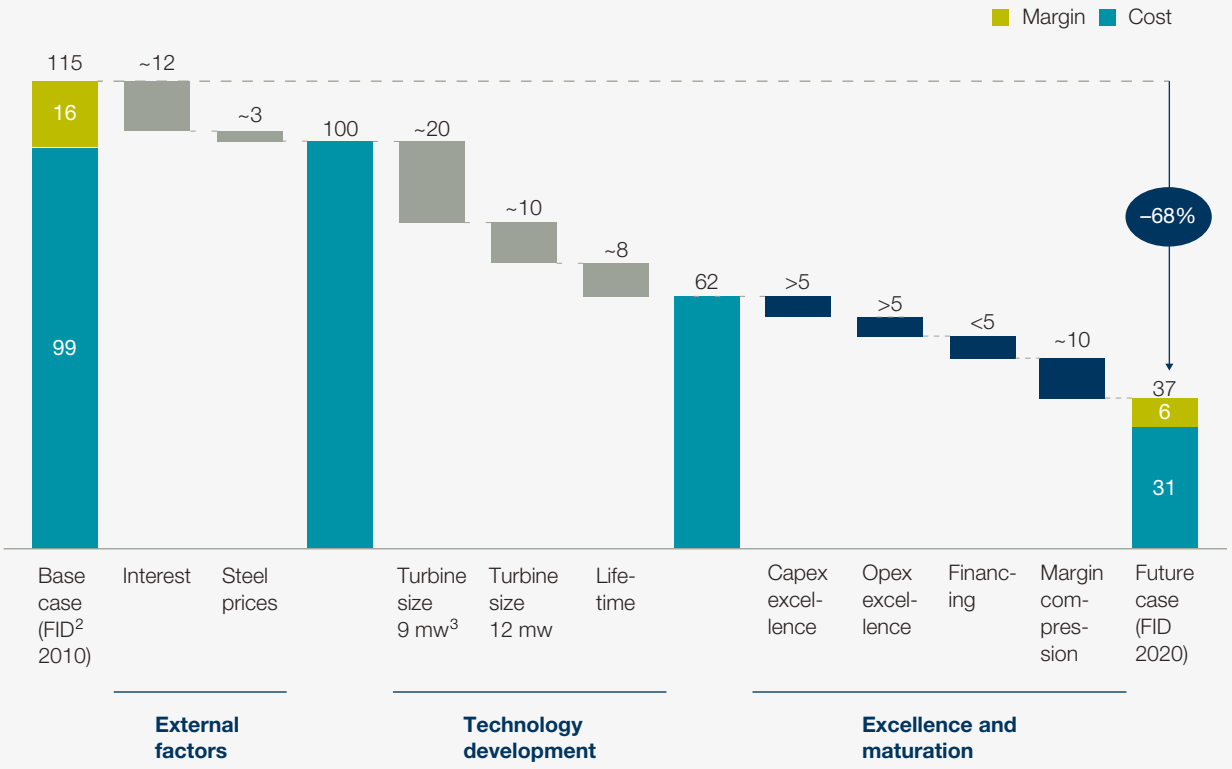
Engineering, procurement, and construction

Value-focused design involves working with all stakeholders, internal and external, to systematically identify technical improvements and value-creation opportunities. For example, the developer and supplier can get together to define the mini-

Exhibit

Cost declines in offshore wind are being driven by external factors, technology development, and excellence.

Potential levelized-cost-of-electricity path, €/mWh,[1] normalized



[1]Megawatt-hour.
[2]Final investment decision.
[3]Megawatts.

Source: Jens Hobohm et al., *Cost reduction potentials of offshore wind power in Germany*, a joint report from the Fichtner and Prognos, 2013, prognos.com; *Cost reduction options for offshore wind in the Netherlands FID 2010–2020*, TKI Wind op Zee (TKI Offshore Wind), October 2015, tki-windopzee.nl; McKinsey analysis

mum technical solutions, ruthlessly eliminating high-cost, low-value specifications. Design optimization is another possibility. The standardization of components and designs across a single offshore wind site, or a fleet of them, reduces the costs of construction, installation, follow-up engineering, and debugging. Manufacturers can then use modular techniques to adapt to specific situations in a cost-efficient way.

Contracting and procurement could add up to 5 to 10 percent in cost savings. Contracting strategy begins with understanding exactly what is expected of the contractor with respect to technical delivery and added value, the complexity of engineering, and fit with the design requirements. Based on a rigorous risk assessment, the developer seeks the best delivery model and pricing structure and optimizes the contract terms to be consistent with this strategy. By brainstorming with the candidate contractors, then assessing their risk profiles, one onshore wind company saved at least 15 percent on the final proposals.

Applying procurement-excellence tools, such as clean-sheet costing, and creating a clear "package procurement" road map can help to find the right price for the right product. At several companies, this rigorous purchasing approach has translated into 15 to 20 percent price reductions in the procurement of turbines.

By their nature, offshore wind platforms are costly to build, so improving project execution offers another avenue to cut costs, by 3 to 5 percent. Integrated performance management ensures that data is collected and shared throughout the project—from the owner to all the suppliers and all the subcontractors. Lean construction comprises a set of principles, operating practices, and methods that improve execution while minimizing waste. In offshore wind, examples include reducing delays in preparing foundations and increasing standardization in the assembly of components.

Operations and maintenance

Offshore wind developers vary widely in their operations and maintenance performance. The best drive down costs while maintaining high availability and safety standards; the rest tend to focus on availability and do not pay enough attention to costs. We estimate that for many projects, improved operations could translate into savings of as much as €10 per megawatt-hour in LCOE. Improved operations start with the relentless application of advanced analytics to improve predictive maintenance, condition monitoring, and component replacement.

Second, operators should establish flexible work contracts for offshore sites that are difficult to access, share technicians across sites, and find the right balance between internal and external technicians to contain labor costs while maintaining quality. Size and proximity to other parks does matter. Building new vessel-logistics concepts such as service-operation vessels, and sharing technicians and fleet with other sites (as done in the offshore oil and gas sector) adds a third opportunity to reduce costs.

Financing

McKinsey analysis shows that a one-percentage-point decrease in the cost of capital brings a 5 to 10 percent improvement in LCOE for renewables. To realize this advantage requires investors having a thorough understanding of the real risk profile that offshore wind assets have compared with other renewable or infrastructure assets.

Another way to reduce financing costs is to make the sector more attractive to a broader group of investors. Offshore wind investments are relatively "chunky," requiring hundreds of millions of euros per park, and "illiquid," meaning they are difficult

to sell without incurring high transaction costs. To overcome these challenges, other asset classes have devised alternative structures, such as publicly traded or private YieldCos; these have had their challenges but can still be attractive. The industry could also consider new structures, combining features such as publicly listed versus private structures, single asset versus broader portfolios, and single-technology focus versus cross-technology.

Reasons for optimism

The world's first wind farm began operating in 1991: the Vindeby project featured 0.45-megawatt turbines. As of 2017, there is more than 14 gigawatts of cumulative installed capacity worldwide.

Other markets have taken note of Europe's progress and are putting into place supportive regulation. China has made offshore wind part of its five-year energy plan. Korea, Poland, Taiwan, and a number of other countries are also considering offshore wind as part of their future energy mix. For example, a major project off the northeast coast of the United States is in the works.

Although in some areas of the world the LCOE of offshore wind may never become at par with, say, solar PV, the value it can bring—as less-intermittent baseload power generation near urban demand centers, offsetting supply deficits from solar PV in winter—can make it a valuable addition to the energy mix.

These brighter prospects have also led to increased interest from oil and gas companies, which are increasing their exposure to the sector. Offshore is a natural fit with their expertise in engineering and in executing complex energy projects in offshore locations.

Offshore's considerable potential would be further enhanced if floating wind platforms could become cost competitive. Fixed-foundation wind parks have to be sited in relatively shallow waters; floating ones could be placed in deeper areas, farther from land, and could open additional markets. There is considerable research going on, with the first floating wind farm being built off the coast of Scotland.

Fast growth, increased investment, bigger parks, falling costs, and new technologies and markets: these are the trends that are defining the offshore sector. Put it all together, and it is fair to conclude that the wind is at the industry's back. ■

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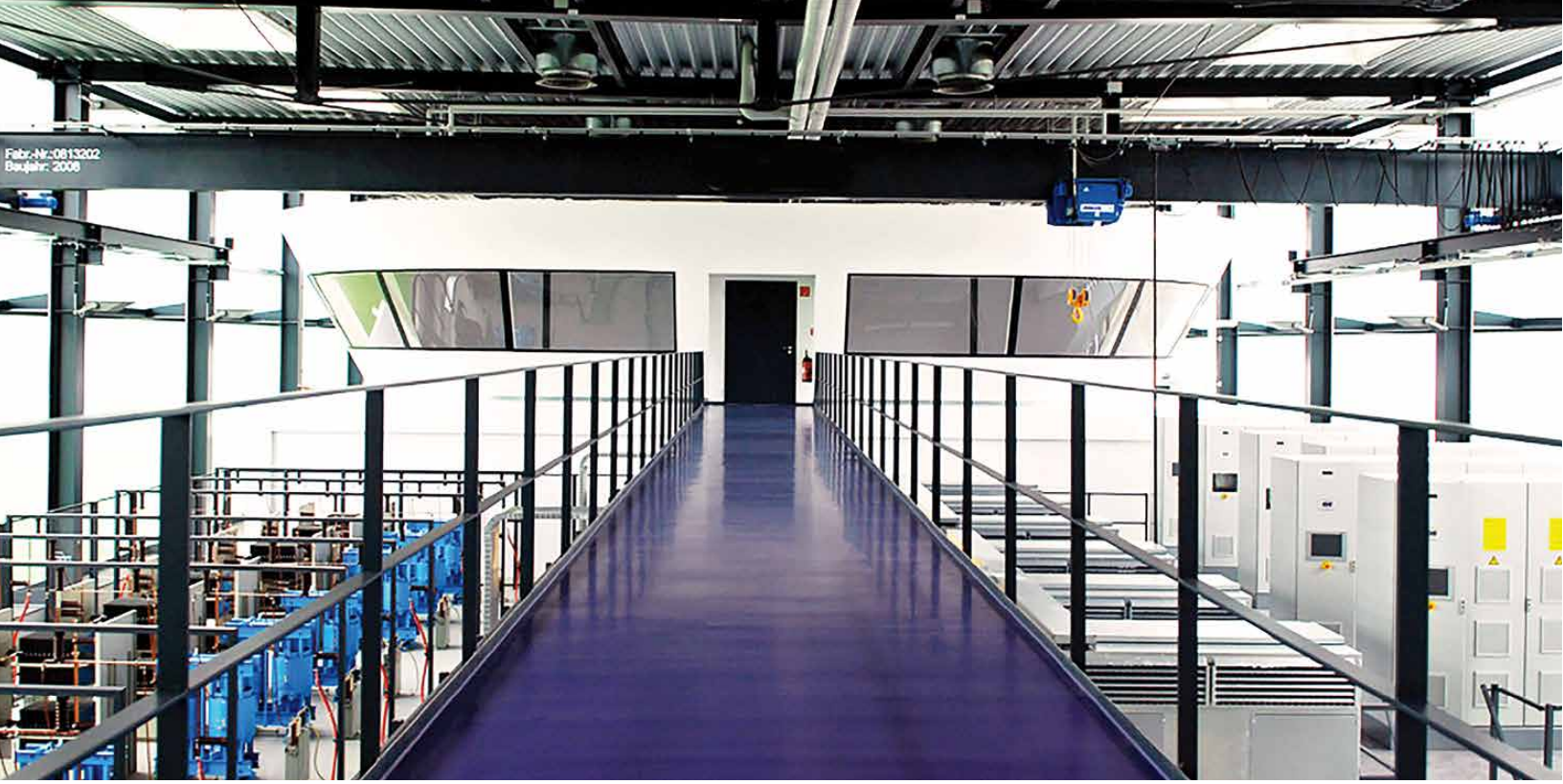

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Battery storage: The next disruptive technology in the power sector

Low-cost storage could transform the power landscape. The implications are profound.

David Frankel and Amy Wagner

Storage prices are dropping much faster than anyone expected, due to the growing market for consumer electronics and demand for electric vehicles (EVs). Major players in Asia, Europe, and the United States are all scaling up lithium-ion manufacturing to serve EV and other power applications. No surprise, then, that battery-pack costs are down to less than $230 per kilowatt-hour in 2016, compared with almost $1,000 per kilowatt-hour in 2010.

McKinsey research has found that storage is already economical for many commercial customers to reduce their peak consumption levels. At today's lower prices, storage is starting to play a broader role in energy markets, moving from niche uses such as grid balancing to broader ones such as replacing conventional power generators for reliability,[1] providing power-quality services, and supporting renewables integration.

Further, given regulatory changes to pare back incentives for solar in many markets, the idea of combining solar with storage to enable households to make and consume their own power on demand, instead of exporting power to the grid, is beginning to be an attractive opportunity for customers (sometimes referred to as partial grid defection). We believe these markets will continue to expand, creating a significant challenge for utilities faced with flat or declining customer demand. Eventually, combining solar with storage and a small electrical generator (known as full grid defection) will make economic sense—in a matter of years, not decades, for some customers in high-cost markets.

In this article we consider, as these trends play out, how storage could transform the operations of grids and power markets, the ways that customers consume and produce power, and the roles of utilities and third parties. Our analysis is directed mostly at developments in Europe and the United States; the evolution of storage could and probably will take a different course in other markets.

Implications for the utility industry

Storage can be deployed both on the grid and at an individual consumer's home or business. A complex technology, its economics are shaped by customer type, location, grid needs, regulations, customer load shape, rate structure, and nature of the application. It is also uniquely flexible in its ability to stack value streams and change its dispatch to serve different needs over the course of a year or even an hour. These value streams are growing both in value and in market scale (Exhibit 1).

Cheap battery storage will pose a challenge for utilities behind the meter (that is, small-scale installations located on-site, such as in a home or business). But it will also present an opportunity for those in front of the meter (large-scale installations used by utilities for a variety of on-grid applications).

Behind the meter

Cheap solar is already proving a challenge to business as usual for utilities in some markets. But cheap storage will be even more disruptive because different combinations of storage and solar will likely be able to arbitrage any variable rate design that utilities create.

Specifically, net energy metering (NEM) refers to rules that allow excess power to be sold back to the grid at retail rates; and feed-in tariffs, which are guaranteed price adders for renewable power, have played an important role in expanding the global market for renewables. In the US states that have implemented such rules, NEM has proved to be a powerful incentive for consumers to install solar panels.

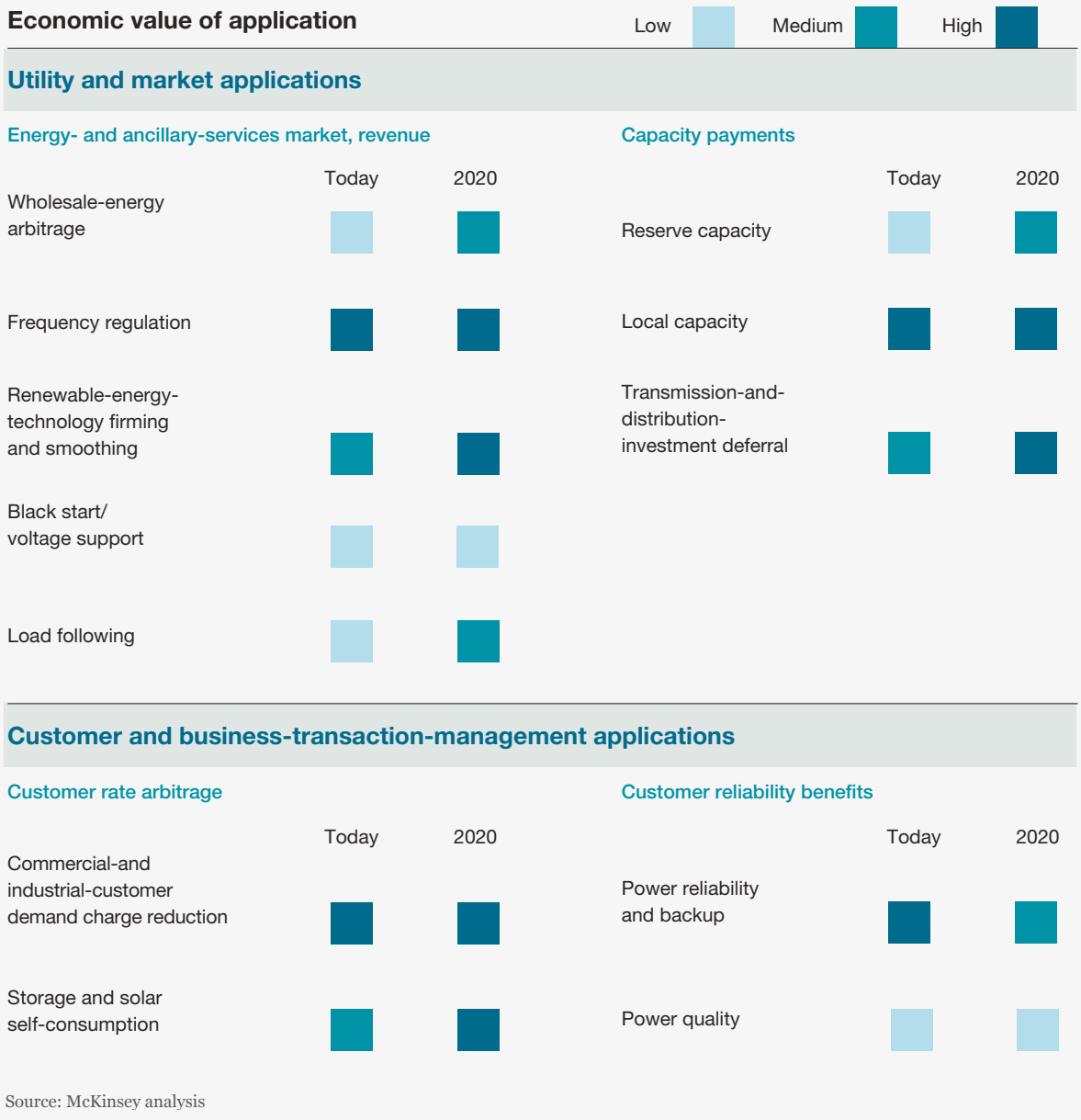
Although it has been helpful for solar, NEM also has put utilities under pressure. It reduces demand because consumers make their own energy; that increases rates for the rest, as there are fewer bill payors to cover the fixed investment in the grid, which still provides backup reliability for the solar customers. The solar customers are paying for their own energy but not paying for the full reliability of being connected to the grid. The utilities' response has been to design rates that reduce the incentive to install solar by moving to time-of-use pricing structures, implementing demand charges, or trying to reduce how much they pay customers for the electricity they produce that is exported to the grid.

However, in a low-cost storage environment, these rate structures are unlikely to be effective at mitigating load losses. This is because adding storage allows customers to shift solar generation away from exports to cover more of their own electricity needs; as a result, they continue to receive close to the full retail value of their solar generation. This presents a risk for widespread partial grid defection, in which customers choose to stay connected to the grid in order to have access to 24/7 reliability, but generate 80 to 90 percent of their own energy and use storage to optimize their solar for their own consumption.

We are already seeing this begin to play out in places where electricity costs are high and solar is widely available, such as Australia and Hawaii.

Exhibit 1

Battery-storage economic value varies by application and is expected to evolve and grow.



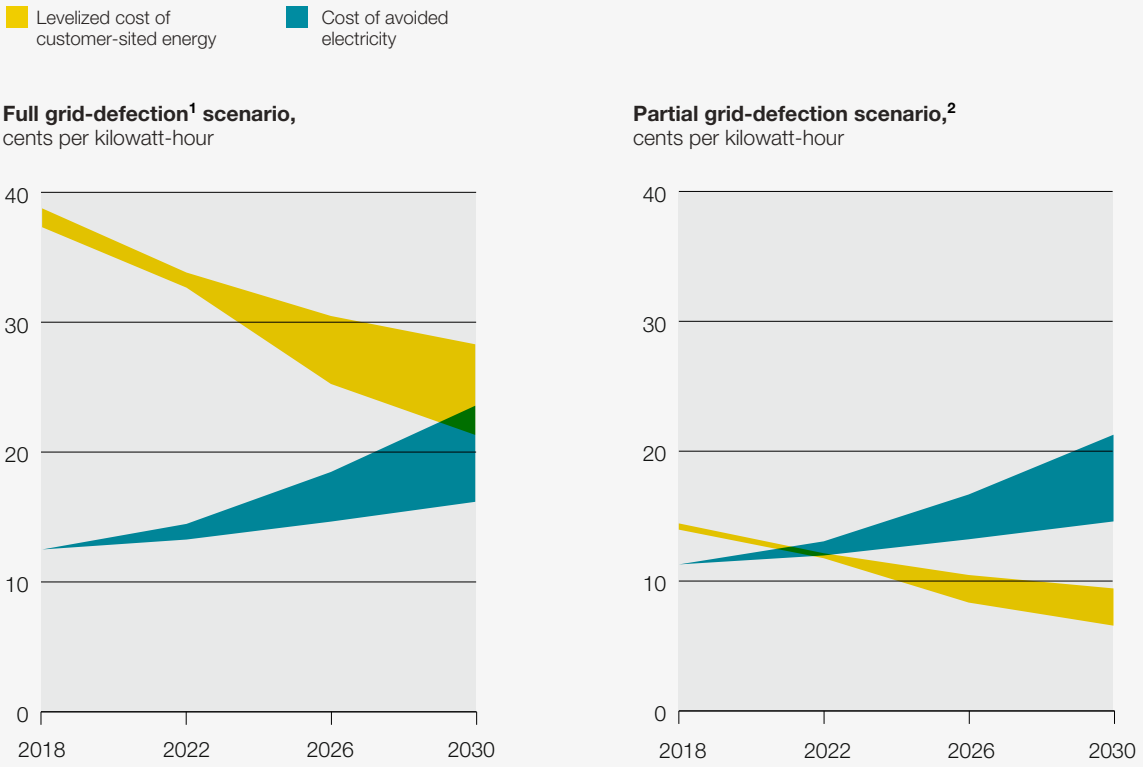
Source: McKinsey analysis

On the horizon, it could occur in other solar-friendly markets, such as Arizona, California, Nevada, and New York (Exhibit 2). Many utility executives and industry experts thought the risk of load loss was overblown in the context of solar; the combination of solar plus storage, however, makes it much more difficult to defend against.

Full grid defection—that is, completely disconnecting from the centralized electric-power system—is not economical today. At current rates of cost declines, however, it may make sense in some markets earlier than anyone now expects. Of course, economics alone will not dictate how much and when customers choose to disconnect from their

Exhibit 2

In some cases, grid defection is beginning to make economic sense.



[1] Grid-defection-economics estimates are based on Arizona residential customer. Partial defection assumes 90% load departure with solar and storage only. Full defection includes a small generator set for backup power. Solar and storage costs are from McKinsey's cost-curve forecast.
[2] 90 percent.

Source: McKinsey analysis

utilities. For example, another important factor is confidence in the reliability of their on-site power. But this dynamic will affect business-model and regulatory decisions sooner.

In front of the meter

Storage can also benefit utilities by helping them to address the challenges of planning and operating the grid in markets where loads are expected to be flat or falling. Regulators in some US states, for example, are testing new models of compensation by offering utilities incentives to earn returns by providing contracts for distributed generation. This would, among other things, allow utilities to defer expensive new investments and reduce the risk of long-lived capital projects not being used.

Utilities are also acting to procure storage assets to address both long-term regulatory requirements and short-term needs, such as reliability and deferring the construction of a new substation. As storage costs drop, such projects could lower generating costs—and, thus, consumer electricity rates—by putting further pressure on existing conventional gas and coal-generation fleets, depressing prices in capacity markets and providing load-following services.

What utilities can do

Utilities must start now to understand how low-cost storage is changing the future. In effect, utilities need to disrupt themselves—or others will do it for them. There are two broad categories of action to consider.

Redesign compensation structures and explore new opportunities

Sooner or later—sooner is better—regulators and utilities will need to find new ways to recover their investment in the grid.

The grid is a long-lived asset that is expensive to build and maintain. Fixed fees for grid access are unpopular with consumers, and regulators are therefore not particularly keen on them, either. However, imposing fixed fees could ensure that everyone who uses the grid pays for it. The volumetric or variable rate structure in general use today is a historical construct. People are used to paying for the energy they use. But as more and more customers generate their own energy, the access to the grid for reliability and market access becomes more valuable than the electrons themselves.

Because any rate-design changes will likely be slow and incremental (particularly those transitioning to fixed charges), utilities need to respond to these new market realities by capturing new earnings opportunities from expanded services and new transaction fees. There are already some interesting initiatives along these lines. In Australia, utilities are becoming solar-and-storage installers and providing advisory services[2]; while in the United States, one pilot program is selling advanced analytics and data-management services to consumers to help them manage their energy use.[3] Utilities in several states are also exploring new services and investing in grid modernization and electrification.

Rethink grid-system planning

Utilities must radically change their grid-system planning approaches. This means investing in software and advanced analytics to modernize the grid. It also means changing how traditional system planning is done, by reconsidering codes and standards (some of which have been in place for decades), moving to circuit-by-circuit nodal planning, and employing asset-health assessments to ensure the highest priority needs on the system are addressed.

Storage can be a unique tool in support of this. The straight economics of changing grid planning, with respect to return on capital, may not look different at first glance. But, because storage is more modular and can be moved more easily, the risk-adjusted value is likely to be much higher. That will enable utilities to adapt to uncertain needs at the circuit level and also to reduce the risk of overbuilding and stranded investments.

The role of third parties

As for third parties—meaning distributed-energy-resource (DER) companies, technology manufacturers, and finance players—there is tremendous potential for growth. But they must be nimble to take advantage of these opportunities.

DER companies can devise new combinations of solar and storage, tailored to specific uses. While storage could eventually provide more customer value and lower bills, new rate structures will be more complex and policy is unlikely to lock in rates for long periods. But shorter periods of defined rates and more complex rate schedules will make it more difficult for DER providers to add new customers, who don't like complexity and want to be sure their investment will pay off. New product offerings and financing creativity could solve these challenges and tempt customers currently sitting on the fence.

Technology players will need to understand how and where to play along the storage value chain, and adapt their offerings to meet customer needs as the technology and use cases quickly evolve.

Financing players, such as banks and institutional investors, will need to create options that adapt and match the investment horizon of the customer. As the market grows more confident of the underlying economics and performance of storage, they will develop financial products adapted to the technology's specific needs. When that happens, financing costs will fall, further expanding the market's potential, creating a virtuous cycle akin to what has happened to solar this past decade.

Battery storage is entering a dynamic and uncertain period. There will be big winners and losers, and the sources of value will constantly evolve depending on four factors: how quickly storage costs fall; how utilities adapt by improving services, incorporating new distributed-energy alternatives, and reducing grid-system cost; how nimble third parties are; and whether regulators can strike the right balance between encouraging a healthy market for storage (and solar) and ensuring sustainable economics for the utilities. All this will be treacherous territory to navigate, and there will no doubt be missteps along the way. But there is also no doubt that storage's time is coming.

[1] Examples include using storage as replacement capacity after the Aliso Canyon shutdown in Southern California, as well as storage participating in a tender for capacity in Australia and in capacity-market auctions in the United States.

[2] Amy Gahran, "Can battery storage recharge Australian utilities?" *Greentech Media*, July 18, 2016, greentechmedia.com; James Paton, "AGL eyes power storage in 1,000 homes to tap solar surge," *Bloomberg*, May 26, 2016, bloomberg.com.

[3] Shay Bahramirad, Patrick Graves, and Joseph Svachula, "Evolution of ComEd asset management," *T&D World*, April 21, 2016, tdworld.com.

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Energy transition: Mission (im)possible for industry?

Dutch industrial companies can thrive in a low-carbon future.

Arnout de Pee, Occo Roelofsen, Eveline Speelman, and Maaike Witteveen

From 1990 to 2014, industrial companies in the Netherlands lowered their greenhouse-gas (GHG) emissions from direct operations by 32 percent—three times as much as other sectors of the Dutch economy. Were this trend to continue, the sector would reach the European Union's intermediate goal of cutting GHG emissions by 40 percent by 2030 well before that year. Sustaining the recent rate of emissions reduction won't be easy, though. Industrial companies have reduced their emissions of GHGs other than carbon dioxide (CO_2) by about 70 percent, yet their CO_2 emissions remain significant—67 million metric tons in 2014, or more than 40 percent of Dutch CO_2 emissions. Many of the new or yet-to-be-developed technologies may be expensive or difficult to implement.

When assessing decarbonization options, industrial companies need to understand their technical feasibility, effectiveness, costs, and benefits, including impacts further up and down the value chains—and do this amid uncertainty about factors such as the future prices of different forms of energy. To provide some initial answers, we analyzed and compared the options that are likely to be available to Dutch industrial businesses. The results of our study point to a comprehensive program for implementing options in a manner that may create value for industrial companies as well as for the Netherlands as a whole.

Our primary findings include the following:

Decarbonizing industry by 60 percent by 2040 will cost approximately €23 billion

The Dutch industrial sector can lower its CO_2 emissions by 60 percent by 2040, compared with 1990, and by 80 percent by 2050, which would be consistent with the European Union's goals of an 80 to 95 percent reduction by 2050. This reduction can be achieved without reducing industrial output.

The total cost of decarbonizing the Dutch industrial sector between now and 2040 would be approximately €21 billion to €23 billion, which is consistent with our previous findings.[1] About €9 billion would be spent on capital investments, and the remaining €12 billion would come from increased operating costs (at current commodity prices).

Under current commodity and technology prices, only about 20 percent of investments have a positive business case. This assumes that the cost of carbon emissions ranges from minus €10 to plus €300 per metric ton of CO_2 avoided.

Decarbonizing industry by 95 percent is also possible but more costly

It is technically feasible for the Dutch industrial sector to lower its CO_2 emissions by 95 percent by 2050, compared with 1990, while also keeping industrial outputs at current levels. The cost of decarbonizing the Dutch industrial sector by that much could be as high as €71 billion between now and 2050. About €24 billion comprises capital investments, and the rest pays for higher operating costs (at current commodity prices). If energy prices fall from their current levels, the total decarbonization cost could be closer to €36 billion.

Aiming for a 95 percent reduction will see fewer investments with a positive business case (under current technology- and commodity-price outlooks). More investments become financially viable as the price of carbon increases.

A portfolio of different decarbonization measures will be needed

Industrial CO_2 emissions (45 million metric tons direct and 22 million metric tons indirect) in the Netherlands now consist of 10 percent process emissions, 30 percent electricity-consumption-related emissions, and 60 percent of emissions related to heat production.

Reducing process and heat-production emissions will require the application of multiple decarbonization options at once: efficiency improvements; electrification of heat production; change of feedstock (for example, switching to bio-based); changes in demand by increasing reuse, remanufacturing, and recycling; changes in the steel-production process; and carbon capture and storage or usage. Together, the selected combination of options could reduce direct CO_2 emissions by 20 million metric tons by 2040. Overall, this would lead to a reduction of CO_2e (carbon dioxide equivalent, the basic unit of GHG accounting) of 60 percent by 2040, compared with 1990. Of course, application of different combinations and contributions of the individual options is also possible and may turn out to be more economical.

Efficiency improvement (two million metric tons or more). Most "quick wins" for energy efficiency have been captured. There are still further gains possible, for some of the other options go hand in hand with efficiency improvement. For instance, electric heat pumps for low-temperature heat offer an efficiency increase of at least 50 percent.

Electrification of medium- and high-temperature heat generation (11 million metric tons by 2040, up to 17 million metric tons by 2050). Electrification of heat production will play a major role in

decarbonizing Dutch industry under any scenario. Some electrification measures, such as hybrid or dual-fuel systems to generate medium-temperature heat (100-plus degrees Celsius), are ready to implement. Other measures would benefit from targeted research and development or further commercialization. These include the development of heat pumps capable of producing medium-temperature heat and the development of electric furnaces to provide high-temperature heat (400-plus degrees Celsius) for refining and ethylene production. Also, production of hydrogen would benefit from innovation to bring down cost levels. In the longer run, hybrid or dual-fuel systems could then switch to electricity and hydrogen instead of electricity and natural gas.

Change of feedstock (0.5 million metric tons). By using bio-based feedstock for chemical-production processes (for example, ethylene and specialty-chemicals production), both production and downstream emissions can be tackled. The first technologies to do so are around but would benefit from further innovation and scale-up to make them more economical. Likewise, for ammonia production, hydrogen produced from electricity and water can be used as feedstock, replacing natural gas. However, electrolysis technology (replacing current steam-methane reforming) is far from cost competitive and would thus benefit from innovation in combination with lower electricity prices.

Change in demand by increasing reuse, remanufacturing, or recycling (approximately one million metric tons). Increasing reuse and recycling would reduce local, and perhaps global, demand for certain products, such as steel or ethylene-based plastics. This would directly lower the carbon emissions resulting from production of those goods.

Change in the steel-production process (approximately three million metric tons). Steel production in the Netherlands could be decarbonized in several ways that resemble other options. One option is to change the feedstock and fuel source, for example, by using charcoal-fed blast furnaces or setting up an electric-arc furnace using direct reduced iron, a furnace fed with iron ore and powered by biogas or hydrogen instead of coal. Another is to increase recycling of steel by using scrap in electric-arc furnaces, or applying carbon capture and storage. These are all major decisions. For this report, we have assumed that by 2040 half of current steel production would switch to a low- or zero-carbon option.

Carbon capture and storage or usage (CCS or CCU) (approximately three million metric tons). Carbon capture can be used to reduce any emissions that cannot be eliminated by other means. With electricity power being more expensive than gas, CCS seems more economical than several alternatives for decarbonization.

Emissions coming from the use of gas or coal for power generation will have to be reduced through installation of renewables. Theoretically, the power industry's use of electricity generated from

Reducing greenhouse-gas emissions 80 percent by 2040 (or 95 percent by 2050) is possible with current and expected near-term technology.

renewables could lower CO2 emissions by 16 million metric tons.[2]

Given an ambitious penetration level of 80 percent for renewables, ten million metric tons of emissions (60 percent) from current electricity use and 11 million metric tons of emissions (100 percent) from added electricity use would be abated. Greening Dutch electricity therefore represents an important and necessary means of decarbonizing industrial emissions.

The cheaper route: 60 percent decarbonization by 2040

At current cost levels, the cheapest route to decarbonize industry by 60 percent by 2040 would involve a combination of energy efficiency, electrification, and CCS or CCU. We estimate that a capital investment of €9 billion would be needed, along with an increase in operational expenses of €12 billion. Overall, the additional cost would be approximately €21 billion over 20 years, though the actual cost would depend greatly on the pace of technological improvements.

The steeper route: 80 percent decarbonization by 2040 and 95 percent by 2050

Reaching 80 percent reduction by 2040 and 95 percent by 2050 is possible even with current and expected near-term technology. Getting there would, however, involve applying more expensive decarbonization options sooner, mainly in two areas: more extensive electrification, through application of electric furnaces in refining and ethylene production, and more extensive use of CCS in refining and chemicals. These methods would reduce emissions by 80 percent by 2040, compared with 1990 (32 million metric tons of direct industry emissions). The estimated cost of this approach is €51 billion by 2040 and €71 billion by 2050.

Implications for the broader energy system

A shift from fossil-based electricity generation to renewables is needed. This would cut current electricity-related industrial emissions of 16 million metric tons CO2e to six million metric tons or lower. Increasing the rollout of renewables would be needed to enable increased industrial demand for electricity. This would also have significant implications for utilities, the power grid, and other elements of the national energy infrastructure.

The development of the Dutch power system, and the resulting energy prices and changes in the availability of low-carbon energy sources, will have a major influence on the feasibility and cost-effectiveness of industrial decarbonization. It will also determine further technology choices and affect industry's international competitiveness.

Many business cases depend on the outlook for commodity prices. Derisking is needed to make the investment choices required.

Over time, a diversification of supply may be needed to meet industry's baseload demand for renewable energy more effectively. Increased

application of hydrogen can play a role here, either through use in hybrid or gas boilers or for backup power generation.

A way forward

Given these conditions, and the long horizons for capital spending, it will be advantageous for industrial companies in the Netherlands to begin to develop a comprehensive plan for decarbonization, including energy-system design. Getting a fast start will increase the likelihood that industrial companies will have effective decarbonization options to choose from as they adjust to changes in the energy system, and thereby stay on track to meet their long-term emissions-reduction goals.

Moreover, in some areas, advancing decarbonization more quickly could help companies improve their long-term competitiveness. It is a delicate balance, however, given the great uncertainty about the future and costs of the energy system. A plan for industrial decarbonization thus needs to be flexible enough to enable businesses to choose their options according to the conditions and trends that actually unfold. ■

[1] In our previous report, *Accelerating the energy transition: Cost or opportunity?,* we estimated that the total cost of lowering greenhouse-gas emissions from industry by approximately 50 percent by 2040 would be €20 billion. This is consistent with our current findings, where we use a slightly steeper decarbonization path (60 percent by 2040).

[2] These indirect emissions include six million metric tons of CO_2 emissions from steel production. Application of renewable electricity supply would only partially reduce these emissions. Hence we include here 16 megatons of emissions.

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Why commercial use could be the future of carbon capture

Emerging technologies point toward a variety of practical—and profitable—industrial applications for carbon dioxide. That could also be good for the planet.

Krysta Biniek, Ryan Davies, and Kimberly Henderson

Nearly two years after the signing of the Paris Agreement to prevent average global temperatures from rising by more than two degrees Celsius, the world continues its urgent search for cost-effective methods of reducing greenhouse-gas (GHG) emissions. Even the surprising growth of renewable energy probably won't make up for the expected increases in emissions from other sources. In all likelihood, staying under the two-degree limit will require the development and rapid adoption of advanced technologies.

Carbon capture and storage (CCS) has long been seen as one technology with the potential to reduce GHG emissions significantly. The basic idea is to collect carbon dioxide gas and confine it underground. CCS hasn't caught on, however, because it is expensive. But a new twist on the concept might change its cost profile. If carbon dioxide could be put to industrial use, the resulting revenues could make carbon capture financially viable.

A few industrial applications for captured carbon dioxide are already in play. One involves using the gas to make chemicals and plastics, such as polyurethane foams for seat cushions. Covestro, formerly Bayer MaterialScience, recently opened a plant that makes these foams from carbon dioxide. Research also suggests that making carbon fiber out of carbon dioxide gas would cost less than the typical production process, which uses polymers. However, the quantity of carbon dioxide that might eventually go into chemicals, plastics, and carbon fiber would be too small—between 40 million

and 90 million metric tons per year—to make an appreciable dent in global GHG emissions. Methods of carbon capture and use (CCU) that take up much larger amounts of carbon dioxide gas will therefore be needed to help reduce overall GHG emissions.

A look at new uses for captured carbon

Creating large-scale CCU technologies won't be easy. One big challenge is that carbon dioxide is a highly inert molecule. Because of this, transforming the captured gas into industrial products typically requires a lot of energy. Another challenge is that oil remains a highly cost-effective industrial feedstock, both as a fuel and as a precursor in the synthesis of other substances, such as plastics.

These factors mean that clever solutions to the energy-balance challenge are required, and it could be years before CCU is a big business with major environmental benefits. Nonetheless, CCU should have a future in an emissions-constrained world. That creates intriguing medium-term prospects for investors, companies, and governments.

Some new applications for captured carbon dioxide are being piloted; others are in the developmental stage. Three of these applications stand out for their potential to reduce emissions and generate revenue: fuel production, concrete enrichment, and power generation. We estimate that carbon usage, driven largely by this trio of applications, could reduce annual GHG emissions by as much as one billion metric tons in 2030, compared with a scenario in which these applications do not develop quickly.

Fuel made from captured carbon

Captured carbon dioxide can technically be converted into virtually any type of fuel or chemical that is otherwise derived from petroleum. The question is how to do this economically enough so that the resulting fuels and chemicals are cost-competitive with those derived from oil.

One method involves causing a chemical reaction between hydrogen and carbon monoxide molecules to create the hydrocarbon chains that make up liquid fuels. Getting the chemistry right is difficult. Producing the chemical reaction is energy-intensive, roughly equivalent to combustion in reverse. And if hydrogen fuel cells are ever adopted more widely, demand for hydrogen could reach the point where it is more economical to use as an energy source than to make liquid fuel. Recently, however, several cheaper, more efficient catalysts to break down carbon dioxide into carbon monoxide have been discovered, a critical first step.

If a goal of synthesizing fuels from carbon dioxide is to reduce GHG emissions, then using energy to power the synthesis makes sense only if the energy is both cheap and low or zero carbon. A way to make this work would be to produce fuel from captured carbon dioxide only when renewable power plants, such as solar or wind farms, are generating excess electricity. This would also provide a means of storing energy from renewable sources in a form that is portable and easy to use in existing industrial equipment.

Another method of turning captured carbon dioxide into fuel depends on using microorganisms to power the necessary chemical reactions. Microorganisms naturally consume carbon dioxide during photosynthesis, which produces simple sugars such as glucose. Some of the microorganisms can then ferment the resulting sugars into ethanol. Other microorganisms produce lipids (along with proteins and starches), which contain hydrocarbon components that can be refined into liquid fuel. Since microorganisms are inefficient at converting solar energy into chemical energy, the trick is to genetically modify them to make ethanol or lipids more efficiently and quickly, or even to excrete liquid fuels directly. Once that is done, one more issue remains: providing the microorganisms with

enough space and the right conditions to live. We estimate that microorganisms producing enough liquid fuel to meet the annual needs of the United States would require a lake one-third the size of California.

More research and investment will be needed to scale these biological methods of making fuel from carbon dioxide up to commercial size. Even so, the long-term potential of these techniques to turn waste gases into valuable products has attracted interest from large industrial firms.

Concrete enriched with captured carbon

The manufacture of cement, which serves as the binding agent in concrete, accounts for roughly 8 percent of global carbon dioxide emissions, a significant share of the total. This is because making cement involves using immense amounts of mechanical and heat energy to quarry rock for limestone and extract the lime by way of a high-temperature treatment process. Cement is then combined with aggregates and water to make concrete.

Captured carbon dioxide can't readily lessen the amount of energy that goes into this process. But using captured carbon dioxide during the making of concrete would sequester the gas in buildings, walls, bridges, sidewalks, and other concrete structures, allowing the material to serve as a major carbon sink.

Carbon dioxide can be added to concrete in two ways. The first is to make the gas into a carbonate mineral aggregate that goes into concrete and construction fill. This is not practical now, because natural aggregate is inexpensive. A more promising approach is to infuse wet concrete with carbon dioxide. This technique, known as "carbon curing," involves curing concrete in a carbon dioxide–rich environment, causing the carbon dioxide to react with water to form carbonate ions, which then react with calcium ions in the concrete to form solid calcium carbonates. This is an exothermic and spontaneous chemical reaction that releases rather than consumes energy.

Carbon curing can produce concrete that is 4 percent carbon dioxide, by mass. Carbon curing can also shorten curing times, increase concrete's water resistance, and strengthen it—improvements that should make it more appealing to concrete makers and construction companies, regardless of the environmental benefits.

Power generation using supercritical carbon dioxide

Repurposing captured carbon dioxide as an ingredient in products such as fuel and concrete represents one means of lowering emissions of the gas. A different approach is cutting GHG emissions from power generation by using carbon dioxide to make turbines run more efficiently. Although this would not repurpose carbon dioxide as a product, it could prevent a significant amount of emissions.

Steam turbines powered by fossil fuels have been used to generate electricity for more than a century. But carbon dioxide, heated and pressurized into a supercritical fluid, transfers heat more readily and takes less energy to compress than steam, which can make turbines more efficient. A conventional steam turbine converts roughly 33 percent of the energy in fuel to electricity. Using supercritical carbon dioxide instead can boost the energy-conversion rate to 49 percent.

Increasing the efficiency of turbines is important because fossil fuels are expected to be important sources of power for decades to come. In principle, supercritical carbon dioxide can replace steam in any power-generation process that relies on steam turbines. Whether it will be economical to do so on

a large scale is another matter. One question is how much it will cost to retrofit or replace steam turbines. Another is whether utilities will be rewarded for switching to turbines that are more energy efficient and less emissions intensive.

These uncertainties make it difficult to predict how supercritical carbon dioxide technology for turbines might affect the power sector or overall GHG emissions trends. But the potential of the technology, reinforced by research investments by industrial heavyweights, means it is worth watching. Early indications of its viability should emerge after Sandia National Laboratories launches its demonstration plant, which is scheduled for 2019.

Scaling up the use of captured carbon

At the moment, none of the three uses listed above for captured carbon dioxide has been developed to the point where it is commercially viable. But all three have the potential to become profitable in the medium to long term as the technologies advance and countries pursue their plans to reduce GHG emissions.

Two major sets of costs need to be addressed. First, the technology used to collect carbon dioxide from the flue gases of power plants and industrial facilities would have to become more cost-effective. Capturing and transporting the gas can cost as much as $80 per metric ton. Firms working in this area expect to halve that cost in the coming years. Second, as noted earlier, the technologies for using captured carbon dioxide need to become more efficient and cost-effective.

CCU technologies also have to win support in industry, which has proven alternatives to fall back on: fossil fuels instead of synthetic ones; ordinary concrete instead of carbon-cured concrete; steam turbines instead of carbon dioxide turbines. Conventional practices can be difficult to overcome, even when better ones come along. Policy makers can play a role in accelerating the development and adoption of CCU technologies. Just as regulatory support helped ensure steady demand for renewable energy in some countries, the right policy environment will encourage companies and investors to get behind CCU.

Reducing and eventually stopping increases in the atmosphere's GHG concentration will require multiple methods of cutting emissions to be used widely. Since existing methods are being adopted slowly, relative to the GHG challenge, new methods may be needed. This is one reason why carbon capture features prominently in some emissions-reduction scenarios: the International Energy Agency, for example, expects carbon storage to account for 14 percent of GHG-emissions reductions from 2015 to 2050. While carbon capture and storage has been slow to catch on, CCU seems to have more promise, partly because of its revenue-generating potential. Making CCU work at scale in the long term will depend on technology investment decisions made today. Companies and governments that provide the right support now may position themselves to reap the benefits from CCU in the years to come. ■

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The future(s) of mobility: How cities can benefit

Autonomous vehicles, electric powertrains, vehicle sharing, and other advances are transforming urban mobility. Planning ahead can help cities capture the benefits of the shift, from cleaner air to easier journeys.

Shannon Bouton, Eric Hannon, Stefan M. Knupfer, and Surya Ramkumar

The way that people get around cities is changing dramatically. Technological advances and new transportation services are making it possible for city dwellers to cross town ever more efficiently and safely. These shifts could have profound economic and social effects. McKinsey analysis indicates that in 50 metropolitan areas around the world, home to 500 million people, integrated mobility systems could produce benefits, such as improved safety and reduced pollution, worth up to $600 billion.

Because each city is unique, the transition to integrated mobility will also play out differently, and produce different results, from one city to the next. The pace and extent of change will depend on factors such as population density, household income, public investment, the state of roads and public-transit infrastructure, pollution and congestion levels, and local governance capabilities.

The private sector will exert important influences, too, as companies adjust to new consumer behaviors. Utilities, for example, will need to manage possible increases in electricity demand resulting from the wider use of electric vehicles. Automakers can expect the automotive revenue pool to grow and diversify as the mix of vehicles sold tilts toward electric and autonomous vehicles. The trend toward connected cars will affect technology companies and insurers, causing disruption and creating opportunities in areas such as data analytics.[1]

With all these forces at work, the transition to integrated mobility will be complicated, even challenging at times. Some cities can get an early start, while others will need to work on developing the right conditions. No matter how ready a city is to move toward advanced mobility models,

municipal officials can already begin developing a vision for what integrated mobility ought to look like and how their cities might evolve accordingly. More important, they can consider how to manage the transition so that its benefits are maximized in line with local priorities for improving residents' quality of life.

To help city leaders structure their thinking, we have created scenarios for how mobility might change in three types of cities: dense cities in developed economies, dense cities in emerging economies, and sprawling metropolitan areas in developed economies. Each scenario accounts for present-day conditions and highlights both opportunities and challenges. In this article, we lay out these visions for the future of mobility, along with ideas about how municipal officials and other urban stakeholders can help their cities navigate toward positive outcomes.

Trends influencing urban mobility

Fast-moving trends are influencing urban-mobility systems around the world. Some trends, like vehicle electrification and the development of autonomous-driving technology, relate directly to mobility. Other, broader trends will also have important implications. The decentralization of energy systems, for example, will make a difference as modes of transportation come to rely more and more on electricity as an energy source. The following trends are likely to have the biggest impact on the development of integrated mobility in cities.

Shared mobility. Ride-hailing services have grown rapidly over the past few years and now compete not only with traditional car-sharing and car-pooling providers but also with public transit and private vehicle ownership. Investments in ride-hailing companies have taken off, too, more than doubling to $11.3 billion in 2015 from $5.3 billion in 2014.

Autonomous driving. Advances in autonomous-driving technology promise to resolve road-safety concerns, reduce the cost of transportation, and expand access to mobility. Autonomous vehicles (AVs) should turn driving time into free time. AVs could also lead to higher overall vehicle mileage, as people take advantage of their convenience by making more trips or even sending AVs to run errands for them.

Vehicle electrification. Global electric-vehicle (EV) sales have risen quickly, from 50,000 in 2011 to nearly 450,000 in 2015. Purchase subsidies, falling battery costs, fuel-economy regulations, and product improvements have contributed to the increase. Bloomberg New Energy Finance estimates that battery costs will drop below $100 per kilowatt-hour in the next decade. If that happens, EVs should achieve cost competitiveness with conventional vehicles.[2]

Connectivity and the Internet of Things (IoT). The spread of IoT applications into vehicles and infrastructure will generate data with a variety of uses. For city dwellers, software systems can facilitate trip planning and guide AVs based on real-time conditions. Transit authorities could use the same data to analyze the movement of people and vehicles, identify bottlenecks, adjust services, and make long-term transit plans.

Public transit. Cities around the world are expanding and improving their public-transit networks. Adding autonomous features to transit vehicles may reduce operating costs, while new deployment models such as fleets of shared vehicles can make transit more flexible and accessible. Using data from IoT-enabled infrastructure can help planners to add capacity and improve reliability so that mass transit remains competitive with private vehicles and mobility services.

Infrastructure. The United Nations Population Division projects that the world's urban population will increase by more than two-thirds by 2050.[3] Such an influx of people could put more strain on city roads, bridges, and tunnels that are already struggling to keep up with increases in vehicle miles. But infrastructure upgrades that favor public or shared transit and bicycling could reinforce a shift away from car ownership.

Decentralization of energy systems. If the cost of renewable power generation continues to fall, then intermittent distributed generation will produce a notable share of the world's electricity over the next 15 years. These trends could accelerate EV uptake by making electricity cheaper, cleaner, and more reliable. Residential solar and energy-storage systems let EV owners recharge their vehicles without buying electricity at retail rates. (In some places, it is already less expensive to power a vehicle with electricity than with liquid fuel.) These systems also reduce demand on urban power grids, which helps to lower electricity prices at peak times and to free more capacity for vehicle charging.

Regulation. As advanced mobility services and technologies have penetrated cities, public officials at the city, regional, and national levels have responded by establishing an array of new regulations. These regulations reflect local priorities and stakeholder influences, which have not always favored integrated mobility. National or state-level regulations, such as tax breaks and incentives for EVs, have given a boost to integrated mobility in many cities, but local regulations, such as traffic rules that reserve bus-only lanes on city streets, could be even more consequential. To capture the benefits of integrated mobility, governments may want to consider creating regulations that encourage consumer-friendly developments while also promoting larger public goals, such as clean air and reduced congestion.

Individually, these trends will have a profound influence. As they unfold in tandem, their effects could be reinforced and multiplied (Exhibit 1). For example, AVs would reduce the cost difference between private car ownership and ride hailing, leading to greater use of shared mobility services. This would affect public transit: research shows that the more people use shared transportation, the more likely they are to use public transit. The adoption of both private and shared AVs should also increase mobility consumption, which would favor the adoption of EVs, since they are more economical than conventional cars when vehicle utilization rates are high.

How cities can manage the transition to integrated mobility

Broadly speaking, integrated mobility systems could improve the lives of city dwellers in several respects. One is environmental quality. As more urban journeys shift—to EVs, shared mobility services, and public transit—tailpipe emissions of carbon dioxide, nitrogen oxides, and fine airborne particulates in cities should go down. This will help reduce health problems, such as respiratory diseases, heart attacks, and premature births, that are aggravated by local air pollution.

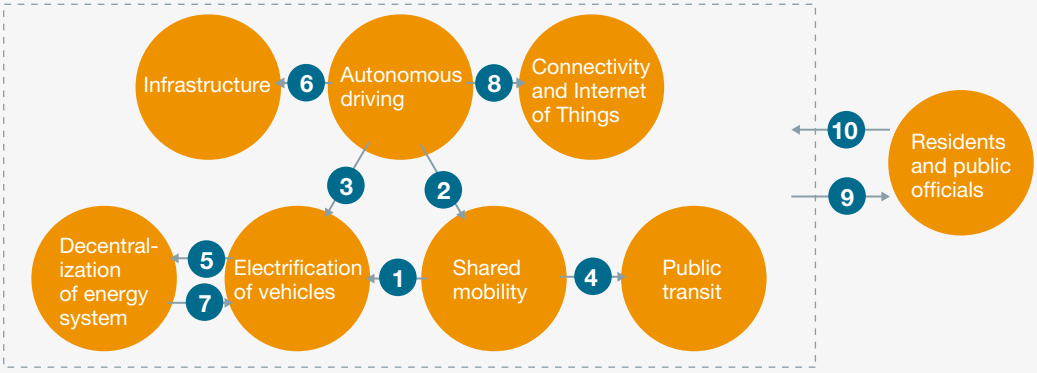
The well-being of citizens should also improve as smarter forms of urban transport prevent traffic accidents. The World Health Organization estimates that 1.25 million people died in road crashes in 2015. But a shift toward AVs would prevent many crashes, and the ensuing traffic slowdowns, by eliminating the human errors that cause the majority of accidents.

Then there is the problem of traffic congestion, which costs more than 1 percent of GDP globally. Congestion could be eased by connected AVs (which can boost the throughput of roads by driving closer together) and sophisticated traffic-management systems, such as dynamic tolling. Other benefits

Exhibit 1

Some emerging mobility trends will have reinforcing effects on one another.

Key mobility trends



Reinforcing effects from mobility trends

1. An uptake in shared mobility will accelerate electrification, as higher utilization favors the economics of electric vehicles.
2. Self-driving functionality could lead to a competitive proposition for shared mobility.
3. Self-driving vehicles, both private and shared, are likely to increase mobility consumption, in which case electric vehicles offer a lower total cost of ownership.
4. An uptake in shared mobility will affect public transit.
5. Electricity demand will surge while demand for fuel goes down; electric-vehicle production at scale could accelerate the drop in battery prices.
6. Self-driving and electric vehicles will require different charging and parking infrastructure, likely freeing up real estate in city centers (eg, street and garage parking) and making suburbs more accessible.
7. Increasing penetration of renewable energy could accelerate the financial and environmental attractiveness of electric vehicles.
8. Self-driving vehicles might accelerate the uptake of Internet of Things applications.
9. Mobility trends could impact residents in ways such as shifts in work formats (eg, taxi employees vs self-employed ride-hailing drivers), real-estate values, and cost and time spent in transit.
10. City authorities can shape their mobility agenda to capture fiscal, social, and environmental benefits through forward-thinking policy.

Source: Bloomberg New Energy Finance; McKinsey analysis

of advanced mobility include expanded access to mobility for citizens who either cannot drive or live far from transport hubs, and the extra free time people will gain from using AVs, shared vehicles, and mass transit more than they do now.

This is not to say that the transition to integrated mobility will have no drawbacks. Shifts in employment, for example, could occur as more AVs and EVs roll out, reducing the need for drivers and mechanics. City officials will also need to make sure that the cost of mobility is equitable, that increases in passenger and vehicle miles resulting from the use of AVs do not worsen pollution, traffic, or safety, and that public transit improves the mobility system as a whole. To maximize the benefits of the mobility transition and prevent changes from imposing significant costs on society, city officials will need to pay attention to several critical topics.

- *Mass transit.* Mass public transit will be essential to preventing congestion as more vehicles take to the road. But if mass transit is infrequent or slow or otherwise unsatisfactory, city residents might switch to low-cost, on-demand shared mobility services, thereby making traffic worse. Governments will need to make sure that mass transit remains a widely appealing alternative to private mobility. Cities might also consider encouraging people to use mass transit by subsidizing trips to and from transit hubs via shared services.

- *Land use.* Changes in the number and mix of city vehicles will have important implications for how land is managed. Consider one relatively mundane land-use issue: parking. Space for parking occupies up to 15 percent of public land in sprawling metropolitan areas. Shrinking vehicle fleets should make it possible to re-purpose some of that space. But some of it will still need to serve the mobility system. Turning some on-street parking spots into zones where passengers can climb into and out of vehicles might improve the flow of traffic. Cities can also consider managing their future development so that it does not result in inefficient land-use patterns.

- *Revenue.* Disruptive change to mobility systems could alter the tax bases of many cities. In the Seamless Mobility or Clean and Shared scenarios, extensive adoption of EVs could reduce revenues from fuel taxes by 20 to 65 percent unless taxation systems are reconfigured. On the other hand, connectivity and the IoT could be used to levy and collect new taxes for the use of infrastructure on a per-mile basis or for time spent driving in heavily traveled districts.

- *Infrastructure.* On average, new roads become congested within seven years. Building more roads may not be enough to accommodate the increases in passenger and vehicle miles that we have projected. Cities will need some mechanisms to lessen demand on roads, such as dynamic pricing. They can also apply new measures to increase capacity. Just as some areas now reserve lanes for low-emissions or high-occupancy vehicles, cities could set aside AV-only lanes so AVs can travel at higher speeds than they might in lanes where they would be surrounded by human-driven vehicles.

Envisioning the future(s) of urban mobility: Three scenarios

To help officials and planners anticipate the future of mobility, we have developed three scenarios. Each one is linked to a particular type of city, defined by levels of economic development, household income, and population density. By looking at today's conditions and modeling how mobility trends could play out in each scenario, we can offer city planners some ideas about which

trends might advance more quickly than others, and what the effects those trends could have on safety, traffic, and the environment. Our analysis suggests that the Seamless Mobility scenario for dense, developed cities would produce the most societal benefits, and that the Clean and Shared scenario for dense, developing cities and the Private Autonomy scenario for high-income, low-density cities would also have significant benefits (Exhibit 2).

Dense, developing cities

Densely settled cities in developing countries face a serious mobility squeeze. Congestion is severe, partly because roads and other forms of transport infrastructure are inadequate and in disrepair, and partly because traffic patterns are complex. Heavy air pollution takes a toll on the health of urban residents. And rapid population growth creates more demand for mobility by the day.

This set of conditions favors the emergence of what we call a Clean and Shared model for urban mobility, characterized by the following shifts:

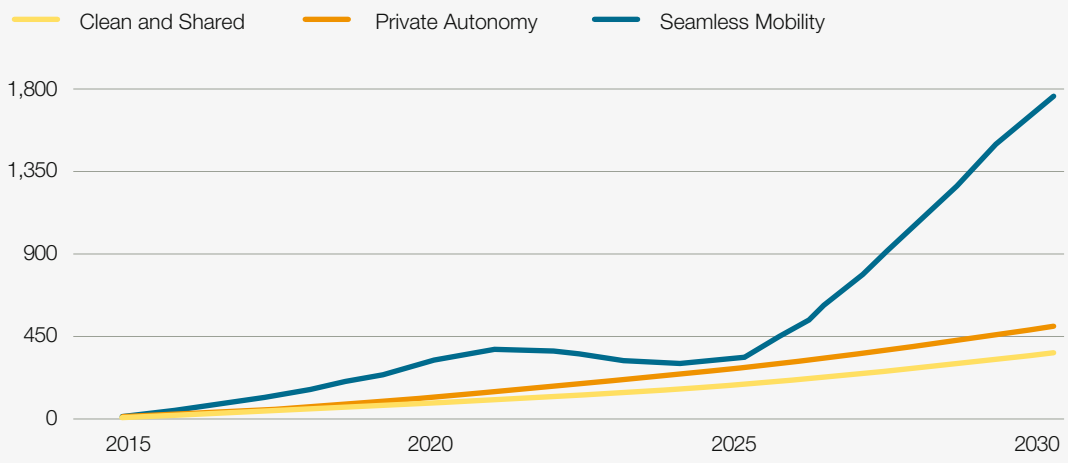
- *More infrastructure improvements.* The most valuable upgrades will be those that make it easier for people to get around using modes of transportation, such as shared mobility services and mass transit, that do not worsen traffic congestion, air pollution, or other pressing problems. Without better infrastructure, though, the benefits of integrated mobility could be curtailed.
- *The expansion of cost-effective forms of transport.* High-capacity public transport and shared mobility services will probably do the most to satisfy rising demand for mobility. We estimate that by 2030, shared light vehicles could account for a third of vehicle-miles traveled in an average-size city.
- *Little uptake of AVs.* Public and shared mobility services will likely favor vehicles driven by people, because labor costs are low, sustaining employment remains a priority for policy makers, and AVs might be stymied by bad roads and heavy traffic.
- *A shift toward EVs.* This would be enabled by advances in decentralized renewable-power generation (for example, rooftop solar) and motivated by concerns about air pollution. We project that approximately 40 percent of vehicles in developing, dense cities will be electric by 2030. These developments could create challenges for utilities, however, given the aging power grids in many dense, developing cities.

Some 15 developing, dense cities, including Delhi, Istanbul, and Mumbai, appear well positioned to make early transitions to integrated mobility, based on their population sizes, above-average GDP per capita, record of implementing public projects effectively, and urgent pollution and congestion problems.

The most valuable upgrades will be those that make it easier for people to get around using modes of transportation, such as shared mobility services and mass transit, that do not worsen traffic congestion, air pollution, or other pressing problems.

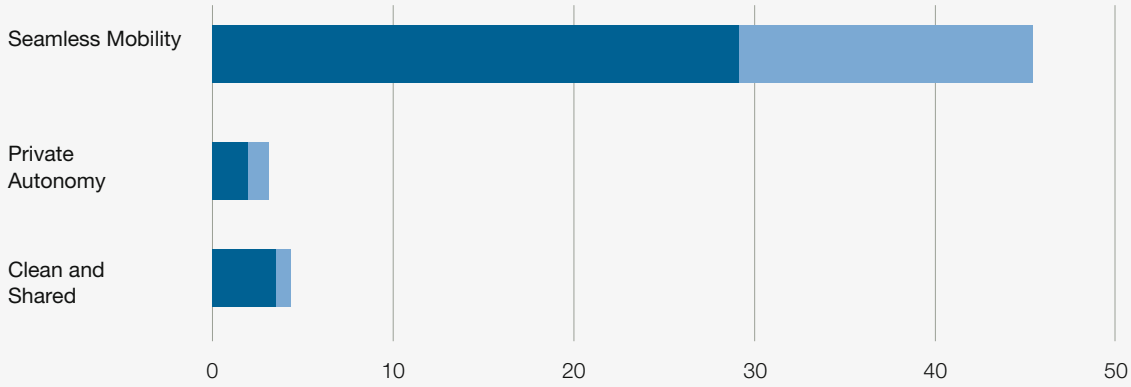
Exhibit 2 **Societal benefits are greatest under the Seamless Mobility scenario and substantial under the other two scenarios.**

Annual benefits per inhabitant, $



Cumulative benefits per city, 2015–30, $ billion

Dark shade indicates low end of estimated range; light shade indicates high end of estimated range.



Source: Bloomberg New Energy Finance; McKinsey analysis

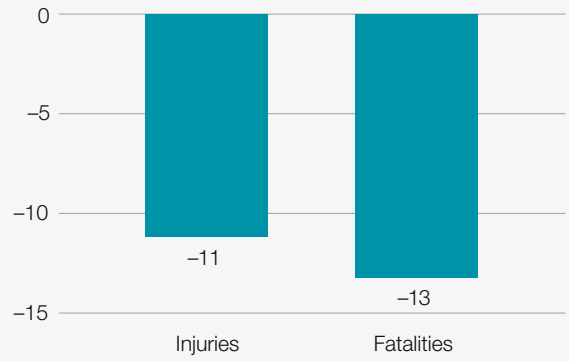
According to our forecasts, these cities stand to gain a lot from mobility advances. We estimate that a developing, dense city of average size could realize $600 million in annual societal benefits by 2030. From 2015 to 2030, these benefits would add up to between $3 billion and $4 billion, or $2,200 to $2,800 per resident. Nearly four-fifths of these benefits will result from improvements in safety (Exhibit 3).

High-income, low-density cities

In the sprawling, suburban-style municipalities of Europe and North America, residents rely mainly on private cars to get around. They also spend

Exhibit 3 **Improvements in safety account for most of the benefits of integrated mobility under the Clean and Shared scenario.**

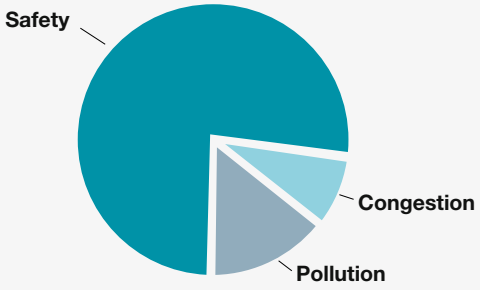
Decreases in injuries and fatalities caused by traffic accidents ...



... produce most of the societal benefits for dense, developing cities

$3 billion–$4 billion for an average city, 2015–30

$2,200–$2,800 per resident



Pollution decreases the most of any scenario—CO_2 by 35%, NO_x by 66%, and PM 2.5 by 81%[1]—even though the societal benefits are modest

[1] CO_2 = carbon dioxide, NO_x = nitrogen oxides, and PM 2.5 = fine airborne particulates.

Source: Bloomberg New Energy Finance; McKinsey analysis

considerable amounts of time on the road. Places like these are conducive to a Private Autonomy model, in which private cars still dominate the mobility mix but new technologies enable different uses. The main features of the Private Autonomy model are as follows:

- *Extensive uptake of AVs.* Most of these will be EVs. This shift would eliminate much of the work of driving, giving drivers more free time. It could also reduce traffic congestion, particularly if cities use infrastructure, such as dedicated AV lanes, to boost AVs' efficiency. On the other hand, as AVs make it more pleasant to travel by car, they could increase the demand for mobility and even encourage more low-density development.
- *More shared mobility.* These services (along with private AVs) could mobilize the elderly, the young, and other groups that cannot drive. They could also spare low-income groups the expense of owning cars. Greater access to mobility, along with the spread of AVs as described above, could cause a 25 percent increase in passenger miles by 2030, according to our forecasts.
- *Higher-impact public transit.* Efficient, flexible, and affordable mass transit, especially along major commuting arteries, will be needed to reduce traffic congestion—but will also face competition from private mobility services. Cities can explore ways of enhancing public transit so that it

remains an appealing alternative to private transportation and meets the mobility needs of people who depend on it.

As we see it, the Private Autonomy model is likely to catch on first in developed suburban cities with high per capita GDP, openness to new technologies, and a successful record of implementing public projects. Such places include Houston, the Ruhr area of Germany, and Sydney.

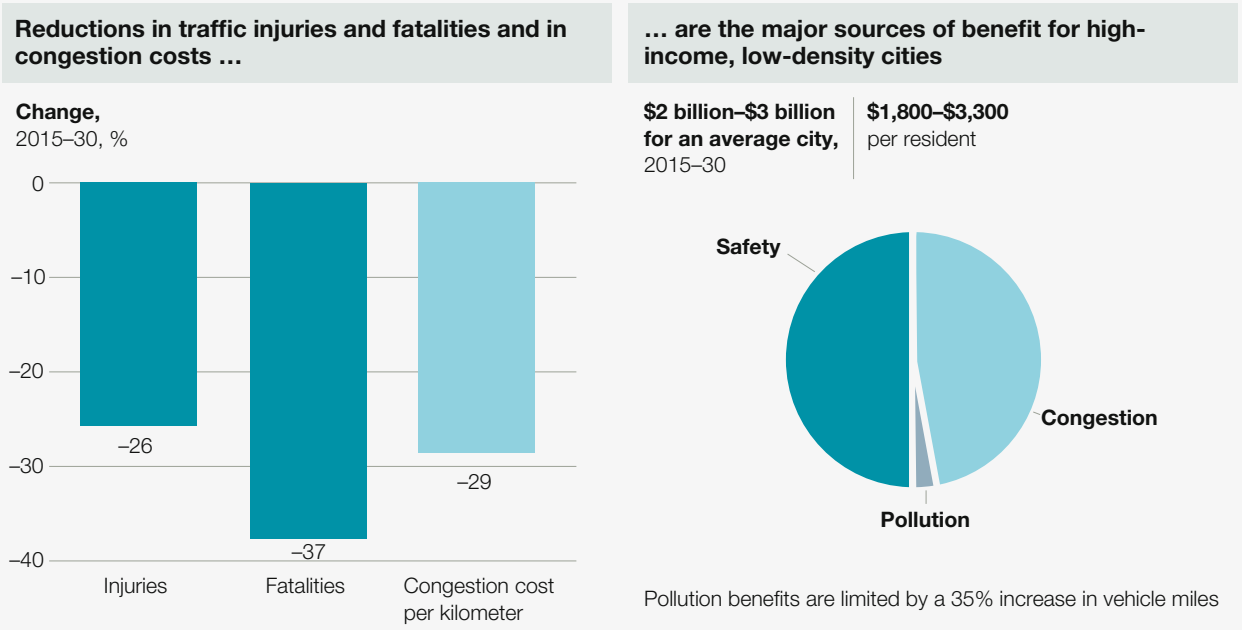
We estimate that a high-income, low-density metropolitan area of average size could realize $500 million in annual societal benefits by 2030—enough to boost its GDP by 0.9 percent. From 2015 to 2030, the benefits would amount to $2 billion to $3 billion for the city and $1,800 to $3,300 per resident (Exhibit 4).

About half of those benefits would come from improvements in passenger and pedestrian safety. Most of the remaining benefits would come from the avoided cost of congestion, assuming that connected AVs are widely used and cities attempt to maximize the efficiency of AVs. But environmental benefits would be small because of an overall rise in vehicle miles.

Dense, developed cities

Good-quality mass transit is the mainstay of urban mobility in high-income, densely settled cities. Some residents supplement their use of public transit with privately owned cars or shared vehicles. E-hailing services have also expanded quickly in these cities. The fact that advanced mobility services have won acceptance in dense, developed cities suggests that AVs and newer forms of shared

Exhibit 4 **In the Private Autonomy scenario, safety and congestion improvements account for nearly all societal benefits of integrated mobility.**



Source: Bloomberg New Energy Finance; McKinsey analysis

mobility, such as peer-to-peer car sharing, will also blend in well. The result would be what we term the Seamless Mobility model: a flexible, highly responsive system that moves residents quickly from place to place, sometimes by switching among modes of transport. The signature elements of this model are as follows:

- *Shared fleet of public AVs.* This fleet could provide many residents with affordable mobility. Using EVs is likely to be most economical. We expect people to travel up to 30 percent more, leading to an overall increase in vehicle miles. This could cause more traffic congestion unless the right planning measures are taken. However, the high utilization of shared AVs should reduce fleet sizes.

- *Integrated mobility platforms.* These will allow cities to gather data from connected vehicles and infrastructure about prices, schedules, and real-time conditions. Cities could use the data to make smarter improvements and give riders the ability to plan and pay for trips, even using multiple providers.

- *Enhanced public transit.* Mass-transit rail systems, walking, and cycling will still offer unrivaled speed and capacity for many journeys. New technologies will enable improvements, such as live updates on the arrival times of buses and trains. And a public AV fleet could offer a more convenient, lower-cost means of transport than buses running along fixed routes. Such changes may be needed to ensure that public transit remains viable.

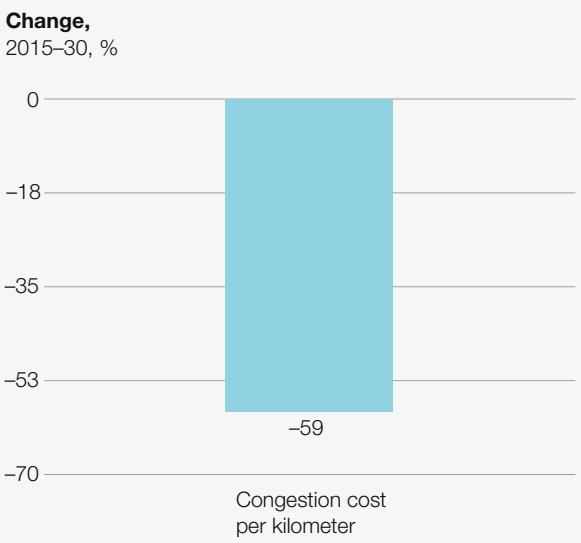
- *Catalytic urban planning.* Planners can alter the urban landscape to enhance mobility. This might involve instituting congestion pricing to prevent traffic slowdowns or demarcating low-emissions zones to speed the uptake of EVs, among other possible changes. If the number of vehicles in Seamless Mobility cities goes down, as we expect it to, and AVs can be directed to park outside city centers, this would reduce the need for parking space and free valuable land area for other uses.

Fifteen dense, developed metropolitan areas have the high-quality public-transit systems, infrastructure-investment capacity, and expertise with public projects that should help them advance toward a Seamless Mobility system before other cities. These pioneer cities include London, Shanghai, and Singapore.

We estimate that Seamless Mobility would yield the greatest social benefits of any integrated model: up to $2.5 billion per year by 2030 in an average city, enough to boost its GDP by as much as 3.9 percent. From 2015 to 2030, the cumulative benefit would be $30 billion to $45 billion, or $6,000 to $7,400 per resident (Exhibit 5). Most of the benefit will come from reduced congestion—provided that cities install infrastructure to let AVs and mass-transit vehicles operate efficiently. Safety and emissions will likely improve on a per-mile basis, but overall increases in mileage will mean that the absolute gains in safety and emissions will remain relatively modest, at just 15 percent of total benefits.

Exhibit 5 **Dense, developed cities would reap most of their benefits from reduced traffic congestion under the Seamless Mobility scenario.**

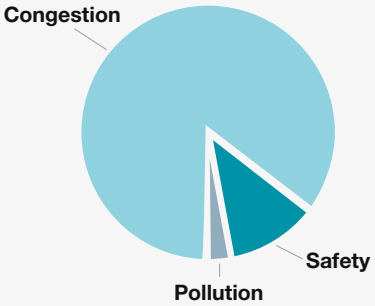
The cost of congestion falls more in this scenario than in any other …



… and accounts for the biggest share of societal benefits

$30 billion–$45 billion for an average city, 2015–30

$6,000–$7,400 per resident



Pollution and safety benefits are relatively small because of overall mileage increases

Source: Bloomberg New Energy Finance; McKinsey analysis

Advances in mobility are already affecting the transportation systems of major cities around the world, though not uniformly. Ride-hailing services, for example, have seen much faster growth than car sharing or EVs. Cities are mostly dealing with these trends in isolation. But cities can gain advantages by looking at the future of mobility in a comprehensive, integrated way that anticipates the dependencies and reinforcing effects among trends. This helps them understand the potential pace and impact of change, analyze trade-offs, and lay out helpful policy prescriptions. Cities that do this well stand a better chance of shaping the future of mobility in a way that balances benefits with potential adverse effects, and thereby improves the lives of their residents. ■

Download the report on which this article is based, *An integrated perspective on the future of mobility*, a joint report from Bloomberg New Energy Finance and McKinsey & Company, on McKinsey.com.

[1] For more, see Eric Hannon, Colin McKerracher, Itamar Orlandi, and Surya Ramkumar, *An integrated perspective on the future of mobility*, a joint report from Bloomberg New Energy Finance and McKinsey & Company, on McKinsey.com.

[2] For more, see Paul Gao, Hans-Werner Kaas, Detlev Mohr, and Dominik Wee, "Disruptive trends that will transform the auto industry," January 2016, McKinsey.com.

[3] *World urbanization prospects: The 2014 revision, highlights*, United Nations, Department of Economic and Social Affairs, Population Division, 2014, esa.un.org.

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Urban commercial transport and the future of mobility

Freight congestion is costly, for both business and the environment. There are ways to do better.

Shannon Bouton, Eric Hannon, and Stefan M. Knupfer

Cities are home to more than half the world's population. They dominate culture and politics and are the showplace of some of history's greatest achievements. On a day-to-day level, cities are the heart of the global economy, accounting for more than 80 percent of world GDP. Roads, rails, and other forms of transportation are the arteries that nourish that heart. When these become clogged, businesses, residents, and cities all suffer. And the economic costs are high—as much as 2 to 4 percent of city GDP.[1]

Last year, McKinsey and Bloomberg New Energy Finance published *An integrated perspective on the future of mobility*, which outlined four trends that are rapidly changing passenger transport: electrification, autonomy, connectivity, and sharing. The same four trends will, to a large degree, shape the future of commercial urban transport, which is the focus of the report on which this article is based.

The movement of goods is an essential part of economic life. Commercial vehicles (CVs) account for a significant share of traffic; they take up space and stop and start with infuriating inexactitude. With a billion more people projected to be living in cities by 2030, and with online and other commerce growing, freight volumes are projected to grow 40 percent by 2050. That means many more CVs on the road (exhibit). Accommodating them will be essential to ensuring the quality of future urban life.

In the report, we identify 20 approaches to reduce congestion related to commercial traffic that are realistic and flexible. The latter is important because cities are different, and solutions that will work in, say, Los Angeles might not be suitable for Beijing or Paris. But some of our solutions—individually and, better yet, combined—will work for all of them. By reducing the number of CVs on the streets, improving efficiency, and shifting the timing of deliveries, congestion and pollution can be greatly reduced. Businesses will lower their delivery costs; consumers will see greater convenience; and cities everywhere will, literally, breathe easier.

Emerging technologies, such as electric vehicles (EVs), droids, and autonomous ground vehicles (AGVs), will lighten the burden of commercial traffic in congested areas. Even better, there are a number of business models and practices, such as parcel lockers and night deliveries, that have already proved themselves. With a regulatory nudge here and a little creative thinking there, scaling up implementation of these could start tomorrow.

One big problem, six powerful solutions

The commercial vehicles that are on the road today typically generate higher nitrogen oxide (NOx) emissions than passenger cars.[2] Also, many of them use diesel engines; compared to gasoline engines, these emit much higher concentrations of particulate matter, a pollutant harmful to health. The consequences can be dire. The World Health Organization estimated that there were three million premature deaths in 2014 due to outdoor air pollution, to which automotive emissions are an important contributor.[3] CVs also contribute to urban traffic woes beyond their numbers. While trucks accounted for 7 percent of urban travel in the United States in 2015, for example, they accounted for 18 percent of congestion.[4] Meanwhile, the demand for deliveries is rising. By 2025, around a quarter of consumers will expect their deliveries the same day, or faster. That will mean even more CVs will be needed.

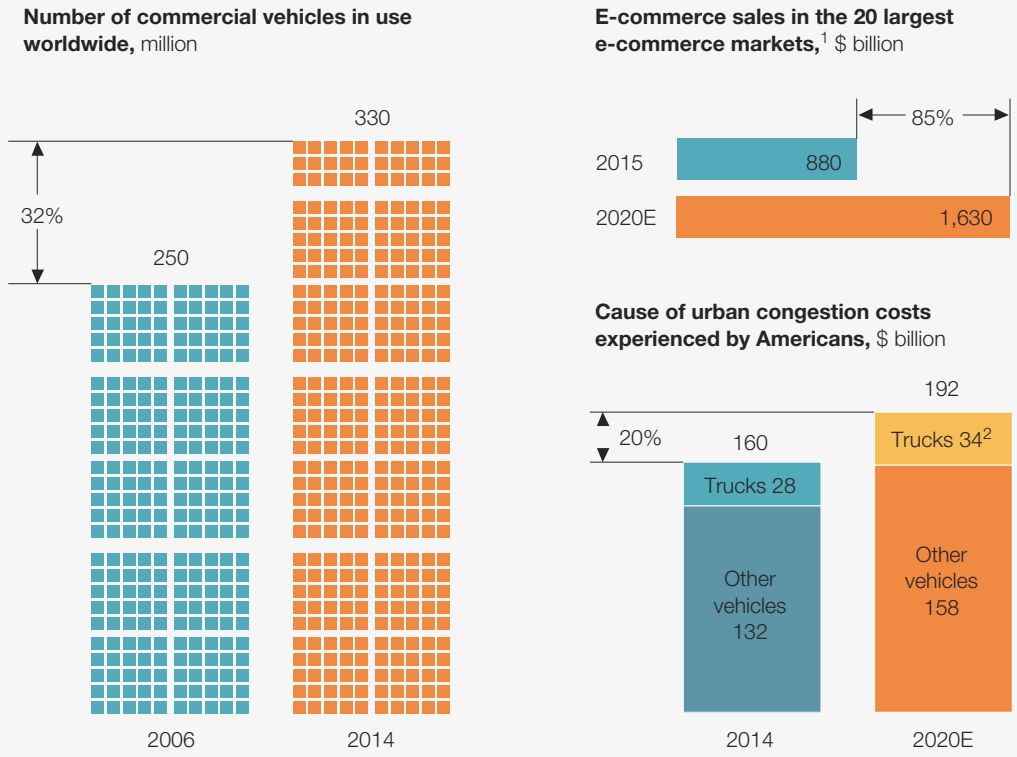
To improve urban commercial transport, we have identified solutions, spread across the delivery value chain from the location of the supplier to the final destination of the receiver. For each one, we evaluated its financial value, social value, and feasibility, given current technology and infrastructure. Of these, several look particularly promising.

First, there are urban consolidation centers (UCCs). UCCs are locations, typically on the outskirts of cities, where deliveries are brought, sorted, and then dispatched. Goods from multiple suppliers can be consolidated into fewer shipments, making it possible to optimize loads and truck sizes, thus cutting down on the number of trips and vehicles required. While UCCs have been around for years, success has been spotty. The business case is becoming stronger, however, as new technologies make implementation easier and the expansion of e-commerce makes it more urgent. In a city like New York, we estimate that the use of UCCs could save companies 25 percent on delivery costs per parcel, while reducing miles driven by almost half.

Second, while cities never sleep, when it comes to allowing night deliveries, most of them take a nap, restricting the practice largely because of concerns about noise. It is possible to train people to work more quietly and to require shippers to attach noise-canceling equipment to delivery vehicles, as Barcelona did in a pilot project that has gone national. By using night deliveries, suppliers can drive bigger trucks on less congested roads; cities would see less peak-hour traffic and lower vehicle emissions.

Exhibit

Easing the burden of commercial traffic in cities will require new technologies, new business models, and new regulations.



[1] Adjusted for inflation.
[2] Assumes same split as 2014 of congestion costs between trucks and other vehicles.

Source: "Number of passenger cars and commercial vehicles in use worldwide from 2006 to 2014," Statista, 2017; *2015 Urban mobility scorecard*, INRIX and Texas A&M Transportation Institute; McKinsey analysis

The solutions make sense in and of themselves. The most powerful effect, however, is when two are more are used together, multiplying their respective strengths. Using a fleet of EVs to supply businesses from UCCs, at night, optimizes vehicle utilization, speeds up delivery, and minimizes noise and pollution. In a city like New York, this triple play could cut costs per parcel by 35 percent, eliminate vehicle emissions if the whole fleet is electric, and require one-third fewer CVs.

What matters, then, is selecting the right options. Different combinations will work for different kinds of cities, different customers (B2B versus B2C), and different time windows (same-day/instant versus multiday delivery). For cities, labor costs and population density will, to a large extent, determine what solutions will work best and how fast they can be adopted. We therefore considered three broad urban archetypes: developed, dense cities such as London or Singapore; developed, suburban cities

such as Los Angeles or Sydney; and developing, dense cities such as Beijing or Mexico City.

Developed, dense cities are likely to be at the forefront of change for freight mobility, because governments and companies in these cities can afford to invest in urban planning and cutting-edge technology. Moreover, high wages favor the business case for technology-intensive solutions. Autonomous vehicles, for example, likely will be expensive initially and thus most worthwhile in places with high labor costs.

Developed, suburban cities, where sprawl is the norm, will need to consider a different set of solutions. Because of the greater distances between points of delivery, UCCs and parcel lockers might not be as effective as they are likely to be in denser cities, where it is possible to site them within walking distance of many people. But other approaches, including electrification and night delivery, are still promising. In the more distant future, drones could play a role delivering small and low-weight parcels in sprawling cities, because they can find places to land.

Finally, in developing, dense cities like Beijing, Mexico City, and Mumbai, our analysis showed that deliveries require twice the mileage on average and result in up to two and a half times higher emissions than in developed, dense cities. Due to local road conditions and low labor costs, these cities are likely to be slower to adopt technologies such as AGV lockers. But load pooling and parcel lockers could work well. Combining the right solutions could bring significant benefits—cutting delivery costs 35 percent and vehicle emissions 65 percent.

These 20 approaches, both alone and in combination, can benefit urban economies, the environment, and society. But for five sectors in particular—retail, logistics, the public sector, automotive, and energy—changes in urban commercial transport will challenge their existing revenue and operating models. As the use of online commerce rises, for example, retailers that adopt new delivery solutions could strengthen their competitive advantage,[5] while decarbonizing their supply chain. Automotive companies will face increasing demand for lower-emission (and eventually autonomous) CVs. Innovation and partnerships beyond the automotive sector will be important.

Looking ahead

Improving the way that people and goods move will require new technologies, new business models, and new regulations. But it will also need new mind-sets—among businesses, governments, and consumers—to imagine a future that is different and better than the present.

Developed, dense cities are likely to be at the forefront of change for freight mobility, because governments and companies in these cities can afford to invest in urban planning and cutting-edge technology.

In our 2016 report, *An integrated perspective on the future of mobility*, we explained why all this matters: "Getting mobility right could be a significant competitive advantage for cities. This shift can help clear the air of pollution and reduce traffic deaths. It is an opportunity to improve the quality of life—day in, day out— for billions of people." That argument applies just as strongly, if not more, to commercial transport.

We recognize that making the transition we describe will not be easy. However, we believe that it is beginning to happen—and that the transition could be even faster for CVs. These are used more intensively, which could help to accelerate the introduction of new technologies.

The need for change is urgent. With many more vehicles and people likely to hit the roads in future decades, the time to start preparing is now. ■

Download *An integrated perspective on the future of mobility, Part 2: Transforming urban delivery*, the report on which this article is based, on McKinsey.com.

[1] Shannon Bouton, Stefan M. Knupfer, Ivan Mihov, and Steven Swartz, "Urban mobility at a tipping point," September 2015, McKinsey.com.

[2] Emissions from new commercial vehicles (CVs) are much lower, even surpassing passenger vehicles. However, given the current age of the fleet and the more intense usage patterns of CVs, they still contribute more emissions overall.

[3] "WHO releases country estimates on air pollution and health impact," World Health Organization, September 27, 2016, who.int.

[4] *2015 Urban mobility scorecard*, Texas A&M Transportation Institute, August 26, 2015, mobility.tamu.edu.

[5] J.H.R van Duin et al., "Understanding financial viability of urban consolidation centres: Regent Street (London), Bristol/Bath, & Nijmegen," *Transportation Research Procedia*, 2016, Volume 16, pp. 61–80.

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Public–private collaborations for transforming urban mobility

Partnerships that let cities take advantage of new mobility services should make urban transportation more accessible, affordable, and efficient.

Shannon Bouton, Diego Canales, and Elaine Trimble

Ride-hailing systems, car- and bicycle-sharing networks, trip-planning apps, and other innovative, technologically sophisticated mobility services are winning users in cities around the world. The positive reception these services have received suggests that city dwellers need convenient, flexible transport options at a range of prices—and that existing private and public mobility services offer fewer options than people might like.

Public transit is indispensable for moving people around quickly, preventing traffic congestion and accidents, limiting pollution, and freeing land for uses more valuable than parking space and roadways. But the challenges facing public-transit systems are well known: rising costs, funding constraints, increases in ridership, and aging infrastructure, among others. Private transportation services have long complemented public-transit systems—informal minibus services are ubiquitous in the cities of developing countries—but can exacerbate other urban challenges such as safety and environmental quality.

As new mobility services proliferate, cities have opportunities to combine them with public-transit systems in ways that will improve the lives of city residents. Yet it isn't obvious how cities can ensure that these services will properly meet their residents' needs. The right mobility formula depends on a complex set of considerations affecting passengers (access, convenience, cost), transit agencies (finance, regulation), and cities as a whole (employment, environmental impact).

So cities around the world have begun to integrate new private mobility services into their transportation systems through partnerships. While it's too soon to tell whether these partnerships are succeeding, they do point toward possibilities that other cities may wish to consider. A new report from the Coalition for Urban Transitions,[1] *Connected urban growth: Public–private collaborations for transforming urban mobility*, aims to help cities evaluate these options. The report summarizes the development of new mobility partnerships, identifies potential applications for new mobility services in public-transit systems, and models the economic and environmental impact of those applications. The findings suggest that cities and their residents stand to benefit greatly from the features new mobility services have introduced into urban transportation systems.

Trends in new mobility services and public–private partnerships

Swelling demand for low-cost, high-quality urban transportation has led to more than 15 years of sustained increases in the ridership of public-transit systems. These conditions have not only put considerable stress on them but also created abundant opportunities for entrepreneurs. New mobility services—capitalizing on advances in technologies such as mobile communications, cashless payments, remote monitoring, data collection, analytics, energy storage, and artificial intelligence—have emerged to offer urbanites a wider array of transport choices than ever before. These services can be grouped into the following four categories:

- *Shared mobility:* Transportation services, including those that rely on private vehicles, for which access or ownership is shared among people financially or physically
- *Product innovation:* Next-generation vehicles and transportation equipment with designs and features that have been engineered for better performance through data analysis
- *Consumer experience:* Information services that combine timetables, fares, and other kinds of information on transportation options and make them available to users in real time, according to their preferences
- *Data-driven decision making:* Services that aggregate data from multiple parts of transportation systems and analyze these data, often using advanced computational methods, to improve the management, planning, and operation of transportation systems

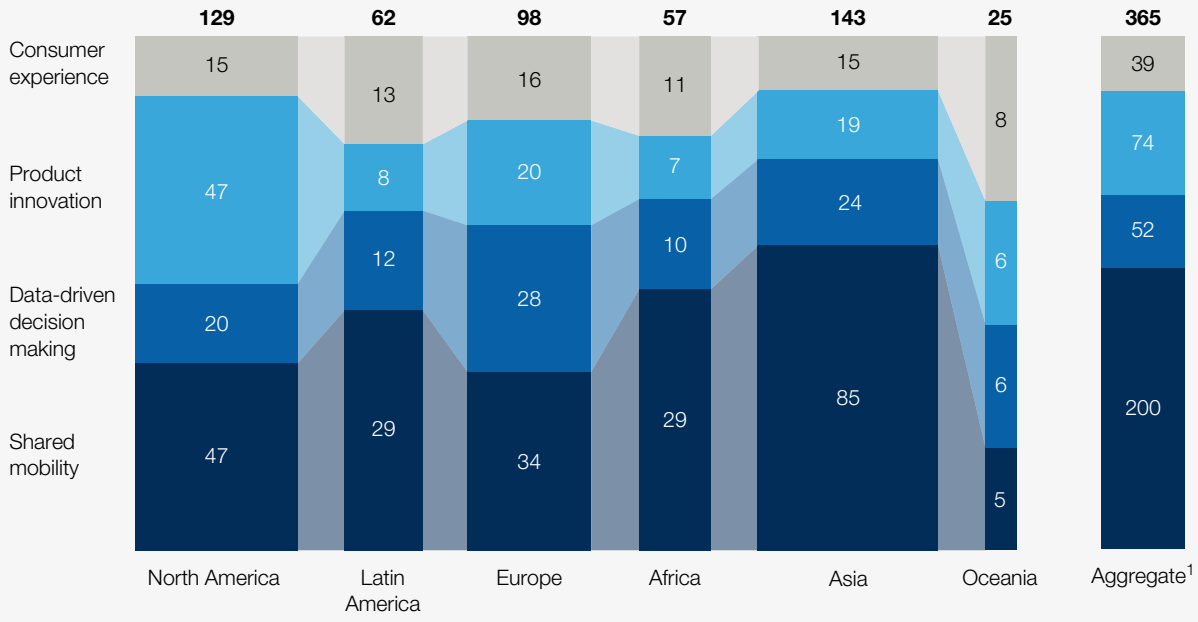
Shared-mobility services account for more than half of all new mobility start-ups around the world, and homegrown providers have cropped up in every region (Exhibit 1). E-hailed motorcycle-taxi services have proved popular in Africa, for example, while India's city dwellers have embraced on-demand shuttle services. Product-innovation companies, which are concentrated in North America, mostly focus on developing self-driving vehicles and electric vehicles. Start-ups that provide information to passengers have flourished as many cities opened access to data about their transit systems. And mapping, navigation, and traffic-monitoring applications dominate the market for data-driven-decision services.

New mobility services have encountered a variety of regulatory environments and competitive situations as they began to operate in cities around the world. Municipal authorities, in turn, have responded in different ways. Certain new mobility services, especially on-demand rides, do not fit neatly within regulatory frameworks developed for more traditional private and public transport. Some city authorities have imposed restrictions on new mobility services or prohibited them outright. Others have taken a more permissive approach to them, choosing to observe how they affect public

Exhibit 1

Homegrown providers of shared-mobility and other innovative transport services have cropped up in every region.

Number of new mobility start-ups



[1] The aggregate number of service providers in each category is less than the sum of the regional counts of service providers because many service providers operate in multiple regions. For the aggregate column, each of these service providers is counted only once.

Source: AngelList; CrunchBase; Coalition for Urban Transitions analysis

transit and existing private-transport providers before deciding what to do.

In 71 cities, the authorities have arranged partnerships with new mobility service providers.[2] These partnerships are diverse, but several common types stand out. One aims to develop consumer-experience services that let passengers easily plan multimodal journeys and purchase the tickets they require. Another common type connects transit agencies with providers of on-demand mobility services: agencies replace bus routes that have the highest fixed costs with on-demand cars or minibuses to give riders greater convenience and flexibility. A third type—first-mile/last-mile applications—uses shared mobility services to provide short trips to and from public-transit stations.

The partnerships between cities and new mobility services point to potential benefits for both cities and their residents. At this early stage, the outcomes of these partnerships have not yet been widely reported. Assessing their implications requires simulating the effects they might have under certain conditions.

Modeling applications of new mobility services for public-transit agencies

To help cities deepen their understanding of what they can achieve by partnering with new mobility services, the Coalition for Urban Transitions modeled the economic and environmental effects of three potential

applications for these services. The three applications reflect the common types of partnerships between cities and the new mobility services described in the previous section (Exhibit 2).

London, Mexico City, and San Francisco were chosen as the settings for the coalition's modeling exercise because they offer a variety of spatial layouts, transit-system characteristics, ridership levels, household-income distributions, and passenger demographics (including smartphone penetration). All of these factors make the results relevant to a range of cities around the world, including those in the Global South. The cities also publish enough data about their transit systems to model the three mobility applications using real-world information.

Dynamic trip-planning and ticketing services

A dynamic trip-planning and ticketing service enables city dwellers to use real-time information to map out urban journeys involving one or more modes of transportation and to purchase all the

Exhibit 2

Three new mobility applications have the potential to make public transportation more attractive and competitive.

Application 1: Dynamic trip-planning and ticketing services

Purpose: Encourage city dwellers to take multimodal journeys by enhancing access to information and simplifying ticket purchases

Benefits: Increased transit ridership; lower environmental impacts

Mechanism: Technology platform, accessed with a mobile app, that integrates information and processes payments and tickets

Partnership model: City transit agencies use third-party technology or contract with service providers

Application 2: On-demand minibuses

Purpose: Streamline mass-transit systems by matching service levels more closely to demand

Benefits: Lower operating costs; easier access to transportation; lower environmental impacts

Mechanism: Fleet of electric minibuses, hailed using a mobile app, replaces underused fixed-route services

Partnership model: City transit agencies use third-party technology or contract with service providers to run fleets

Application 3: First- and last-mile ridesharing

Purpose: Broaden access to transportation for underserved city areas

Benefits: Increased transit ridership and utilization; lower system operating costs; expanded transit access

Mechanism: Subsidies paid to passengers for on-demand shared rides from areas with poor transit access to transit hubs

Partnership model: City transit agencies contract with ride-hailing companies to provide shared rides

Source: Coalition for Urban Transitions analysis

necessary tickets at once through an app. Studies have shown that enhancing the convenience for riders through such dynamic platforms increases overall public-transportation use by almost 2 percent. Public-transit agencies can also analyze the data such services collect about the activities of users—in line with applicable data-privacy laws—to identify potential improvements for their systems. Dynamic trip-planning and ticketing services are already available in several cities. Los Angeles, for example, partnered with Conduent to develop Go LA, an app to plan and pay for trips using various modes of transportation, including public transit, personal vehicles, bicycles, and new mobility services. Whim is an application that offers dynamic planning and ticketing for trips using public transit, shared cars, and taxis in and around Helsinki.

In the models the Coalition for Urban Transitions created for London, Mexico City, and San Francisco, dynamic trip-planning and ticketing services that transit agencies developed in-house reduced their operating costs enough to pay back the up-front investments within as little as two years. The coalition also calculates that such services would increase kilometers traveled by public transport and decrease kilometers traveled by private vehicles. By 2020, such a citywide modal shift would cut annual greenhouse-gas emissions in the three cities by 500,000 metric tons—Mexico City would benefit most—and reduce their total transport emissions by up to 6 percent.

On-demand minibuses

Most modes of public transportation offer little day-to-day operational flexibility. A bus, for example, travels on fixed schedules along predetermined routes to established stops and can hold only a certain number of passengers. On-demand mobility services would let cities change the routes and capacity of certain transit modes according to fluctuations in passenger demand. Companies such as Ridecell and TransLoc offer routing platforms that can help transit agencies run their own on-demand minibus fleets. Transit agencies have also partnered with companies to introduce on-demand services.

The Coalition for Urban Transitions modeled the effects of replacing underperforming bus routes with on-demand minibus services covering the same areas. The service would pick up passengers at designated points in response to requests submitted through smartphones. Algorithms would optimize the routes minibuses travel between the requested pickup and drop-off points and adjust the number of minibuses in use as demand varied.

The coalition's economic analysis indicates that an on-demand minibus service replacing four under-performing bus routes in Greater London would break even after three to four years and generate profits for the public-transit agency thereafter. The coalition's environmental projections, which covered all three cities, suggest that minibuses would have higher capacity-utilization rates and travel shorter distances than fixed-route buses do. These improvements would cut emissions of greenhouse gases, airborne particulates, and nitrogen oxides even if the minibuses ran on gasoline. Deploying electric minibuses would reduce emissions by more than 66 percent in all three cities and by more than 90 percent in some cases.

First- and last-mile ride sharing

Studies conducted in the United States show that the use of public transit drops by up to 90 percent when passengers must walk more than half a mile to the nearest transit stop. To counter this effect, cities have experimented with bike-sharing and car-sharing systems, as well as extended bus routes, and used other methods to shorten the time passengers travel to and from public-transport stops. Ride-sharing services are now enabling additional new responses to this first-mile/last-mile problem.

One of the most practical and promising solutions is to cover part of the cost that public-transit passengers pay for ride-sharing services that shuttle them on short trips to or from public-transport stops.

Deploying electric minibuses would reduce emissions by more than 66 percent in all three cities and by more than 90 percent in some cases.

The point is to encourage more people to use public transport instead of personal motor vehicles for most of their journeys. This approach is particularly relevant for cities where some neighborhoods have such limited access to public transport that residents mostly choose either to reach transit stations by driving their personal vehicles or to drive those vehicles for the entire journey. Several programs of this kind are up and running: one town in the Eastern United States expects to save taxpayers $5 million to $10 million over 20 years by subsidizing shared rides instead of building more parking lots near train stations.

The coalition's model of a program to serve the residents of San Francisco neighborhoods with limited transit access suggests that the program could pay for itself if low-income households received limited subsidies for shared rides. Increasing the amount of the subsidy and expanding the program to additional households would require the transit agency to spend more. If the program encouraged people to use mass transit instead of a personal motor vehicle by helping them reach public-transport hubs in shared vehicles, the environmental benefits for each city could be significant.

As demand for urban mobility continues to increase, public-transit systems, roadways, and other forms of infrastructure will come under greater financial and physical strain. Entrepreneurs are creating new mobility services, which are giving cities additional new options to augment or support public transit.

None of this will be straightforward, but the effort should be worthwhile. Partnerships that let cities take advantage of new mobility services should make urban transportation more accessible, affordable, and efficient—improvements that all city dwellers should welcome. ■

Download *Connected urban growth: Public–private collaborations for transforming urban mobility*, the report on which this article is based, on McKinsey.com.

[1] McKinsey is working with the Coalition for Urban Transitions, an initiative of New Climate Economy, to understand the economic case for better urban development that can also enhance national economic, social, and environmental performance.
[2] As of August 2016.

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A strategic approach to climate action in cities: Focused acceleration

Prioritizing efforts in four areas could help cities achieve 90 to 100 percent of the emissions reductions needed by 2030.

Shannon Bouton, Michael Doust, Simon Hansen, Stefan M. Knupfer, Malcolm Shield, and Cynthia Shih

There is now widespread recognition in the international community that the commitments made by national governments under the Paris Climate Agreement in 2015 cannot be achieved without concerted action by cities. Fortunately, many mayors have shown strong commitment to tackling climate change and a willingness to collaborate to achieve this goal. C40 Cities, a network of mayors of the world's megacities committed to addressing climate change, responded to the Paris Agreement by publishing an analysis—*Deadline 2020*[1]—of the emissions-reduction pathway their cities would need to achieve to play their part in keeping global average temperature rise within "safe" limits (below 1.5°C). As individual C40 cities now increase the ambition of their climate plans accordingly, our new report, *Focused acceleration: A strategic approach to climate action in cities to 2030*, takes that work a stage further by analyzing the biggest opportunities for cities to accelerate the reduction of their carbon emissions.

While the technologies and expertise exist to limit the temperature increase to 1.5°C, the challenge is still formidable. With cities already stretched to meet multiple competing priorities, city leaders must determine the critical actions that can change their current emissions trajectory and work proactively with their stakeholders to build and invest in the infrastructure and incentives needed to make significant progress toward those actions. That means prioritizing actions around initiatives

that catalyze systemic change. For the report, C40 Cities has partnered with the McKinsey Center for Business and Environment to quantitatively assess the biggest opportunities for emissions reduction and what they will mean for different types of cities around the world.

We started with the more than 450 emissions-reduction actions identified in *Deadline 2020* and prioritized 12 opportunities across four action areas that have the greatest potential in most global cities to curb emissions and put cities on a 1.5°C temperature-rise pathway through 2030. Our analysis recommends that cities pursue a strategy of "focused acceleration" within these 12 carbon-reduction opportunities. This recommendation is based on a proven management approach that more progress can be made by concentrating on a small number of high-value opportunities than by spreading efforts over hundreds of potential actions. Success will require cities to find creative ways to tackle operational challenges, including aligning stakeholders, supply chains, procurement practices, and financing.

By implementing a focused-acceleration approach, cities could achieve 90 to 100 percent of their 2030 emissions targets and build the knowledge and foundational capabilities needed to reach net zero carbon by 2050 (exhibit). At the same time, the incremental investment required to achieve 2030 emissions targets is significant: roughly $50 to $200 per metric ton of CO_2 equivalent. However, all opportunities provide a positive return on investment in the mid to long term, whether through direct cash flow for investors (for example, in the case of renewables and efficiency improvements) or broader boosts to economic activity in the city (for example, transit-oriented development). For many opportunities, up-front investments are paid back within five to ten years.

This article, an edited extract from the full report, provides a short overview of the four action areas—power, buildings, mobility, and waste management. It also offers a high-level look at how cities may differ in their approach to capturing these opportunities.

Decarbonizing the electricity grid

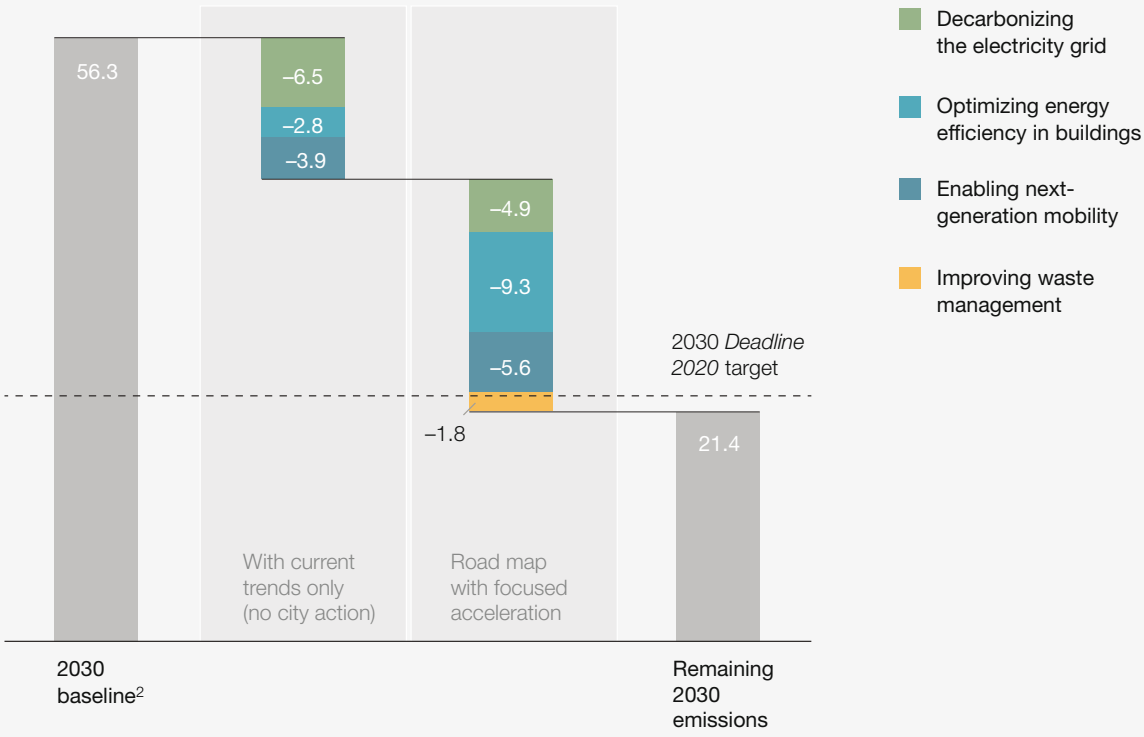
Cities—and the world—cannot achieve a 1.5°C trajectory for temperature increase without a massive expansion of large-scale renewable power generation, known as "decarbonizing the grid." While cities may believe they have little influence over the grid mix, in fact, they often represent a major portion of any local electric utility's customers, potentially giving them significant leverage to shape the emissions profile of the electricity consumed within their metropolitan area. Still, capturing this opportunity will not be easy, and cities cannot do it alone. Utilities and regulators must play a central role in ensuring that the overall mix of renewables is appropriately balanced at a system level and that critical components such as energy storage are in place to ensure grid reliability. Nevertheless, cities have an essential role to play by setting clear decarbonization goals, aggregating demand for renewables, promoting energy efficiency, and shifting more urban energy consumption to electricity (especially in transportation and heating). Through focused acceleration, and close collaboration between utilities and regulators, cities could achieve a grid mix of 50 to 70 percent renewables (specifically, solar and wind, balanced with other zero-emission generation sources such as hydro) by 2030 depending on local resource characteristics and market and regulatory structure. This level would capture 35 to 45 percent of the total emissions reductions needed in that time frame at a cost as low as $40 to $80 per megawatt-hour.[2]

Optimizing energy efficiency in buildings

In buildings around the world, heating and cooling account for 35 to 60 percent of total energy demand and, on average, produce nearly 40 percent of emissions. Again, reducing energy use and emissions from buildings will not be easy; it will require significantly more focused effort than most cities

Exhibit **Cities that use a strategic approach targeting 12 opportunities could achieve their 2030 emissions targets.**

Emissions in 2030,[1]
metric tons of CO_2 equivalent (annual), average of 6 illustrative city types



[1] Figures may not sum, because of rounding.
[2] Assumes technologies and policies remain fixed from 2015.

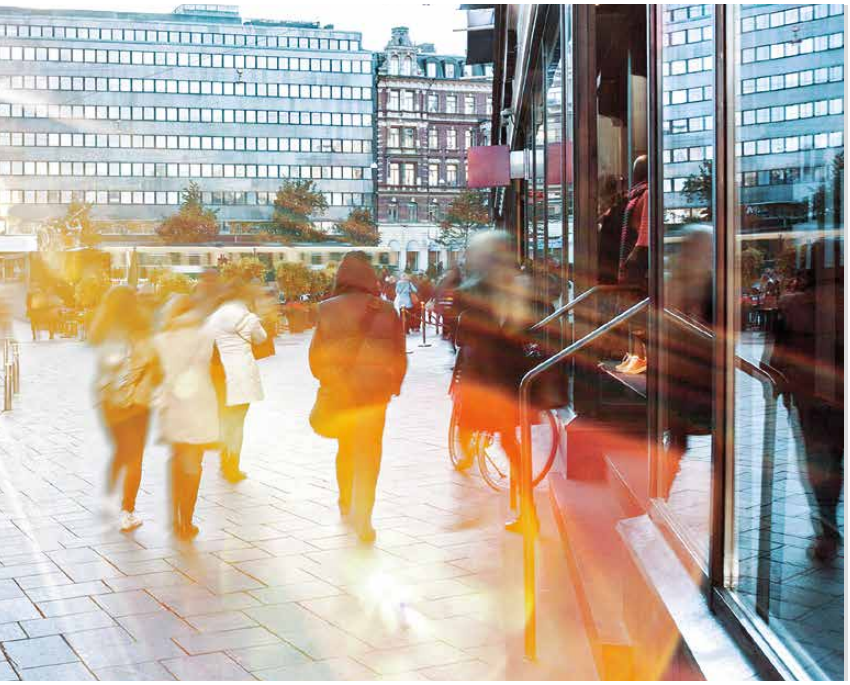
Source: McKinsey analysis

have currently undertaken. However, multiple decades of pilots and success stories suggest that focused acceleration in this space can pay off. Several opportunities based on widely available technologies offer the potential to significantly reduce emissions from buildings. These include raising building standards for new construction, retrofitting building envelopes, upgrading heating, ventilation, and air-conditioning and water-heating technology, and implementing lighting, appliance, and automation improvements. While cities generally have more influence over this area than they do many others, progress will still require city leaders to work closely with building owners, both residential and commercial; real-estate developers; and building occupants. This action area is particularly important: since building stock tends to turn over only every 30 to 50 years, getting it wrong will lock in emissions, and potential costs, for decades. In contrast, getting it right will reduce energy costs—as well as provide more resilient, comfortable spaces to live, work, and play—for city residents through 2050 and beyond. Focused acceleration in this action area can close 20 to 55 percent of the gap between current emissions trends and 2030 abatement targets, depending on

the local climate and population growth of the city, at an average cost of $20 to $100 per metric ton of CO_2 equivalent.

Enabling next-generation mobility

City leaders now have access to an unprecedented range of mobility options. Multiple reinforcing trends in mobility and land-use planning are already transforming the experience of getting around in cities. The key to reducing emissions through these trends is to ensure that all residents have access to a variety of attractive, affordable low-carbon mobility options. The development of complete, compact communities that meet the mobility needs of residents and businesses is foundational to building stronger cities and enabling next-generation mobility. Transit-oriented development implemented today promotes smart densification through better land-use planning and lays the foundation for more multimodal transport and reduced carbon emissions in the long term. Initiatives to encourage walking and cycling within cities' existing land-use patterns as well as targeted enhancement of mass transit, such as the introduction of bus rapid transit (BRT) on main arteries, can collectively start to lower emissions in the short term. In addition, cities can accelerate emissions reductions by enabling the uptake of next-generation vehicles, which take advantage of new electric, shared, connected, and autonomous technologies, and by optimizing freight transport and delivery. Focused acceleration in this action area can contribute emissions reductions equal to 20 to 45 percent of 2030 targets, depending on urban income levels and population density. In the process, these efforts can increase GDP by reducing congestion and transforming the quality of life for residents by alleviating local air pollution and improving equitable access to mobility options.



Improving waste management

Cities can tackle waste emissions in a resource-effective way by adopting a "highest and best use" approach: first reducing waste upstream; then repurposing as much useful finished product as possible; then recycling, composting, and otherwise recovering materials for use; and, finally, managing disposal to minimize emissions of any remaining organic matter. Methane emissions from waste have 86 times the near-term global-warming potential of carbon dioxide, making it an urgent priority for preventing the worst effects of climate change. And reducing waste has an outsize impact on the full life-cycle emissions of consumption. Innovative models for waste management can help cities rethink their need for traditional collection and disposal infrastructure, and forward-looking cities are already going further and planning the transition to a fully "circular economy," shifting resource consumption from linear flows to continuous reuse. Depending on the starting point of existing waste-management services, as well as the composition of waste, focused acceleration can achieve up to 10 percent of the emissions reductions needed by 2030, as well as provide numerous benefits to local resource resilience and health.

City leaders now have access to an unprecedented range of mobility options. Multiple reinforcing trends in mobility and land-use planning are already transforming the experience of getting around in cities.

How different cities can achieve their carbon-reduction targets

To demonstrate the scale of action needed to achieve 100 percent of a city's emissions-reductions target by 2030 through focused acceleration, we have modeled sample road maps for six illustrative city types. These road maps show where different cities could choose to focus and why, along with the critical enablers needed to achieve zero carbon by 2050. As important, these road maps demonstrate the practical impact of focused acceleration across different types of cities.

For example, a "Large, Middle-Income, Semi-Dense City" could focus on accelerating highly visible initiatives to help residents experience how a low-carbon future looks and feels in everyday life. For such a city, the installation of solar power on municipal and suitable private rooftops as well as at community sites would be good demonstration projects. Policies to bolster population density in select districts, such as transit-oriented development, new BRT routes, and cycling-friendly street design, could increase density by 6 percent and improve average walkability by 2030. The city might also commit to 100 percent of zero-emission buses by 2030, along with electric-vehicle-friendly measures such as low-emission zones that help accelerate electrification of personal and commercial vehicles used on city streets.

In contrast, a "Small, High-Income, Innovator City" has only modest sunlight but abundant wind and hydropower. The city faces cold winters, so heating dominates energy use in commercial and residential buildings. Residents are accustomed to many different modes of transport, and many have already given up their cars. To build on this already strong foundation, the city seeks to create a grid mix of 70 percent centralized renewables by 2030. In mobility, it sets a target of 100 percent zero-emission buses, while promoting car sharing and connected technologies. The city's efforts also include achieving one or more types of energy-efficiency retrofits in 100 percent of privately owned buildings by 2030.

Whether cities are in the early stages of developing and implementing their carbon-reduction programs or contemplating how to build on their existing robust efforts, these road maps can serve as an illustration of how they might choose to maximize the benefits of carbon-reduction efforts across the 12 priority opportunities identified in the full report.

Achieving *Deadline 2020* targets will not be easy. Cities will need to ensure that they move beyond quick wins to a focused-acceleration approach in priority areas. Furthermore, cross-sector partnerships will be essential both to successfully

capture the opportunities as well as to ensure that city initiatives incorporate system-level considerations, especially in grid decarbonization. The opportunities laid out in the full report will generate a wide range of benefits beyond carbon emissions—from reduced congestion, better public health, and greater productivity to improved quality of life and increased resilience. Highlighting the economic and social benefits of jobs, reduced air pollution, improved road safety, and reclaimed commute time can help mayors make the case for investments today in our collective future.

The action areas laid out in the report represent the first phase of carbon-reduction strategies. Cities that build a world-class tool kit to capture these opportunities, including streamlined procurement, access to capital, relationships with other cities to learn from their best-practice experiences, and partnerships with the private sector and government, will be well positioned to tackle the next set of emissions-reduction opportunities. Achieving 2030 target reductions will also lay the foundation to pursue opportunities that take longer to play out—such as densification and land-use planning—but that will be critical in achieving the deeper decarbonization required to meet 2050 targets.

With climate action as a top priority, the report offers a viable way forward for cities of all sizes and means. Progress will require summoning the will, leadership, and commitment to make progress, but having a defined path forward will be a critical advantage. ■

Download *Focused acceleration: A strategic approach to climate action in cities to 2030*, the report on which this article is based, on McKinsey.com.

[1] *Deadline 2020: How cities will get the job done*, C40 Cities and ARUP, 2016, c40.org.
[2] Based on recent tenders for large-scale renewables.

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From 'why' to 'why not': Sustainable investing as the new normal

More institutional investors recognize environmental, social, and governance factors as drivers of value. The key to investing effectively is to integrate these factors across the investment process.

Sara Bernow, Bryce Klempner, and Clarisse Magnin

Sustainable investing has come a long way. More than one-quarter of assets under management globally are now being invested according to the premise that environmental, social, and governance (ESG) factors can materially affect a company's performance and market value. The institutional investors that practice sustainable investing now include some of the world's largest, such as the Government Pension Investment Fund (GPIF) of Japan, Norway's Government Pension Fund Global (GPFG), and the Dutch pension fund ABP.

The techniques used in sustainable investing have advanced as well. While early ethics-based approaches such as negative screening remain relevant today, other strategies have since developed. These newer strategies typically put less emphasis on ethical concerns and are designed instead to achieve a conventional investment aim: maximizing risk-adjusted returns. Many institutional investors, particularly in Europe and North America, have now adopted approaches that consider ESG factors in portfolio selection and management. Others have held back, however. One common reason is that they believe sustainable investing ordinarily produces lower returns than conventional strategies, despite research findings to the contrary.

Among institutional investors that have embraced sustainable investing, some have room to improve their practices. Certain investors—even large, sophisticated ones—integrate ESG factors into their investment processes using techniques that are less rigorous and systematic than those they use for other investment factors. When investors bring ESG factors into investment decisions without relying on time-tested standard practices, their results can be compromised.

To help investors capitalize on opportunities in sustainable investing, this article offers insights on how to integrate ESG factors with the investment process—from defining the objectives and approach for an investment strategy, through developing the tools and organizational resources required to manage investments, to managing performance and reporting outcomes to stakeholders. It is based on more than 100 interviews we conducted with CEOs, chief investment officers, ESG leaders, investment managers, and others at a range of investment funds about their experiences with sustainable investing: how they got started, what practices they follow, what challenges they encountered, how they resolved them, and how they have enhanced their sustainable investing approaches over time.

Sustainable investing takes off and pays off

Once a niche practice, sustainable investing has become a large and fast-growing major market segment. According to the Global Sustainable Investment Alliance, at the start of 2016, sustainable investments constituted 26 percent of assets that are professionally managed in Asia, Australia and New Zealand, and Canada, Europe, and the United States—$22.89 trillion in total. Four years earlier, they were 21.5 percent of assets.

The most widely applied sustainable investment strategy globally, used for two-thirds of sustainable investments, is negative screening, which involves excluding sectors, companies, or practices from investment portfolios based on ESG criteria. But ESG integration, which is the systematic and explicit inclusion of ESG factors in financial analysis, has been growing at 17 percent per year. This technique is now used with nearly half of sustainable investments.

The scale of the sustainable investing market differs greatly from region to region. European asset managers have the highest proportion of sustainable investments (52.6 percent at the beginning of 2016), followed by Australia and New Zealand (50.6 percent) and Canada (37.8 percent). Sustainable investing is less prevalent in the United States (21.6 percent), Japan (3.4 percent), and Asian countries other than Japan (0.8 percent), but the gap is narrowing. From 2014 to 2016, the volume of sustainably managed assets grew significantly faster outside Europe than it did in Europe.[1]

Recent years have also seen some of the world's largest institutional investors expand their sustainability efforts. Japan's GPIF, the largest pension fund in the world with $1.1 trillion in assets, announced in July 2017 that it had selected three ESG indexes for its passive investments in Japanese equities. In December 2015, the Dutch pension fund ABP, which is the second largest in Europe, declared two ESG-related goals: to reduce the carbon-emissions footprint of its equity portfolio by 25 percent from 2015 to 2020, and to invest €5 billion in renewable energy by 2020.

Our interviews with institutional investors reveal a wide range of reasons they pursue sustainable investing. The three most common motivations are as follows:

Enhancing returns. Sustainable investing appears to have a positive effect, if any, on returns. Researchers continue to explore the relationships between ESG performance and corporate financial performance, and between ESG investment strategies and investment returns. Several studies have shown that sustainable investing and superior investment returns are positively correlated. Other studies have shown no correlation. Recent comprehensive research (based on more than 2,000 studies over the last four decades) demonstrates sustainable investing is uncorrelated with poor returns.[2] For many investors, the likelihood that sustainable investing produces market-rate returns as effectively as other investment approaches has

provided convincing grounds to pursue sustainable investment strategies—particularly in light of the other motivations described next.

Strengthening risk management. Institutional investors increasingly observe that risks related to ESG issues can have a measurable effect on a company's market value, as well as its reputation. Companies have seen their revenues and profits decline, for instance, after worker-safety incidents, waste or pollution spills, weather-related supply-chain disruptions, and other ESG-related incidents have come to light. ESG issues have harmed some brands, which can account for much of a company's market value. Investors have also raised questions about whether companies are positioned to succeed in the face of risks stemming from long-term trends such as climate change and water scarcity.

Aligning strategies with the priorities of beneficiaries and stakeholders. Demand from fund beneficiaries and other stakeholders has driven some institutional investors to develop sustainable investing strategies. This demand has followed greater public attention to the global sustainability agenda. Sustainable investing strategies seem to have particular appeal among younger generations: some two-thirds of high-net-worth millennials surveyed in the United States agreed with the statement, "My investment decisions are a way to express my social, political, or environmental values." More than one-third of high-net-worth baby boomers expressed the same belief—a noteworthy proportion, given that baby boomers are a major constituency for institutional investors.[3] Some investors wish to "do good" for society by providing capital to companies with favorable ESG features (without compromising risk-adjusted returns).

As more investors consider ESG factors, they are likely to encounter certain common challenges. There are some lessons they should keep in mind on how to define their approaches and maximize the benefits of sustainable investing.

How leading investors integrate sustainability

In reviewing the experiences of leading institutions, one theme stands out: sustainable investing is more effective when its core activities are integrated into existing processes, rather than carried out in parallel. Deep integration is readily achievable because the disciplines of sustainable investing are variations on typical investment approaches. Following, we explore how elements of sustainable investing can be integrated with investors' existing capabilities across six important dimensions (Exhibit 1).

Linking sustainable investing to the mandate

To succeed, sustainable investment strategies must derive from an institution's overall mandate. Yet investment mandates do not always call for sustainable strategies. The following questions can help investors interpret their mandates with respect to ESG issues and define targets for their sustainable investment strategies:

Does the investment mandate demand sustainability? If so, what factors are emphasized? Some investment mandates include ESG considerations or even specific ESG objectives. For example, the management objectives of Norges Bank, which manages Norway's GPFG, call for the bank to "integrate its responsible management efforts into the management of the GPFG" and note that "a good long-term return is considered dependent on sustainable development in economic, environmental, and social terms, as well as well-functioning, legitimate, and efficient markets."

How can the directives of a more general mandate help shape a sustainable strategy? Many funds have a mandate similar to that of a large Canadian pension fund: to "maximize returns without undue

Exhibit 1

Leading institutions apply sustainable investing practices across six dimensions of their investment process and operations.

Source: McKinsey analysis

risk of loss." A focus on value creation provides the basis for a strategy that accounts for long-term ESG trends by, for example, avoiding investments in companies or sectors exposed to material sustainability risks.

How will the success of the sustainable investment strategy be judged? Leading institutional investors define and track progress against clear metrics and targets for their sustainable strategies. Some targets have to do with their own activities: for example, the proportion of their portfolio managed with respect to ESG factors. (In some asset classes such as government bonds, sustainable practices are less developed and may thus take more time to apply than in asset classes such as public equities.) Others might consist of goals for the ESG performance of portfolio companies, such as reductions in carbon emissions or the ratios between executive pay and worker pay.

Defining the sustainable investment strategy

A sustainable investment strategy consists of building blocks familiar to institutional investors:

a balance between risk and return and a thesis about which factors strongly influence corporate financial performance. The following questions can help investors define these elements:

Are ESG factors more important for risk management or value creation? The balance between managing risks and producing superior returns will help determine the sustainable investing strategy. If the mandate focuses on risk management, then the strategy might be designed to exclude companies, sectors, or geographies that investors see as particularly risky with respect to ESG factors, or to engage in dialogue with corporate managers about how to mitigate ESG risks. If value creation is the focus, on the other hand, investors might overweight their portfolios with companies or sectors that exhibit strong performance on ESG-related factors they believe are linked to value creation.

What ESG factors are material? At first glance, this question might seem basic. Investors ordinarily look closely at factors they consider material and devote less attention to other ones. (Not surprisingly, research has shown that companies that focus on material ESG issues produce better financial performance than those that look at all ESG issues.) Determining which ESG factors matter, though, isn't always easy. Some efforts to identify material factors are under way. In the United States, for instance, the Sustainability Accounting Standards Board has developed the leading approach for identifying the unique ESG factors that are material in each sector. Investors may wish to conduct additional analysis to assess materiality for their own portfolios. The selection of material factors is often influenced to some extent by exposure to asset classes, geographies, and specific companies. For example, governance factors tend to be especially important for private equity investments, since these investments are typically characterized by large ownership shares and limited regulatory oversight.

Selecting tools for sustainable portfolio construction and management

Most institutional investors that integrate ESG factors in their strategies use at least one of three main techniques for portfolio construction and management: negative screening, positive screening, and proactive engagement (Exhibit 2). Once an investor has set priorities, it can select these techniques accordingly, using the following questions as a guide:

Is risk management a focus? Negative screening is essential for investors that wish to constrain risk. It entails excluding companies (or entire sectors or geographies) from a portfolio based on their performance with respect to ESG factors. Negative screening was the basis for many of the earliest sustainable investing strategies. The availability of ESG performance data (for example, carbon emissions) now allows investors to apply more nuanced and sophisticated screens, filtering out companies that do not meet their standards or are below industry averages for particular ESG factors.

Is value creation a focus? Performance-focused investors can use negative screening to eliminate companies that may be less likely to outperform in the long run. They can also practice positive screening, by integrating the financial implications of ESG performance in their fundamental analysis. With this approach, many of the same research and analysis activities that investors perform to choose high-performing assets are extended to cover material ESG factors. In this way, investors can seek out assets with outstanding ESG performance or sustainability-related business priorities (such as high energy efficiency). For example, the Third Swedish National Pension Fund (AP3) more than doubled its investments in green bonds during 2016 to lower the fund's carbon footprint, on the grounds that a more sustainable portfolio can improve both the return and the risk profile of the fund.

Exhibit 2

Institutional investors use at least one of three techniques to integrate ESG factors in portfolio construction and management.

	Negative screening	Positive screening	Proactive engagement
Description	• Avoid material environmental, social, and governance (ESG) risks or comply with values-based investment thesis • Exclude particular companies or sectors from investment universe based on ESG concerns	• Acknowledge potential positive correlation between ESG quality and returns • Integrate financial implications of ESG factors in research and analysis • Weight fund toward holdings with higher ESG quality	• Identify ESG as a lever for value creation • Pursue improvements in a company's ESG performance by engaging with board or management
Examples of application	Exclusion of companies for such reasons as: • Noncompliance with values chosen by the government or fund • Recommendations by ESG team • Additional qualitative analysis of ESG risks	• Investment managers include ESG factors in fundamental analysis • Investments concentrate on specific sustainability themes (eg, green bonds, clean tech, low carbon)	• Dialogue and involvement with enterprises in which investors hold significant stakes and see potential to create value by improving ESG performance (eg, by increasing energy efficiency)

Source: McKinsey analysis

Does the investor engage with management teams? Some institutional investors try to improve the performance of portfolio companies by taking board seats or engaging in dialogue with management. This approach can also be helpful in sustainable investing strategies: an institutional investor might choose to acquire a stake in a company with subpar ESG performance and then engage with its management about potential improvements. If an institutional investor ordinarily takes board seats or engages management teams, then it might consider adding sustainability issues to its agenda. Some investors also take part in external collaborations, such as Eumedion in the Netherlands, that collectively engage companies in dialogues on sustainability issues and pool shareholder voting rights to influence management decisions.

Developing sustainable investment teams

A few leading investors embed ESG specialists within their investment teams, though some opt for other arrangements. The following three questions can help institutional investors fit

their ESG-focused staff and resources into their existing operations:

What expertise is needed to carry out the sustainable investing strategy? The factors and techniques an investor chooses will determine what expertise is required. Investors that emphasize environmental performance, for instance, will need specialists in relevant environmental topics and management practices. Those that actively engage with management teams may need specialists with executive experience. Companies that rely on screening techniques will likely benefit from expertise in quantitative analysis.

How should an investor obtain ESG expertise? In-house ESG teams range from one or two full-time staff members to 15 or more, depending on portfolio size and the approach to sustainable investing. Some investors may not need full-time ESG staff at all. Commercial databases offer good-quality information about companies' ESG performance, and external advisors can provide targeted support. In addition, many institutional investors take part in external networks such as the United Nations Principles for Responsible Investment (PRI) and the Portfolio Decarbonization Coalition, which support investors in incorporating ESG factors in their investment decisions. Leading investors also continuously build the ESG capabilities of their portfolio managers.

Where should ESG specialists fit into the organization? Some investors put their ESG specialists outside the investment team (for example, within a communications group). Leading investors typically embed ESG experts within their investment teams, with a head of ESG who reports to the chief investment officer. ESG specialists then provide ongoing support to portfolio managers. Some funds have made it a priority to hire ESG specialists with strong investment backgrounds. For example, the Canada Pension Plan Investment Board hired a senior investment professional as its head of ESG. Other funds have chosen not to have dedicated ESG specialists but to assign responsibility for related issues to ESG-trained portfolio managers. At one Scandinavian investor, portfolio managers must fully account for all drivers of risk and return, including those related to ESG factors.

Monitoring the performance of investment managers

Whether institutional investors use internal or external managers to oversee their portfolios, they must regularly review managers' performance. Before hiring external managers, they also conduct thorough due diligence. Our interviews suggest that institutions with sophisticated approaches to sustainable investing have made ESG considerations an integral part of their performance-management processes. The following two questions can help investors devise effective means of monitoring performance:

How can investors ensure that external managers conform to their sustainable investing strategy? Leading funds have integrated ESG elements into their due-diligence processes for external managers. The United Nations PRI has developed an ESG-focused questionnaire for this purpose, and some investors have created their own ESG scorecards. Side letters, which augment the terms of a contract, can be used to specify ESG performance standards for an external manager. Once an external manager has been hired, leading investors evaluate the manager's ESG performance as part of the semiannual or annual performance reviews. The Second Swedish National Pension Fund (AP2), for example, developed an ESG assessment tool for reviewing external private equity managers. Some leading investors have a continuous dialogue with their external managers, through which potential ESG issues can be flagged and discussed.

How can investors ensure that their in-house investment team adheres to the sustainable strategy? Leading funds also make ESG considerations part of their processes for

managing the performance of in-house portfolio managers. Some funds have tools for checking whether portfolio managers have complied with ESG requirements and, in some cases, whether the ESG performance of their portfolios meets certain standards or contributes to the investor's overall ESG targets. A few investors have also begun experimenting with linking managers' ESG performance to their compensation.

Reporting on sustainable investing practices and performance

Leading institutional investors reinforce their commitment to sustainable investment by disclosing performance and describing their management practices. The most advanced provide detailed descriptions of how they are enacting their sustainable investment strategies, along with quantitative measures of their performance relative to targets. The following questions can help when it comes to shaping effective approaches to external reporting:

What is the goal of reporting on ESG performance? Investors should define what they hope to accomplish via external reporting and disclosure. Government pensions, for example, may have to fulfill public-policy requirements. Other institutions may wish to demonstrate how they meet beneficiaries' expectations, or use reporting as a means of holding portfolio companies accountable to drive change. This technique is particularly relevant to proactive engagement: investors can exert influence on portfolio companies by describing the performance gaps they have identified and the improvements that companies are making.

What information should be disclosed? Investors generally have wide discretion on what to disclose about their sustainable investment approach: strategies, companies excluded, ESG performance measures, and accounts of management dialogues, to name a few. Over the past few years, disclosures have become more detailed in areas such as policies, targets and outcomes, focus areas, and specific initiatives. For example, the Fourth Swedish National Pension Fund (AP4) issues disclosures on all of these topics, along with a list of excluded companies and an assessment of the direct environmental impact of the fund's operations.

Disclosing different kinds of ESG information serves different purposes. To fulfill public-policy requirements and show that practices meet beneficiaries' expectations, some investors disclose how policies and strategies are integrated in the investment process, measurable ESG targets and outcomes, and data on shareholder votes or company dialogues. To encourage portfolio companies to strengthen ESG performance, disclosing information about high-priority ESG factors, company dialogues, and exclusion lists may be helpful.

What's next?

Embedding sustainable investment practices into investment processes is a long-term endeavor, by which most investors gradually adopt more sophisticated techniques. The practices described previously, already in wide use, can help investors develop or refine sustainable investing strategies. It is also worth considering the following approaches, which are still evolving among investors at the front of the field:

Assessing the entire portfolio's ESG risk exposure. A few funds have begun to systematically assess how their entire portfolios are exposed to material ESG risks (notably, climate change and energy consumption). Such a broad review requires significant staff time, resources, and capabilities. It also means developing a view on the long-term development of ESG-related factors and related market forces (for example, sales of electric vehicles and movements in energy prices) and their impact on the financial performance and valuations of

holdings. In addition, advanced investors are developing dashboards of key indicators to watch, with trigger points that call for mitigating actions to manage risks effectively. Recent efforts to establish industry-wide standards for measuring a carbon footprint have resulted in progress, but an established set of metrics across most other sustainability topics has yet to be developed.

Using ESG triggers to find new investment opportunities. If assessing a whole portfolio with regard to ESG risks is one side of a coin, then seeking investment opportunities based on ESG factors is the other side. As with assessing risk exposure, institutional investors will need a point of view about ESG-related trends and their long-term effects on asset prices. One way to develop a thesis is to identify the most significant trends and the sectors they influence (for example, asking what opportunities will be created by the widespread shift toward renewable energy).

Integrating the UN Sustainable Development Goals (SDGs). The 17 SDGs were developed to "end poverty, protect the planet, and ensure prosperity for all." Several European funds are exploring ways to link their sustainable investing strategies to the SDGs. Early approaches involve prioritizing certain SDGs and planning investment strategies to improve corporate performance in those areas. For example, in July 2017, the Dutch pension funds APG and PGGM jointly published *Sustainable development investments: Taxonomies*, which includes an assessment of the investment possibilities associated with each of the SDGs. AP2 also publishes examples of how its investments contribute to the SDGs. This creates transparency on how the institutional-investor community can be a catalyst for change for a more sustainable society, addressing some of the prioritized challenges of humankind.

The sustainable investing market has grown significantly as demand for sustainable investment strategies has surged and as evidence has accumulated about the benefits of investing with ESG factors in mind. Some of the world's leading institutional investors are at the forefront of adopting sustainable investing strategies. Most large funds are seeking to develop their sustainable strategies and practices, regardless of starting point. While some are struggling to define their approach and to make good use of ESG-related information and insights, our interviews with institutional investors make clear that this doesn't have to be the case. The methods that institutions already use to select and manage portfolios are highly compatible with sustainable strategies, and close integration can have significant benefits for institutional investors and beneficiaries alike. ■

[1] *Global sustainable investment review 2016*, Global Sustainable Investment Alliance, March 2017, gsi-alliance.org. The review's definition of "sustainable investment" includes the following activities and strategies: negative/exclusionary screening; positive/best-in-class screening; norms-based screening; integration of environmental, social, and governance factors; sustainability-themed investing; impact/community investing; and corporate engagement and shareholder action.

[2] Alexander Bassen, Timo Busch, and Gunnar Friede, "ESG and financial performance: Aggregated evidence from more than 2000 empirical studies," *Journal of Sustainable Finance & Investment*, December 2015, Volume 5, Number 4, pp. 210–33.

[3] *2014 U.S. Trust insights on wealth and worth*, U.S. Trust, Bank of America, June 2014, ustrust.com.

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Creating value through sustainable design

Companies can promote sustainability by following good design practices to provide innovative and aesthetically pleasing solutions for customers and users.

Sara Andersson, David Crafoord, Tomas Nauclér, and Josh Rosenfield

Good design can do wonders to enhance user experiences. By focusing on customers and their preferences, designers can also drive growth and uncover new business opportunities, helping companies innovate for future user needs. In this transcript of a McKinsey Podcast, Sara Andersson and David Crafoord, of Veryday—a design consultancy within McKinsey's Design Practice—and Tomas Nauclér, a senior partner in the Sustainability and Resource Productivity Practice, speak with McKinsey Publishing's Josh Rosenfield about how companies can design for value and sustainability.

Josh Rosenfield: *Design is one of the buzziest terms in business, but it's also a term that gets used across a wide range of disciplines. So it can mean different things to different people. David, how do you define design?*

David Crafoord: Design is a process. The idea is to develop purposeful and innovative solutions that embody functional and aesthetic demands and that are based on needs and the intended user.

It's applied on digital and physical services and processes as well as environments. We focus a lot on genuine user insight to create new business opportunities with the aim to build strong brands and sustainable solutions. So we do put people in the center, and it's natural for us to balance user experiences as well as product life cycles.

Josh Rosenfield: *How does that differ from the way that companies ordinarily think about or practice design?*

Sara Andersson: The first component here that we'd like to emphasize is the thorough people understanding. What we advocate is consumer understanding that goes beyond knowing what people are doing right now in order to understand how to innovate for future user needs. It's valuable to know why people are doing what they do, how they feel about it, and what they dream of doing in the future. The best way to do this is to spend time with people.

You also need to get to know the needs of other stakeholders that influence your process and solutions. This might be, for example, suppliers or manufacturers or retailers.

David Crafoord: Some people think that users don't really know what they actually need. Part of the design process is to find that sort of tacit knowledge of what people want and desire.

Sara Andersson: We have a second component as well that's an iterative process with many loops of "concepting" and testing. A typical way to start out would be with just pen and paper, sketching concepts or scenarios. This could rapidly be followed by first prototypes—simple physical models or paper mock-ups that present the digital concept. You could even act out concepts if it's a service you're designing, to get a feel for it. But the point is to get it done quickly, and to get the experience and the feedback from users. Then refine and test again. The people-driven approach is key, together with system thinking. We're creating value from different perspectives in this way. We create value for the users and for all the other people involved in the process. We create value for the business that is providing the solutions. And the transformation that many businesses are starting to commit to these days is to add value also from a sustainability perspective. The exciting thing is the synergies that you can find here.

Josh Rosenfield: *You've talked about a design process that's highly customer oriented. How does this approach ultimately help companies to improve their margins and market share?*

Tomas Nauclér: Traditional product companies use design to create a good-looking or palatable product that customers want to have. They are just in the discovery process of understanding how the experience of using the products, and using them end to end, will drive adoption and growth.

Tesla is a good example of a product that is not designed purely as a nice-looking car but actually as an experience of how you use it. In the extension of that, our clients need to not only think about their traditional product but also the whole chain of how mobility, as an example, is being consumed.

Josh Rosenfield: *How does that approach to design create more value than an approach that's more conventional?*

Tomas Nauclér: We've done these analyses for different industries where we've said, "What is the waste in a total system end to end?" You probably have heard the example where a commercial vehicle is used 30 percent of the time—it is actually running only 40 percent of the time, or 40 percent of the vehicle is filled with goods. At rush hour, it's only occupying 10 percent of the pavement in a city. If we could have a seamless end-to-end experience and movement of goods, we could probably take those wastes down by a factor of three to five to ten. That is basically what the sustainable system of the future looks like.

David Crafoord: Moving water is a huge cost when it comes to energy. I was working with one of the market leaders in pumping water. Together with the technical team, we reduced the energy by 50 percent. The thing was that the pumps are put into wastewater holes, and it's very dirty. What happens is that the dirt gets stuck onto the pumps, so it actually insulates the pumps, so they get overheated. We added an internal pump that cleaned the water around the engine. So we actually cooled the engine rather than creating a system that was heating up the engine. By adding a second layer around the engine, we could cool it down with the water that we were pumping. That made a huge difference.

Tomas Nauclér: Typically, what we've found is that if you have the right design, at the right price point, that is driving sustainability and customer experience in a demonstrable way—that is a key driver of growth for your offering.

Josh Rosenfield: *Can you take us through an example or two of a design process that was successful in adding value for customers, for the company, and for a wider set of stakeholders?*

Sara Andersson: I'd like to run you through a project that we did for Arlanda, Stockholm's international airport. We developed a new departure-sequencing tool [DST] that helps air-traffic controllers to better plan and manage all departures in the airport.

When we started this project, the current way of working was very old and very analog. Air-traffic controllers were moving and stacking paper labels that represented flights. The goal was to create a system that could improve the air-traffic controllers' precision when it came to predicting takeoff time, so that traffic could be tighter and safer. We started out gaining a thorough understanding for the air-traffic controllers' task, what their major challenges were, and what they would like to improve about their situation. Then we started developing a new flight-labeling system, quickly prototyping, and also working in a very collaborative way with the air traffic controllers in several workshops, in tests of the wire frames, in order to create a common understanding and to share ideas. We ended up entirely reinventing the mental model for how to perceive runways and upcoming flights. The way users interact with this content is easy and intuitive.

The value for these users is very clear. The new DST greatly facilitates their task, and they love working with it. The new system focuses on getting the aircraft from their terminals according to the timetable, and up in the air without getting stuck in a queue. The time between leaving the terminal and being up in the air is greatly reduced, and fuel consumption is reduced as well. A reduction of just one minute in queue per departure results in reduced fuel consumption of at least 1.5 million tons of fuel per year. This, in turn, gives a reduction of carbon dioxide emissions of about 3.5 million tons per year, which makes a big difference for both local environments and the climate.

Tomas Nauclér: We will most certainly see this development in other sectors. The same discussion is happening in the marine sector, where many players are thinking about how to seamlessly integrate the ship from sea, all the way to port, and get the material out of the port, without all the lead-time losses and costs associated with waiting and holding.

Josh Rosenfield: *Those sound like instances where you helped a business come up with new ways of meeting customer needs. Are you seeing any other examples of this?*

Sara Andersson: We have been doing a project where we set up a living lab. The background is urbanization. People will have to live in much smaller spaces. Cities will be more densely populated. But with these smaller spaces come a

lot of challenges. So we set up this living lab and had people living it, testing future solutions that might facilitate small-space living and finding out how people felt about them. One solution that we implemented in the living lab was moving walls that could flexibly create a social area. They helped families to create boundaries between private spaces and social ones.

Josh Rosenfield: *That's a good example of how you used customer feedback to design better products. It's also becoming easier to collect feedback from products directly, in real time, using onboard sensors and connectivity. How do you see the Internet of Things [IoT] changing product design and performance?*

Sara Andersson: I really believe that the ability of connected products to provide a wide range of feedback—that this will surely be vital in the shift toward designing more effective products and processes, circular ones. When the whole idea of a circular economy emerged in the '70s, we were of course far from connected products. Now we have sensors already integrated in a lot of products that allow us to learn about usage patterns. It allows us to track locations and to measure performance. In the product-as-service scenario, sensors in consumer products could notify the service provider of needed maintenance, sparing the users from taking any action at all. With information generated from sensors on usage patterns, users can also be advised on better ways of using their products, or get information on how they might benefit from a product update.

Tomas Nauclér: A consumer example could be that we will have clothes that are IoT synced, where you can pay for use, or where you could even have somebody pinging you and asking you, "Can I buy it back and sell it to somebody else?"

Josh Rosenfield: *Shifting to a circular economy is an interesting notion. It's going to require whole systems to be redesigned, so companies, their suppliers, and their customers can easily use resources over and over.*

Sara Andersson: We believe strongly that many companies will need to make a shift from selling products to providing these products as services. Retaining ownership over your materials has an obvious financial value. You will reduce or even eliminate, perhaps, your need for raw materials. But what we also see happening with the growth of the sharing economy is a changing consumer mind-set. People are increasingly looking to free themselves of product ownership. They prefer to purchase the functionality or experience of a product instead. Most people now use services like Spotify and Netflix that give them the content they want. In the mobility area, we also see a strong and growing trend toward car-sharing and mobility-on-demand services.

People are increasingly looking to free themselves of product ownership. They prefer to purchase the functionality or experience of a product instead.

For businesses, the value is in the materials they stay in control of. But there is also tangible value in the relationships they build with their customers when offering products as services. There would be a continuous dialogue that you're having with the user.

David Crafoord: There are also very interesting points when it comes to the self-driving cars. Normally, many people see the car as an extension of themselves and as a status symbol. But what happens when you're not driving the car yourself? Are you considering it to be a status symbol? Or is it just a transportation utility?

It will be a huge paradigm shift for society in general, because from a sustainability point of view, a self-driving car will create much less CO_2 emissions. It will save a lot of lives when it comes to safety.

Josh Rosenfield: *It seems like more companies are adopting design approaches that are more customer oriented and developing concepts that create more value for them and for their customers. As a practical matter, how can a company reposition design as a strategic discipline?*

Tomas Nauclér: There are two challenges for a typical company to drive design to customer experience at scale. The first ability is to have the design capability centrally somewhere in the organization but also out in each of the units that are going to deliver it, because it needs to come back from the customer.

Second, how do you scale them? This is where many companies are having challenges. Many times, they have not standardized processes. They are not used to scaling up service processes or service experiences across the corporation. They are used to product launches of hard products, not services.

If you're going to make this transition you need to have a top-down push. You need to have a very clear goal set by the corporate team and the CEO to mobilize the organization as a whole.

Sara Andersson: I would also encourage any company that's applying a design process to widen their brief and to keep an open mind. If you have too narrow a brief, if you tell your development department that, "We need to design these new widgets," then you're narrowing down your solutions base—and also the chance that you end up with an innovative solution.

It's about understanding the user needs and letting them lead the way. So in the end, it might be what you set out to design—a widget—but it could also turn out to be a service or another kind of solution.

The service that you end up designing could be something that generates more profit for the company. Plus it's providing a better experience for its customers. So people-driven design methodology really has the potential to spark radical innovation. ■

Sara Andersson is an alumna of McKinsey's Stockholm office, where **David Crafoord** is a director of industrial design and **Tomas Nauclér** is a senior partner; **Josh Rosenfield**, a senior editor with McKinsey Publishing, is based in the New York office.

Sustainability's deepening imprint

Companies are more active than ever in pursuing sustainability to align with values and engage employees and customers. To see financial returns, though, integrating sustainability into core functions is key.

As environmental, social, and governance issues have become ever more important influencers of customer and employee expectations, organizations have tightened their embrace of the sustainability programs that address those issues. According to McKinsey's latest survey on the topic,[1] companies are increasingly formalizing the way they govern sustainability programs, as well as elevating the importance of diversity and inclusion.[2] And a larger share of respondents than ever before say the top reason for implementing a sustainability agenda is better alignment between an organization's practices and its goals, missions, or values.

The results also shed light on how companies are deploying technologies to manage and support their sustainability agendas. For example, companies have greatly increased their use of both familiar tools, such as energy-efficient equipment, and more innovative ones, such as digital platforms. Despite these advances, many organizations still struggle to capture financial value from their sustainability efforts. Integrating sustainability into one or more core business functions, for instance, is a practice that can help. The integration of sustainability into functional work doubles the likelihood that a company will report financial value from these efforts.

Deeper engagement with sustainability as key issues and stakeholders evolve

Nearly six in ten respondents say that their organizations are more engaged with sustainability than they were two years ago—and just 9 percent that engagement has declined. In some industries, the shares reporting greater engagement are even larger: more than 80 percent of respondents in consumer packaged goods and three-quarters of those in infrastructure, for example. Respondents also report that their organizations have increased

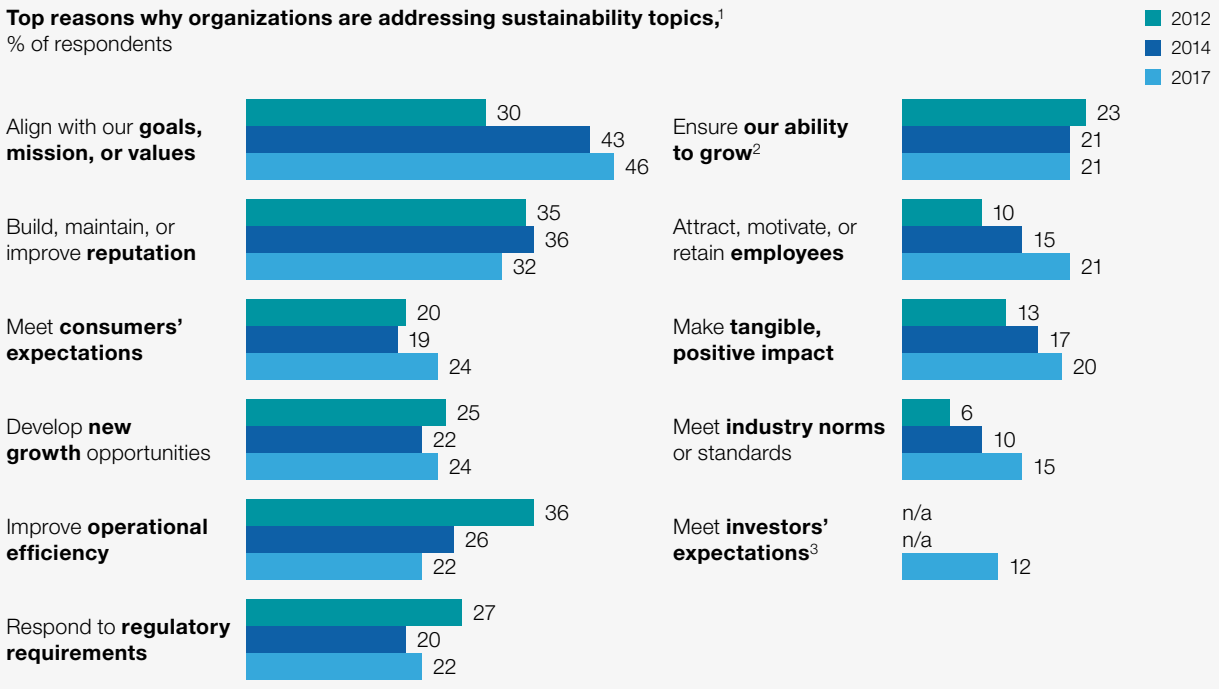
their formal governance of sustainability: 70 percent say their companies have some form of governance in place, compared with 56 percent in 2014. What's more, an increasing share of respondents (16 percent, up from 12 percent previously) now report that their companies have a board-level committee dedicated to sustainability issues.

When asked about their companies' top reasons for addressing sustainability, respondents most often cite alignment with the organization's own goals, mission, and values. The results also suggest that some stakeholders are becoming more important.

Meeting consumer expectations is now among the top five reasons, and the share citing the attraction, motivation, or retention of employees also grew since 2014 (Exhibit 1).

The sustainability topics that matter most to businesses vary across industries (Exhibit 2). Respondents cite diversity and inclusion among the top five most important topics, and it is a top three issue in financial services and high tech. Five years ago, when respondents were asked which issues would be most important by now, renewable energy and waste management topped the list.

Exhibit 1 **The opinions of consumers and employees are increasingly cited as top reasons why organizations address sustainability.**

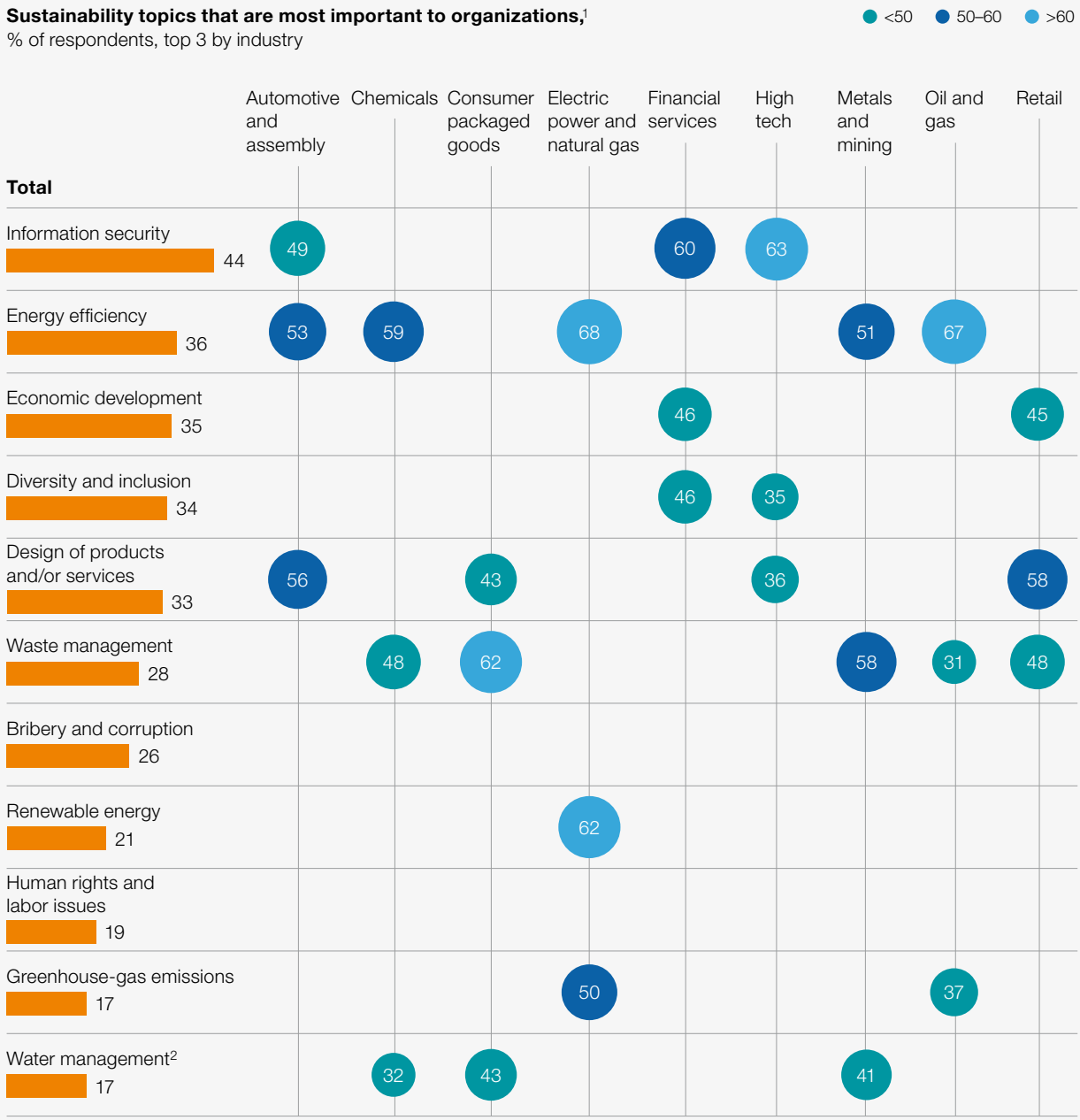


[1] Out of 14 reasons that were presented as answer choices. In 2012, n = 4,145; in 2014, n = 2,905; and in 2017, n = 2,422.
[2] In 2012 and in 2014, choice was "Strengthen competitive positioning (eg, securing essential inputs to production, responding to competitive pressure)."
[3] "Meet investors' expectations" was not offered as an answer choice in 2012 and in 2014.

Source: McKinsey analysis

Exhibit 2

The sustainability topics that matter most to businesses vary by industry.



[1] Out of 16 topics that were presented as answer choices. Total n = 2,771. For automotive and assembly, n = 169; for chemicals, n= 93; for consumer packaged goods, n = 100; for electric power and natural gas, n = 136; for financial services, n = 350; for high tech, n = 224; for metals and mining, n = 78; for oil and gas, n = 78; and for retail, n = 91. Respondents working in all other industries (ie, industries that are not represented by a statistically significant number of respondents) are not shown.

[2] For example, water scarcity, quality, sanitation.

Source: McKinsey analysis

But relative to other topics, renewable energy has fallen in importance over the same period—during which installations of renewable-energy sources also increased.[3] Waste management, too, is no longer among the top five topics that matter most to respondents' organizations.

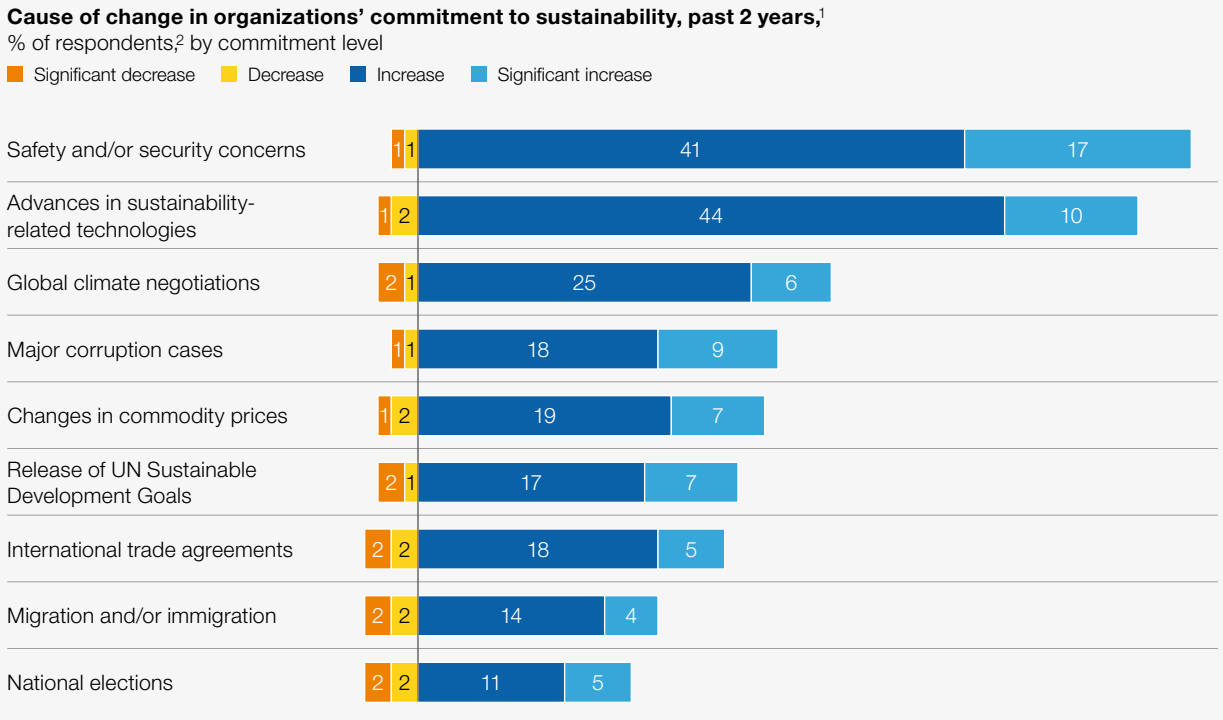
Technology's growing role

This year, the survey also looked at the influence of key trends or events on the organizations' commitment to sustainability. Respondents indicate that advances in sustainability-related technologies, as well as safety and security concerns, are the top reasons these organizations have increased their commitment. Other events, such as national elections, the release of UN Sustainability Development Goals, and global climate negotiations have had less influence (Exhibit 3).

Since our last survey, the cost of sustainability-related technologies has dropped dramatically,[4] making it cheaper and easier for companies to use them—renewable energy, energy storage, digital platforms, and advanced data analytics, in particular. Accordingly, respondents report the wider adoption of various technologies across all regions, notably India and the Middle East and North Africa, compared with five years ago (Exhibit 4). Among these technologies, the greatest gains in adoption have occurred in big data and advanced analytics, as well as digital platforms.

Exhibit 3

Safety concerns and technological advances are the top reasons for a growing commitment to sustainability.



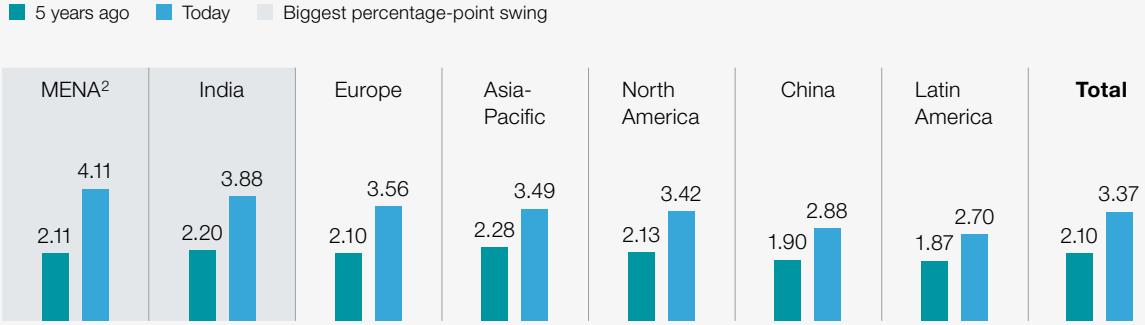
[1] Total n= 2,422.
[2] Respondents who answered "no change" or "don't know" are not shown.

Source: McKinsey analysis

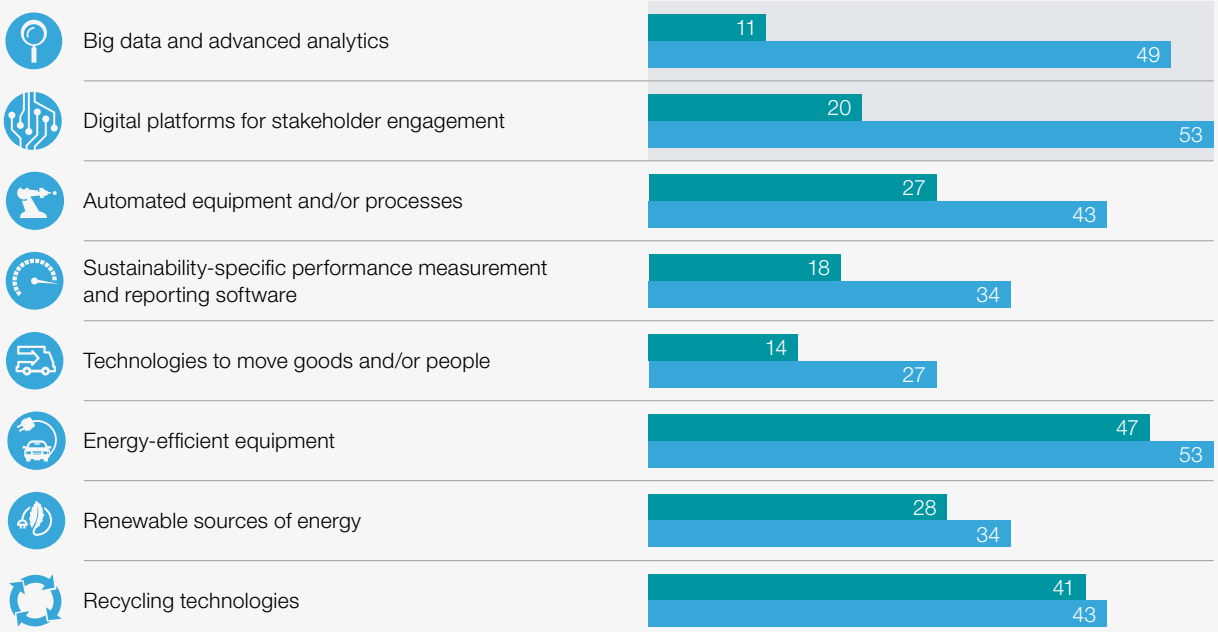
Exhibit 4

Respondents report wider adoption of sustainability-related technologies across all regions over the past five years.

Average number of technologies used in pursuit of sustainability,[1] out of 8



Technologies used in pursuit of sustainability,[3] % of respondents



[1] In Middle East and North Africa, n = 85; in India, n = 224; in Europe, n = 887; in Asia–Pacific, n = 265; in North America, n = 547; in China, n = 41; in Latin America, n = 171; total n = 2,422. Respondents working in other developing markets (n = 202) are not shown.
[2] Middle East and North Africa.
[3] Total n = 2,422. Technologies are arranged in descending order, based on the percentage-point differences between the "today" and "5 years ago" responses. Respondents who answered "other," "none of the above," or "don't know" are not shown.

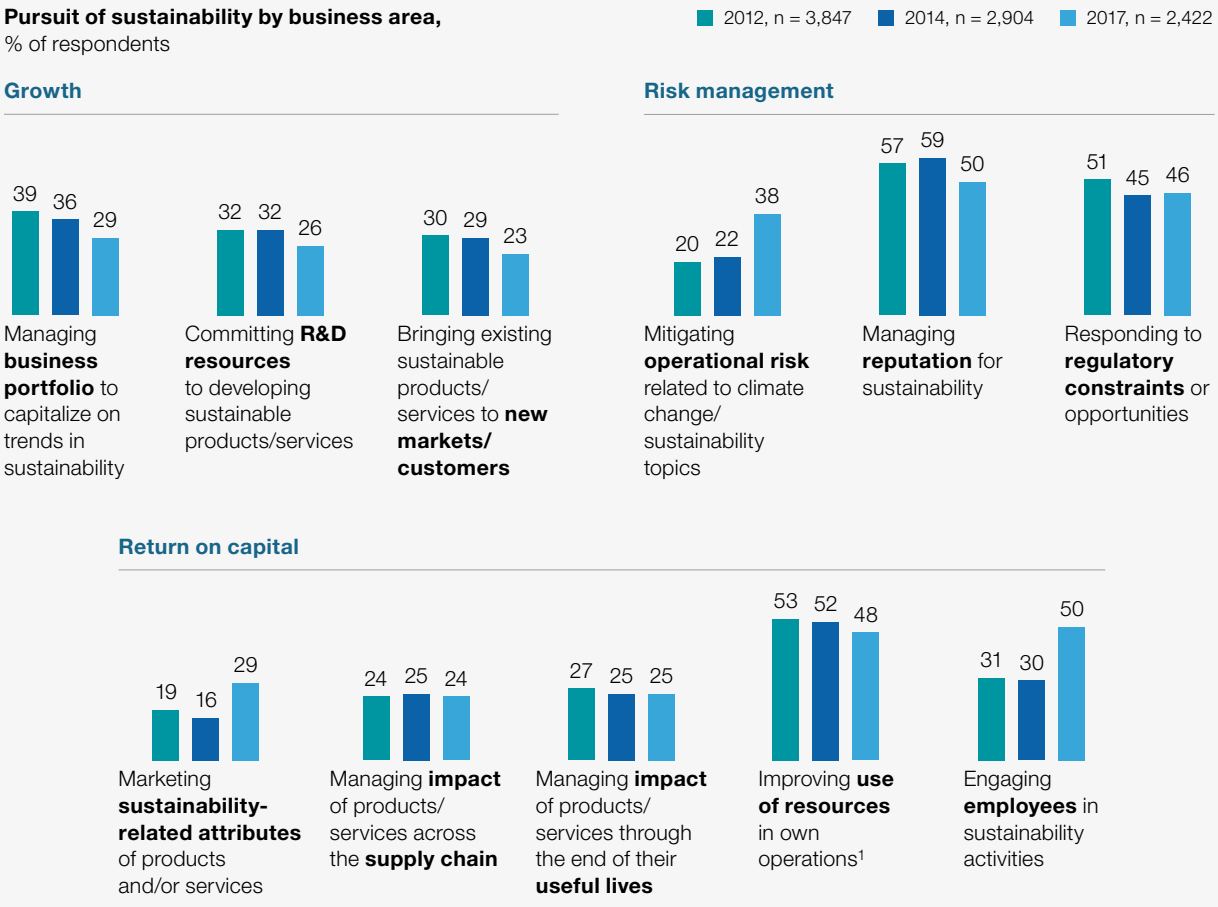
Source: McKinsey analysis

Meanwhile, 49 percent of respondents in India say their companies have adopted renewable sources of energy—the highest percentage of all regions, up from 28 percent five years ago. Responses from the Middle East and North Africa also show that organizations in that region have accelerated their adoption of energy-efficient equipment more than their counterparts in other regions have.

The gap between values and action

Respondents report little change in the number of activities their organizations are pursuing to achieve sustainability goals. The survey asked about 11 such activities in three categories: growth, return on capital, and risk management, as we have done since 2011.[5] In the areas where organizations were most active in previous years—managing reputation, improving resource efficiency, and responding to regulatory constraints—they remain active still. Companies are more active than before in only three of the 11 areas. But in line with the most common reasons that organizations are pursuing sustainability, two of these three areas relate to employees and customers: engaging employees in sustainability-related activities and marketing sustainability-related attributes to customers (Exhibit 5).

Exhibit 5 **On the whole, fewer organizations are pursuing growth-related sustainability activities than did so in previous years.**



[1] For example, water, energy, or waste.

Source: McKinsey analysis

Notably, respondents indicate that their organizations' pursuit of all three growth-related activities has declined in recent years. One-quarter of respondents say their companies are committing R&D resources to sustainable products or services, down from one-third in 2014. Among respondents who say their companies are pursuing all three, 39 percent report a positive financial impact from their sustainability programs; by contrast, only 26 percent of all respondents say the same.

On average, nearly two-thirds of respondents say they expect that activities across the three categories will create value for their organizations in the years ahead, up from 58 percent in the past two surveys—and perceptions of value-creation opportunities vary by industry (Exhibit 6). More than 80 percent of retail-sector respondents, for example, see modest or significant potential value in managing the sustainability impact of their supply chains, compared with 60 percent of all others.

Even within industries, the results indicate notable differences between the activities that organizations are pursuing and the activities that executives think have the most potential for creating value. Nearly two-thirds of respondents in metals and mining say they see significant value in bringing existing sustainability-related products—conflict-free minerals, for example—to new markets or customers; only 7 percent, though, say that their organizations are doing so. More than 60 percent of financial-services respondents see significant value potential in managing the business portfolio to capitalize on sustainability trends, but only 28 percent say this is something their organizations actually do.

Limited integration with core functions

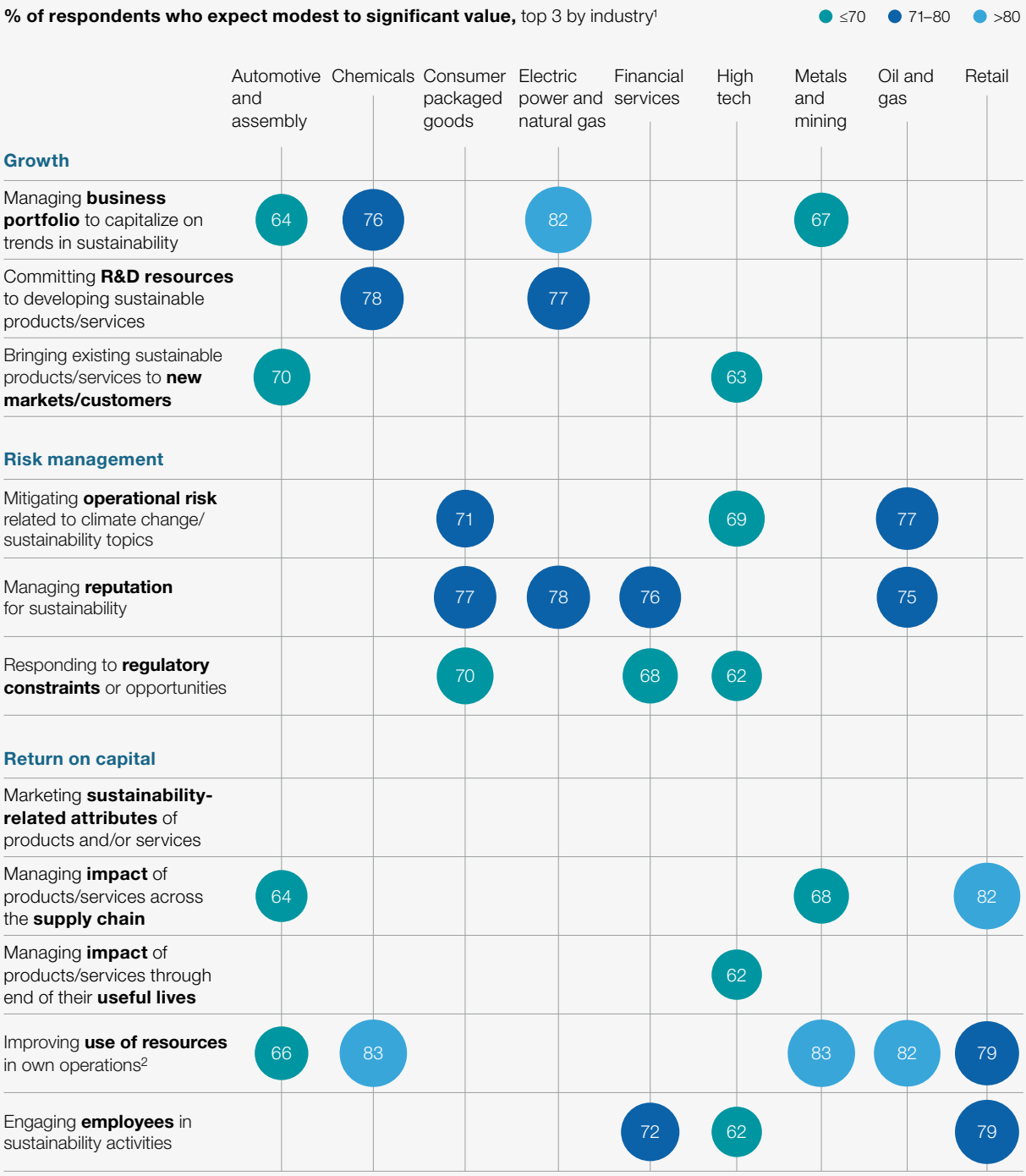
Companies not only struggle to pursue the sustainability activities with the highest potential value but also find it challenging to measure the financial implications accurately. One in five respondents say they don't know what financial impact sustainability programs have had on their organizations in the past five years. Respondents whose companies have measured the financial impact are as likely to say that sustainability is a cost as to say that it creates value.[6] What's more, about one-quarter of respondents say that they don't know how much, if anything, their organizations spend on sustainability-related initiatives—and a similarly small share say sustainability's financial benefits are clearly understood across their organizations.

One place to start, the results suggest, is integrating sustainability into core business functions—and finance, in particular. The survey asked how integrated sustainability is into 11 core business functions, and respondents indicate that integration into finance is the least common. Yet, along with R&D and strategic planning, integration with the finance function appears to yield the greatest value (Exhibit 7). Respondents who say that sustainability is formally integrated into at least one of the functions—regardless of which—are at least twice as likely to report a positive financial impact as those who say that sustainability isn't integrated into any of them.

Executives should develop sustainability strategies with the same rigor they use to develop business strategy, and with the overall business strategy in mind.

Exhibit 6

Perceptions vary by industry on the top value-creation opportunities from sustainability over the next five years.



[1] In automotive and assembly and in high tech, the same percentage of respondents expect value from multiple opportunities, causing ties.
[2] For example, water, energy, or waste.

Source: McKinsey analysis

Exhibit 7 **The results suggest that integrating sustainability into core functions can have a positive financial impact.**

[1] Respondents who answered "other" or "don't know" are not shown. Total n = 2,422.
[2] Includes respondents who report either modest or significant value creation from their organizations' sustainability programs; those who answered "significant cost," "modest cost," "minimal to no cost or value," or "don't know" are not shown. Total n = 2,422.
[3] Not applicable; sustainability is not formally integrated into any function.

Source: McKinsey analysis

But finance is not the only function where the results suggest room for improved integration: less than one-quarter of respondents say that sustainability is formally integrated into the sales and marketing function. What's more, only 18 percent say that employee compensation is linked to sustainability performance at their organizations. And even though respondents saythat both customers and employees are increasingly powerful drivers for acting on sustainability, only one-third report that employees across the organization understand how sustainability efforts align with the overall strategy.

With technology, we see similar results. Even as respondents identify technological advances as a main reason for the growing commitment to sustainability, just one-quarter report the formal integration of sustainability into IT. Digital platforms and energy-efficient equipment are cited most often as the technologies that support

sustainability work. But stronger integration with IT could foster stronger stakeholder engagement with customers, employees, and suppliers.

Looking ahead

In response to the evolving priorities and reasons to pursue sustainability, here are some steps that companies can take to adapt their approaches and capture greater value from their sustainability efforts:

- *Align sustainability strategy with business strategy.* Executives should develop sustainability strategies with the same rigor they use to develop business strategy, and with the overall business strategy in mind. This will enable their sustainability efforts to deliver value to the business, especially when the sustainability strategy is translated into clearly articulated goals, metrics, and lines of accountability across the organization (as would be the case in other areas of strategy development).

- *Enhance governance for better results.* In our experience, companies with good governance structures to oversee and manage their sustainability efforts see better financial results from it. The survey confirms this: value creation is nearly twice as likely when at least one formal governance structure is in place. There is no "right" governance structure—an organization's setup should align with its overall sustainability approach and strategy. Some companies may have teams that focus on sustainability, while others use cross-functional leadership teams to drive their programs. But regardless of structure, there are some key success factors, including executive-team oversight and clear lines of accountability, that will support better financial *and* sustainability results.

- *Embed sustainability into business functions.* The survey results indicate a gap between the reasons for addressing sustainability and where in the company sustainability actions are pursued. Since alignment with a company's goals, mission, and values is the most common reason for action on sustainability issues, there is an opportunity to embed sustainability programs into the fabric of the business. Most companies have a sizable opportunity to integrate sustainability into more of their core business functions—from finance to sales and marketing to HR—and for functional leaders to have their own sustainability action items—all of which would help close the gap between reasons and actions. ■

[1] The online survey was in the field from May 16 to May 26, 2017, and received responses from 2,711 participants representing the full range of regions, industries, tenures, company sizes, and functional specialties. Of these respondents, 2,422 said their companies are pursuing sustainability programs and answered the full survey. To adjust for differences in response rates, the data are weighted by the contribution of each respondent's nation to global GDP.

[2] The first of these surveys, conducted in September 2007, involved 2,687 participants from around the world. The respondents represented the full range of regions, industries, company sizes, tenures, and functional specialties.

[3] International Renewable Energy Agency, Abu Dhabi, Renewable Energy Statistics 2017.

[4] For more, see "How technology is reshaping supply and demand for natural resources," McKinsey Global Institute, February 2017, on McKinsey.com.

[5] "The business of sustainability: McKinsey Global Survey results," October 2011, McKinsey.com.

[6] Twenty-eight percent of all respondents whose companies measure the financial impact of their sustainability programs say that sustainability is either a significant or a modest cost. By comparison, 26 percent say that sustainability has created either significant or modest value.

The contributors to the development and analysis of this survey include **Anne-Titia Bové**, a specialist in McKinsey's São Paulo office; **Dorothee D'Herde**, a director of sustainability in the London office; and **Steven Swartz**, a partner in the Southern California office.

They would like to thank Georgia Dempsey, Josh Rosenfield, Daniella Seiler, and Amy Tsui for their contributions to this work.

How nudges can help the environment

Small changes in behavior can make a difference.

Scott Nyquist

When Richard Thaler was awarded the Nobel Prize for economics in October 2017, it could be argued he won the world's most prestigious award for proving something that most of us non-Nobel Prize winners knew already: people are not entirely rational economic animals. We are influenced by, among other things, hunches, peer pressure, habit, inertia, short-term thinking, optimism, emotion, loss aversion, ignorance—and the list goes on. Thaler himself promised to spend his prize money "as irrationally as possible."

Unlike many previous Nobel winners, though, Thaler's work can and has been translated into widespread real-life actions—again, in ways that most of us would readily recognize. In Thaler's 2008 book, *Nudge,* coauthored with Cass Sunstein, who now teaches at Harvard, he argued that governments and other organizations can (and should) "nudge" people to act in specific, positive ways.

Here is one famous example. When the Amsterdam airport put an image of a fly in the basin of a urinal, men's aim improved markedly, and spillage fell 80 percent. That's a nudge. Another, more consequential one: make it easier for people to save for retirement—for example, by requiring them to opt out of automatic savings deductions—and enrollment soars. Ditto for organ donations. Put the

healthy goods at eye height in school cafeterias, and students eat more of them. Another nudge.

A nudge is different from an incentive in that the latter usually employs economic force—to save money, for example, or to lower tax bills. So a congestion charge—a price for vehicles to enter a city—is not a nudge. It's a toll, or a kind of tax. Ditto for cap-and-trade systems to regulate pollutants.

Are there ways for nudges to help with the environment? I think that there are, and that this potential is only beginning to be explored. There are good examples already.

Nudging people through social norms is one approach. The United Kingdom, for example, successfully helped people cut their at-home energy use (and thus their costs) by sending bills that showed occupants how much energy they were using compared with their neighbors. Cobb County, Georgia, did something similar with water use. During a period of shortage, county authorities sent tips on how to cut usage to one group of residents, and saw a small effect (about 1 percent). To another group, it sent not only tips but also a letter comparing the household's consumption with the county average. The result was a reduction of almost 5 percent.

Changing the conditions around a choice is another classic style of nudging. Take food waste. In a range of experiments, studies have shown that smaller plates at all-you-can-eat buffets (combined with signs noting that seconds were OK) result in people not piling on as much. Everyone is happy: the consumer goes home satisfied, the restaurant saves money, the garbage worker has less to haul. While I am not quite sure this is a nudge in the Thaler sense, this can also be done by changing rules and regulations. For example, my McKinsey colleagues recently published a report on commercial mobility—think vans and trucks. They noted that by allowing more deliveries to be made at night—something that is often not allowed because of concerns about noise—traffic, emissions, and costs could all be greatly reduced.

Another kind of nudge is what might be called "active convenience." Copenhagen cut littering by almost half by painting green footsteps leading to bins, following a suggestion from an external policy group, iNudgeYou. Yet another nudge comes in the form of information. In the United States, the Energy Star label for appliances is a widely accepted standard of performance. People don't need to know their BTUs from their ABCs to know that an Energy Star fridge is efficient. Buildings with the Energy Star designation or

A nudge is different from an incentive in that the latter usually employs economic force—to save money, for example, or to lower tax bills.

certification under the Leadership in Energy and Environmental Design (LEED) designation command a commercial premium.

Most of these examples are small scale, of course. But the idea of nudges is relatively new, and with a little creativity and experimentation, I think there is a great deal of room to do more.

To its critics, nudging is, well, creepy. Not only is some unseen authority watching, but it's also trying to change your behavior, sneakily. Thaler acknowledges the idea's limits and has proposed a sensible way of differentiating between nudges and malign manipulation. In the latter, the "nudge" is presented misleadingly; it's difficult to opt out; and the nudgee doesn't benefit. One example: signing up for a "free" product, and then being billed for hefty shipping charges and having to connect with a call center to stop the madness.

At any rate, the whole idea of nudges is that they are subtle, no fuss, even quiet—and good for those being nudged. It's hard to see them as a major problem. Certainly, men at the Amsterdam airport are not complaining. ■

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