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Peering into energy's crystal ball

McKinsey's predictions were broadly on target in 2007. Here's how things could turn out during the next eight years.

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Back in 2007, McKinsey did two pieces of groundbreaking research that still inform how I think about energy—the resource-productivity framework and the greenhouse-gas cost curve (exhibit).[1] And then, with metaphorical holding of breath, we made forecasts based on that work. My colleague Matt Rogers and I thought it would be interesting to look back at these predictions—which were broadly on target, with a few clunkers—and then consider what might come next.

Win some, lose some

The 2007 research looked at a number of potentially disruptive technologies and assessed their prospects. Here's how we did:

- Solar. Photovoltaic (PV) installations have taken off much faster than we expected. Costs fell steeply, driving adoption. The compression of costs happened throughout the solar-energy system, from sourcing raw materials to manufacturing to installation and service. We expected costs to fall to $2.40 per watt by 2030 but weren't bullish enough; in fact, they are on course to hit $1.60 per watt by 2020.

- Wind. We projected that the global base of 94 gigawatts installed in 2007 would expand to 800 gigawatts by 2030. Again, growth has been faster than expected, with close to 370 gigawatts of installed capacity by 2014. That's a 22 percent increase compared to our prediction for 2014. The key, again, was lower costs. Also, manufacturers improved their maintenance protocols and turbine efficiency. A cautionary note: new onshore wind installations dropped by more than 20 percent in 2013.

- Batteries. In 2007, we published our first greenhouse-gas cost curve, which measured the relative economics of dozens of different ways of curbing emissions. At that time, we did not even include electric vehicles; we expected that the big improvements would come from internal-combustion engines. But innovation in consumer devices (smartphones, tablets, and laptops) is changing the game for large-format batteries. In 2007, large-format lithium-ion storage cost about $900 per kilowatt-hour; today, the cost is about $380, and it's on track to drop below $200 in five years.

- Unconventional oil and gas. We did see shale coming, but we were way off in terms of how fast mass-scale production would happen and how low costs would go. As gas prices peaked in 2008, a massive wave of innovation was unleashed. Result: US unconventional-oil production rose from almost nothing in 2007 to 3.7 million barrels a day in 2014.

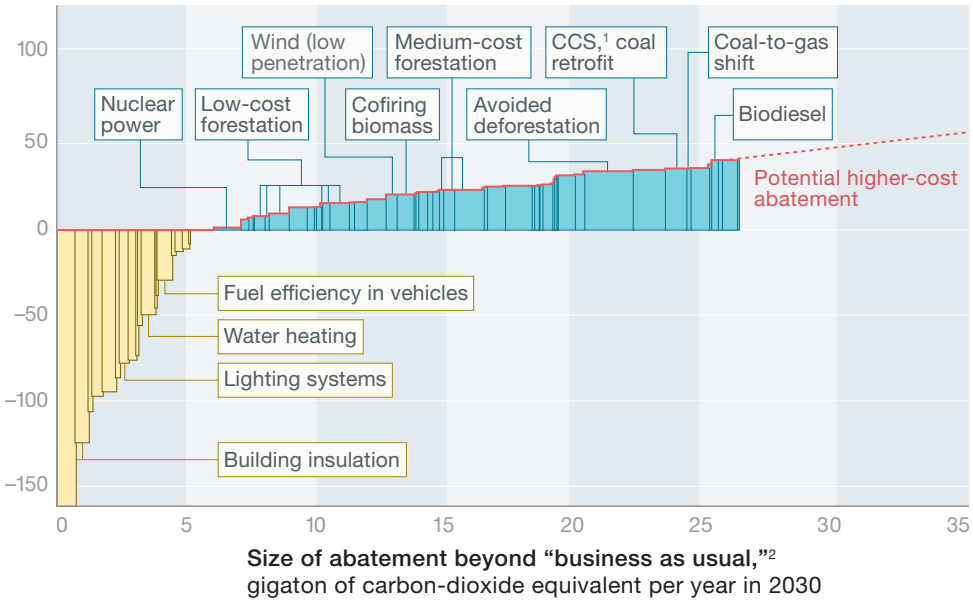
- Energy efficiency. Innovation has come faster than we expected; the forces we thought would hold it back, such as high adoption costs and the slow pace of improvement, proved surmountable. Today we are at a tipping point in consumer behavior; cheap mobile communications, for example, are enabling the connected home. And hardware costs have fallen. For example, LED bulbs now cost about $12 each, down by 80 percent from 2010.

In all these areas, we got the direction right, but not the speed. In other cases, unforeseen events or pressure from competing technologies had the opposite effect on our predictions. Specifically, we saw a bigger future for nuclear, but cost overruns, cheap natural gas, and the 2011 disaster at Fukushima derailed these expectations. Biofuels have also stalled. In 2007, we projected annual consumption of 14 billion gallons by 2030; reality is nowhere near on pace. A lack of innovation and low oil prices have hurt demand for biofuels. Finally, we were too bullish on carbon capture and storage (CCS), a way to make the burning of coal much cleaner. High costs and technical difficulties have slowed adoption. Today, only 13 CCS projects are in operation, and others have been

Exhibit

The classic 2007 global cost curve estimated the size and cost of feasible approaches to abatement by 2030.

Global cost curve for greenhouse-gas abatement (selected measures labeled)



[1]Carbon capture and storage.
[2]"Business as usual" is emissions growth driven mainly by rising demand for energy and transport around the world and by tropical deforestation.

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canceled or delayed—4 in 2013 alone. As a whole, then, we were too optimistic about most fossil fuels and not optimistic enough about most renewables, natural gas, and efficiency. If all these energy trends continue—and, of course, they might not—what are the implications?

Without venturing too deep into the geopolitical weeds, consider what happens to countries—such as Iran, Saudi Arabia, and Venezuela, whose economies rely heavily on fossil fuels—if demand for their oil peaks or growth slows. Just a decade ago, the idea that the United States is now the largest producer of petroleum and natural-gas hydrocarbons[2] would have seemed ludicrous. Today, the country sends diesel fuel to

Europe, gasoline to Latin America, and natural gas to a growing number of markets. Almost no crude oil now moves across the Atlantic to the United States; almost all of it moves to Asia. These shifts are changing the dynamics of regional markets around the world and shifting the center of trading and pricing to Asia.

Low prices and uncertainty, meanwhile, are making the pressure on oil and gas companies to improve their performance more urgent. Disappointing conventional-exploration results, declining production efficiency, and rising capital intensity have harmed the confidence of investors. Utilities are already struggling to deal with competition from on-site generation—energy from rooftop panels, gas turbines, or other sources that are produced for a specific place—and valuations have tumbled in many markets.

For consumers, the biggest change will probably be on the road. Electric vehicles accounted for under 1 percent of US sales in 2014 and for even less globally—but the pace is picking up. McKinsey's Energy Insights unit projects that in 2030, about 10 percent of all cars in the 34 member countries of the Organisation for Economic Co-operation and Development will be at least partially electric. China has set an ambitious target of five million electric or plug-in hybrid vehicles on its roads by 2020. Autonomous (self-operating) trucks in mining and farming are delivering big savings on labor and carbon-dioxide emissions. Car-sharing services are taking off in Europe and the United States, while Lyft, Uber, and others have upended the taxi business and begun to change patterns of personal vehicle ownership and public-transport choices.

More predictions

All in all, our 2007 research and predictions held up reasonably well. So let's try again. Here's how we see a few important trends:

- Gas will be king. In China and the United States, the future is bright for gas because demand is expanding—for example, in the shift to gas for heavy road transport. Cities in California,

Illinois, New York, and elsewhere are equipping their fleets with gas-powered vehicles. In Asia, gas isn't used as much, because resources are monopolized. In Europe, where energy demand is declining, many markets are looking to coal rather than gas.

- Solar will grow fast but remain small compared with conventional sources. Crashing prices in solar may be the key to bringing power to the more than 1.3 billion people who currently do without. A future of distributed generation would allow countries to leapfrog the cost and complexity of building reliable grids. PV is set to capture by far the largest slice of the renewables pie.

- Coal will grow more slowly but will remain huge. The king of fossil fuels is still top of the heap in Asia and will probably remain the fuel of choice. While China is making ambitious moves toward cleaner energy, a true shift away from coal is not imminent. In the United States and Europe, coal is under pressure from regulators and low natural-gas prices. According to the US Energy Information Administration, coal still accounts for 39 percent of US electricity generation today, but that's down from almost 50 percent a decade ago; moreover, no new coal-fired capacity is expected to come on line. And although coal is proving irresistible as much of Europe shifts away from nuclear and continues to experiment with renewables and shale gas, its attraction will fade in time as a result of environmental concerns.

- Value will continue to migrate from generation to services. Distributed generation, dispatchable demand, and the digital grid are redefining the power system. Disruptors are cutting out traditional utilities as new technologies (and financing techniques) let customers opt out of traditional energy supplies.

Finally, a word about outlier technologies—things that aren't particularly popular or feasible at the moment. Nuclear could be a surprise winner. Small modular reactors can provide 24-hour power, without the immense capital expenditure of traditional nuclear reactors. Yes, nuclear is controversial in many countries, but as an emission-free source of constant power, it may be difficult to avoid.

And then there's hydrogen. Admittedly, the hype has been wrong before, but it's interesting that Toyota remains optimistic enough to be working with the Japanese government and others to build a fueling infrastructure. Toyota is focused on making longer-range hydrogen-fuel-cell vehicles the standard for clean transportation.

So that's our take. If we're wrong—and we're sure to be in some areas—we'll let you know in, say, another eight years.

[1] For McKinsey's 2007 resource-productivity framework, see the full report from the McKinsey Global Institute, *Curbing global energy-demand growth: The energy productivity opportunity*, May 2007. For an excerpt of a forthcoming McKinsey book on resource productivity, see Markus Hammer and Ken Somers, "Manufacturing growth through resource productivity," March 2015. McKinsey has done a number of cost curves, over time and for different countries: For the full 2007 cost curve, see Per-Anders Enkvist, Tomas Nauclér, and Jerker Rosander, "A cost curve for greenhouse gas reduction," *McKinsey Quarterly*, February 2007. All of the above are available on mckinsey.com.

[2] Linda Doman, "US remained world's largest producer of petroleum and natural gas hydrocarbons in 2014," US Energy Information Administration, April 7, 2015, eia.gov.