

Curbing the growth of global energy demand

The opportunities for improvement are huge, but market forces alone won't realize them.

**Diana Farrell, Scott S. Nyquist,
and Matthew C. Rogers**

The options available to mitigate the world's energy problems disconcert policy makers and executives alike. Securing new supplies of fossil fuels is difficult and often presents geopolitical risks; new technologies associated with alternative sources of energy, although attractive, involve significant levels of uncertainty and could have unintended consequences.¹ Meanwhile, the prospect of reducing energy demand evokes fears that the consumer's convenience and comfort would be compromised—an unattractive proposition anywhere and an unacceptable one in the developing world, where globalization and rapid economic growth, fueled by increased energy consumption, are improving the prospects of hundreds of millions of people.

Yet McKinsey research² shows that the growth of worldwide energy demand can be cut in half or more over the next 15 years, without reducing the benefits that energy's end users enjoy—and while supporting economic growth. The key is a concerted global effort to boost energy productivity (the amount of output achieved from each unit of energy consumed).³

¹ William K. Caesar, Jens Riese, and Thomas Seitz, "Betting on biofuels," *The McKinsey Quarterly*, 2007 Number 2, pp. 52–63.

² A joint research project conducted by the McKinsey Global Institute (MGI) and McKinsey's global energy and materials practice. For the full report underlying this article, see *Curbing Global Energy Demand Growth: The Energy Productivity Opportunity*, May 2007, available free of charge online at www.mckinsey.com/mgi.

³ Like labor or capital productivity, energy productivity measures the output and quality of goods and services generated with a given set of inputs. Energy productivity can be improved either by reducing the energy inputs required to produce a given level of energy services or by increasing the quantity or quality of economic output. Readers interested in the methodology underpinning this article should read Diana Farrell, Scott S. Nyquist, and Matthew C. Rogers, "Making the most of the world's energy resources," *The McKinsey Quarterly*, 2007 Number 1, pp. 20–33.

Article at a glance

McKinsey research shows that the growth in worldwide energy demand can be cut in half or more over the next 15 years without reducing the benefits end users enjoy. The key is a concerted global effort to boost energy productivity.

This article's exhibits examine the opportunities by focusing on four sectors that represent 98 percent of all end-user demand for energy. Capturing the full range of opportunities would save the equivalent of 64 million barrels of oil a day and help reduce greenhouse gases significantly. But market forces alone won't produce these outcomes.

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The exhibits that follow examine these opportunities by focusing on four sectors that represent 98 percent of end-use demand for energy around the world. Capturing the full range of these opportunities would improve global energy productivity by 135 quadrillion British thermal units (QBTUs), saving the equivalent of 64 million barrels of oil a day—almost 150 percent of the energy the United States consumes now. What's more, an intensive focus on improving energy productivity would spur new markets for demand-side innovation and thus generate important business opportunities for manufacturers, utilities, and other companies.

Yet market forces alone will not produce such outcomes. The obstacles that thwart improvements in energy productivity include information gaps, market-distorting subsidies, an inadequate financing infrastructure, and misaligned incentives. To overcome such barriers, policy makers must terminate distorted policies, make the price and use of energy more transparent, create new market-clearing and financing mechanisms, and selectively implement demand-side energy policies (such as new building codes and appliance standards) while also encouraging demand-side innovation by companies. Although these actions will be difficult politically, the rewards would be profound. Capturing the opportunities we have identified would not only cut the growth of energy demand dramatically but also be among the most economically attractive ways to reduce greenhouse gas emissions.

Opportunities and barriers**Residential buildings**

The residential sector, accounting for 25 percent of total end-use demand⁴ for energy, represents the largest opportunity to raise energy productivity, by the equivalent of 21 percent of the sector's demand in 2020. The adoption of available technologies (including high-efficiency building shells,

⁴We made end use the foundation of our analysis and therefore allocated the power sector's energy consumption and losses to end-user segments instead of following the standard distinction between "primary" and "delivered" energy demand.

compact fluorescent lighting, and high-efficiency water heating) would cut the growth of the sector's energy demand to only 1.0 percent a year, from 2.4 percent—reducing end-use demand for energy by 32 QBTUs in 2020, equivalent to 5 percent of global end-user demand in that year.

What would prevent this reduction from happening? For one thing, consumers at all income levels tend to base their decisions about energy use on the convenience and comfort associated with the fuel and appliances they use, not just on financial considerations. What's more, even if consumers wanted to make the cost of energy a higher priority, they often lack the capital to invest in more efficient technologies, the information needed to make the right choices, or both. The monthly energy bills most households get, for example, don't itemize the electricity consumption of different appliances. If consumers won't pay for high-efficiency appliances with lower operating costs, home builders and appliance suppliers are less likely to make positive-return energy-saving choices when they buy materials or invest in technology. In any case, it's difficult for intermediaries to capture positive-return opportunities, because the market for individual homes is so fragmented.

Furthermore, the subsidization of residential energy prices, common in some countries, reduces the incentive for consumers to save energy. Removing subsidies and implementing metered usage where it isn't currently in place would offer significant opportunities to improve energy productivity (Exhibit 1). We estimate that the removal of the current subsidy on natural gas in Russia, for instance, would save more than 2 QBTUs by 2020.

EXHIBIT 1

Subsidizing inefficiency in the residential sector

		Expected reduction in energy demand in residential sector after removal of subsidies	
Country	Subsidy	Savings opportunity as % of projected fuel demand ¹ in given country, 2020	Reduction possible by 2020, QBTUs ²
China	Liquefied petroleum gas (LPG)/kerosene	21	0.32
India	LPG/kerosene	21	0.37
	Electricity	14	0.31
Russia	Electricity	9	0.07
	Natural gas, heat	43	2.20

¹Assumes price of oil at \$50 per barrel and 3.2% annual growth in GDP.

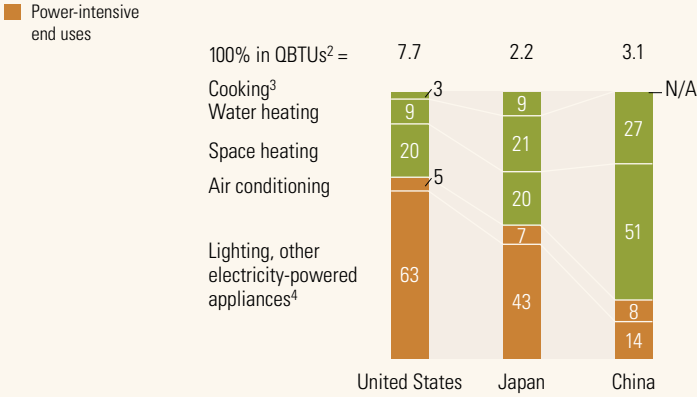
²Quadrillion British thermal units.

Source: McKinsey Global Institute analysis

EXHIBIT 2

Energy on demand

Breakdown of commercial-sector delivered energy demand,¹ 2003, %



¹Delivered energy demand includes only energy end consumption; excludes energy consumed in producing and distributing electricity.

²Quadrillion British thermal units.

³Data on cooking not available for China.

⁴For example, refrigeration, ventilation, office equipment, among others.

Source: Energy Data and Modelling Center (EDMC), *2005 Handbook of Energy & Economic Statistics in Japan*, Tokyo: The Energy Conservation Center; International Energy Agency (IEA); Lawrence Berkeley National Laboratory; McKinsey Global Institute analysis

Commercial buildings

Office and retail buildings, hotels and restaurants, and schools and hospitals together represent 10 percent of global end-use demand. Sixty percent of the current energy demand in the commercial sector comes from developed countries, reflecting the fact that energy demand in the commercial sector tends to take off at a later stage of economic development and as the share of services increases in an economy. Seventy-five percent of the growth we expect in commercial-sector energy demand by 2020 will come from the developing world, however—and fully 48 percent of it from China.

We identified opportunities to raise energy productivity in this sector by the equivalent of 20 percent of its demand in 2020. The nature of the opportunities varies by level of economic development. In developed countries basic energy services (such as space and water heating) account for approximately one-third of all energy use; in poorer countries such services can account for more than three-quarters of it (Exhibit 2). The biggest opportunities for developing countries thus tend to be in improving the insulation of buildings and the energy efficiency of large appliances. Reducing demand from the use of smaller appliances (for instance, by reducing standby power consumption) is more relevant to developed economies.

Why do so many untapped opportunities remain? First, the people who make the decisions that determine energy productivity often don't benefit from the savings gained by consuming less energy: neither landlords nor tenants have much motivation to invest in ways that would benefit the other party. Second, commercial buildings have a high turnover rate, which reduces the payback time that many businesses require when they make energy-saving investments. In the United States, for instance, nearly three-quarters of commercial energy users require a payback of less than two years, which limits the range of feasible energy-saving options. Finally, more than 20 percent of the commercial sector's energy demand comes from municipalities, universities, schools, and hospitals. The stringent capital constraints facing them often limit their ability to invest in energy-saving technologies.

Road transport

Road transport currently represents 16 percent of global energy demand and 46 percent of global demand for petroleum products.⁵ In this sector, unlike the residential- and commercial-building sectors, information on the price and efficiency of fuels is readily available to end users. In addition, fuel costs account for a significant part of the overall expense of transportation, so fuel efficiency is important for transportation companies and individual consumers. Most available opportunities to boost energy productivity have therefore already been identified and implemented, except in countries (largely oil-producing ones) where fuel subsidies reduce the incentive to improve energy productivity.

The removal of fuel subsidies is thus a very large opportunity to improve the sector's energy productivity (Exhibit 3). Cutting them by 80 percent would reduce global demand for road transport fuel by 5 percent—the equivalent of shaving 2.5 million barrels a day off global fuel demand—and would also improve social welfare if more efficient transfer-payment mechanisms replaced subsidies.

Outside the subsidized regions, we found opportunities to improve energy productivity by the equivalent of 9 percent of global road transport demand in 2020, comparable to increasing the average fuel economy of the world's automobile fleet by about five miles a gallon. These opportunities exist because consumers sometimes choose not to pay up front for future fuel savings, perhaps because they respond to nonfinancial considerations, such as style or comfort, or don't have access to credit. Consequently, automakers don't always make every possible positive-return investment in

⁵ MGI also studied air transportation, where we found few viable and currently available improvements to energy productivity that won't already be implemented by 2020. To reduce energy demand from air transport, it would be necessary to reduce levels of air travel or the consumer's comfort (by increasing the number of seats on planes).

EXHIBIT 3

Savings by the barrel

Regions with significant fuel subsidies	Road transportation fuel demand		
	Expected reduction if subsidies are reduced globally by 80%		2020 base case, ² million barrels per day
	Million barrels per day	As % of whole ¹	
Middle East	1.7	43	3.9
Mexico, Central America	0.4	30	1.3
Venezuela, Caribbean	0.2	30	0.7
Southeast Asia	0.2	8	2.8

¹Figures for reduction in barrels per day do not sum to percentages of whole, because of rounding.

²Assumes price of oil at \$50 per barrel and 3.2% annual growth in GDP.

Source: McKinsey Global Institute analysis

raising fuel economy, because they can't be certain that they'll recoup the cost from consumers.

Of course, fuel prices matter too. Higher fuel taxes in Europe, for instance, create incentives for automakers—and consumers—to adopt fuel-efficient technologies at lower oil prices than would be true in regions such as the United States, where fuel taxes are lower; the average vehicle's fuel economy is 37 percent higher in Europe than in the United States.⁶ Indeed, we estimate that in Europe more than half of the efficiency-improvement technologies available to automakers today would have positive economic returns at an oil price lower than \$60 a barrel, as against none in the United States. In an environment of sustained high oil prices, such findings could have significant competitive implications for automakers everywhere.

Industry

The industrial sector currently uses more energy than any of the other sectors we studied (47 percent of global end-use demand), though its demand is growing more slowly than that of the others.⁷ Industry is also the most heterogeneous end user, with highly energy-intensive sectors (such as steel, chemicals, and aluminum) and a broad array of less energy-intensive ones (such as food processing and textiles).⁸

⁶Measured in liters per 100 kilometers driven.

⁷We believe that demand for energy will grow by 2.1 percent a year from 2003 to 2020 in the industrial sector but by 2.3 percent a year in the other sectors we examined.

⁸For this study, we examined three major categories of industrial end users in detail: selected petrochemicals (ethylene and products derived from it, nitrogenous fertilizers, and chlorine-caustic), the steel industry, and the pulp and paper industry. Together, these end users represent 33 percent of global industrial energy demand and more than 45 percent of the industrial sector's growth projected in our base-case scenario to 2020.

EXHIBIT 4

Curbing the growth of US energy demand

Opportunities for improving energy productivity in the US industrial sector

Technology/method ¹	Description	Industrial sectors affected	Energy savings as % of 2020 demand within affected sectors (unless otherwise specified)
Heat recovery in production of mechanical, electrical power			
• Cogeneration	Employing combined heat and power systems to capture and use heat that would otherwise be lost	Across sectors	3
• Steam generation best practices	Optimizing efficiency of steam generation in both operations and maintenance	Across sectors	5 ³
• Plant-level integration of energy systems	Identifying synergies, eg, reconfiguring factory to use excess heat generated by 1 process as input into another	Specifically energy-intensive sectors ²	3 ⁴
Optimized motor-driven systems			
	Upgrade motors and optimize systems in pumps, compressors, fans	Across sectors	2
Gasification			
	Increasing efficiency in use of low-grade fuels that are by-product of production in some energy-intensive industries	Petroleum refining, pulp and paper	6
Membranes			
	Replacing energy-intensive separation processes; multiple applications in various industrial sectors	Chemicals, food processing	2–3
Near-net-shape casting			
	Integrating casting and hot-rolling of steel into 1-step process, thereby reducing need to reheat steel before rolling	Steel, metals	10

¹In order of largest to smallest by estimated absolute value of energy savings.²Based on aluminum, chemicals, food processing, steel, petroleum refining, pulp and paper.³Percentage of total steam energy inputs.⁴Percentage of total energy losses.

Source: Lawrence Berkeley National Laboratory; US Department of Energy; McKinsey Global Institute analysis

Opportunities to improve energy productivity in this sector represent 16 to 22 percent of its total demand in 2020. In the United States, for example, we noted significant opportunities in every part of the sector we studied (Exhibit 4). Two of the largest are the recovery of heat generated in the production of mechanical or electrical power and the optimization of motor-driven systems, such as pumps and compressors. These technologies offer substantial benefits to the developing world as well. In China, for instance, rapid growth and favorable economics make new capital development

attractive. We reckon that implementing best-practice energy-efficient technologies in all new Chinese industrial-production capacity would cut global energy demand in 2020 by 13 QBTUs—fully 10 percent of the global energy productivity opportunities we identified.

One reason for the large scale of the opportunities in the industrial sector is that many companies in it are government-owned or protected from competitors by regulation. Without market pressure, such companies have scant motive to boost their energy productivity. Even private-sector companies face barriers, however. In industries where energy costs are a small portion of overall costs, for example, managers who aren't responsible for ongoing operating expenses often make decisions that affect energy productivity (for example, when a company's IT department chooses its computer hardware). What's more, industrial companies sometimes apply internal-rate-of-return hurdle rates of 20 percent or more to plant-level investment projects because of the cumulative risks associated with costs, future prices, and operations. These high hurdle rates also apply to energy-saving projects, which may be less risky.

Capturing the opportunities

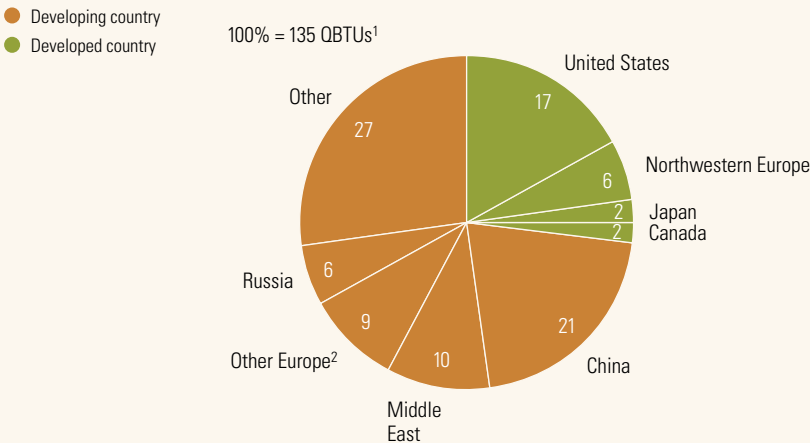
Developed versus developing economies

To a large extent, capturing the 135 QBTUs of opportunities for energy-productivity improvement we've identified will depend on the commitment

EXHIBIT 5

Developing opportunities

Potential improvement in energy productivity by region, 2020, %



¹Quadrillion British thermal units.

²Includes Baltic States, Eastern and Mediterranean Europe, North Africa.

Source: McKinsey Global Institute analysis

of the developing world, which accounts for nearly three-quarters of them (Exhibit 5). The reason is that developing countries tend to start from a much lower base of capital stock (industrial-production capacity, for instance, or fleets of vehicles) and grow more rapidly than developed economies. What's more, it is much cheaper to incorporate energy-saving features in new capital than to retrofit. The additional cost of installing energy-saving double-pane windows in a new building, for instance, is significantly less than the cost of upgrading an existing one's single-pane windows.

China, in particular, will play a crucial role because of its size and rapidly growing influence in the world economy. Indeed, we estimate that in 2020 China's opportunity for energy productivity improvement will be as high as 31 QBTUs—5 percent of global energy demand in that year. China's power sector alone will generate 16 percent of the global growth in energy demand that we expect from 2003 to 2020, so it really matters whether the country meets that demand with power plants at current efficiency levels or with new, high-efficiency plants. Although addressing such issues will be difficult, we believe that measures to improve energy productivity can actually help China's economy. In fact, given the country's relatively low labor costs in building, these opportunities may well have higher returns there than the 10 percent or so we have observed elsewhere. Moreover, China could be a considerable source of innovation as it develops and tests new energy-efficient devices for use in markets around the world.

Overcoming market failures

For leaders in developing and developed markets alike, improving energy productivity is an obvious point of departure for achieving energy policy objectives of all stripes. But as we've seen, market forces alone won't capture the opportunities.⁹ How can governments remove the distortions and market inefficiencies holding back energy productivity and, at the same time, create an environment that encourages businesses to seek innovative ways of tapping into the resulting opportunities?

Incentive programs implemented through energy intermediaries are an attractive option in the residential and commercial sectors (Exhibit 6). Today, the returns of many utilities are based on the volume of electricity delivered, which encourages them to promote growth in demand. Instead, governments could reward improvements in energy efficiency among end

⁹The barriers to capturing energy productivity opportunities matter even when energy costs are quite high. We found, for example, that a sustained oil price of \$70 a barrel wouldn't significantly affect energy demand, because the energy prices that most consumers pay don't directly reflect global oil prices, and higher oil revenues tend to boost energy consumption in oil-exporting countries.

users. Such an environment would encourage companies to find ways to overcome information barriers as well as agency problems.¹⁰

For their part, utilities can establish technologies for two-way communication between themselves and their customers that facilitate changes in the way consumers use energy. With advanced metering, for instance, consumers can see how their electricity consumption varies over time. This information, coupled with differential pricing (charging premium prices for energy used during peak times, and vice versa) gives customers an incentive to shift their consumption patterns away from peak times. By doing so, demand for expensive peak power-generation capacity can be reduced.

¹⁰ In the construction industry, for example, an agency problem often exists between builders and consumers, as the former has little incentive to focus on energy efficiency because the latter may be reluctant to spend more now for a building, apartment, or home that promises energy savings in the future.

EXHIBIT 6

What governments can do

Sector	Barrier to increased energy productivity	Policy/program to overcome barrier	Example
Residential/commercial	Lack of information; principal-agent problems	Incentive programs	<ul style="list-style-type: none"> • US Energy Efficiency Programs (EEPs) work through utilities to encourage innovative ways of overcoming barriers to improved energy productivity
		Information policies	<ul style="list-style-type: none"> • EU Energy Efficiency Certification for appliances enables energy users and intermediaries to understand trade-offs involved with energy choices and thus help overcome principal-agent barriers • Advanced metering or technologies for 2-way communication between a utility and its customers enable consumers to shift their consumption patterns away from peak times
		Standards	<ul style="list-style-type: none"> • Mandatory consumption standards for standby power could reduce energy usage of common appliances to 1 watt per hour from 20–60 watts per hour • With 30% penetration, mandatory use of compact fluorescent lighting could capture up to 3% of residential sector's potential for higher energy productivity
Transport	Consumers reluctant to pay up front for future fuel savings	Fuel-economy standards, fuel taxes	<ul style="list-style-type: none"> • Europe has tighter fuel efficiency standards and higher fuel taxes than the United States and therefore uses, on average, 27% less fuel per mile driven
Industrial	Lack of incentives or information	Information and incentive programs	<ul style="list-style-type: none"> • Removing energy subsidies and tracking financial performance of public-sector industries would increase incentives to use energy economically • Initiating demonstration projects and energy audits within private-sector companies can provide information and encourage capture of opportunities • Facilitating financing of positive-return capital projects (eg, replacing old, inefficient steel plants with new, more efficient ones; adopting technology policies that promote adoption of energy-saving technologies in developing countries)

Companies such as CenterPoint Energy, Entergy, and Pacific Gas and Electric (PG&E) are already implementing these technologies in the United States. Adopting these and other demand-side programs across the United States could accelerate the efficiency improvements that utilities could intermediate by about 1 percent a year relative to the business-as-usual scenario.

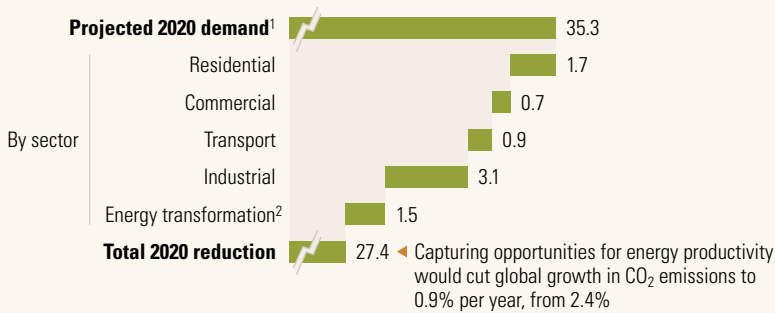
Once utilities can itemize their bills, other interesting options become viable for them. Some are already experimenting with market-based programs that allow energy services companies to identify and compete for energy-saving opportunities as an alternative to building new power-generation capacity. These companies can, for example, combine the engineering expertise needed to reduce energy consumption with financial services that would help municipalities, universities, schools, and hospitals to bridge the gap between their current expenditures and future energy savings. In new-housing developments, energy services companies could help builders find new ways of financing positive-return investments in energy-efficient homes. Similarly, energy productivity gains could be accelerated if incentives were created to upgrade existing assets when they change hands, by providing lower financing costs for buyers of energy-efficient homes, requiring commercial upgrades and expansions to meet new building codes, or developing consumer-financing vehicles of longer duration for efficiency investments.

In addition to fostering innovative market solutions, governments may want to consider tighter standards. By 2020, applying stricter fuel economy rules to the US transport sector (along the lines of those planned in Europe and Japan) would improve the world's fuel economy by four miles a gallon—the equivalent of saving four million barrels of oil a day. Likewise, in China we estimate that introducing world-class insulation standards and energy-efficient heating and cooling packages in new residential construction would save eight QBTUs by 2020, or 6 percent of the global energy productivity opportunity we identified.

Governments also have an important role to play in areas such as power plants and refineries, where new, high-efficiency assets could replace old, less efficient ones, thus raising energy productivity and generating attractive economic returns. Appropriate energy and environmental policies could help provide incentives for the upgrades. In areas such as the manufacture of appliances, evidence suggests that targeted standards encourage economies of scale that could relatively quickly make the price of high-efficiency appliances comparable to that of less efficient equipment under the previous standard.¹¹ The premium consumers now pay for above-standard efficiency often acts as a disincentive.

¹¹ Steven Nadel, "Appliance and equipment efficiency standards," *Annual Review of Energy and the Environment*, 2002, Volume 27, pp. 159–92.

EXHIBIT 7

Better productivity, fewer emissionsPotential reduction in CO₂ emissions through enhanced energy productivity, 2020, billion metric tons¹Assumes price of oil at \$50 per barrel and 3.2% annual growth in GDP.²Power generation and refining sectors.

Source: McKinsey Global Institute analysis

Environmental benefits

If the concerted efforts of companies and policy makers can improve the world's energy productivity to the extent we believe possible, the environmental benefits would be significant; this is fortunate because addressing global externalities (such as greenhouse gases) is extremely difficult. Even the price mechanism can have perverse effects. Our research shows that a shift to \$70 for a barrel of oil, from \$30, makes power generators shift from oil to coal, which is more carbon dioxide-intensive, thus increasing carbon dioxide emissions from the power-generation sector by 8 percent globally.

These dynamics make the possibility of curbing emissions by pursuing positive-return energy productivity opportunities particularly alluring. We estimate that capturing them would contribute up to half of the emission abatement required to cap the long-term concentration of greenhouse gasses in the atmosphere at 450 to 550 parts per million (Exhibit 7), a range that some experts suggest would meet the goal of preventing average global temperatures from rising by more than 2 degrees Celsius (3.6 degrees Fahrenheit). **Q**

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