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March 2009

Averting the next energy crisis: The demand challenge

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Preface

This report is the result of ongoing research collaboration between the McKinsey Global Institute (MGI) and McKinsey's global energy and materials (GEM) practice to understand the microeconomic underpinnings of global energy demand. In this report, we examine the outlook for energy demand across the range of end-use sectors and take a view on the trajectory of energy supply across fuel types.

Diana Farrell, former director of MGI, provided strong leadership on this project, as did colleagues from McKinsey's global energy and materials practice (GEM), notably Ivo Bozon, Pedro Haas, Occo Roelefson, and Matt Rogers. We also thank Jaana Remes, senior MGI fellow, for her consistent support and advice. Jaeson Rosenfeld led the project team for MGI with Koen Vermelfoort and Greg Terzian from the GEM practice. The project team included Wayne Hu, Sendil Palani, Utsav Sethi, and Anjan Sundaram from MGI; Marte Guldemond, Anniken Hoelsaeter, Prabhnoor Jolly, Cristian de Pace and Fonger Ypma from the GEM practice; and Rahul K. Gupta, Shobhit Awasthi, and Rahul Tapariya from McKc Analytics.

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This work is part of the fulfillment of MGI's mission to help global leaders understand the forces transforming the global economy, improve company performance, and work for better national and international policies. As with all MGI research, we would like to emphasize that this work is independent and has not been commissioned or sponsored in anyway by any business, government, or other institution.

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Executive summary

The world has been witnessing extraordinary volatility in energy prices in the past five years. Crude oil prices escalated as robust demand for energy, particularly from rapidly growing developing economies, combined with supply shock; even as crude hit record highs, economic growth and energy demand appeared to be immune. Then suddenly, everything changed. The credit squeeze and subsequent GDP slowdown have seen energy-demand growth slow down rapidly and prices drop sharply in response. Producers began to cut back on capital projects, and some companies struggled to find credit to drill attractive wells or build new power capacity.

Amid this high degree of uncertainty on both the demand and supply side of the energy equation, observers are keen to gain an understanding of how the supply-demand balance will evolve given the current global economic downturn. For how long is energy demand likely to contract? To what degree will today's credit constraints impact supply and for how long? How will the post-downturn balance between demand and supply play out—and with what effect on energy prices? This analysis by the McKinsey Global Institute (MGI) and McKinsey's global energy and materials (GEM) practice seeks to answer some of these questions.

Amid exceptionally high uncertainty about the future path of GDP in different regions during this turbulent period, we have looked at energy-demand growth projections using both mainstream current GDP projections and a range of alternative scenarios around these estimates.[1] The "moderate" case projects a global GDP downturn producing a total 4.7 percent gap to trend—felt mostly in 2008 and 2009—and then recovery in 2010. MGI's moderate case assumes that, under current consensus GDP projections, energy-demand growth will experience a short-term lull in 2009 due to the global economic downturn and the credit squeeze but is likely to rebound sharply thereafter across all fuel types. As demand recovers, CO_2 emissions will grow rapidly.[2]

However, we should note that consensus forecasts for global GDP have been subject to downward revision month after month since mid-2008. For this reason, we have added to our analysis a "severe" and a "very severe" case to reflect the successive downgrading of growth forecasts. In the event that we find ourselves in a more severe scenario that sees a reduction in credit to the non-financial sector, our severe case produces a gap to trend of 6.7 percent while the gap in the very severe case is 10.8 percent. This very severe case depicts a downturn a full three points worse than any global downturn since World War II, and lasts into 2012. Using

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[1] The GDP projections used in this report are a composite of projections from the *World Economic Outlook*, International Monetary Fund, November 14, 2008, and Global Insight GDP projections, December 5, 2008. Note that the 4.7 percent decline from trend is also very close to the IMF's *World Economic Outlook* in January 2008, which called for slower GDP growth than in its November release, which we used for our composite case. For our precrisis case, we use Global Insight, January 2008. For our severe and very severe cases, we reduced moderate-case growth equally across all regions.

[2] For those interested in a detailed discussion of CO_2 abatement, please see *Pathways to a low-carbon economy*, Climate Change Special Initiative, McKinsey & Company, January 2009 (www.mckinsey.com).

these three cases, we hope to cover a broad range of possibilities for the depth and length of the downturn.

Looking toward recovery, it is notable that, in our moderate case, developing regions will account for more than 90 percent of global energy-demand growth to 2020, with demand growth most rapid in the Middle East. In stark contrast, growth of liquids demand—including petroleum products and biofuels—and oil demand more specifically could reach peak demand in the United States, according to our moderate case. We project that the United States will actually cut its per capita energy demand to 2020, partly reflecting action to boost the economy's energy productivity—the level of output achieved from the energy consumed.

Globally, potential exists for liquids-demand growth to outpace that of supply, laying the groundwork for a possible new spike in oil and natural gas prices.[3] This is true in both the moderate-case scenario as well as in a low-GDP case—although the imbalance would appear at a later date in the severe case. Although the supply of coal and gas appears to be sufficient to prevent long-term price inflation for these fuels, growth in the supply of oil will slow markedly.

What should policy makers do to head off a renewed imbalance between oil supply and demand, and how can they do so at the lowest possible cost? Our research shows that there is significant potential to abate oil-demand growth at a reasonable cost. Many of the levers available offer positive returns to investors and the potential for carving out profitable positions in new markets. While policy has made some progress in abating energy demand—over and above the short-term impact of recessionary conditions—much remains to do.

ENERGY-DEMAND GROWTH WILL FLATTEN IN THE SHORT TERM

A number of factors are working in concert to bear down on energy-demand growth today. Demand is now reacting to the hangover of high energy prices in 2008; to significantly tighter credit conditions; and to what appears to be a relatively deep and entrenched slowdown in global GDP. The demand response is particularly marked in the case of petroleum, where demand is concentrated in some of the sectors hardest hit by the economic slowdown including automotive, industrials, trucks, and air transport.

GDP is the most important driver of energy-demand growth (Exhibit 1).[4] Our moderate case—which we have built using a composite of GDP projections by the International Monetary Fund and Global Insight—envisages that 2008 and 2009 will see the economic trough with negative GDP growth in developed economies in aggregate. Developing economies will see a marked projected deceleration in GDP growth from 5.1 percent in 2008 to 3.9 percent in 2009.[5]

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[3] Oil prices would rise globally, and natural gas prices would rise in regions where gas is tied to crude oil via power-sector switching or by pricing agreements such as the Japanese Crude Cocktail (JCC).

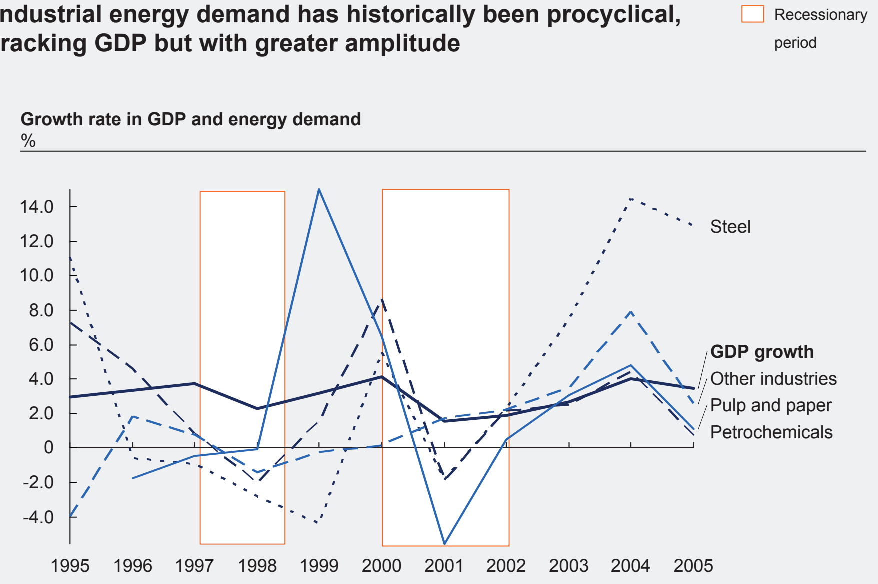
[4] The other major drivers are energy prices and regulation.

[5] *World Economic Outlook*, International Monetary Fund, November 14, 2008; Global Insight, December 5, 2008. Note that the 4.7 percent decline from trend is also very close to the projection in the *World Economic Outlook* released in January 2008, which projected slower GDP growth than the IMF's November Outlook, which we used for our composite case.

Global energy demand grew at a rate of 3.1 percent a year between 2002 and 2007, but we expect a marked deceleration in the pace of growth in 2007 to 2009 to a rate of only 1.0 percent per annum in our moderate case. In developed economies, energy demand will contract by 1.2 percent while energy-demand growth in developing countries will slow to between 1.5 and 2.2 percent. If a very severe global downturn unfolds, it is possible that global energy demand could contract instead of slowing (but still remaining positive) in our moderate case. Our severe case is based on a deeper, more prolonged reduction in credit to the nonfinancial private sector, with an additional 2 percentage point reduction in trend global GDP. In our severe case, demand for oil, coal, and gas is negative in 2007 to 2009. In our very severe case, demand stagnates for longer with oil demand only reaching 2007 levels by 2011.

Exhibit 1

Industrial energy demand has historically been procyclical, tracking GDP but with greater amplitude



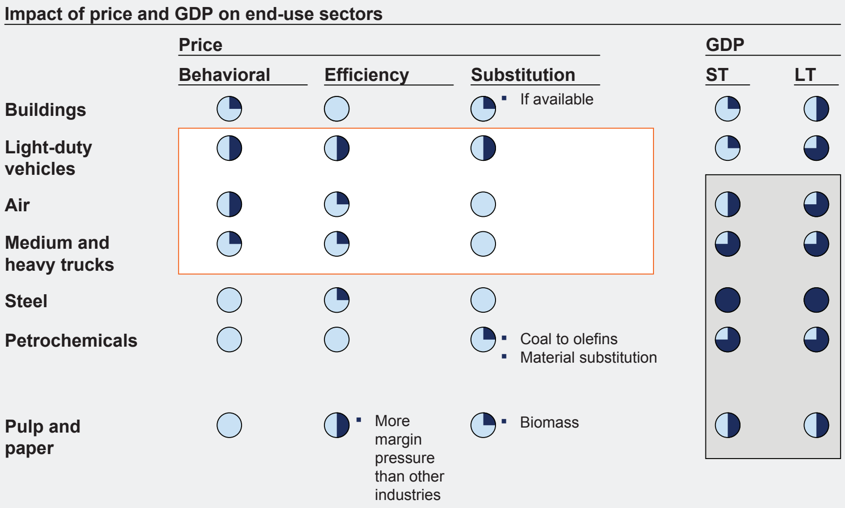
Source: IEA; Global Insight; McKinsey Global Institute analysis

Oil prices, too, have had a progressively negative impact on energy demand since 2004. Declines in oil demand have been mostly in developed economies while non-Organisation for Economic Co-operation and Development (OECD) energy-demand growth relative to GDP remained fairly robust up to 2007. Prices provoke the strongest short-term response in those sectors—light-duty vehicles (light vehicles) and air transportation—where fuel accounts for a high share of total costs and where taxes and other factors do not act as a significant cushion against market-price fluctuations (Exhibit 2). Developed countries show a stronger response because their demand is more concentrated in price-responsive sectors and because many non-OECD regions subsidize petroleum usage in the price-responsive sectors.

Exhibit 2

Price responses are concentrated in transportation, while industrial sectors' growth tends to respond more to GDP

☐ Price-driven
▨ GDP-driven



Impact of price and GDP on end-use sectors

	Price			GDP	
	Behavioral	Efficiency	Substitution	ST	LT
Buildings	◔	○	◔ ▪ If available	◔	◑
Light-duty vehicles	◑	◑	◑	◔	◕
Air	◑	◔	○	◑	◕
Medium and heavy trucks	◔	◔	○	◕	◕
Steel	○	◔	○	●	●
Petrochemicals	○	○	◔ ▪ Coal to olefins ▪ Material substitution	◕	◕
Pulp and paper	○	◑ ▪ More margin pressure than other industries	◔ ▪ Biomass	◑	◑

Source: McKinsey Global Institute analysis

THE MEDIUM TO LONG TERM WILL SEE A STRONG REBOUND IN ENERGY-DEMAND GROWTH ACROSS FUELS

As the world economy recovers, so too will energy-demand growth, particularly for core fuels such as diesel, which has a high income and low price elasticity, and few available substitutes. Once GDP growth returns to its long-term trend, we expect that energy-demand growth will also rebound. From 2010 to 2020, MGI's moderate case projects that energy-demand growth will recover to 2.3 percent per annum, nearly a full point faster than the period from 2006 to 2010, with global energy demand reaching approximately 622 quadrillion British thermal units (QBTU) in 2020.

Developing regions will account for more than 90 percent of global energy-demand growth to 2020. We project that the Middle East will have the fastest-growing energy demand of any major region, driven by the stepping up of industrial capacity building to take advantage of the Middle East's oil and gas supplies, as well as high, continuing growth in the region's vehicle stock, reflecting increasing wealth. Meanwhile, the Middle East will likely continue to see only limited efforts to improve energy efficiency. During the same period, our moderate case projects energy-demand growth in both China and India growing by 3.6 percent.

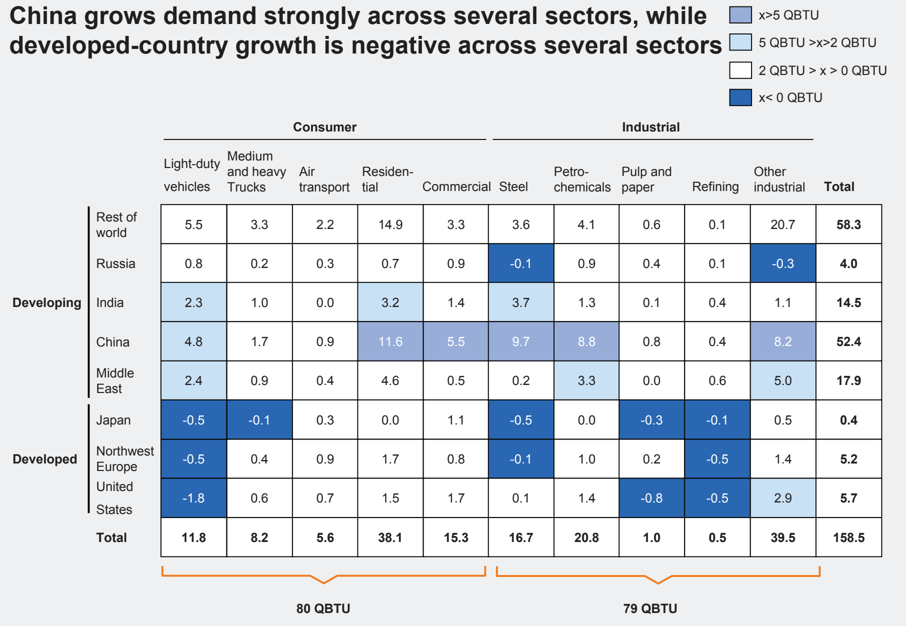
However, energy-demand growth will be virtually flat in the United States and Japan while Europe will see energy demand growing at a rate of some 1 percent, reflecting the inclusion in this region of many developing economies. In our moderate case, US liquids demand contracts marginally at a rate of 0.1 percent per annum and oil demand specifically by 0.4 percent a year to 2020, broadly in line with Energy Information Administration (EIA) projections. US demand for fossil fuels—natural gas, oil, and coal—has actually peaked in our moderate case, remaining exactly flat to 2020. Of these three fuels, demand for only natural gas is projected to grow in the United States—at a rate of just 0.6 percent a year.

Breaking energy-demand growth down into different sectors, we see end-use demand increasing about equally in consumer- and industry-driven sectors. This reflects the increasing weight of developing countries, and it is in contrast to our previous report in which we saw consumer-driven sectors accounting for close to 60 percent of long-term energy-demand growth, largely as a result of ongoing consumer demand in developed countries. The fastest-growing sectors will be steel, petrochemicals, and air transportation. Developing countries, including notably China and India, which are both investing heavily in long-distance transportation and infrastructure, will drive energy demand in these sectors. Efficiency improvements will have little impact on energy-demand growth of petrochemicals and air transport, in particular, as the opportunities to boost energy productivity have been largely captured and remaining opportunities are smaller in these sectors than in others.

Light vehicles will see one of the slowest rates of energy-demand growth. Although the vehicle stock will grow very strongly in China, India, and the Middle East, very rapid efficiency improvements across many other regions will help dampen demand from this sector in aggregate. Although we project an increased share of electric vehicles (EV) to 2020, there won't be a real impact on energy-demand growth until 2020 to 2030.

Five sectors within China—residential, commercial, steel, petrochemicals, and light vehicles—will account for more than 25 percent of overall energy-demand growth (Exhibit 3). Other sectors that make a large contribution to overall energy-demand growth are India's light vehicles, residential, and steel sectors, and the light vehicles and petrochemicals in the Middle East. In contrast, there are several sectors in different countries that will see energy demand contract, including the light-vehicles and pulp-and-paper sectors in developed economies, the former driven by efficiency regulations, as we have discussed, the latter by a shift from paper to digital media.

Exhibit 3



China grows demand strongly across several sectors, while developed-country growth is negative across several sectors

▨ x>5 QBTU
▨ 5 QBTU >x>2 QBTU
☐ 2 QBTU > x > 0 QBTU
■ x< 0 QBTU

		Consumer					Industrial					
		Light-duty vehicles	Medium and heavy Trucks	Air transport	Residen-tial	Commercial	Steel	Petro-chemicals	Pulp and paper	Refining	Other industrial	**Total**
Developing	Rest of world	5.5	3.3	2.2	14.9	3.3	3.6	4.1	0.6	0.1	20.7	**58.3**
	Russia	0.8	0.2	0.3	0.7	0.9	-0.1	0.9	0.4	0.1	-0.3	**4.0**
	India	2.3	1.0	0.0	3.2	1.4	3.7	1.3	0.1	0.4	1.1	**14.5**
	China	4.8	1.7	0.9	11.6	5.5	9.7	8.8	0.8	0.4	8.2	**52.4**
	Middle East	2.4	0.9	0.4	4.6	0.5	0.2	3.3	0.0	0.6	5.0	**17.9**
Developed	Japan	-0.5	-0.1	0.3	0.0	1.1	-0.5	0.0	-0.3	-0.1	0.5	**0.4**
	Northwest Europe	-0.5	0.4	0.9	1.7	0.8	-0.1	1.0	0.2	-0.5	1.4	**5.2**
	United States	-1.8	0.6	0.7	1.5	1.7	0.1	1.4	-0.8	-0.5	2.9	**5.7**
	Total	**11.8**	**8.2**	**5.6**	**38.1**	**15.3**	**16.7**	**20.8**	**1.0**	**0.5**	**39.5**	**158.5**

Source: McKinsey Global Institute Global Energy Demand Model 2009

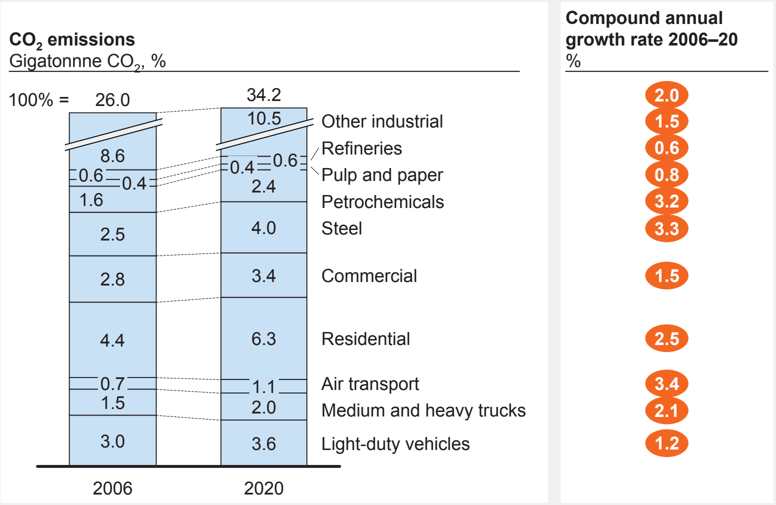
The fuel mix will change only modestly to 2020 given the very large installed base of energy-using capital stock and relatively minor differences in growth rates among fuels. Coal continues to be the fastest-growing fuel (with China and India driving almost 100 percent of that growth) and oil the slowest-growing.

CO_2 emissions will grow marginally more slowly than energy demand

CO_2 emissions will grow slightly more slowly than energy demand as carbon-intensive coal use increases more quickly than that of other fuels but rapid growth in renewables help to offset this (Exhibit 4). China's emissions will continue to grow at 3.7 percent per year, outpacing energy-demand growth of 3.5 percent per annum. CO_2-emissions growth will be flat or negative in developed regions due both to slow energy-demand growth and regulations that cause a shift to renewables and natural gas.

Exhibit 4

CO_2 emissions are projected to grow at 2.0 percent per annum



Source: McKinsey Global Institute Global Energy Demand Model 2009

The fastest-growing end-use sectors in terms of emissions are air transport, steel, and petrochemicals. In these sectors, CO_2 emissions largely grow in line with energy demand by end use. Light-vehicles emissions grow less quickly than energy demand due to the sector's increasing use of biofuels.

A RESUMPTION OF OIL PRICE INCREASES COULD DEVELOP AS REBOUNDING DEMAND OUTPACES GROWTH IN SUPPLY

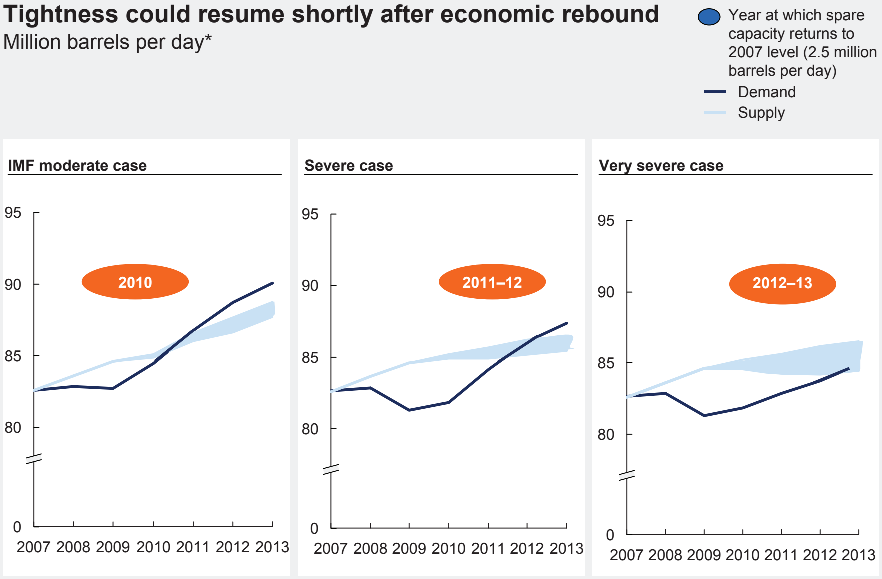
Without further action to abate energy-demand growth, spare capacity levels in the oil market could return to the low levels that we witnessed in 2007 as soon as 2010 to 2013, depending on the depth of the economic downturn.

The supplies of gas and coal do not appear to be a constraint to demand growth in most regions. Although temporary imbalances could exist between now and 2020, the overall long-term supply-demand path looks relatively balanced.

However, a different story could emerge in the oil market with the possibility of market tightness returning between 2010 and 2020 (Exhibit 5). McKinsey's GEM practice expects that oil supply will grow more slowly than oil demand at a $75 oil price (Exhibit 6). Therefore, a change in the oil price or policy, or a combination of the two, will be necessary to ensure that demand and supply are in balance. Many policy levers are available to achieve this rebalancing of supply and demand, including incentives to shift petroleum out of boiler-fuel applications, the removal of petroleum-product subsidies, and further incentives for higher fuel efficiency or EVs.

Exhibit 5

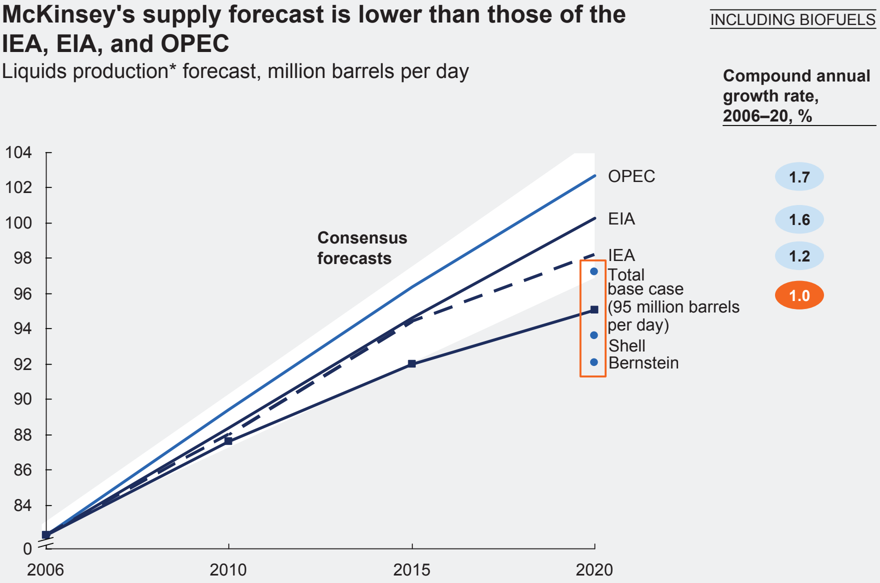
Tightness could resume shortly after economic rebound
Million barrels per day*



* Crude oil at the well head; includes biofuels and excludes refinery gains.
Source: McKinsey Global Institute Global Energy Demand Model 2009; McKinsey GEM practice

Exhibit 6

McKinsey's supply forecast is lower than those of the IEA, EIA, and OPEC
Liquids production* forecast, million barrels per day



* Includes crude oil, condensate, natural gas liquids, bitumen, ultraheavy oil, coal-to-liquids, gas-to-liquids, biofuels, and shale; does not include refinery processing gains.
Source: IEA; OPEC; EIA; Total; Shell; Bernstein; McKinsey Petroleum Supply Model

NEW POLICIES BOOSTING ENERGY PRODUCTIVITY ARE STARTING TO MITIGATE ENERGY-DEMAND GROWTH

Regulatory action to boost energy efficiency among various end users has begun to have a measurable impact on the trajectory of energy-demand growth. There has been evident progress in capturing available opportunities to boost energy productivity, although many more opportunities remain.

Our latest research projects that energy productivity will grow at 0.9 percent a year, at about the same rate as the 1.0 percent we projected in 2007. Energy productivity will rise across all regions with China leading the way. We project that the United States will actually cut its per capita energy demand to 2020—the only region to do so—although the level will still remain 50 percent above the average level in the

European Union (EU). Further action to boost energy productivity could abate global energy demand by between 16 and 20 percent of the projected 2020 level, representing a cut in energy-demand growth to this point of almost two-thirds.

This opportunity is somewhat smaller than we estimated in our 2007 report, which projected that policies were available to abate demand by between 20 and 24 percent (around two-thirds of energy-demand growth to 2020). There are several reasons for this, but the most important is that policy makers have since put in place regulations that will capture an estimated 15 QBTU of the overall opportunity, notably action in the United States and the EU on fuel-efficiency standards in the light-vehicles sector and mandates to boost the share of renewables in the energy mix in several countries. Also, the shorter time to 2020 has negated some of the opportunities, because a small portion of the capital stock has turned over since the time of our last report. That said, the potential now is more substantial on a per annum basis—it could reduce demand growth from 2.1 percent per annum to 0.5 percent per annum. The shorter time period to 2020 (17 years in our last report and 14 years now) and the fact that a large percentage of the opportunity is in retrofits or capital stock that will still turn over by 2020 explains the greater impact on demand growth.[6]

POLICY MAKERS CAN DO MUCH MORE TO ABATE OIL DEMAND

Given the risks of a resumption of imbalance in the oil market, importing-country policy makers should take care to include action on the demand side in their thinking (Exhibit 7). Addressing the issue of demand holds more promise for a coordinated response than supply given that oil demand is more concentrated than supply—Europe, the United States, and China represent 50 percent of demand in 2020, while the top three supply countries—Saudi Arabia, Russia, and the United States—together represent only one-third of supply. Rather than competing for supply, oil-importing countries might choose instead to coordinate demand policies such as fuel-efficiency standards and new technology investments to abate demand, or to use the strength of their coordinated demand policies as bargaining chips with oil-exporting countries when pursuing supply additions. It is important to note that oil serves a valuable role in being a relatively inexpensive transport fuel (and lower carbon compared to some alternatives such as coal).

There is significant value in reducing the likelihood of another oil-price peak, through a combination of boosting energy productivity and fuel substitution, while maintaining supply investment during the downturn and credit crunch. Both importing and exporting countries could benefit by coordinating demand- and supply-side policies. Many opportunities for low-cost or even positive internal rate of return (IRR) opportunities exist to abate oil demand through efficiency or substitution, assuming an oil price of $75 a barrel. Moreover, policy plays a critical role in determining future demand for oil, offering scope for some mutually beneficial long-term tradeoffs between demand policy and supply installation.

In the short term, there are a number of levers available to abate oil demand growth in a relatively cost-effective way. MGI research finds that policy makers could achieve abatement of between 6 million and 11 million barrels per day by 2020, the amount required to keep demand and supply in balance. For instance, removing

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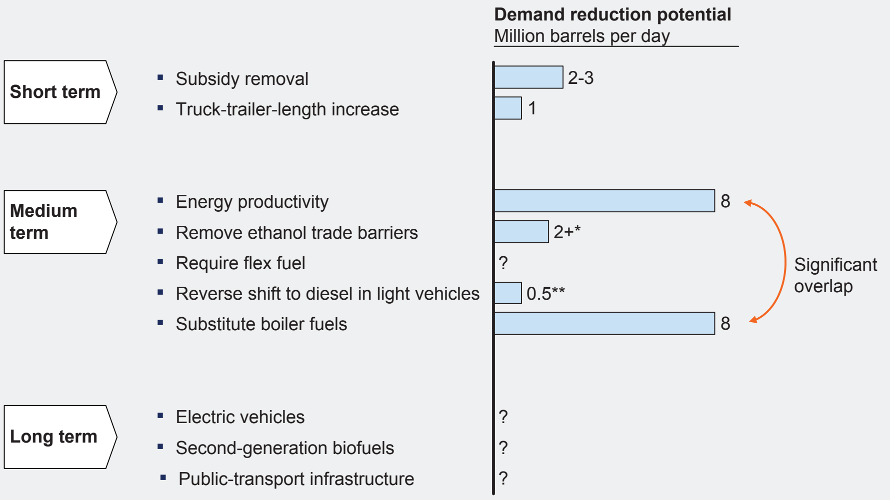
[6] Since this analysis was completed, a number of countries have announced large economic stimulus packages, some of which have a significant energy component. For instance, in the United States, some $106 billion, or nearly 14 percent, of the $787 billion stimulus package signed by President Barack Obama is earmarked for green-energy initiatives and includes tax breaks, loan guarantees, and incentives. In the EU, some $60 billion in stimulus packages will go to green measures, including more than $17 billion for energy efficiency and nearly $19 billion for clean cars.

subsidies, largely in the Middle East, could reduce 2020 demand by 2 million to 3 million barrels per day in 2020. Increasing the size limit for trucks could save between 0.5 million and 1.0 million barrels per day.

Exhibit 7

Significant levers are available to abate oil demand



* Includes only increase in Brazilian ethanol; other countries could also grow production but are excluded from estimate.

** Only represents diesel demand abatement as switching to gasoline keeps overall petroleum products demand unchanged.

Source: McKinsey Global Institute analysis

In the medium term, an emphasis on shifting to fuels that are potentially more plentiful offers additional abatement potential. While the impact of such shifts will not be as rapid as the removal of subsidies or increasing truck size, the advantage is that these shifts do not depend on new technologies and most of them have IRRs potentially near or above 10 percent (depending on oil and diesel prices).

- Capturing energy productivity opportunities could abate 20 percent of 2020 demand across fuels but only 10 percent in oil. In light vehicles, there is potential to abate an additional 2 million barrels per day of demand by implementing stricter vehicle efficiency across economies. Action to boost energy productivity in industry and buildings offer the potential to abate an additional 6 million barrels per day.

- Removing trade barriers to sugar-cane ethanol could help abate oil demand. Given that the EIA projects that the United States will fall short of biofuel mandates, this may be a viable measure to fill the gap.

- Requiring all vehicles to be flex-fuel (i.e., running on a blend of more than one fuel, often gasoline and ethanol) would achieve greater fleet flexibility at an estimated cost of less than $100 per unit.

- Reversing the shift to diesel in passenger vehicles could save 0.5 million barrels per day.

- Substituting boiler fuels could abate up to 8 million barrels per day.

Another set of demand-abatement levers, based on technologies that are currently in the research phase or are nascent, will become available in the longer term. Continued investment in such technologies can further contribute to achieving long-term balance between supply and demand in energy markets. If pursued with sufficient aggression, and combined with the other levers described, such investment could lead to demand peaking beyond 2020. The key areas for investment are to support research into EVs, biofuels, and public-transportation infrastructure, the latter particularly in developing countries that are even now building public-transportation capacity on a large scale.

* * *

It would be all too easy to respond with complacency to a short-term easing back of energy-demand growth. Once the global economy begins to recover, energy demand will bounce back too, imposing costs on consumers and businesses and on the climate in the form of CO_2 emissions. There is even potential for oil market demand to grow more quickly than supply, risking another oil market shock. In these circumstances, losing the momentum on action to rein back energy demand could turn out to be a high-risk strategy—particularly given early evidence that policy to boost the economy's energy productivity is already having an impact.

1. Energy demand set to rebound after short lull

- Energy demand grew at a rate of 3.1 percent a year between 2002 and 2007, but we expect a marked deceleration in the pace of growth in 2007 to 2009 to a rate of only 1.0 percent per annum in our moderate downturn scenario.
- Demand will rebound with economic recovery. MGI's moderate scenario projects energy-demand growth of 2.1 percent a year from 2006 to 2020, marginally slower than the 2.2 percent growth projected in our 2007 report.
- More than 90 percent of energy-demand growth to 2020 will be in developing countries with five end-use sectors in China—residential, commercial, steel, petrochemicals, and light vehicles—accounting for more than 25 percent of total growth; meanwhile, US demand for fossil fuels will experience zero growth to 2020.
- Regulation has begun to have a measurable impact in abating growth in energy demand, capturing an estimated 15 QBTU of the opportunity to boost energy productivity. This potential now stands at 16 to 20 percent of 2020 demand, down from 20 to 24 percent estimated in MGI's 2007 report.
- On a per dollar of GDP basis, every major region is projected to cut emissions per unit of GDP in the period to 2020; in the case of China, its emissions are expected to be cut by half.

The strong downturn in global GDP—particularly in developed countries—in 2008 and 2009 will rein back growth in energy demand slightly in the period to 2020 compared with MGI projections in 2007.[1] However, there is also evidence that new energy efficiency regulations around the world are beginning to bear down on energy intensity in some energy end uses and contributing to slower energy-demand growth. MGI's moderate projection now is that energy demand will grow at 2.1 percent a year in 2006–2020, marginally slower than the 2.2 percent growth we projected in our 2007 report.[2] Should GDP grow at our severe or very severe assumptions in the short term, the annual demand growth rate from 2006 to 2020 would be reduced to 2.0 and 1.9 percent respectively. Since these scenarios forecast GDP-growth slowdowns until 2012 at the latest, their impact on growth rates over the entire period are muted.

---

[1] We choose to use the term *downturn* rather than *recession* when defining our GDP cases. The commonly used definition of a recession is at least two consecutive quarters of negative economic growth. The global economy's slowest year of growth on a PPP basis was 1982—at a real 1.1 percent. By this standard, the global economy has likely never been in a *recession* since the 1930s. Neither does the typical peak-to-trough measurement system of downturns work on a global basis. Instead, we define a global downturn as any period in which global GDP growth has been 0.5 percent or more below trend PPP growth rate of 4 percent for one or more years. The gap from trend is measured as 4.0 percent annual GDP growth for each year with 3.5 percent or less global GDP growth and aggregated across the downturn (which is assumed to have ended in the first year that global GDP growth exceeds 3.5 percent).

[2] *Curbing global energy-demand growth: The energy productivity opportunity*, McKinsey Global Institute, May 2007 (www.mckinsey.com/mgi).

However, the current slackening in oil markets through a combination of sustained high prices and contracting GDP may not last long. Under our different GDP scenarios, market tightness could easily return between 2010 and 2013 as demand in non-OECD countries is likely to rebound strongly from today's slowdown—just at the point that supply is compromised by cuts in investment in response to today's economic downturn and the credit squeeze.

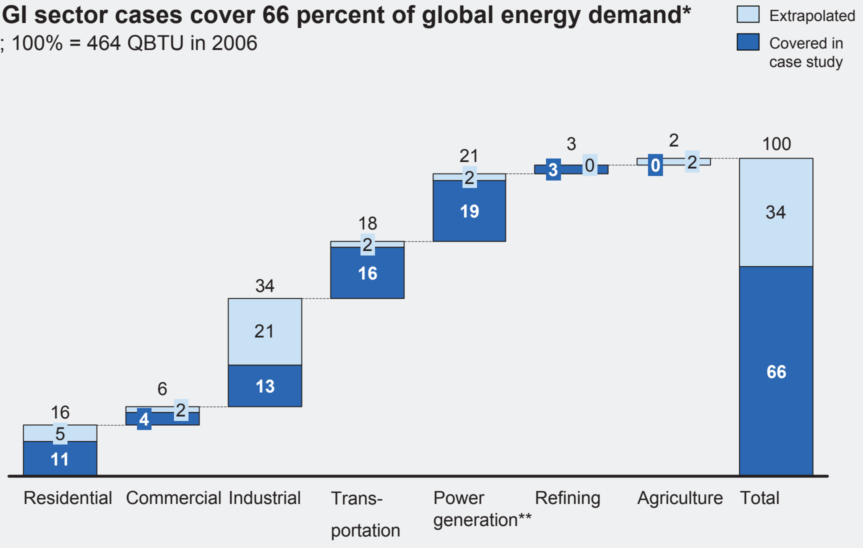
GDP IS THE MOST IMPORTANT DRIVER OF DEMAND

The three key macroeconomic factors that drive global energy demand are GDP growth, energy prices, and energy regulations. We model the impact of these three factors at the sectoral level where we can best understand their impact on energy demand. MGI's bottom-up energy demand model covers sectors accounting for two-thirds of global energy demand, while we extrapolate energy-demand growth projections for the other one-third using historical correlations (Exhibit 1.1). For each sector, we analyze microeconomic factors relating to demand for energy services, energy intensity, energy efficiency, and the fuel mix (Exhibit 1.2).

Exhibit 1.1

MGI sector cases cover 66 percent of global energy demand*

%; 100% = 464 QBTU in 2006



* This year we added medium and heavy trucking to MGI's analysis, and South Korea, Australia and New Zealand, and Middle East power models.

** In the rest of this report, power generation demand is allocated to end-use segments.

Source: IEA; McKinsey Global Institute analysis

Exhibit 1.2

Demand: bottom-up understanding per end-use sector

Macro drivers

- **GDP growth/other macro factors** (e.g., urbanization)
- **Energy policy**
  (e.g., CAFE standards)
- **Energy pricing** (wholesale and end-user prices)
- **Innovation/new processes** (e.g., EVs, DRI in steel making, coal-to-olefins)

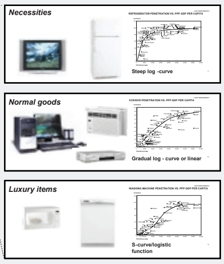
Tie macro and micro

- Analyze historical relationships between macro- and micro-drivers, project forward
- Incorporate any future trend shifts
- Run sensitivities

Sector micro energy demand model (ten sectors)

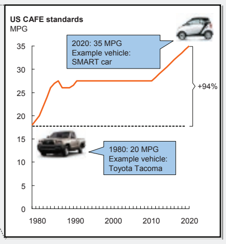
① **Demand for energy services** (e.g., vehicle stock)
- Create intensity/penetration curves
- Project energy using capital forward using GDP growth (vehicle stock)
- Moderate projections to account for policies, reaction to prices, innovation

② **Intensity** (e.g., VMT, vehicle mix)
- Project forward using historical trend, relationships to GDP
- Layer in price effects (e.g., VMT reaction for price)
- Determine policy impacts (e.g., "gas-guzzler" fuel tax)



③ **Efficiency** (e.g., miles per gallon)
- Determine impact of regulation using vintage models (e.g., CAFE standards)
- Consider historical efficiency trends and forecast for efficiency (e.g., Boeing aircraft efficiency forecasts)
- Create economic model for efficient technology adoption based on consumer behavior (e.g., payback model for auto fuel efficiency at different price levels)

④ **Fuel mix**
- Historical fuel-mix trends
- Impact of price of fuel switching (e.g., coal vs. gas trade-off in power sector)
- Penetration of new processes that shift fuel mix (e.g., EVs, direct reduction steel making)

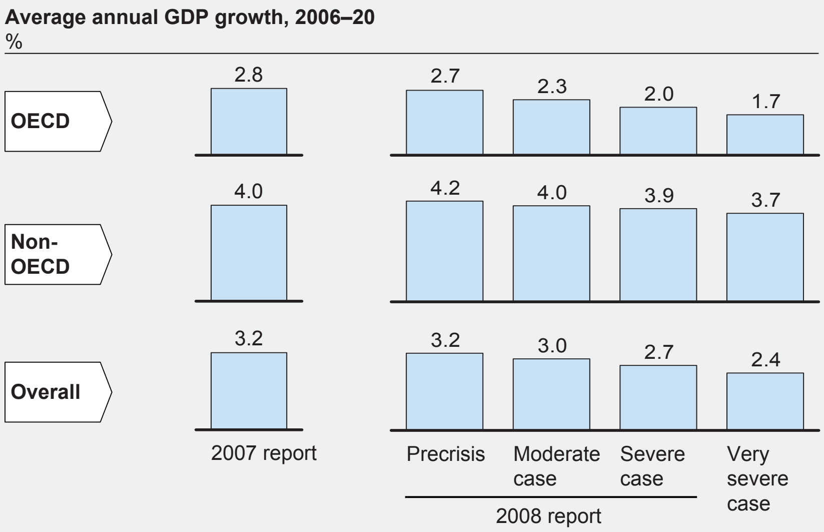


Source: McKinsey Global Institute analysis

Of the three major macro drivers, GDP growth impacts energy demand with by far the greatest force, albeit often indirectly through such factors as car sales, steel production, and growth in the housing stock. In our moderate downturn case, Global GDP is projected to grow at 3.0 percent per annum to 2020 somewhat slower than the 3.2 percent projected in 2007 as well as the projection early in 2008 before much of the developed world entered into a recession. It is noteworthy that the major downward revision in GDP growth has occurred more strongly in OECD economies that are less energy intensive than developing economies and that this has therefore muted the potential impact of recessionary economic conditions in the near term on global energy-demand growth (Exhibit 1.3). In the OECD, the moderate case foresees 2008 and 2009 experiencing the economic trough, with negative GDP growth in developed economies in aggregate in 2009. In developing economies, our moderate case assumes a marked deceleration in GDP growth from 5.1 percent in 2008 to 3.9 percent in 2009 (Exhibit 1.4)

Exhibit 1.3

Overall GDP growth rates are lower than MGI's previous projections, particularly in OECD economies

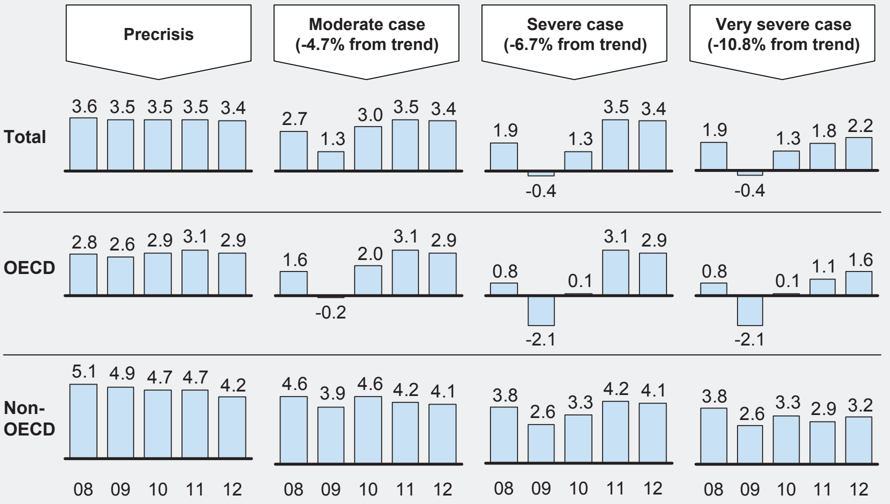


Source: IEA; Global Insight; McKinsey Global Institute analysis

Exhibit 1.4

GDP growth projected to slow markedly in 2008, 2009 with rebound in 2010 in moderate downturn case

GDP growth assumptions*



Source: IEA; Global Insight; McKinsey Global Institute analysis

Since GDP growth is highly uncertain at the time of writing, we provide four scenarios for GDP growth: precrisis, moderate, severe, and very severe. The precrisis case is merely for illustrative purposes, showing the path of energy demand had GDP growth continued on the trend that was projected before the economic crisis.

Our moderate-case scenario reflects the GDP loss that occurs as a reduction in available credit combined with high commodity prices causes a contraction in consumption, employment, and investment in developed markets. Although developing markets are not expected to decline, growth also slows as exports, as well as net external capital inflows, decline. We base the magnitude of this contraction on a composite case we constructed from the International Monetary Fund's *World Economic Outlook* and Global Insights GDP projections, and project a global downturn totaling a cumulative 4.7 percent gap to trend, with recovery in 2010.[3]

We do not base our severe and very severe scenarios on a rigorous projection of GDP. Instead, these cases involve simple adjustments downward from the moderate case. The severe scenario represents a 6.7 percent reduction in trend growth over a three-year period, while the very severe case represents a 10.8 percent reduction in trend growth over a five-year period. In all of our scenarios, global GDP growth rebounds to between 3 and 3.5 percent a year after the downturn ends. If we compare both of these scenarios with previous downturns, they would rank in the top five global downturns since World War II, with the very severe case representing a significantly worse downturn than any experienced since the Great Depression. We note that we have adjusted our cases to purchasing power parity (PPP) weights to allow for historical comparison with past downturns (Exhibit 1.5).

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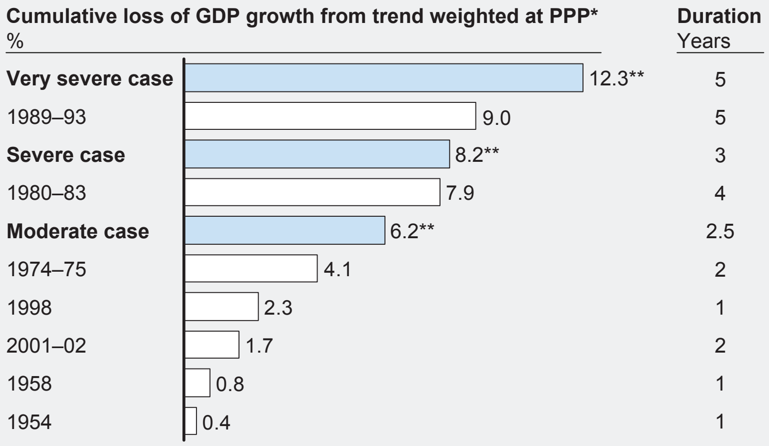
3 *World Economic Outlook*, International Monetary Fund, November 14, 2008; Global Insight GDP projections, December 5, 2008; note that the 4.7 percent decline from trend is also very close to the IMF's World Economic Outlook in January 2008, which called for slower GDP growth than in its November release, which we used for our composite case.

Exhibit 1.5

All three downturn scenarios are on par with some of the more severe global downturns



* Downturn defined as one or more consecutive years in which global GDP is more than 0.5 percent below trend growth rate of 4.0 percent.

** Numbers weighted at purchasing power parity (PPP) exchange rates for comparability, instead of real GDP weights that we usually use.

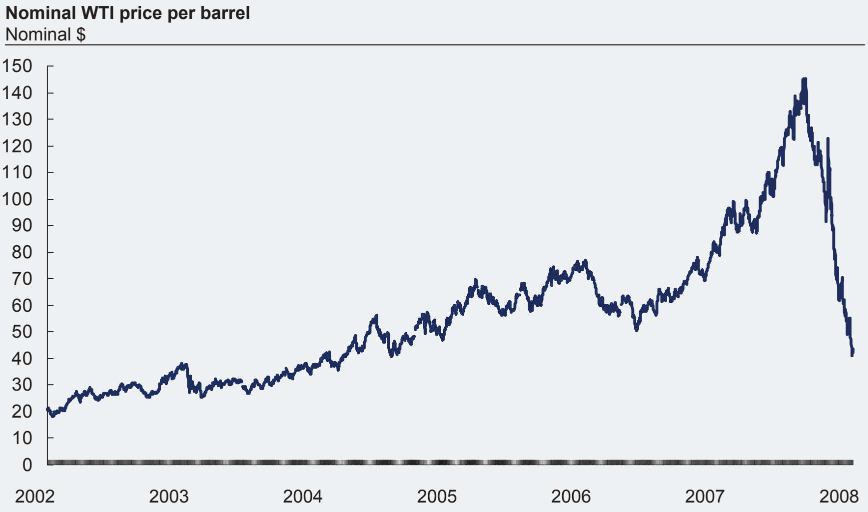
Source: Angus Maddison, personal Web site; McKinsey Global Institute analysis

We provide these three cases as a way for the reader to put the energy-demand projections in this report in the context of today's highly uncertain economic times. Point estimates simply aren't reliable in such an unpredictable situation.

Turning to energy prices, another driver of energy-demand growth, prices climbed across the board until mid-2008, led by oil. The price of crude oil has risen consistently since 2002, reaching historic highs in late 2007 through mid-2008 when oil prices came off their peaks in response to weaker worldwide demand (Exhibit 1.6) (see "MGI's price assumptions").

Exhibit 1.6

Oil prices have risen since 2002 and skyrocketed temporarily from late 2007 to mid 2008



Source: EIA

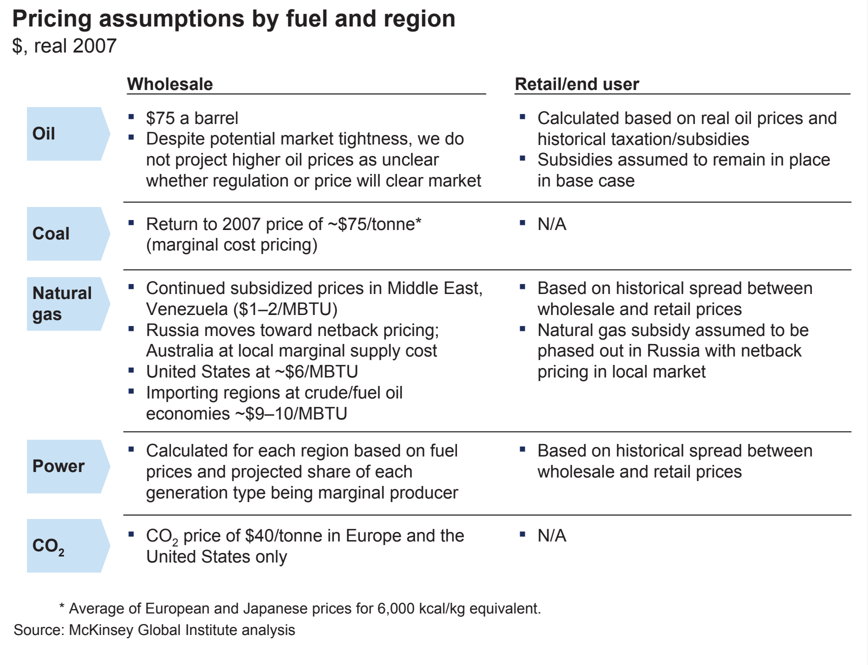
MGI's price assumptions

MGI's scenarios assume that real crude oil prices will return to $75 a barrel by 2010 with natural gas prices following crude in regions that import crude oil. In regions that meet most of their needs with indigenous supply, we project prices to remain at either subsidized levels (e.g., Middle East) or at marginal cost (e.g., Australia), with the local marginal field setting the price for natural gas. A major exception to these trends is Russia. The Russian government has mandated netback pricing by 2011, meaning local prices would be set by the price that could be obtained in the export market less taxes and transportation costs.

We assume a more moderate increase to approximately $3 per million British thermal units (MBTU) for the sake of our projections (netbacks at $75 oil would imply $7 per MBTU). We assume that coal prices return to a marginal cost of production in each region as well, even though they rose strongly in 2008. MGI projects that power prices will stay roughly at 2007 levels as they are calculated using fuel pricing (with coal and gas predominating) and dispatch curves that are roughly similar to 2007 levels.

We assume that CO_2 prices remain stable at current real levels, with only the EU and the United States assumed to have CO_2 taxes in place. MGI translates all prices into the price for end users, factoring in current tax and subsidy regimes as well as distribution and transformation margins (Exhibit 1.7).

Exhibit 1.7



Pricing assumptions by fuel and region

$, real 2007

	Wholesale	Retail/end user
Oil	▪ $75 a barrel ▪ Despite potential market tightness, we do not project higher oil prices as unclear whether regulation or price will clear market	▪ Calculated based on real oil prices and historical taxation/subsidies ▪ Subsidies assumed to remain in place in base case
Coal	▪ Return to 2007 price of ~$75/tonne* (marginal cost pricing)	▪ N/A
Natural gas	▪ Continued subsidized prices in Middle East, Venezuela ($1–2/MBTU) ▪ Russia moves toward netback pricing; Australia at local marginal supply cost ▪ United States at ~$6/MBTU ▪ Importing regions at crude/fuel oil economies ~$9–10/MBTU	▪ Based on historical spread between wholesale and retail prices ▪ Natural gas subsidy assumed to be phased out in Russia with netback pricing in local market
Power	▪ Calculated for each region based on fuel prices and projected share of each generation type being marginal producer	▪ Based on historical spread between wholesale and retail prices
CO_2	▪ CO_2 price of $40/tonne in Europe and the United States only	▪ N/A

* Average of European and Japanese prices for 6,000 kcal/kg equivalent.

Source: McKinsey Global Institute analysis

Historically high energy prices had a delayed impact on energy-demand growth for a number of reasons including, at that time, abundant credit, the significant depreciation in the dollar, incentives from auto manufacturers aimed at supporting sales, and in many economies, fuel subsidies that have shielded consumers and businesses from the true price of energy. In economies that do not have significant fuel subsidies—notably the United States—high crude prices have had a progressive impact on energy demand (see "The impact of the high crude price in the United States" at the end of this section).

We note that these projections are a function of how the trajectory of energy demand will react to assumed prices; readers should therefore not take them as forecasts. In the case of oil, the energy demand path implied by our assumption of a $75 a barrel oil price would certainly eventually require higher prices in order to clear the market given our projections of supply trends. Of course, we see that the pace of regulatory intervention has recently accelerated, and this implies that policy makers could mitigate or even avert completely any supply-demand imbalances that develop. For the purposes of projecting energy demand, MGI has opted to assume a given price and to specify a set of policy actions that could balance supply and demand. Should a set of demand-mitigating policy actions (or lower GDP growth) not occur, then demand would have to be mitigated through higher prices.

Regulation has begun to have a measurable impact on the trajectory of energy-demand growth, with some evident progress in capturing available opportunities to boost energy productivity—the level of output achieved from the energy consumed—although many more opportunities remain. The most marked impact of regulatory intervention to boost energy productivity has been in the case of light vehicles; in this sector, we have seen an effect on gasoline demand and, to a lesser extent, diesel demand. Going forward, the US Energy Independence and Security Act (EISA) of 2007 will have a major impact on light vehicles through the implementation of new CAFE standards. The EU also has strict CO_2-emissions standards for light vehicles that require improved fuel economy. For their part, China and Korea have tightened fuel-economy standards for light vehicles.

A second major area of regulatory action is in renewables. A number of countries have put in place major renewables mandates in the light-vehicles and power sectors. The EU has set a 20 percent share of renewables target in power generation, which is highly aggressive. Mandates are also in place globally that will require nearly 5 million barrels a day of biofuels—most of them in gasoline—by 2020. This is likely to have dramatic implications for refining in particular.

In China, the Top-1000 Energy-Consuming Enterprises program, part of the government's aim to reduce the country's energy intensity by 20 percent between 2005 and 2010, has already had a strong impact on industrial energy demand.[4] Because China is the world's largest consumer of industrial energy, this will have an impact on global energy demand.

SHORT-TERM ENERGY DEMAND COULD CONTRACT IF GDP SLOWDOWN IS SEVERE

Energy demand grew at a rate of 3.1 percent a year between 2002 and 2007, but we expect a marked deceleration in the pace of growth in 2007 to 2009 to a rate of only 1.0 percent per annum. If the severe-case global downturn were to unfold, it is possible that energy demand could actually decrease. Even in our moderate-case scenario, we project that energy demand in developed economies will contract by 1.0 percent while energy demand in developing countries will slow to between 1.5 and 2.2 percent (Exhibit 1.8). By 2010, however, demand growth recovers in our moderate case, with energy demand rebounding to 2.4 percent in that year. In our

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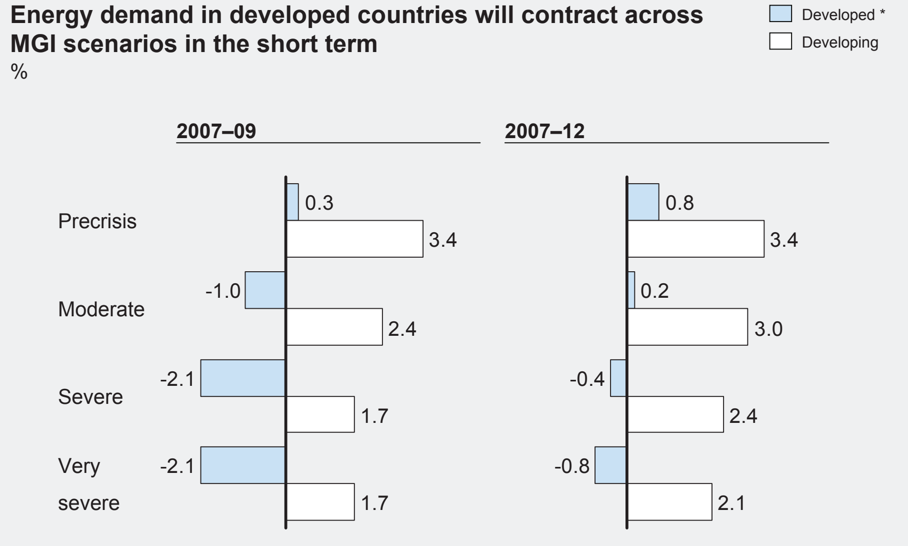
[4] The Top-1,000 program determines 2010 energy-consumption targets for each enterprise. In 2004, the energy consumption of the top 1000 Chinese enterprises accounted for 33 percent of national energy consumption and 47 percent of industrial energy consumption. See L. Price, X. Wang, and Y. Jiang, *China's Top-1000 Energy-Consuming Enterprises Program: Reducing Energy Consumption of the 1000 Largest Industrial Enterprises in China*, Lawrence Berkeley National Laboratory, 2008 (http://china.lbl.gov/node/157http://china.lbl.gov/node/157).

severe-case scenario, energy demand remains depressed beyond 2009, registering only 0.9 percent growth in 2010, before rebounding to 2.7 percent in 2011. In our very severe scenario, demand growth does not rebound until 2012, registering growth rates of 1.0 and 1.2 percent in 2010 and 2011 respectively. This is in sharp contrast to the recent past when we estimate that developing-country energy demand grew at between 4.9 and 7.4 percent between 2002 and 2007. [5]

Exhibit 1.8

Energy demand in developed countries will contract across MGI scenarios in the short term

%



* Developed regions include the United States, Canada, Northwest Europe, and Japan.

Source: McKinsey Global Institute Global Energy Demand Model 2009

The prospect of an overall contraction in energy demand may appear to be unlikely given that global GDP growth is projected to remain positive in all scenarios. However, two factors sharpen the decline in energy demand: (1) procyclical responses to the GDP downturn in several sectors that are heavy consumers of energy and (2) the hangover from rising prices through mid-2008. Regulation, the third driver of energy-demand growth, can have minor impacts on short-term energy demand but largely has effects in the medium to long term.

The most dramatic decline in our moderate scenario is for oil demand, which contracts by 0.1 percent per annum from 2007 to 2009.[6] This reflects the fact that the impact of high prices is greatest for this fuel. Demand for gas and coal continues to run at a rate of some 1 percent a year in our moderate case. However, in our very severe GDP scenario, demand for all three fuels is negative in 2007 to 2009 (Exhibit 1.9). Looking at 2010 and beyond, oil demand would recover in 2010 in our moderate case—growing at 1.8 percent. However, in our severe and very severe cases, growth would only be at 0.3 percent in 2010, and recovery would be delayed until 2011 and 2012 respectively. Natural gas and coal would follow similar patterns.

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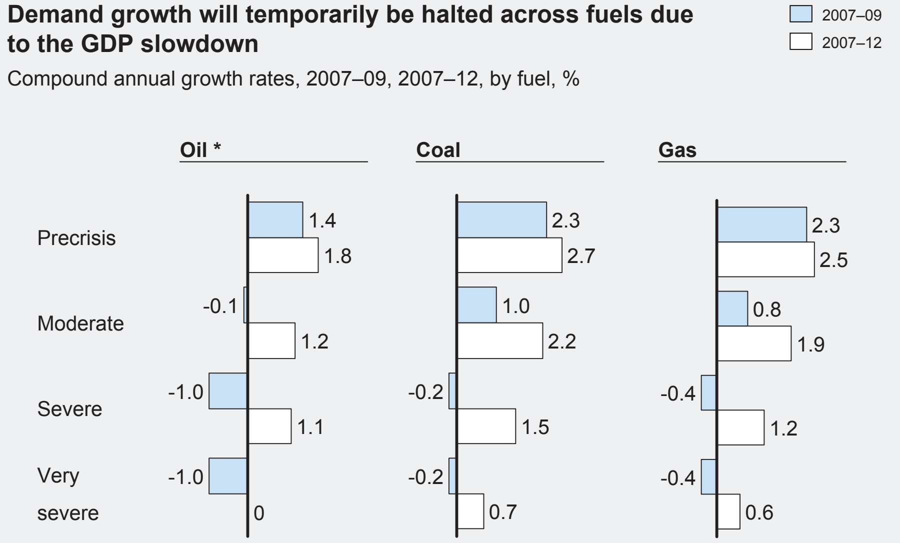
5 We derive the 4.9 percent from IEA Balances 2002–2006, and 7.4 percent from the BP Statistical Review of World Energy 2008.

6 In this paper, oil does not include biofuels; biofuels are included in the liquids section. In this section, we include biofuels in the demand category “renewables/other.”

Exhibit 1.9



Demand growth will temporarily be halted across fuels due to the GDP slowdown

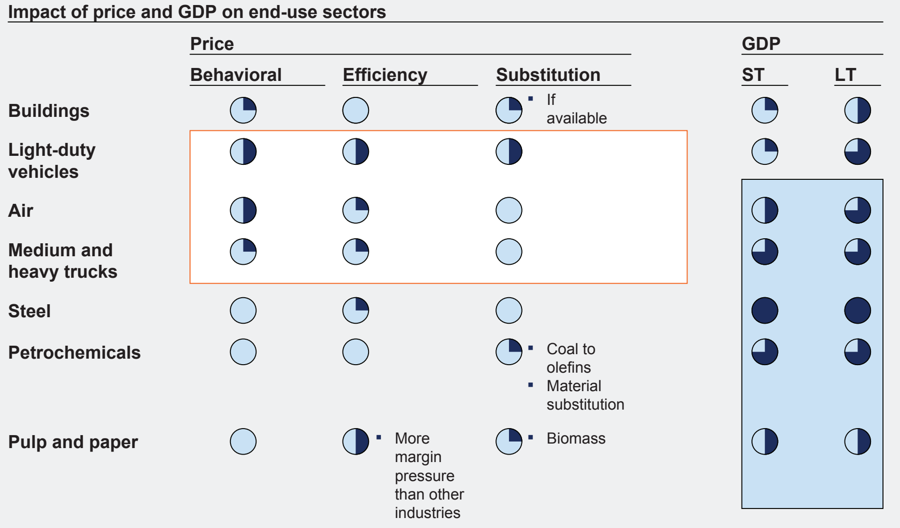
Compound annual growth rates, 2007–09, 2007–12, by fuel, %

* Not including biofuels.

Source: McKinsey Global Institute Global Energy Demand Model 2009

Prices provoke the strongest short-term response in those sectors where fuel accounts for a high share of total costs—i.e., where taxes and other factors do not act as a significant cushion against market-price fluctuations. The two sectors in which demand responds most strongly to price are light vehicles and air transportation (Exhibit 1.10).

Exhibit 1.10



Price responses are concentrated in transportation, while industrial sectors' growth tends to respond more to GDP

☐ Price-driven
▨ GDP-driven

Impact of price and GDP on end-use sectors

	Price			GDP	
	Behavioral	Efficiency	Substitution	ST	LT
Buildings	◔	○	◔ ▪ If available	◔	◑
Light-duty vehicles	◑	◑	◑	◔	◕
Air	◑	◔	○	◑	◕
Medium and heavy trucks	◔	◔	○	◕	◕
Steel	○	◔	○	●	●
Petrochemicals	○	○	◔ ▪ Coal to olefins ▪ Material substitution	◕	◕
Pulp and paper	○	◑ ▪ More margin pressure than other industries	◔ ▪ Biomass	◑	◑

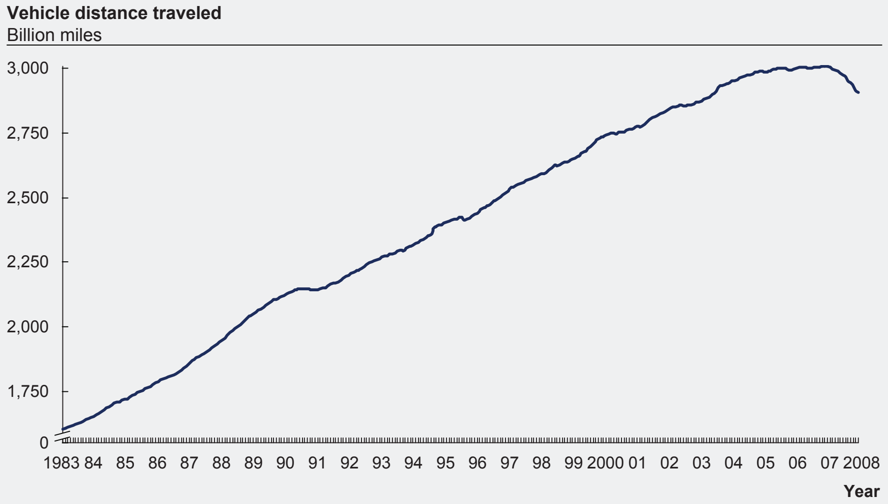
Source: McKinsey Global Institute analysis

In the case of light vehicles, gasoline represents a major expenditure for vehicle owners, particularly for lower-income segments of the population. Academic studies have shown a short-term behavioral elasticity of minus 0.2 to end-use fuel prices—i.e., if gasoline prices increase by 25 percent, demand falls by approximately 5 percent.[7] Only applications in which very short-term fuel substitution is possible would have a higher elasticity than this (in the energy field, elasticities in goods and services across an entire economy can be much stronger). In the United States, which taxes gasoline relatively lightly and where the exchange rate didn't dampen swings in crude-oil prices, light-vehicle miles traveled actually declined in response to price in 2007 and 2008 (Exhibit 1.11).

Exhibit 1.11

US vehicle miles traveled shows the short-term price impact most dramatically …

Moving 12-month total on all roads



Source: US Federal Highway Administration

Air transport has the same elasticity to fuel prices as light vehicles at minus 0.2.[8] This mainly reflects the fact that consumers buy fewer airline tickets as prices go up and, in response, airlines reduce unprofitable routes (or go out of business altogether). When oil prices spiked in 2007 to mid-2008, jet fuel became an increasingly high percentage of costs for airlines (Exhibit 1.12). The number of loss-making routes increased rapidly, leading to a string of airline bankruptcies and a dramatic decline in revenue passenger miles/kilometers (RPM/RPK).

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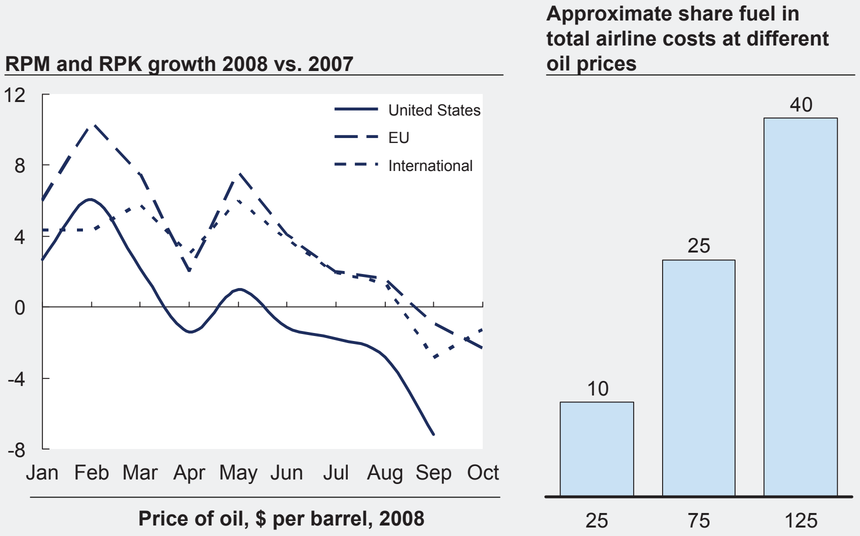
[7] Molly Espey, "Gasoline demand elasticity revisited: an international meta-analysis of elasticities," *Energy Economics* 20 (1998), 273–95.

[8] This is derived from taking the average price elasticity of air travel overall and multiplying it times the percent share of jet fuel in a ticket price. See David Gillen, William Morrison, and Christopher Wilson, "Air Travel Demand Elasticities: Concepts, Issues and Measurement," available at http://www.fin.gc.ca/consultresp/Airtravel/airtravStdy_-eng.asp.

Exhibit 1.12

… along with air transport, where a large percentage of costs are in fuel
%



Source: IATA; US Bureau of Transportation Statistics; Association of European Airlines; McKinsey Global Institute analysis

Academic studies have shown truck transport to have a short-term elasticity that is about half of that in light vehicles and air transport.[9] Nevertheless, because we saw a widening in diesel-gasoline spreads particularly in 2008, we project that trucks, too, react to price.

Most other sectors do not show this short-term price response because, in these cases, there is a lack of easy fuel substitutes, and fuel accounts for only a small percentage of overall costs that can be passed on to the end user. Take petrochemicals as an example. Although the price of oil, a key input, rose continuously from 2002 to 2008, demand in this sector did not weaken until GDP growth slowed. The same is the case in buildings where consumers see energy as a key source of comfort and convenience and treat these as higher priorities than price per se. In this sector, rising energy prices have had very little impact on demand and, indeed, academic studies have estimated the short-term energy elasticity in this sector at only minus 0.1.

Most sectors react largely to trends in GDP. In fact, industrial sectors tend to respond procylically to GDP. Many basic materials are subject to huge swings in demand due to inventory drawdowns downstream in the value chain. Furthermore, procylical durables and construction use such basic materials as inputs, only exacerbating the procyclicality in these industries (Exhibit 1.13 and 1.14). We see evidence for this effect in recent data from the steel sector. In October 2008, when the true extent of the financial crisis and the downturn started to become more apparent, global steel production dropped by 7.5 billion tonnes (8 percent) in a single month—and by nearly 4 billion tonnes (10 percent) in China, the world's largest producer (Exhibit 1.15). Although trucking and air transportation are not subject to the same inventory impacts as basic materials, they also display some procyclicality. This is the case in trucking because of its role in moving durable and construction goods; in air transportation, the fact that air travel is a "luxury good" both for businesses and consumers cuts demand disproportionately more than any weakening or decline in GDP.

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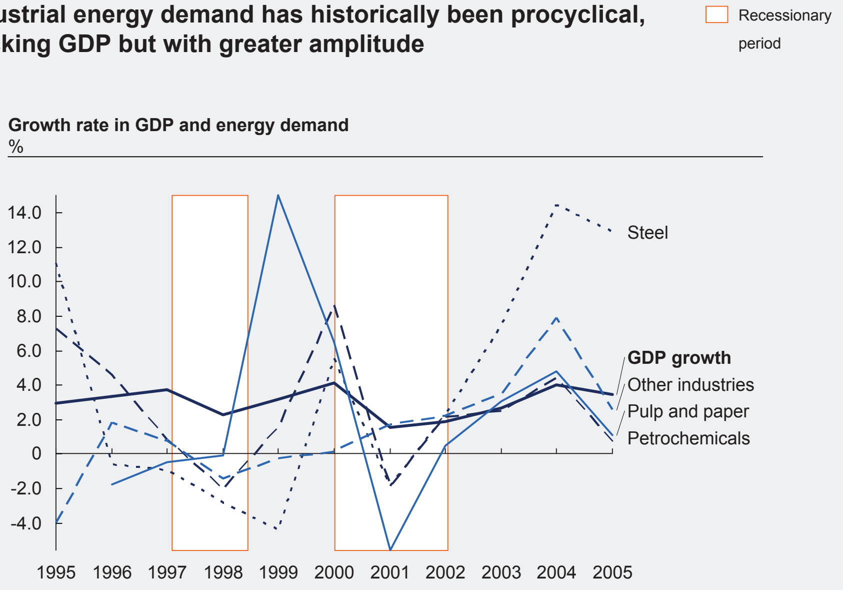
[9] *Transportation Elasticities: How Prices and Other Factors Affect Travel Behavior*, Victoria Transport Policy Institute, March 2008.

Exhibit 1.13

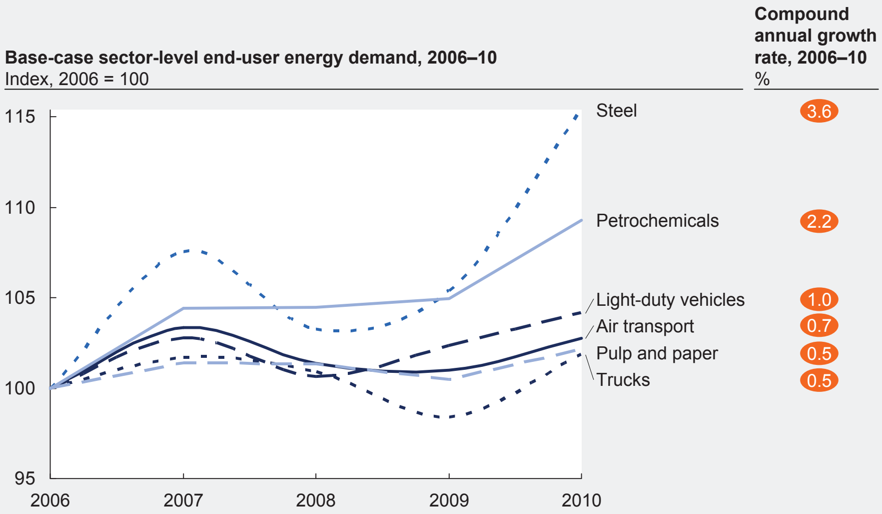
Industrial energy demand has historically been procyclical, tracking GDP but with greater amplitude



Source: IEA; Global Insight; McKinsey Global Institute analysis

Exhibit 1.14

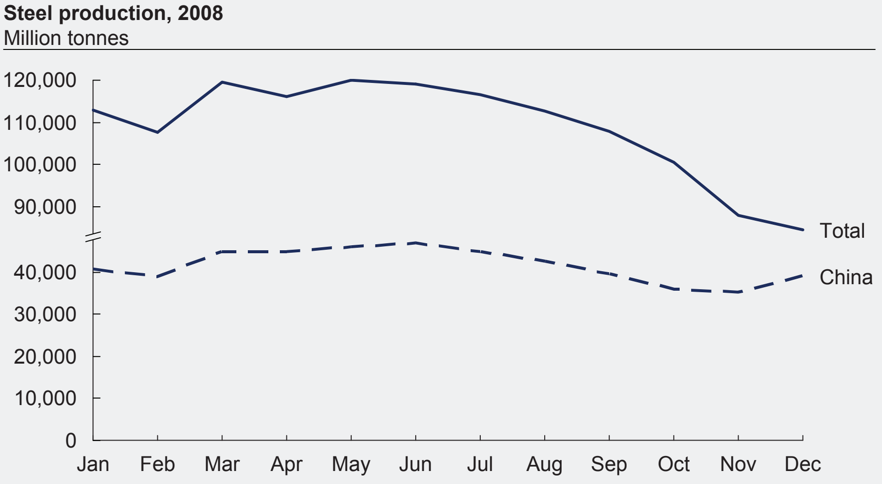
Demand slowed in 2007 in light vehicles and air transport on price effects; most other sectors were impacted by GDP slowdown in 2008–09



Source: McKinsey Global Institute Global Energy Demand Model 2009

Exhibit 1.15

Global steel production dropped sharply in late 2008, impacting coal demand

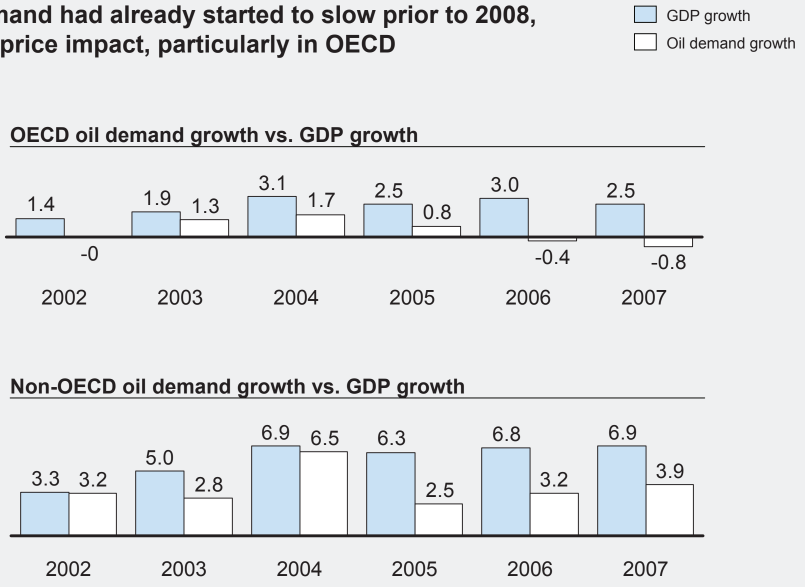


Source: World Steel Association

Looking at the overall impact of price across sectors, we see a progressive impact that has gained strength since 2004. Declines in energy demand have been particularly sharp in developed economies, although we have seen non-OECD energy-demand growth relative to GDP growth decline significantly too (Exhibit 1.16). The largest reductions in demand growth have been in light distillates in developed economies, likely driven by gasoline in the light-vehicles sector. Fuel-oil demand has also declined sharply, likely reflecting a switch to natural gas where this is possible (Exhibit 1.17).

Exhibit 1.16

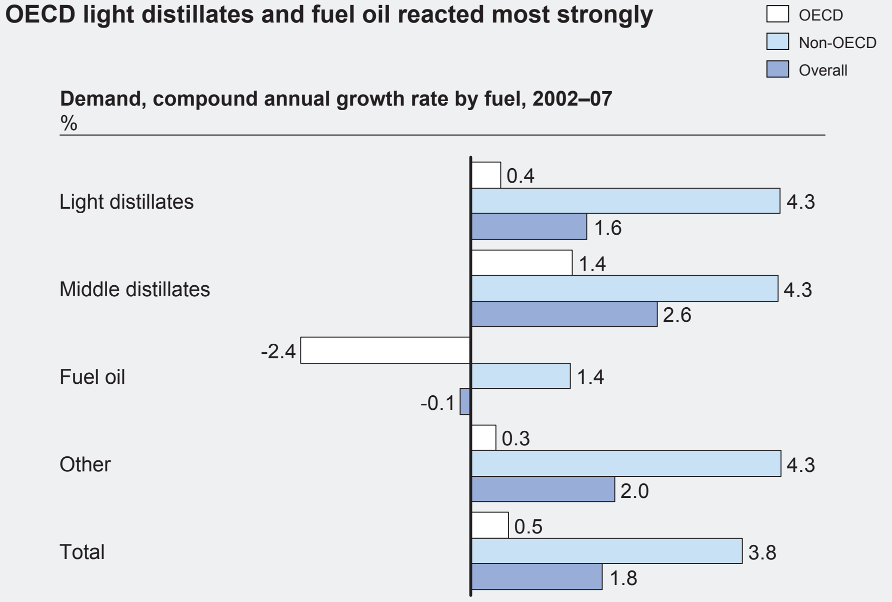
Oil demand had already started to slow prior to 2008, due to price impact, particularly in OECD
%



Source: *BP Statistical Review of World Energy 2008*; Global Insight

Exhibit 1.17

OECD light distillates and fuel oil reacted most strongly



Source: *BP Statistical Review of World Energy 2008*

The impact of the high crude price in the United States

The United States provides a unique and interesting window into how crude prices work themselves through the world. While crude prices rose strongly from 2000 to 2006, the reaction in US oil consumption was quite muted. However, in 2007 and 2008, the reaction became sharply more marked as prices spiked to near-record highs. What explains this strong reaction? Is it that a much-discussed "tipping point" was reached?

In fact, there were some much more complex underlying factors that help clarify the story. In 2000 to 2006, US consumers were feeling the crunch of higher gasoline prices. On average, gasoline increased by 1.3 percentage points as a share of disposable income (Exhibit 1.18). However, only the first quintile of consumers—the poorest—were actually cutting their purchases of gasoline by any meaningful volume. Overall, consumers decreased their volumetric purchases of gasoline by only 0.2 percent while real pump prices rose by nearly 50 percent and real crude oil prices by 85 percent (Exhibit 1.19). Historical academic studies would have predicted a reduction in demand of between 4 and 8 percent.

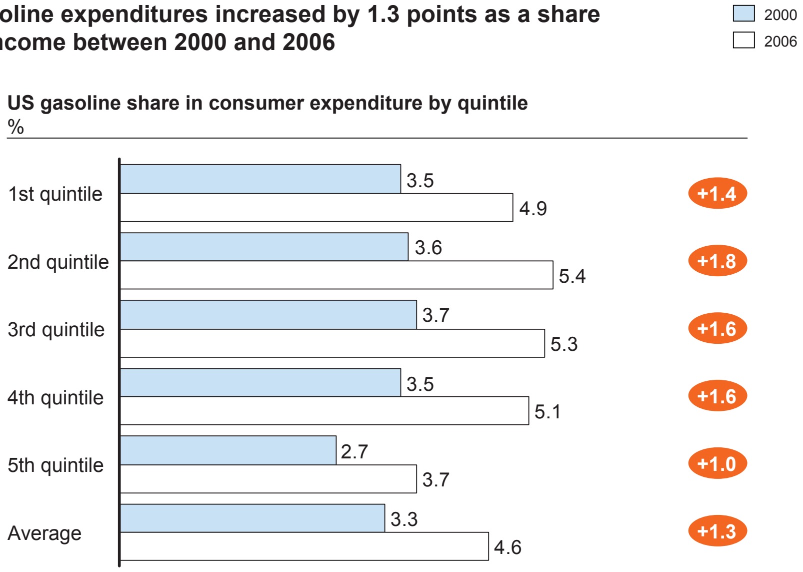
In fact, consumers were able to offset the increase in gasoline prices completely by reducing other transportation expenditures, particularly the purchases of new and used cars. The prices of cars were dropping very strongly in this time period, with the nominal price of used cars declining by 10 percent, for example. Because of this, consumers reduced their real expenditure share in new and used cars by 1.5 percentage points on average, completely offsetting the expenditure increase (Exhibit 1.20).

By late 2007, a number of factors combined to bring the oil price increase to a head. First, consumer levels of indebtedness reached record levels, with savings reaching zero (Exhibit 1.21). Second, oil prices doubled in just one 12-month period peaking in July 2008 at $145 a barrel. Consumers reacted swiftly, as shown in the graph of US VMT, which actually declined precipitously in 2008.

Meanwhile, price reactions were occurring in other regions as well, but likely not as strongly as in the United States. Subsidies and taxes, as well as a weak dollar, were reducing the percentage price fluctuations. Globally, each doubling of real gas prices resulted in only about a 25 to 30 percent increase in weighted-average global pump prices. Meanwhile, a doubling of crude oil price in the United States would increase pump gasoline prices by 60 to 70 percent because low taxes and exchange-rate fluctuations do not dampen crude price movements as they do in other countries.

Exhibit 1.18

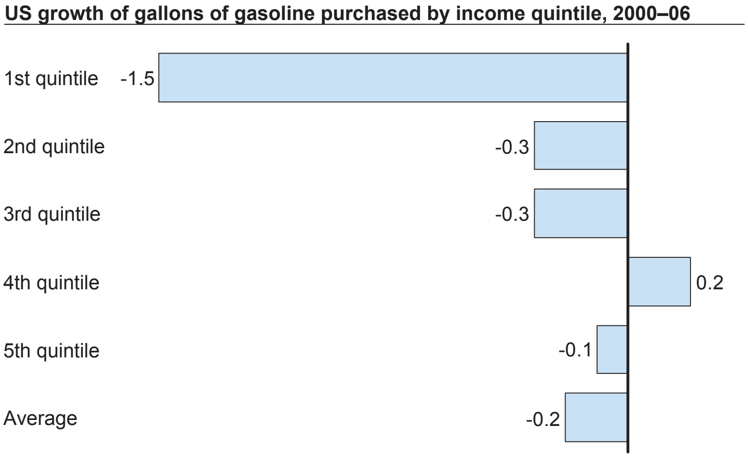
Gasoline expenditures increased by 1.3 points as a share of income between 2000 and 2006



Source: *BLS Personal Consumption Expenditure Survey*; McKinsey Global Institute analysis

Exhibit 1.19

Volume of gasoline purchased declined significantly only in the first quintile and was stable at the per household level
%

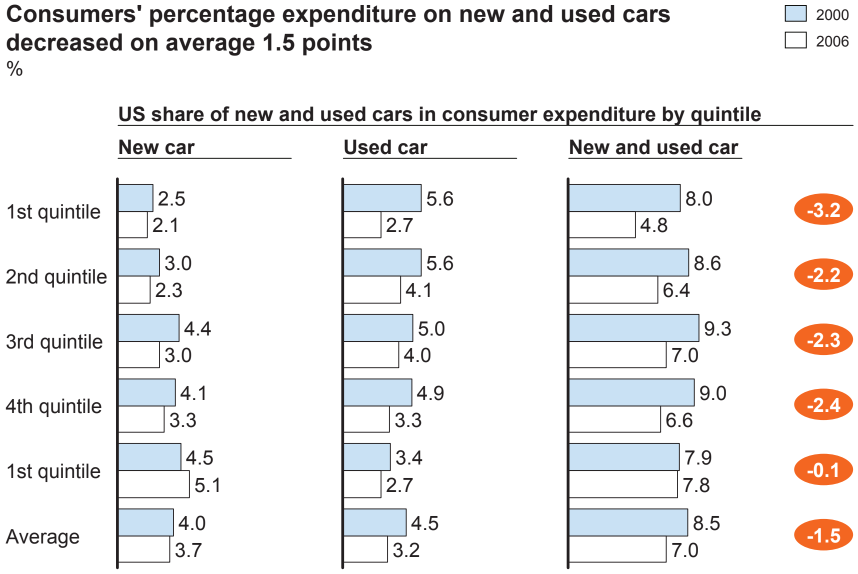


Source: *BLS Personal Consumption Expenditure Survey*; IEA; Joint Oil Data Initiative; EIA; McKinsey Global Institute analysis

Exhibit 1.20

Consumers' percentage expenditure on new and used cars decreased on average 1.5 points

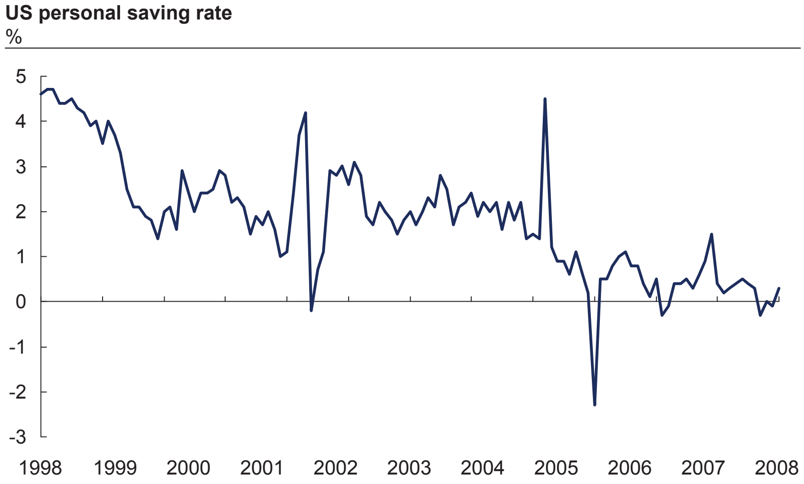
%



Source: *BLS Personal Consumption Expenditure Survey*

Exhibit 1.21

Dissaving further to finance higher gas consumption costs does not appear a viable option by 2008



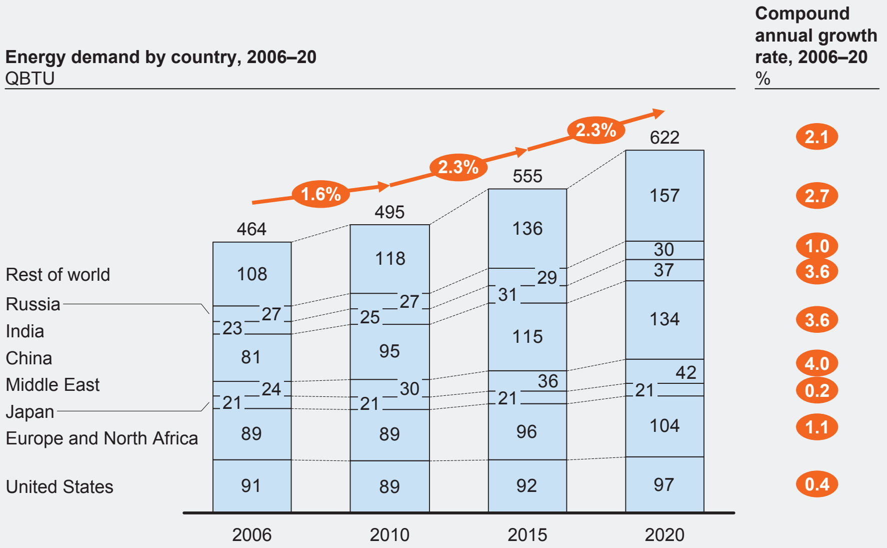
Source: US Department of Commerce; Bureau of Economic Analysis; Federal Reserve Bank of St. Louis

IN THE LONG TERM, ENERGY-DEMAND GROWTH WILL REBOUND AS GDP RETURNS TO TREND

Once GDP growth returns to its long-term trend, we expect that energy-demand growth will also rebound. From 2010 to 2020, MGI's moderate case projects that energy-demand growth will recover to 2.3 percent per annum, nearly a point faster than the period from 2006 to 2010 (Exhibit 1.22). Even in our severe and very severe cases, the rebound occurs, albeit in 2011 in the severe case and in 2012 in the very severe case. In the severe case, energy demand grows 2.4 percent between 2010 and 2020, and the very severe case at 2.3 percent, so the impact of lower GDP growth is actually isolated in the years to 2012 in all of our scenarios.

Exhibit 1.22

Long term, MGI expects energy-demand growth to rebound when GDP growth picks up by China, the Middle East, and India



Source: McKinsey Global Institute Global Energy Demand Model 2009

More than 90 percent of energy-demand growth will be in the developing world

Looking at growth in different regions, developing regions will account for more than 90 percent of global energy-demand growth to 2020 (Exhibit 1.23). We project that the Middle East will have the fastest-growing energy demand of any major region, driven by the stepping up of industrial capacity building to take advantage of the Middle East's oil and gas supplies, as well as high, continuing growth in the region's vehicle stock, reflecting increasing wealth. The energy-heavy development strategies of Middle Eastern countries, coupled with large energy subsidies to consumers, will continue to make growth highly energy intensive.[10] During the same period, we see energy-demand growth in both China and India increasing by 3.6 percent. Energy-demand growth will be virtually flat in the United States and Japan while Europe will see energy demand growing at a rate of some 1 percent, reflecting the inclusion in this region of many developing economies. Meanwhile, our moderate case projects that demand for fossil fuels in the United States has (at least temporarily) peaked, remaining exactly flat through 2020. Natural gas is the only fossil fuel projected to grow, at a rate of 0.6 percent per annum.

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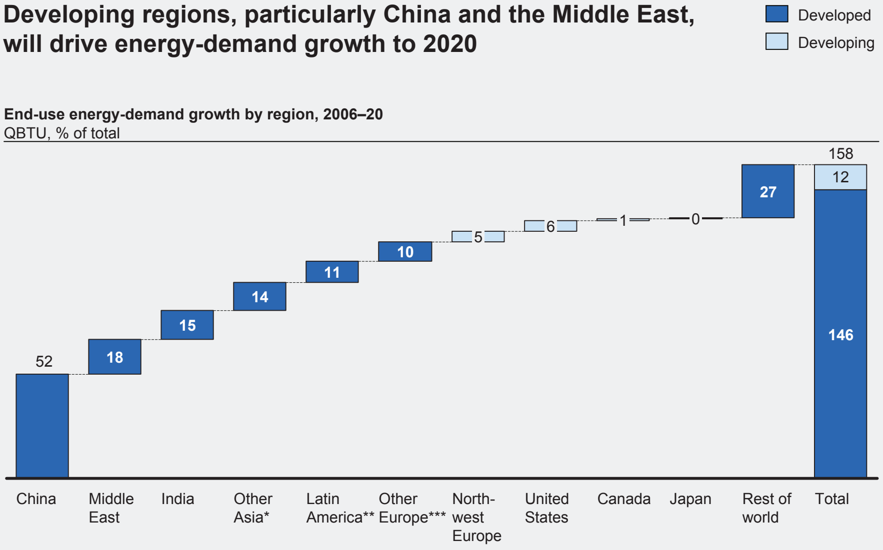
[10] For more detail, see *Fueling sustainable development: The energy productivity solution*, McKinsey Global Institute, October 2008 (www.mckinsey.com/mgi.)

Exhibit 1.23

Developing regions, particularly China and the Middle East, will drive energy-demand growth to 2020

End-use energy-demand growth by region, 2006–20
QBTU, % of total



* Includes Australia and South Korea.
** Includes South America and Mexico.
*** Includes Baltic/Eastern and Mediterranean Europe and North Africa.
Source: McKinsey Global Institute Global Energy Demand Model 2009

Energy-demand growth will be spread equally among consumer and industry sectors

Breaking energy-demand growth down into different sectors, we see end-use demand increasing about equally in consumer- and industry-driven sectors. This is in contrast to our previous report in which we saw consumer-driven sectors accounting for close to 60 percent of long-term energy-demand growth (Exhibit 1.24). The fastest-growing sectors will be steel, petrochemicals, and air transportation. Developing countries, including notably China and India, which are both investing heavily in long-distance transportation and infrastructure, will drive energy demand in these sectors. Efficiency improvements will have little impact on energy-demand growth in petrochemicals and air transport, in particular, as the opportunities to boost energy productivity are smaller in these sectors than in others (Exhibit 1.25).

Exhibit 1.24

China grows demand strongly across several sectors, while developed-country growth is negative across several sectors

x>5 QBTU
5 QBTU >x>2 QBTU
2 QBTU > x > 0 QBTU
x< 0 QBTU

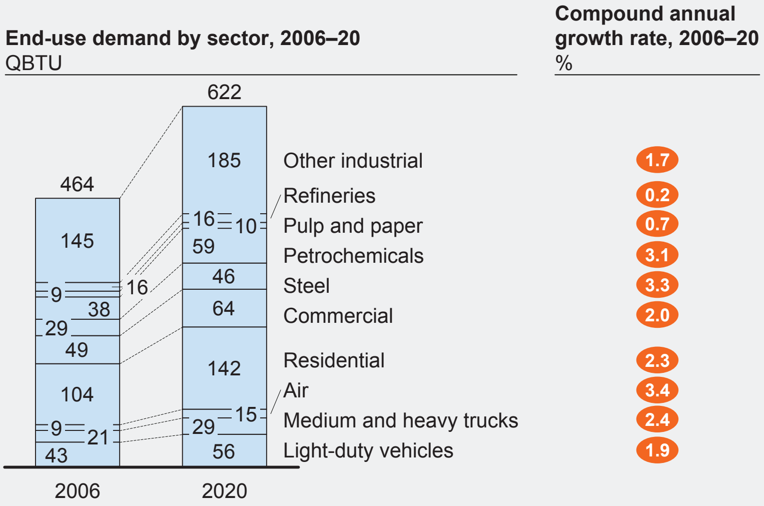
		Consumer					**Industrial**					
		Light-duty vehicles	Medium and heavy Trucks	Air transport	Residen-tial	Commercial	Steel	Petro-chemicals	Pulp and paper	Refining	Other industrial	**Total**
Developing	Rest of world	5.5	3.3	2.2	14.9	3.3	3.6	4.1	0.6	0.1	20.7	**58.3**
	Russia	0.8	0.2	0.3	0.7	0.9	-0.1	0.9	0.4	0.1	-0.3	**4.0**
	India	2.3	1.0	0.0	3.2	1.4	3.7	1.3	0.1	0.4	1.1	**14.5**
	China	4.8	1.7	0.9	11.6	5.5	9.7	8.8	0.8	0.4	8.2	**52.4**
	Middle East	2.4	0.9	0.4	4.6	0.5	0.2	3.3	0.0	0.6	5.0	**17.9**
Developed	Japan	-0.5	-0.1	0.3	0.0	1.1	-0.5	0.0	-0.3	-0.1	0.5	**0.4**
	Northwest Europe	-0.5	0.4	0.9	1.7	0.8	-0.1	1.0	0.2	-0.5	1.4	**5.2**
	United States	-1.8	0.6	0.7	1.5	1.7	0.1	1.4	-0.8	-0.5	2.9	**5.7**
	Total	**11.8**	**8.2**	**5.6**	**38.1**	**15.3**	**16.7**	**20.8**	**1.0**	**0.5**	**39.5**	**158.5**

80 QBTU **79 QBTU**

Source: McKinsey Global Institute Global Energy Demand Model 2009

Exhibit 1.25

Air, steel, and petrochemicals grow the fastest of all sectors, while refining and light-duty vehicles grow the slowest



Source: McKinsey Global Institute Global Energy Demand Model 2009

Light vehicles will see one of the slowest rates of energy-demand growth. Although the vehicle stock will grow very strongly in China, India, and the Middle East, very rapid efficiency improvements across many other regions will help dampen demand from this sector in aggregate. Although we project an increased share of EVs to 2020, there won't be a real impact on energy-demand growth until 2020 to 2030.

Five sectors within China—residential, commercial, steel, petrochemicals, and light vehicles—will account for more than 25 percent of overall energy-demand growth. Other sectors that are notable for their large contribution to overall energy-demand growth are India's light-vehicles, residential, and steel sectors, and light vehicles and petrochemicals in the Middle East. This second group of five sectors represents another 10 percent of the global energy-demand growth we project. In contrast, several sectors in different countries will see energy demand contract. Most notable are the light-vehicles and pulp-and-paper sectors in developed economies, the former driven by efficiency regulations, the latter by a shift from paper to digital media.

There will be little overall change in the fuel mix

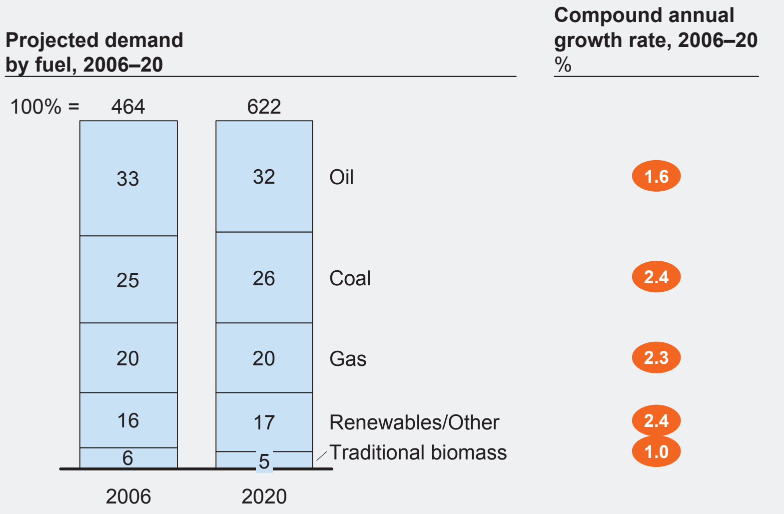
Turning to the fuel mix, this will change only modestly to 2020 given the very large installed base of energy-using capital stock and relatively minor differences in growth rates among fuels (Exhibit 1.26). However, within this aggregate picture, coal continues to be the fastest-growing fuel and oil the slowest-growing.

Coal consumption is driven by the inexorable proliferation of electricity-using appliances in buildings and by continued urbanization in developing countries, not least in China and India. These two countries are both particularly coal intensive and are among the fastest-growing regions in the world, accounting for nearly 100 percent of coal demand growth to 2020 (Exhibit 1.27). Relatively slow growth in oil demand will reflect the impact of regulation, short-term behavioral responses to price, increasing biofuels (which we categorize in this report as "biomass/other"), and the continued migration from residual fuel oil and diesel to other fuels (particularly natural gas) in the power, industrial, and buildings sectors where they are used as boiler fuels. Natural gas growth is again fastest in China and India, although from a lower starting point. Given its commitment to increase natural gas prices to netbacks, Russia's gas demand is projected to be quite slow (Exhibit 1.28). The "renewables/other" category grows at about the rate of coal and gas. However, within this grouping, traditional biomass and nuclear demand rise more slowly, while renewables such as wind power and biofuels grow briskly.

Exhibit 1.26

The global fuel mix changes very little with growth rates of the major fuels within 1 percent of each other

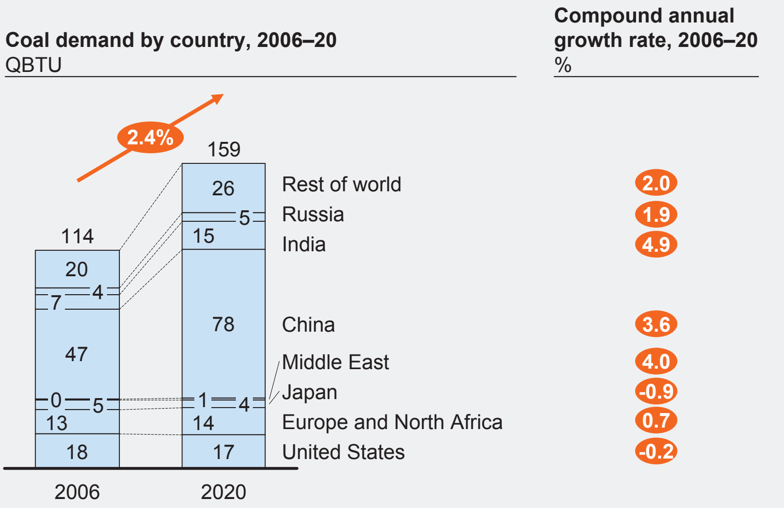
%, QBTU



Source: McKinsey Global Institute Global Energy Demand Model 2009

Exhibit 1.27

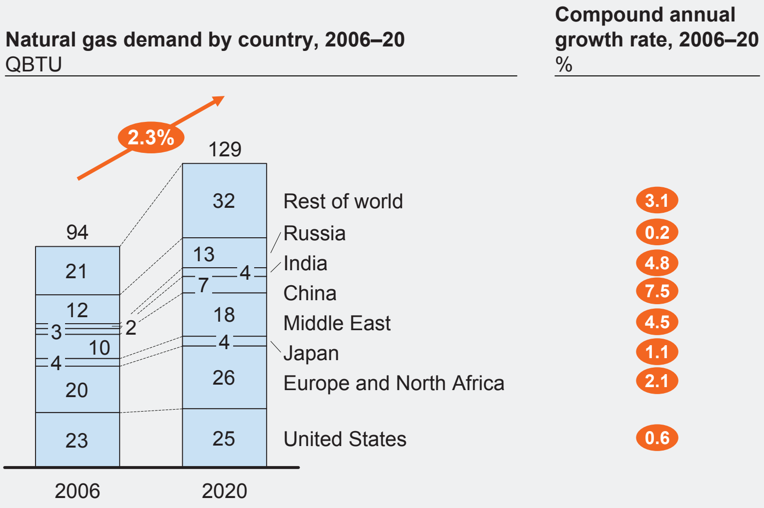
China and India are projected to account for nearly 100 percent of coal demand growth



Source: McKinsey Global Institute Global Energy Demand Model 2009

Exhibit 1.28

China and India are projected to grow natural gas demand the fastest; the United States and Russia the slowest



Source: McKinsey Global Institute Global Energy Demand Model 2009

Since we project that oil supply will grow more slowly than oil demand at a $75 oil price, a change in either the oil price or policy, or a combination of the two, will be necessary to bring demand and supply in balance. Many policy levers are available to achieve this rebalancing of supply and demand, including incentives to shift petroleum out of boiler-fuel applications, the removal of petroleum-product subsidies, and further incentives for EVs (see section 4.1 of this report for detail) (Exhibit 1.29). Meanwhile, gas and coal supply do not appear to be a constraint to demand growth in most regions. Although temporary imbalances could exist between now and 2020, the overall long-term supply demand path looks relatively balanced.

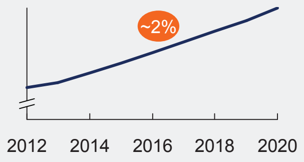
Exhibit 1.29

MGI sees two longer-term oil-demand scenarios with supply a constraint

Unconstrained, liquid demand

After the dip …

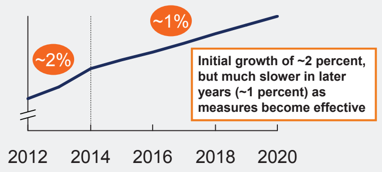
A **.. demand goes back to longer-term fundamentals and follows current trends**



Implications

- Supply pressure
  - –Lots of effort to unlock new, expensive supply (biofuels)
  - –Rising supply cost curve
- Higher prices to reduce and substitute demand

B **.. a real adjustment in demand based on new policies, lower GDP growth, lower subsidies, and/or behavioral changes**



Initial growth of ~2 percent, but much slower in later years (~1 percent) as measures become effective

- Policy interventions to constrain demand from current trend
  - –Incentives to substitute in industrial, buildings, power
  - –Subsidy removal, particularly in Middle East
  - –"Japanese" instead of "US" transport development, including electric vehicles

Source: McKinsey Global Institute analysis

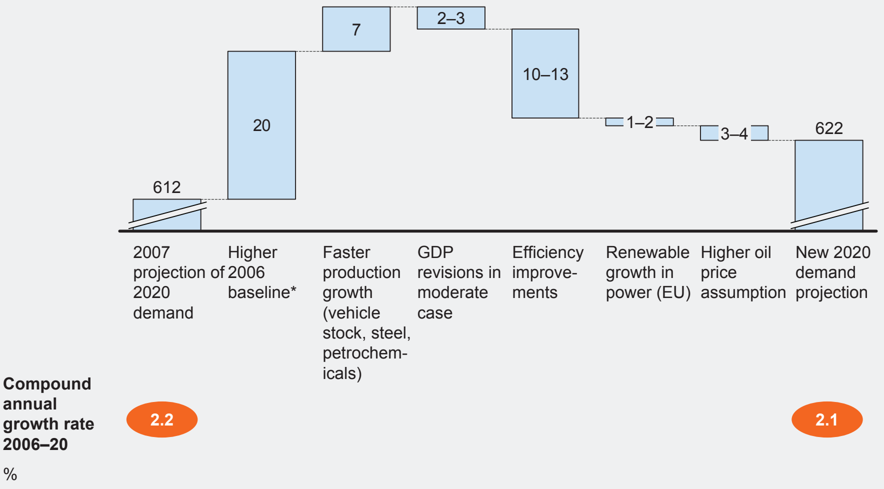
MGI'S ENERGY DEMAND PROJECTION HAS NOT CHANGED MUCH SINCE 2007, DESPITE A SHIFTING BACKDROP

Since MGI's last energy demand projections in 2007, the world has changed quite dramatically in some respects; think the credit squeeze, economic slowdown, and regulatory change on a broad front. Nevertheless, our updated projections are not dramatically different.

We now project global energy demand to reach approximately 622 QBTU in 2020 globally—only about 1.5 percent more than we projected in 2007. What lies behind this revision? It appears that demand grew about 1 percent per annum more quickly in 2003–06 than had seemed to be the case when we published our previous report, boosting demand by 14 QBTU more than we projected in 2006. Extrapolated out to 2020, this represents an additional 19 QBTU of demand. However, this extra demand was balanced by downward revisions to GDP, a higher assumption for long-term oil prices, and new efficiency and renewables regulations. Looking at all these developments together, MGI's projection for energy demand in 2020 is broadly unchanged, although we now project growth to slow from 2.2 percent per annum to 2.1 percent (Exhibit 1.30).

Exhibit 1.30

Our demand projections are 1.5 percent higher in 2020 than MGI's 2007 report; however, several factors have changed



* Due to faster than expected 2003–06 demand growth.
Source: McKinsey Global Institute Global Energy Demand Model 2009

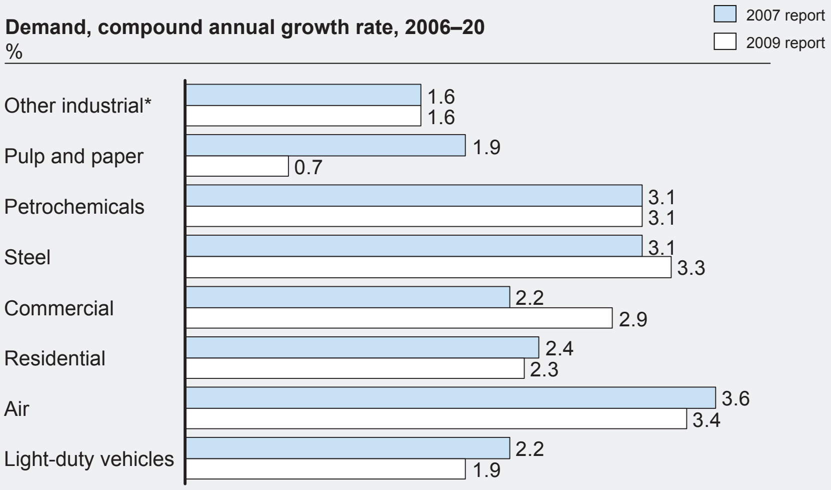
The sectors that have borne down most on aggregate energy-demand growth are light vehicles and road transport more broadly, and buildings; it is no coincidence that it is in these sectors where efficiency regulations have been most robust. Among other sectors, we cut growth projections in energy demand of the pulp-and-paper sector from 1.9 percent to 0.7 percent, due to both lower than expected demand growth and higher projected efficiency capture. Lower output in this sector will have a direct impact on its energy consumption, as well as an indirect impact from reducing margins that force producers to target cost savings, including energy productivity opportunities (Exhibit 1.31).

Looking at individual countries, MGI has revised demand projections downward for most countries except for India, whose projected compound annual growth rate has doubled to 3.6 percent. Three sectors explain most of the increase in India's projected demand—light vehicles, steel, and residential. Of these three, the most important drivers of demand growth are light vehicles and steel. The vehicle stock and production growth have accelerated recently, and rapid growth is expected to resume after the current global GDP slowdown (Exhibits 1.32 and 1.33).

In terms of fuels, we have revised our oil-demand projections down most dramatically, while we have revised up the "renewables/other" category (Exhibit 1.34).

Exhibit 1.31

Pulp and paper, road transport, and commercial have slowed the most since 2007 report; steel and petrochemicals have stayed strong

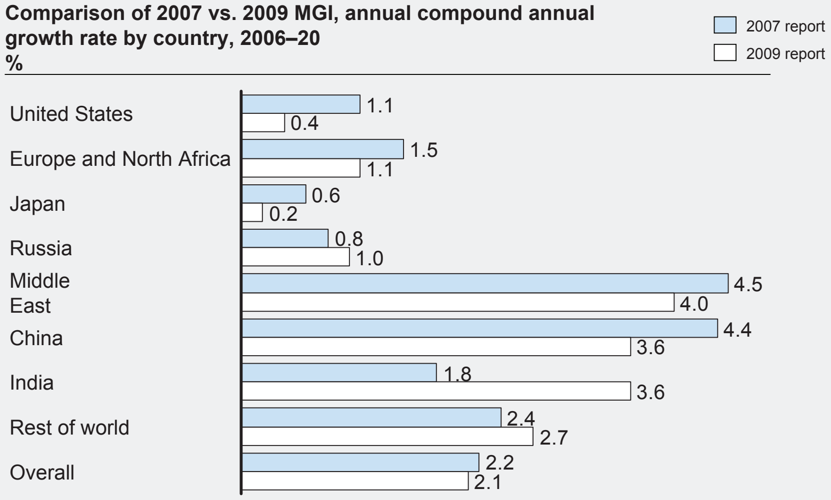


* Includes refineries.

Source: McKinsey Global Institute Global Energy Demand Model 2009

Exhibit 1.32

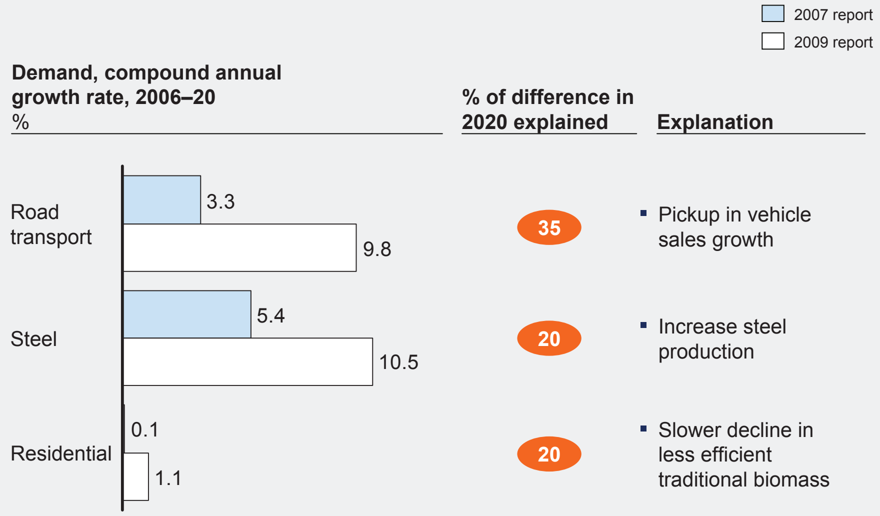
MGI's forecasts have been revised downward across many regions, and upward in India and Rest of World



Source: McKinsey Global Institute Global Energy Demand Model 2009

Exhibit 1.33

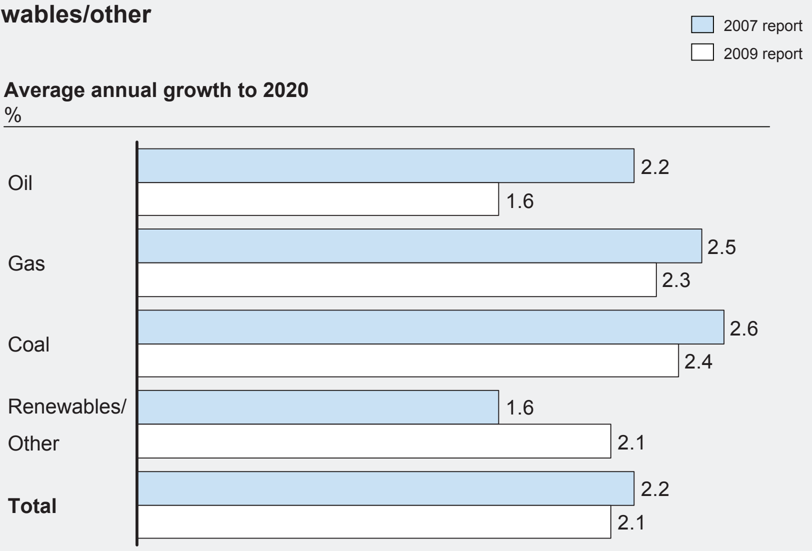
Road transport, steel, and residential explain most of the demand difference between prior and new India demand projections



Source: McKinsey Global Institute Global Energy Demand Model 2009

Exhibit 1.34

MGI's fuel-level projections have all gone down except for renewables/other



Source: McKinsey Global Institute Global Energy Demand Model 2009

MGI's energy demand projections are very close to those of the IEA

At the country level, MGI's energy demand projections are very close to those of the International Energy Agency (IEA). The largest difference between the two projections is energy-demand growth in Russia, which could be the result of different assumptions about the removal of natural gas subsidies, and in Europe, which is likely because of different regional definitions (MGI's definition includes more developing countries) (Exhibit 1.35).[11]

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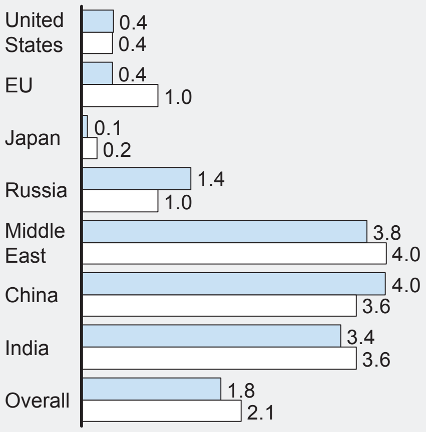
[11] MGI assumes gas prices rising from $0.70 per MBTU in 2005 to $7 per MBTU in 2020, expressed in real 2007 dollars.

Exhibit 1.35

IEA's and MGI's projections are relatively close across most regions

🟦 IEA *World Energy Outlook 2008*
☐ MGI

Comparison of IEA *World Energy Outlook 2008* vs. MGI projected growth rates by country



Potential reason

- N/A
- We include some non-OECD countries in MGI's European region
- N/A
- Removal of gas subsidies in Russia in MGI's model
- N/A
- Slightly higher efficiency assumptions in MGI due to Top-1,000 program
- N/A

Source: IEA *World Energy Outlook 2008*; McKinsey Global Institute Energy Demand Model 2009

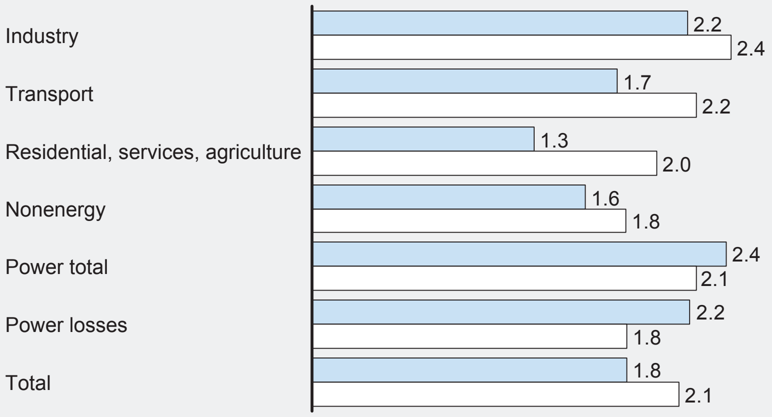
However, MGI's projections at the level of end users shows faster energy-demand growth across sectors but slower demand growth in the power sector. MGI's renewables assumptions, as well as its assumptions about overall efficiency in traditional power plants, appear to be higher than those of the IEA (Exhibit 1.36).

Exhibit 1.36

IEA's slightly lower projected demand across all end-use sectors is offset by slower power-sector loss growth in MGI's projections

🟦 IEA *World Energy Outlook 2008*
☐ MGI

Average annual growth to 2020
%



Source: IEA *World Energy Outlook 2008*; McKinsey Global Institute Global Energy Demand Model 2009

On fuels, MGI projects faster demand for oil and "renewables/other" than the IEA, but slower demand for coal (Exhibit 1.37). The IEA sees supply growing slowly, leading to a rise in the price of oil.[12] We interpret this to imply that the IEA's oil-demand path is supply constrained at growth of 1.2 percent per annum. A rough triangulation of the IEA's assumptions with those of MGI shows that MGI's oil-demand growth projections are roughly compatible at the IEA's assumption of a $100 a barrel real oil price to 2015 and a $120 per barrel real price to 2030, given the IEA's stated oil-price elasticity of minus

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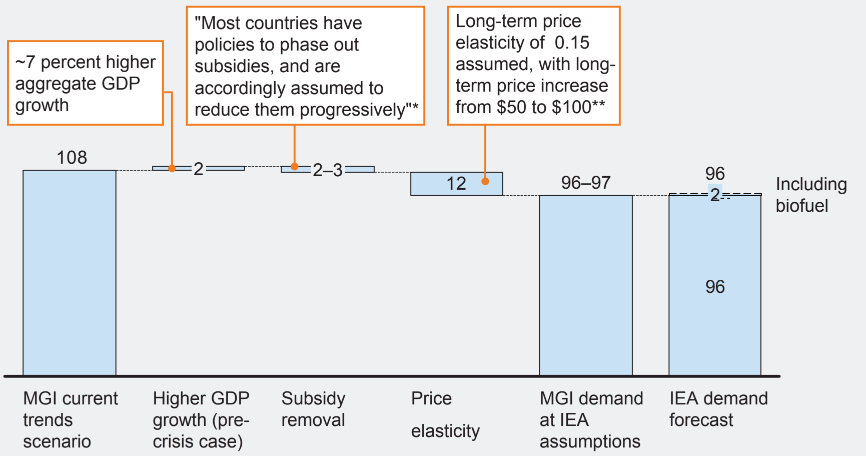
[12] World Energy Outlook 2008, IEA, 2008.

0.15. Given the wide range of estimates of oil-price elasticity—ranging from minus 0.05 to minus 0.5 in published academic work—such a price projection certainly has a wide band of uncertainty around it, on both the high and low sides (Exhibit 1.38).

Exhibit 1.37

Using IEA's assumptions, MGI's liquids demand would be 96–98 million barrels per day, consistent with IEA projections

ROUGH ESTIMATE



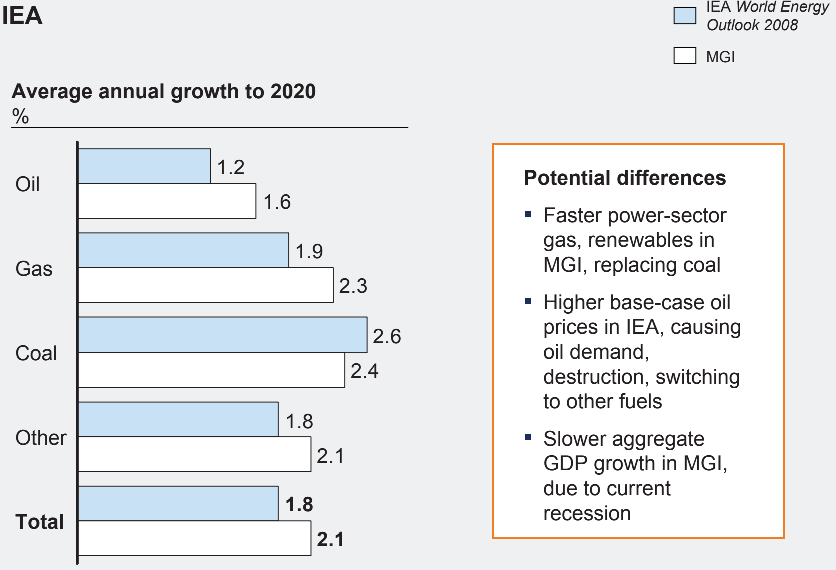
* *World Energy Outlook 2008*, IEA, p.59.

** IEA states a price elasticity of minus 0.15 in *World Energy Outlook 2008*, pg. 98.

Source: IEA *World Energy Outlook 2008*; McKinsey Global Institute analysis

Exhibit 1.38

MGI's fuel-level projections are very close to those of the IEA



Potential differences

- Faster power-sector gas, renewables in MGI, replacing coal
- Higher base-case oil prices in IEA, causing oil demand, destruction, switching to other fuels
- Slower aggregate GDP growth in MGI, due to current recession

Source: IEA *World Energy Outlook 2008*; McKinsey Global Institute Global Energy Demand Model 2009

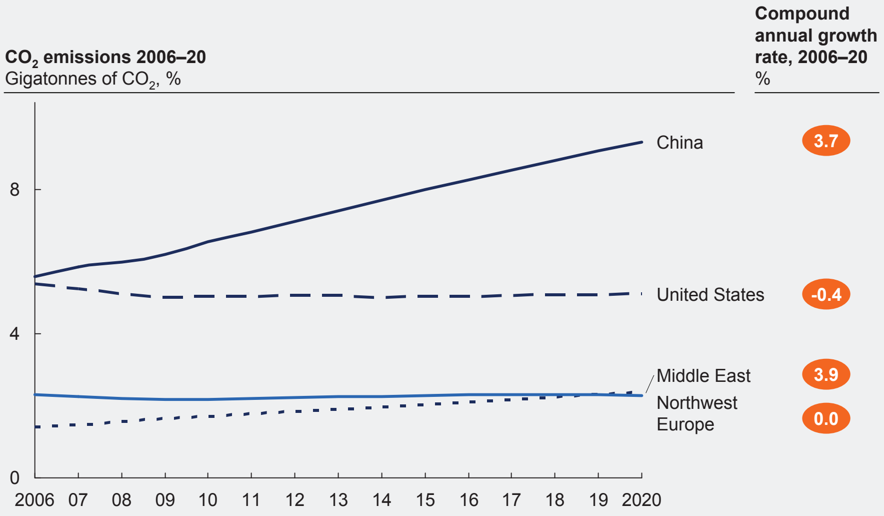
Comparing MGI's projections with those of the EIA released in December 2008, both MGI and the EIA project a 0.4 percent per annum growth rate in energy demand for the United States to 2020.

CO$_2$ emissions will grow marginally more slowly than energy demand

CO$_2$ emissions will grow slightly more slowly than energy demand as carbon-intensive coal use increases more quickly than that of other fuels but rapid growth in renewables helps to offset this. China will continue to grow briskly at 3.7 percent per year, outpacing its energy-demand growth of 3.5 percent per annum. CO$_2$ -emissions growth will be flat or negative in developed regions—such as the United States and Northwest Europe—due both to slow energy-demand growth as well as regulations that cause a shift to renewables and natural gas (Exhibit 1.39).

Exhibit 1.39

China and Middle East grow CO_2 emissions quickly; the United States is actually reducing carbon emissions in MGI's moderate case

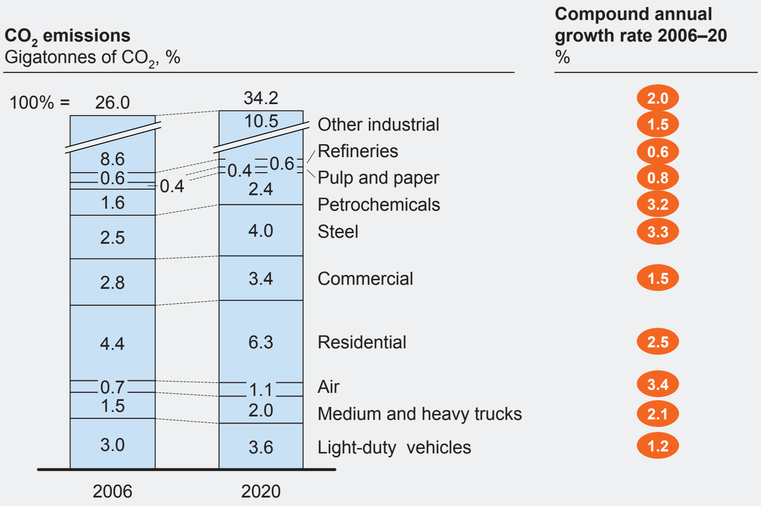


Source: McKinsey Global Institute Global Energy Demand Model 2009

The fastest-growing end-use sectors in terms of emissions are air transport, steel, and petrochemicals. In these sectors, CO_2 emissions largely grow in line with energy demand by end use. Light-vehicle emissions grow less quickly than energy demand due to the sector's increasing use of biofuels (Exhibit 1.40).

Exhibit 1.40

CO_2 emissions are projected to increase at 2 percent per annum, with air transport and petrochemicals showing the strongest growth

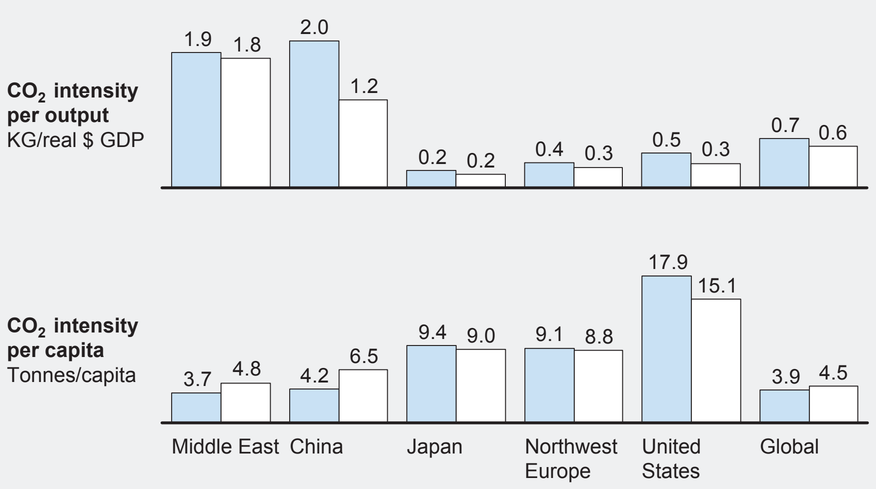


Source: McKinsey Global Institute Global Energy Demand Model 2009

On a per dollar of GDP basis, every major region is projected to cut emissions per unit of GDP in the period to 2020—in the case of China, its emissions are expected to be cut by half. MGI sees the United States cutting emissions dramatically on a per capita basis; reductions in emissions on a per GDP basis will also fall in Northwest Europe and Japan (Exhibit 1.41).

Exhibit 1.41

The United States remains the largest per capita CO_2 emitter to 2020, but emissions fall strongly; China cuts its GDP emissions intensity by nearly half



Source: IEA; Global Insight; McKinsey Global Institute Global Energy Demand Model 2009

WHILE ENERGY PRODUCTIVITY IS IMPROVING, A LARGE OPPORTUNITY REMAINS

In our last report, we showed that large opportunities to reduce energy-demand growth while making investments that had a 10 percent or more IRR could slow energy-demand growth to 2020 by two-thirds. We estimated that opportunities to cut demand by between 20 and 24 percent were available across all regions and many of the sectors that we have analyzed (see “What is energy productivity?”).

This latest analysis finds that the size of the opportunity is now slightly smaller at between 16 and 20 percent of 2020 demand—but that abatement in this order of magnitude would still cut energy-demand growth by more than two-thirds to 2020 (Exhibit 1.42).

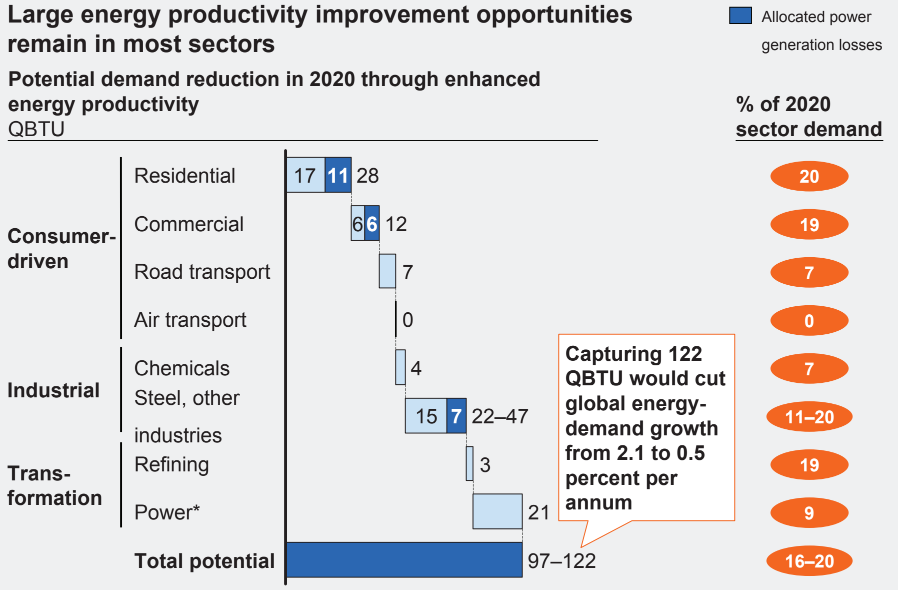
Several factors have reduced the size of the energy productivity opportunity. The most important of these is that policy makers have put in place regulations that will capture almost 15 QBTU of the opportunity. Most notable are CAFE standards in the United States, stronger building efficiency standards in the United States and Europe, and the Top-1,000 program for industrial efficiency in China. Another important factor is the shift in the profile of energy-demand growth. Also, because we are now further along in the analyzed period to 2020, some opportunities have already been rendered out of date since new capital stock has been installed with less than optimal energy efficiency. Finally, we have scaled back a few of the opportunities in the industrial sector. For instance, we have used slightly less optimistic assumptions for the penetration of thin-slab casting in steel, leading to approximately a 2 percent decrease—or 12 QBTU—in the overall size of the energy productivity opportunity (Exhibit 1.43).

Adding all these items together gives a reduced energy productivity opportunity relative to our 2007 report. That said, the majority of the opportunity still exists, and in fact the impact of capturing the opportunity would actually slow demand growth even more on a percentage basis. Last time, the energy productivity opportunities would have cut demand growth by two-thirds, and this time by more than three-quarters. The shorter time period over which the opportunity would be captured (14 years versus 17 years) explains this.

Exhibit 1.42

Large energy productivity improvement opportunities remain in most sectors

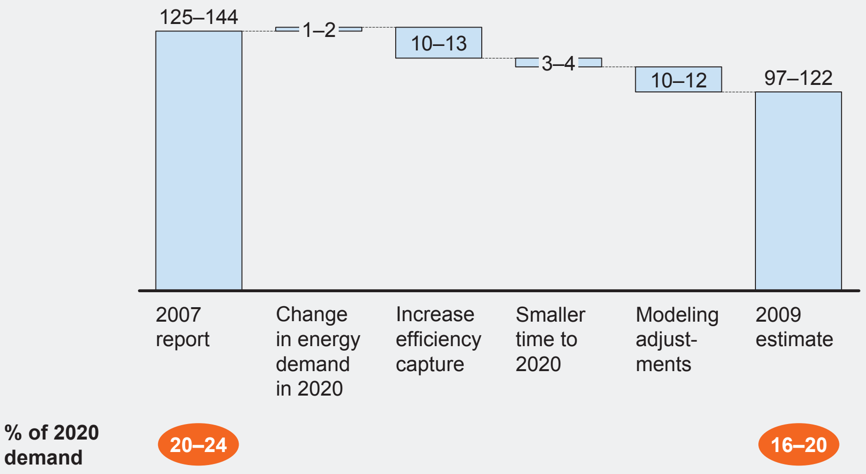
Potential demand reduction in 2020 through enhanced energy productivity
QBTU



* Additional opportunity after taking into account final power demand savings in end-use sectors.
Source: McKinsey Global Institute analysis

Exhibit 1.43

The energy productivity opportunity has narrowed since MGI's last report QBTU

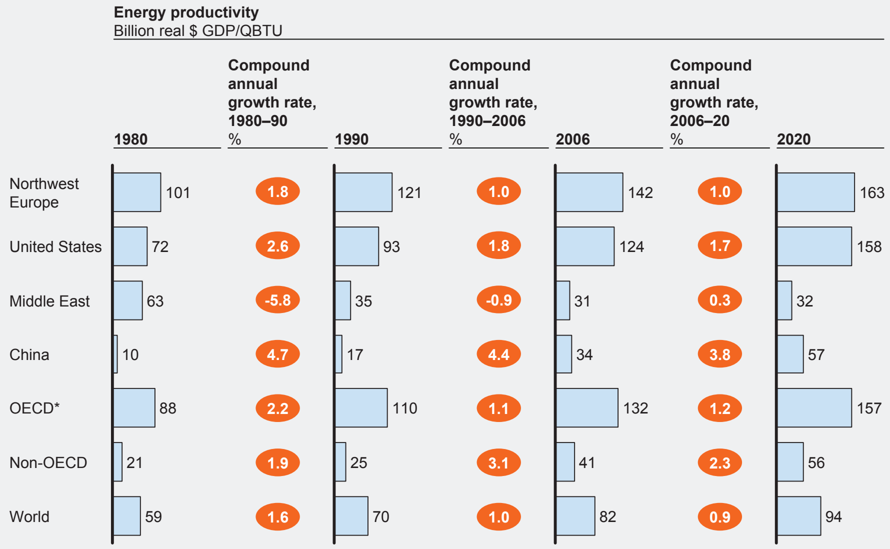


Source: McKinsey Global Institute Energy Demand Model 2009

Overall, we expect energy productivity to increase on the basis of GDP per unit of energy across all regions and that China will lead the way (Exhibit 1.44). Interestingly, we project that the United States will actually cut its per capita energy demand to 2020—the only region to do so. In the period to 2020, we now project that energy productivity on the basis of GDP per unit of energy will grow at 0.9 percent globally. However, compared with the period from 1980 to 1990, when twin oil shocks catalyzed a strong policy response, growth in energy productivity is some 0.7 percent a year slower in the period ahead. (Exhibit 1.45)

Exhibit 1.44

All regions will increase their energy productivity level

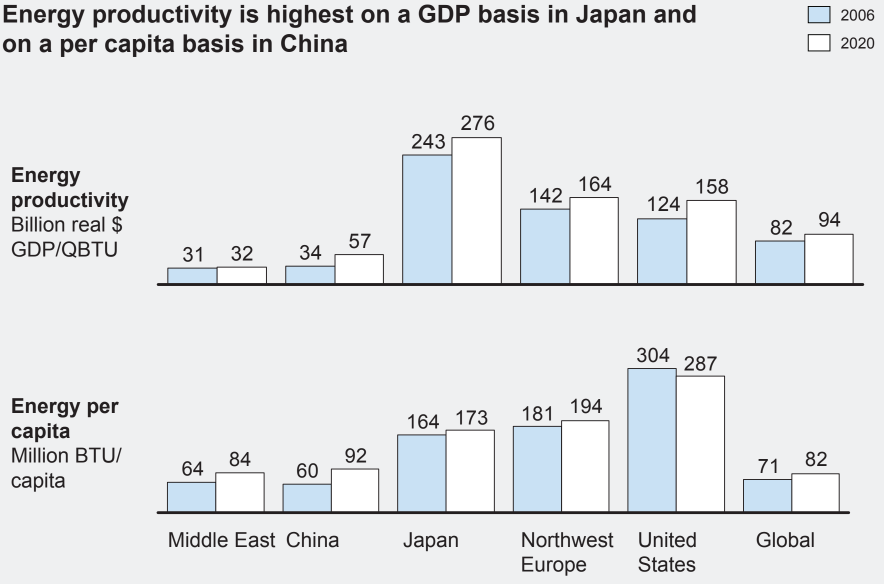


* Including North Africa.

Source: IEA; Global Insight; McKinsey Global Institute Global Energy Demand Model 2009

Exhibit 1.45

Energy productivity is highest on a GDP basis in Japan and on a per capita basis in China



Source: IEA; *Main Economic Indicators*, OECD; Global Insight; McKinsey Global Institute Global Energy Demand Model 2009

What is energy productivity?

Any successful program that addresses today's mounting energy-related concerns needs to be able to rein in energy consumption without limiting economic growth. Higher energy productivity is the most cost-effective way to achieve this goal.

Like labor or capital productivity, energy productivity measures the output and quality of goods and services generated with a given set of inputs. MGI measures energy productivity as the ratio of value added to energy inputs, which is $79 billion of GDP per QBTU of energy inputs globally. Energy productivity is the inverse of the energy intensity of GDP, measured as a ratio of energy inputs to GDP. This currently stands at 12,600 BTUs of energy consumed per dollar of output globally.

Energy productivity provides an overarching framework for understanding the evolving relationship between energy demand and economic growth. Higher energy productivity can be achieved either by higher energy efficiency that reduces the energy consumed to produce the same level of energy services (e.g., a more efficient bulb produces the same light output for less energy input), or by increasing the quantity or quality of economic output produced by the same level of energy services (e.g., providing higher value-added services in the same office building). We define energy productivity opportunities as capital investments or expenditures that would reduce energy demand and have an IRR of 10 percent or more. We do not include in our analysis those items that change the "level of energy service"—such as turning down the thermostat or walking to work.

We attempt to proxy energy productivity improvement rates using two measures—GDP per unit of energy and BTU consumed per capita. It's important to note that increasing GDP per unit of energy indicates rising energy productivity while per capita BTU moves inversely to energy productivity improvements. These measures provide us only with an indication of the capture of the energy productivity potential; other factors can lead to improvements in this measure including higher energy efficiency in the sector mix through deindustrialization, for instance, and the capture of non-energy productivity opportunities, including, for example, investments that have less than a 10 percent IRR or require behavioral change.

2. Liquids demand tightness could return between 2010 and 2013

- Liquids demand will be stagnant in the short term due to impact of high prices in 2007 and the credit squeeze. MGI's moderate case projects that liquids demand will grow only weakly by 0.4 percent in 2009 but will rebound in 2010 to post growth of 2.1 percent. In our very severe case, demand would remain almost flat until 2012.

- From 2006 to 2020, liquids demand will grow at 1.9 percent a year, somewhat slower than the 2.2 percent growth projected in MGI's 2007 report. Excluding biofuels, oil demand will grow at a projected 1.7 percent per year.

- MGI has revised down its projections because the strong GDP contraction in 2008 and 2009 and the capture of energy efficiency opportunities in light-duty vehicles will lead to lower liquids demand than anticipated in 2007 in developed economies.

- In developed economies, MGI projects only marginal 0.2 percent annual growth in liquids demand between 2006 and 2020, while liquids demand will grow at 3.4 percent per year in developing economies.

- Without further action to abate energy-demand growth, spare capacity in liquids could return to the low capacity levels witnessed in 2007 as soon as 2010 to 2013, risking a second spike in oil prices.

- Policy makers could achieve the 6 million to 11 million barrels per day of demand reduction needed to keep supply and demand in balance through low- or no-cost levers. Among these levers are subsidy removal, removing oil from boiler applications, and increasing fuel-efficiency standards further.

- EVs will not have an impact until beyond our 2020 forecast period, given their low installed base and need for further technological development.

OVERVIEW

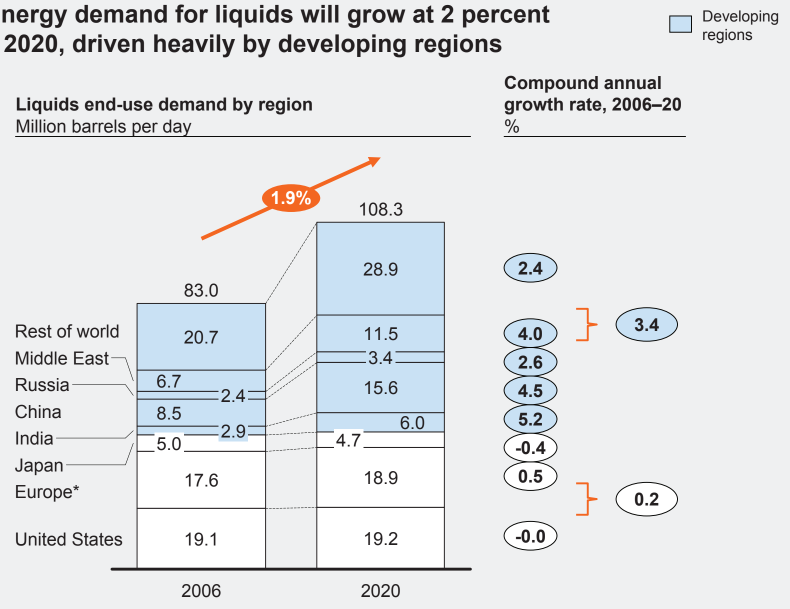
In this section, we describe the energy demand for liquids, which includes not only petroleum products such as gasoline and diesel but also biofuels. This is a segment of energy demand that has been particularly volatile recently and has dominated much of the discussion on global energy. Only a short while ago, we witnessed a strong demand environment bolstered by a booming economy, relatively low prices, heavy subsidies, and strong demand growth in developing regions. But this situation has suddenly turned upside down, and we now see a world in which oil demand is falling globally for the first time in almost three decades.

This section will address some fundamental questions about how the supply-demand balance for liquids may evolve as a result of the current economic downturn. How low is demand likely to fall? How soon will the supply-demand balance become constrained again after growth returns? How much will policy changes to promote efficiency and substitution away from oil drive down long-term demand? Alternatively, could we see rapidly accelerating liquids-demand growth coming out of the downturn, and could this coincide with a squeeze in the supply capacity, leading to a spike in prices back toward record levels?

In our moderate case, we project that liquids demand will grow at 1.9 percent per year from 2006 to 2020, somewhat slower than the 2.2 percent growth we projected in our 2007 report.[1] Excluding biofuels, oil demand will grow at a projected 1.6 percent per year. We have revised down our projections, primarily because of the lower expected demand we now see in developed economies, due to the strong GDP contraction in 2008 and 2009, but also because of the capture of energy efficiency opportunities in light-duty vehicles anticipated as a result of new energy efficiency regulations. These factors combine in developed economies to produce liquids-demand growth of only a marginal 0.2 percent per annum between 2006 and 2020. The flip side of this is that virtually all liquids-demand growth will come from developing regions, growing at 3.4 percent per year during this period (Exhibit 2.1).

Exhibit 2.1

Global energy demand for liquids will grow at 2 percent through 2020, driven heavily by developing regions



* Including Mediterranean Europe and North Africa, and Baltic/Eastern Europe.
Source: IEA; McKinsey Global Institute Global Energy Demand Model 2009

In the short term, we expect liquids demand to remain stagnant as the credit squeeze takes effect and as high prices from 2007 hang over the market. Indeed, liquids demand will likely contract more steeply than GDP as several large industrial consumers of oil are procyclical in nature.

While demand shows an immediate response to macroeconomic conditions, supply lags. As long as the oil price is above the marginal cost in the vast majority of oil fields, companies do not shut in production. The economic situation makes companies hold back investments, but that reduces supply only in two to four years. Meanwhile, supply projects that were already in progress will likely continue to completion, with projects stalled in 2009 and 2010 having impact only a few years down the road. Because of this we expect spare capacity levels in 2009 to reach levels not seen since the late 1980s (Exhibit 2.2).

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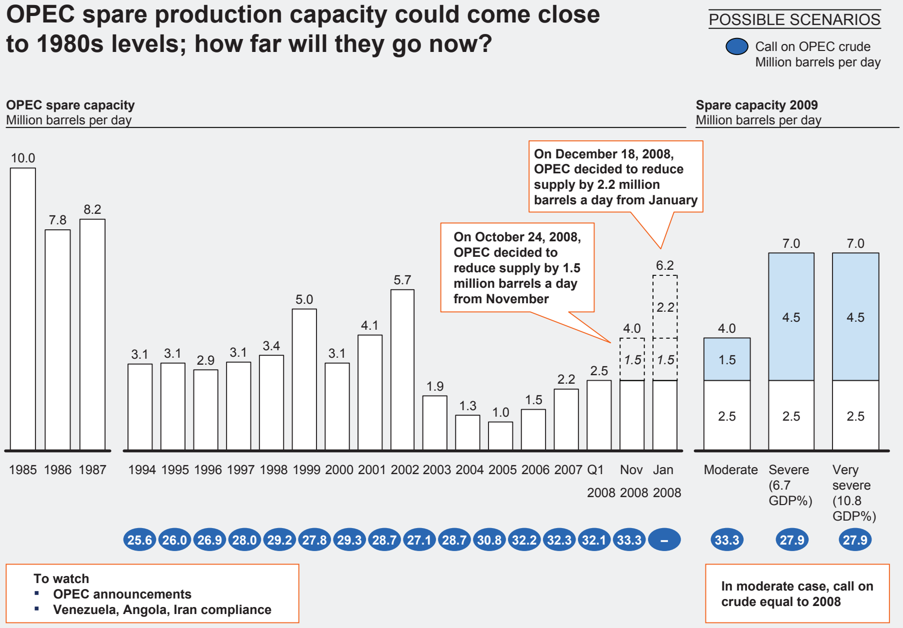
[1] The difference between the 1.9 percent cited here and the 1.6 percent cited in section 1 is that the "liquids" figures in this section include biofuels and the "oil" figures in section 1 do not.

Exhibit 2.2

OPEC spare production capacity could come close to 1980s levels; how far will they go now?



On December 18, 2008, OPEC decided to reduce supply by 2.2 million barrels a day from January

On October 24, 2008, OPEC decided to reduce supply by 1.5 million barrels a day from November

To watch
- OPEC announcements
- Venezuela, Angola, Iran compliance

In moderate case, call on crude equal to 2008

Source: IMF; Bloomberg; BP; McKinsey analysis

Although the supplies of coal and gas appear to be sufficient to prevent long-term price inflation for these fuels, growth in the supply of oil will slow markedly. Given that we project diesel demand to grow much more quickly than gasoline in the long term, we also see the distinct possibility that diesel gasoline spreads could hold steady or increase even further than we saw in 2008, increasing the cost of goods transportation. Furthermore, given certain assumptions about prospects for the refining sector and crude oil supply, diesel could pull the entire crude market price higher.

While policy makers have already taken steps in some regions to reduce demand growth (e.g., through CAFE standards), without further action to abate energy-demand growth, spare capacity levels could return to the low levels that we witnessed in 2007—and as soon as 2010 to 2013, depending on the length and depth of the economic downturn. This holds out the prospect of a second spike in oil prices, although looking to the long term, we would expect a combination of policy and price to return supply and demand to broad balance.[2]

LIQUIDS DEMAND WILL STAGNATE IN THE SHORT TERM DUE TO GLOBAL ECONOMIC WEAKNESS

In the short term, we expect liquid demand to be stagnant due to the impact of high prices in 2007 and the impact of the credit squeeze. MGI's moderate case projects that liquids demand will increase by 0.2 percent from 84.7 million barrels per day or 153.3 QBTU in 2007 to 84.9 million barrels per day, or 154.0 QBTU, in 2008. In 2009 we see liquids demand increasing only slightly, by 0.4 percent, to 85.2 million barrels per day, or 154.3 QBTU—much lower than the respective 0.2 and 3.4 percent growth we projected using precrisis trend GDP assumptions. Demand growth would rebound in our moderate case in 2010, registering 2.1 percent growth to reach 87.0 million barrels per day.

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[2] For a discussion of why crude prices spiked in 2008, see for example James D. Hamilton, "Understanding Crude Oil Prices," NBER Working Paper No. 14492, November 2008.

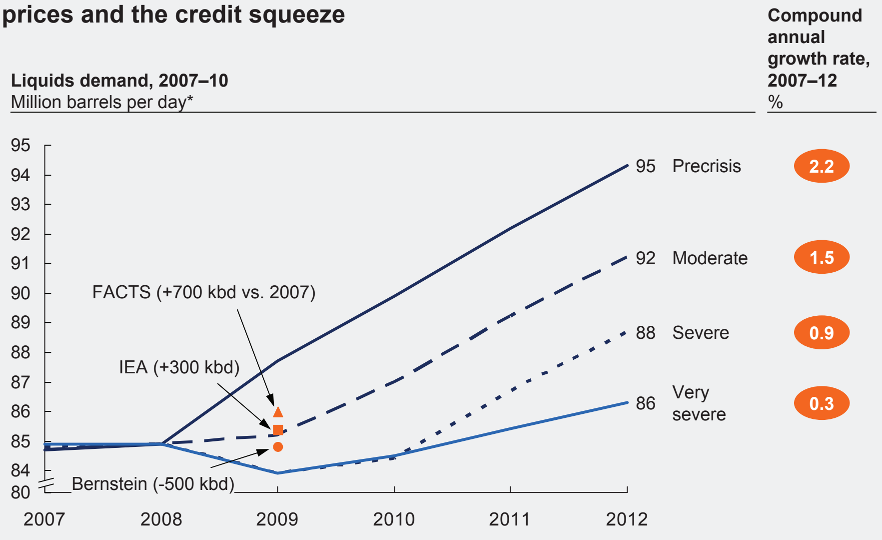
If the credit squeeze were to prove both prolonged and more severe than we assume in our moderate case—a severe case that assumes a 6.7 percent GDP gap to trend—liquids-demand growth could go negative, staying flat in 2008 and shrinking by 1.1 percent in 2009 to 83.9 million barrels per day. We would see a slight rebound to 84.4 million barrels per day in 2010, but this would still be 400,000 barrels per day below 2007 levels.

Under an even more severe downturn—our very severe case that assumes a 10.8 percent global gap to trend—the recovery in liquids demand would be much weaker, with demand reaching only 84.4 million barrels per day by 2010 and 86.3 million barrels per day by 2012.

MGI's short-term demand estimates are in line with projections from other sources. While we project an increase in demand in our moderate case of 500,000 barrels per day between 2007 and 2009, FACTS projects a 700,000 barrels a day increase, while IEA projects a 300,000 rise. Another noted source, Bernstein, projects a 500,000 barrels per day decrease in liquids demand over the same time frame—falling in between MGI's moderate and severe cases, the latter projecting a fall in demand growth of 900,000 barrels per day (Exhibit 2.3).[3]

Exhibit 2.3

Demand for oil will slow markedly, impacted by high 2007 prices and the credit squeeze



* Crude oil at the well head; refinery gains effect included in demand.

Source: IEA *Oil Market Report*, December 2008; Bernstein, October 2008; FACTS, October 2008; McKinsey Global Institute Global Energy Demand Model 2009

In developed regions, liquids demand drops 2.1 percent per year between 2007 and 2009 in the moderate case, while developing regions see liquids-demand growth slowing to 2.6 percent per year. This demonstrates the short-term impact of the global economic slowdown. In our precrisis case, we projected that developed regions would see their liquids demand shrink by 0.5 percent per year between 2007 and 2009 while developing regions would see robust growth of 4.1 percent. Looking at regions, we see the largest drops in demand in the United States, Europe and North Africa, and Japan, geographies that the downturn will hit hardest. By comparison, we now project Middle East liquids-demand growth of 6.3 percent in our moderate case, only slightly slower than the robust 7.1 percent we estimated before the crisis.

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[3] *Oil Market Report*, IEA, December 11, 2008; Bernstein, October 16, 2008; FACTS, October 8, 2008.

Two factors lie behind the overall shrinkage in liquids demand, even if GDP growth remains positive during the downturn as projected in our moderate case—the overreaction to the GDP downturn by several liquids-heavy sectors, and the impact of rising prices through mid-2008. Industrial sectors tend to respond more to GDP, while transportation sectors are more sensitive to price (Exhibit 2.4). Although regulations meant to limit demand growth have recently been put in place (e.g., US CAFE standards), the real impact from any recent regulation will be in the medium to long term.

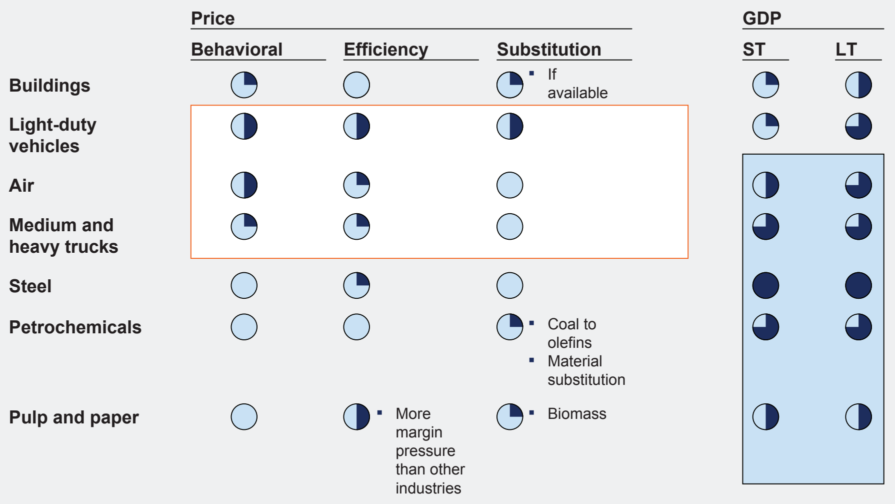
Exhibit 2.4

Price responses are concentrated in transportation, while industrial-sector growth tends to respond more to GDP

PRELIMINARY

☐ Price-driven
🟦 GDP-driven

Impact of price and GDP on end-use sectors



	Price			GDP	
	Behavioral	**Efficiency**	**Substitution**	**ST**	**LT**
Buildings	◔	○	◔ ▪ If available	◔	◑
Light-duty vehicles	◑	◑	◑	◔	◕
Air	◑	◔	○	◑	◕
Medium and heavy trucks	◔	◔	○	◕	◕
Steel	○	◔	○	●	●
Petrochemicals	○	○	◔ ▪ Coal to olefins ▪ Material substitution	◕	◕
Pulp and paper	○	◑ ▪ More margin pressure than other industries	◔ ▪ Biomass	◑	◑

Source: McKinsey Global Institute analysis

Take the response to GDP first. Many basic-materials sectors are highly procyclical, displaying huge swings in demand due to inventory drawdowns downstream in the value chain. Furthermore, durables and construction use these basic materials as inputs, exacerbating industrial procyclicality. Trucking and air transportation do not have the same inventory impacts as basic materials but also show a degree of procyclicality. Trucking declines because of its role in moving durable and construction goods, while air transport declines because consumers and companies both respond to cut demand.

Transport and some industrial subsegments—notably steel and petrochemicals—are responsible for virtually all of the liquids demand reduction (Exhibit 2.5). In our precrisis analysis, we projected demand growth of 4.5 and 4.3 percent for petrochemicals in 2008 and 2009 respectively. For this report we have lowered these projections, and these now show petrochemical liquids demand increasing by 0.4 percent and contracting by 6.0 percent in 2008 and 2009, respectively, due to declining sectoral output. In short, a severe downturn would cut energy demand in this sector by some 40 percent. Both air transport and truck transport liquids demand also decline significantly, accounting for one-quarter of the overall demand abatement in liquids that we would expect in the case of a severe global downturn.

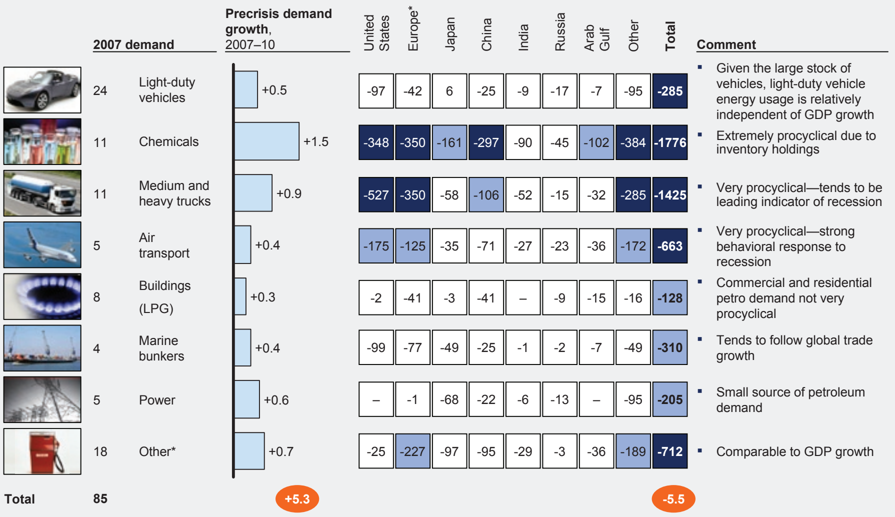
Within transportation, truck diesel demand is much more procyclical than light-vehicles gasoline demand, as GDP declines in sectors such as construction and basic materials tend to impact the movement of goods more than the usage of passenger cars. Indeed, liquids demand in light vehicles is minimally affected by the downturn, shrinking by 2.1 percent in 2008 and increasing by 1.7 percent in 2009 in our severe case, compared with growth shrinking by 1.9 percent in 2008 and increasing by 2.0 percent precrisis. In 2010, medium and heavy trucks account for 1.4 million barrels per day in demand reduction between the precrisis and severe cases, while light vehicles account for only 0.3 million barrels per day in demand reduction. Therefore, our work shows that price spreads between gasoline and diesel—which were at historic highs in 2008—will narrow (and potentially even reverse) particularly in the case of a prolonged downturn because diesel demand falls in the face of the downturn more than gasoline demand (Exhibit 2.6). We already see this narrowing taking place in 2009.

Exhibit 2.5

Recession-related demand reduction is mostly in chemicals, trucks, and air transport

Excluding refining conversion effect

☐ >-100 kbd
▨ <-250 kbd
■ > 250 kbd



Demand abatement—region
Effect of severe case on 2010

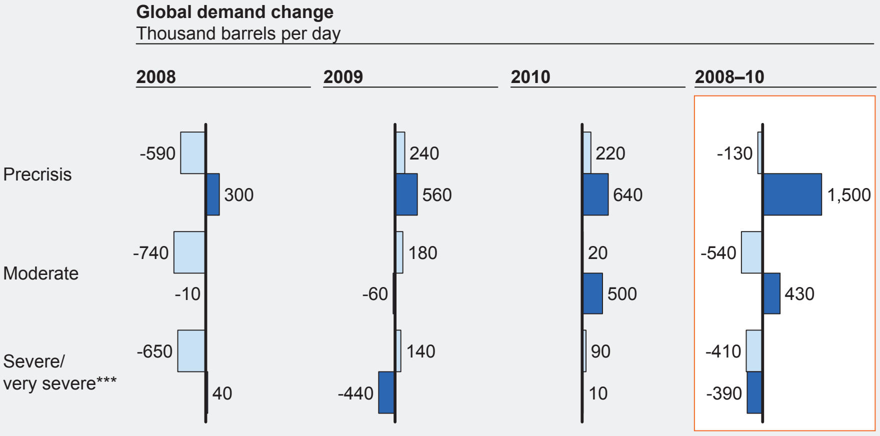
	2007 demand		**Precrisis demand growth**, 2007–10	United States	Europe*	Japan	China	India	Russia	Arab Gulf	Other	**Total**	**Comment**
	24	Light-duty vehicles	+0.5	-97	-42	6	-25	-9	-17	-7	-95	**-285**	Given the large stock of vehicles, light-duty vehicle energy usage is relatively independent of GDP growth
	11	Chemicals	+1.5	-348	-350	-161	-297	-90	-45	-102	-384	**-1776**	Extremely procyclical due to inventory holdings
	11	Medium and heavy trucks	+0.9	-527	-350	-58	-106	-52	-15	-32	-285	**-1425**	Very procyclical—tends to be leading indicator of recession
	5	Air transport	+0.4	-175	-125	-35	-71	-27	-23	-36	-172	**-663**	Very procyclical—strong behavioral response to recession
	8	Buildings (LPG)	+0.3	-2	-41	-3	-41	–	-9	-15	-16	**-128**	Commercial and residential petro demand not very procyclical
	4	Marine bunkers	+0.4	-99	-77	-49	-25	-1	-2	-7	-49	**-310**	Tends to follow global trade growth
	5	Power	+0.6	–	-1	-68	-22	-6	-13	–	-95	**-205**	Small source of petroleum demand
	18	Other*	+0.7	-25	-227	-97	-95	-29	-3	-36	-189	**-712**	Comparable to GDP growth
Total	85		**+5.3**									**-5.5**	

* Including agriculture, oil refining, rail transport, iron and steel, pulp and paper, and other industrials.
Source: McKinsey Global Institute Energy Demand Model 2009

Exhibit 2.6

If the downturn is deep, gasoline/diesel spreads should narrow in the short term, especially in 2009

☐ Fossil gasoline*
■ Fossil diesel **



* Motor gasoline less ethanol production.
** IGO (industrial gas oil) for all end uses (transport, buildings, industrial, and power) less biodiesel.
*** Severe- and very severe-case equivalent to 2010; very severe-case slow growth continues in 2011 and 2012.
Source: McKinsey Global Institute Energy Demand Model 2009

Turning to the response to price, the most direct impact of changes in prices are those sectors that are least insulated from the market through, for instance, energy taxes and subsidies. This is most acutely the case in light vehicles and air transport. In contrast, other sectors, including petrochemicals and buildings, do not react strongly to price because of a lack of suitable alternative energy sources (for a detailed discussion of such elasticities, see the individual sector chapters in section 3 of this report).

We believe that gasoline demand responds to price increases in the short term more than diesel demand for several reasons. First, academic studies have shown that gasoline demand has about twice the price elasticity of diesel demand. Putting this more precisely, passenger vehicle transport, accounting for most of gasoline demand is twice as price elastic as heavy trucking, which has a high share of diesel demand.[4] In addition, a range of applications, including industry, buildings, and power, use diesel, and in these cases the short-term price elasticity is much lower or even zero (except applications with switchability). Fossil-gasoline-demand growth in the light-vehicles sector drops sharply by 3.6 percent in 2008 in response to price increases, while fossil diesel demand drops by only 0.2 percent.

Most other liquids-using sectors do not react strongly to price in the short term due to a lack of easy substitutes and the fact that energy prices are a small percentage of overall costs and can often be passed on to the end user. For instance, the petrochemicals sector did not abate demand for liquids before the GDP downturn despite the fact that the price of key input liquids increased continuously from 2002 to 2008. Similarly for buildings, energy is a key input for comfort and convenience, and rising prices have had very little impact on demand. In this sector, academic studies often estimate short-term price elasticity at a low minus 0.1, compounded by taxes and subsidies that buffer the price.

Turning to the supply picture, unlike demand, the supply of liquids keeps growing in the short term—from 84.3 million barrels per day in 2007 (including refinery gains and biofuels) to 86.4 million barrels per day in 2009 in our moderate case. With most projects already in the pipeline continuing, Organization of the Petroleum Exporting Countries (OPEC) spare capacity will rise (Exhibit 2.7). However, the credit squeeze is likely to have an impact on supply capacity three or more years into the future (Exhibit 2.8). Some planned capital-intensive projects and marginal, quick-response projects (e.g., infill drilling or enhanced oil recovery (EOR)) are being delayed as a result of financing constraints, capital prudence, anticipation of dropping supplier costs, and uncertainty of future oil prices (Exhibit 2.9).

As a result of falling demand, increasing supply capacity, expanding biofuel supply, and enhanced refining conversion capacity, the market could see excess supply capacity increase from 2.5 million barrels per day in 2007 to 4.0 million and 5.0 million barrels per day in 2009 in the short term under our moderate case. This would create temporary breathing room for a market that had very tight demand supply fundamentals in 2007 and 2008. If a more severe downturn were to unfold, we could see excess supply capacity grow as large as 6 million to 8 million barrels per day in 2009. Calls for OPEC production cuts could therefore significantly affect market prices, and these are likely to fluctuate between full-cost and marginal-cash-cost pricing over the next few years, depending on the effectiveness of OPEC's cuts. The coordination of such cuts grows more difficult the deeper the downturn, and tend to lead to longer periods of cash-cost pricing.

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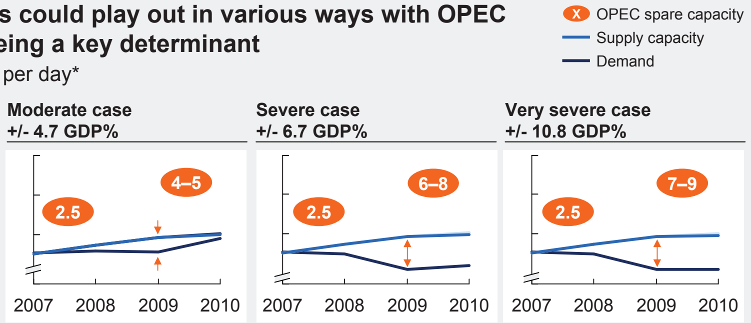
4 *Transportation Elasticities: How Prices and Other Factors Affect Travel Behavior*, Victoria Transport Policy Institute, March 2008.

A deeper and longer downturn increases the potential for lower prices. However, these lower prices actually can lead to market tightness returning more quickly. Low prices will either increase demand or at least have a neutral impact, while they will have a negative impact on supply.[5] Because of this, even in a longer and deeper downturn, market tightness is projected to return shortly after the end of the downturn in any scenario.

Exhibit 2.7

Credit crisis could play out in various ways with OPEC behavior being a key determinant

Million barrels per day*



OPEC scenarios	Moderate case	Severe case	Very severe case
Cut and comply	**Full cost or demand pricing ($50–$80 per barrel or $80–$100+ per barrel)**	**Full cost pricing** **($50–$80 per barrel)**	**Hard to imagine**
Don't absorb excess capacity	**Hard to imagine**	**Marginal cash cost** **($25–$40 per barrel)**	**Marginal cash cost** **($25–$40 per barrel)**

?

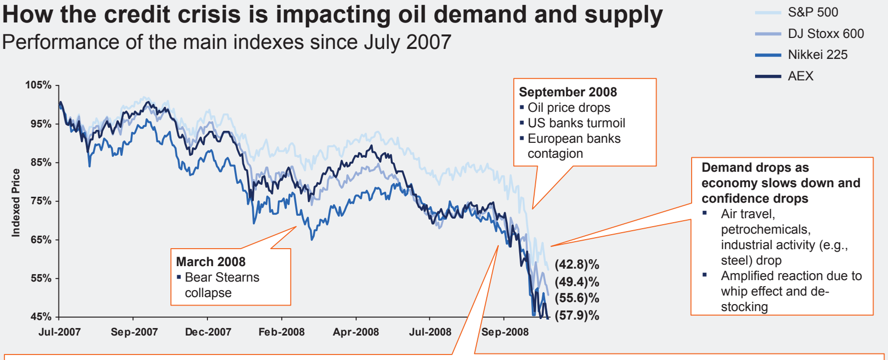
* Crude oil at the well head; includes biofuels and excludes refinery gains.

Source: McKinsey Global Institute analysis

Exhibit 2.8

How the credit crisis is impacting oil demand and supply

Performance of the main indexes since July 2007



Supply: Reduce new supply efforts because of ...

(2007 production impact)

Supply: Reduce new supply efforts because of ...	Short-term supply impact	Medium-term impact	Long-term impact
Low-impact case: Low oil prices push short-term marginal efforts out of the money	▪ Stripper wells (550 kbd in the United States) ▪ Low volume onshore wells ▪ Short lead time Brownfield wells		
Medium-impact case: Poor credit availability reduces programs of cash-constrained companies	▪ Dependents (~5 million barrels per day in the United States and United Kingdom) reduce activity level ▪ NOCs/others		
High-impact case: Capital prudence oil price outlook and view on reducing OFSE costs leads to project deferment	▪ IOR/EOR projects	▪ Infill offshore projects	▪ Large pre-FDI projects – Unconventionals – (Ultra) DW – Megaprojects

Source: Bloomberg, Goldman Sachs Equity Research; data as of October 24, 2006

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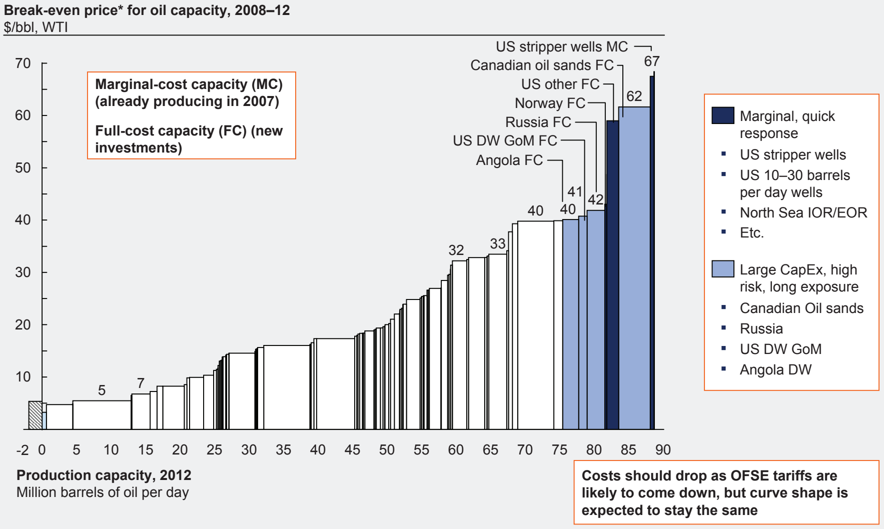
[5] Dermot Gately and Hillard G. Huntington, "The assymetric effects of changes in prices and income on energy and oil demand," *Journal of Economic Literature*, August 2001. In this paper, Gately and Huntington show that the increasing oil prices negatively impact demand, while decreasing prices have less impact on increasing demand.

Exhibit 2.9

Marginal short projects and high CapEx, long-exposure projects will be the first to suffer delay

ESTIMATES



Costs should drop as OFSE tariffs are likely to come down, but curve shape is expected to stay the same

* Assumes an IRR of 10 percent for new capacity additions and cash break-even for existing production capacity.

Source: Wood Mackenzie; EIA; Interstate Oil and Gas Compact Commission; McKinsey GEM practice

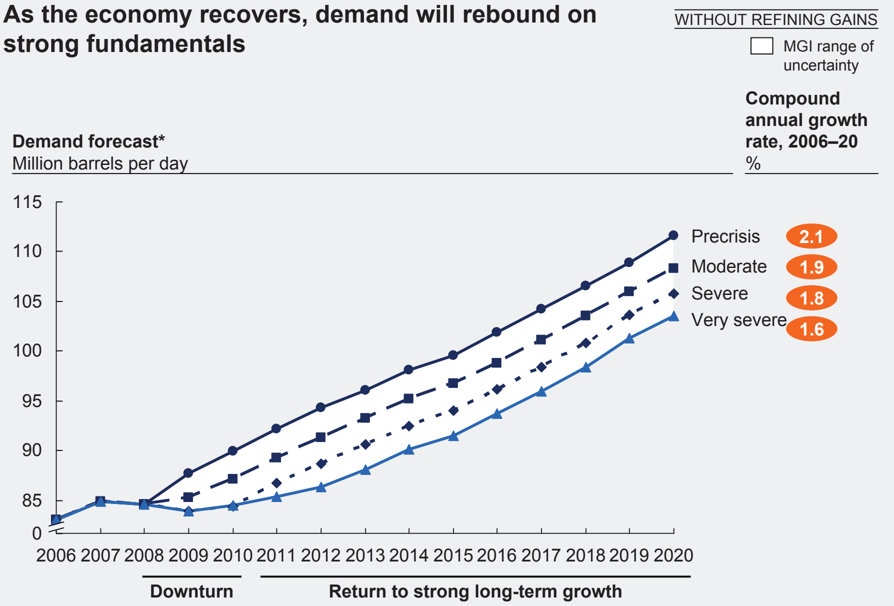
WHEN THE DOWNTURN ENDS, LIQUIDS DEMAND WILL POST 2 PERCENT PLUS ANNUAL GROWTH

Once the global economy recovers from the downturn, liquids-demand growth will also rebound due to strong long-term growth fundamentals in developing countries (Exhibit 2.10). Under the moderate case, demand will want to grow at a projected 2.1 percent in 2010 and thereafter through 2020 at a projected 2.2 percent per annum in an unconstrained case, a full point faster than the period between 2006 and 2010.

Developing regions will account for more than 90 percent of global energy-demand growth to 2020 (Exhibit 2.11). Emerging bands of middle-class consumers and industries in emerging markets, particularly China and the Middle East, are crossing the $5,000 per household or $1,500 per capita income threshold above which consumers and industries have historically demonstrated a strong demand for the comfort, convenience, and environmental benefits that come from using oil (Exhibit 2.12). Due to this trend, we project that China and India will be the fastest-growing regions at 4.5 and 5.2 percent per year respectively between 2006 and 2020, with China representing 28 percent of all global liquids-demand growth. The Middle East will also be a fast-growing major region following the downturn, driven by increasing capacity building of industrial plants that take advantage of the Middle East's liquids and gas supplies, as well as a strongly rising vehicle stock as wealth increases. The United States and Japan will see liquids demand almost flat during this period, while Europe's growth rate will be near 1 percent, boosted by the inclusion of many developing countries in this region.

Exhibit 2.10

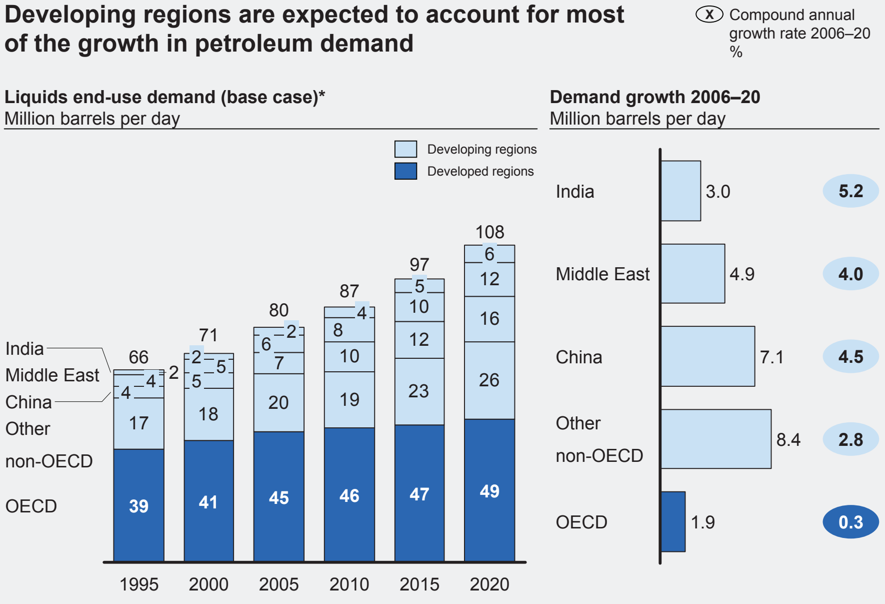
As the economy recovers, demand will rebound on strong fundamentals



* Unconstrained by supply, excluding refinery gain effects (~2 million barrels per day in 2020).
Source: McKinsey Global Institute Global Energy Demand Model 2009

Exhibit 2.11

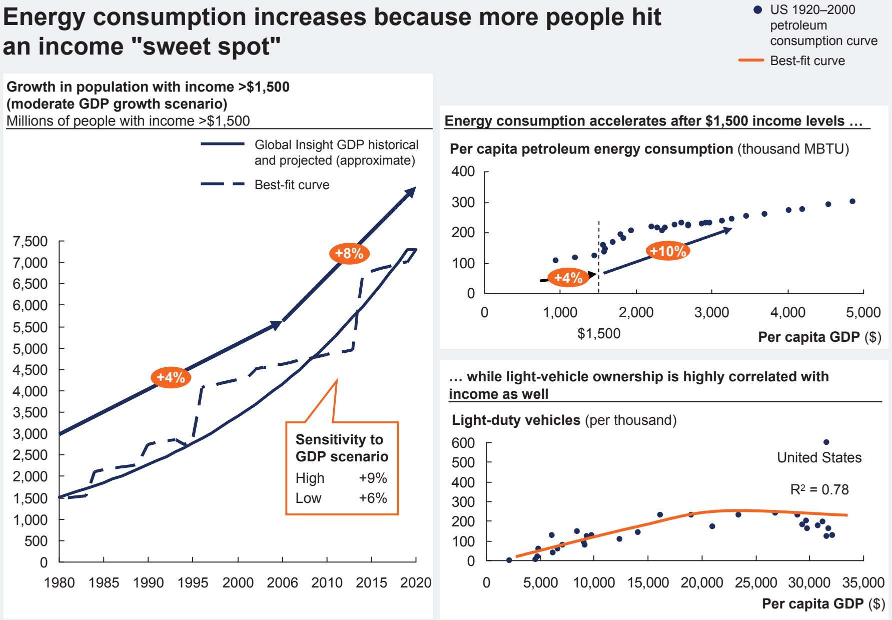
Developing regions are expected to account for most of the growth in petroleum demand



* Unconstrained by supply, excluding refinery gain effects (~2 million barrels per day in 2020).
Source: McKinsey Global Institute Global Energy Demand Model 2009

Exhibit 2.12

Energy consumption increases because more people hit an income "sweet spot"



Source: McKinsey Global Institute Global Energy Demand Model 2009

Overall, we project the largest source of demand growth will come from the light-duty-vehicles sector, representing 6.2 million barrels per day, or 25 percent of all liquids-demand growth between 2006 and 2020. Three other sectors—chemicals, medium/heavy trucks, and air transport—also represent a large portion of total liquids energy-demand growth, growing 5.3 million, 4.1 million, and 2.9 million barrels per day respectively between 2006 and 2020. Combined with light vehicles, these four sectors represent roughly 75 percent of all liquids-demand growth between 2006 and 2020 (Exhibit 2.13).

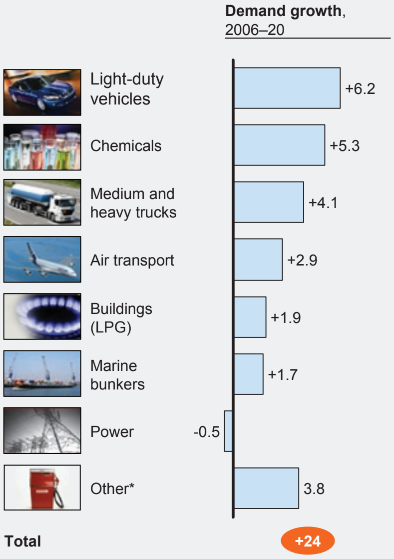
We project the fastest demand growth in petrochemicals and air transport, which will grow at 3.7 and 1.8 percent respectively in 2010, and then by 3.2 and 3.8 percent per annum from 2010 to 2020. Over the entire period from 2006 to 2020, petrochemicals and air transport liquids demand is projected to grow at 2.9 and 3.4 percent per year respectively. Developing countries such as China and India drive liquids demand in these sectors, due to heavy investment in these economies in long-distance transportation and infrastructure. In petrochemicals and air transport, in particular, efficiency improvements make little impact on demand as the opportunity to boost energy productivity is smaller in these sectors than in others.

Although fuel demand for light vehicles represents the largest source of liquids demand, we expect it to grow more slowly than the average. We project that light-vehicles liquids demand will grow at only 1.7 percent between 2006 and 2020, slower than overall liquids growth of 1.9 percent (Exhibit 2.14). In the medium term, we project light-vehicles demand to grow at 1.8 percent in 2010 and then 1.9 percent per year between 2010 and 2020. Underlying this slow growth are two opposing trends: a fast-growing global vehicle stock in developing regions, offset by strong efficiency improvements mostly in developed regions (for detail, see chapter 3.1). The global vehicle stock will grow at an average of 3.3 percent per year, while the stock in China and India will expand at 11 and 10 percent per annum respectively, with a strong rebound expected after the current downturn. However, at the same time, the efficiency of the vehicle stock will improve at 1.5 percent per year, with the United States, the EU, and China leading the way at 1.5 percent, 1.9 percent, and 3.3 percent respectively. Overall, we project that light-vehicles liquids demand in

China will grow at 8.2 percent per year between 2010 and 2020, while we expect rates of demand growth in the United States, Japan, and Europe of minus 0.7, minus 2.3, and minus 1.1 percent per year respectively.

Exhibit 2.13

Transport and chemicals are key drivers of liquids demand

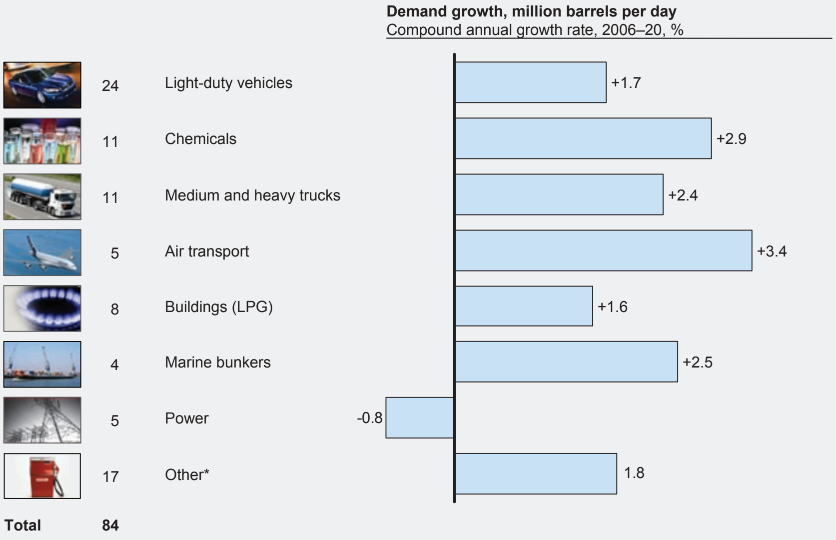


	Demand growth, 2006–20	Key 2020 underlying drivers
Light-duty vehicles	+6.2	+ BRIC vehicle stock growing up to 12 percent per annum **– Recent fuel-efficiency regulations in United States, EU, China, South Korea** **– Penetration of 7 percent of EVs/hybrids**
Chemicals	+5.3	+ Ethylene growth 4.4 percent per annum 2020 (Tecnon) + Limited price elasticity and few substitution opportunities
Medium and heavy trucks	+4.1	+ Trucks and freight km grow slightly slower than GDP (2.2 percent) **+ Limited engine-efficiency improvement (~0.9 percent per year)**
Air transport	+2.9	– ST reduction of spoke-to-spoke; LT grows with GDP (3.6 percent) as **aircraft fuel-efficiency gain is roughly fixed**
Buildings (LPG)	+1.9	+ Urbanization in developing countries (42 to 59 percent in China) – Diesel reduction in United States/EU for household heating
Marine bunkers	+1.7	– Increased oil price will reduce growth of global trade from 4 percent to 2.6 percent (slower than GDP)
Power	-0.5	– Residual fuel oil continues to decline (3 percent per annum) + Some growth in IGO mostly in Arab Gulf and Asia
Other*	3.8	+ Flat residual fuel oil, increase in diesel/IGO
Total	+24	+ GDP growth 3.1 percent (vs. 3.4 percent over last 30 years)

* Includes agriculture, oil refining, rail transport, steel and iron, pulp and paper, and other industries.
Source: McKinsey Global Institute Global Energy Demand Model 2009

Exhibit 2.14

Despite being key driver of liquids demand, light-vehicles demand is projected to grow more slowly than other large sectors



* Includes agriculture, oil refining, rail transport, steel and iron, pulp and paper, and other industries.
Source: McKinsey Global Institute Global Energy Demand Model 2009

The increasing share of EVs that we project has only a small effect by 2020, with the bulk of the impact not projected to come until 2020 to 2030. Although EVs represent a significant percentage of new vehicle sales, given the size of the existing stock (particularly in the United States and Europe), we project EVs would still represent only approximately 8 percent of vehicle stock by 2020 (for more detail on EVs, see chapter 3.1).

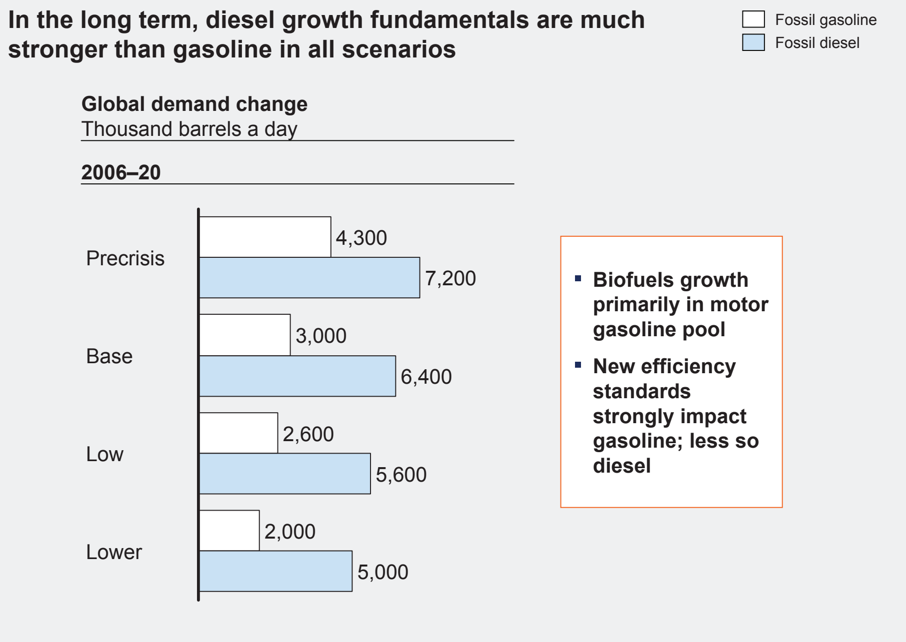
Despite the fact that energy-demand growth in the light-vehicles sector is already lower than in many other sectors, there are available levers that could reduce demand growth even further. Some examples include the removal of energy subsidies—particularly in Iran and Saudi Arabia—and policies or other factors that dramatically impact the rate of EV adoption (for detail, see chapter 3.1).

The prospect of a demand imbalance between gasoline and diesel is a significant concern, given slow gasoline-demand growth relative to diesel-demand growth. Overall at a fuel level, we expect fossil gasoline to grow at only 1.0 percent per year between 2006 and 2020. Fossil-gasoline-demand growth is low in part because demand in the light-vehicles sector dropped more sharply by 3.6 percent in 2008 in response to price increases. In addition, in the long run, energy demand for gasoline in the light-vehicles sector will experience a significant supply-side impact from the rapid 14.4 percent annual growth of biofuels from 2006 to 2020, which for the most part will replace gasoline in light vehicles. We project roughly 3 million barrels per day of blended ethanol by 2020, leaving global fossil gasoline demand growth at only 1 percent per year.

We expect fossil diesel to grow at a much faster 1.8 percent per year between 2006 and 2020. This is because, compared with light vehicles, there is a relative dearth of efficiency opportunities in medium and heavy vehicles. Strong fossil diesel growth relative to fossil gasoline growth suggests distillates appears set to be the premium fuel for the long term while gasoline looks more like a by-product. Indeed, diesel could price at a significant premium to gasoline - as we saw in 2008 - after the downturn ends (Exhibits 2.15 and 2.16).

Growth in other fuel types may mitigate this petroleum fuel imbalance. In our moderate case, naphtha—primarily used in ethylene production for petrochemicals—grows at a strong 3.2 percent per year between 2006 and 2020 due to the strength of petrochemicals growth. This is particularly important because naphtha can be converted into gasoline, which could help alleviate the product demand imbalance between gas and diesel. We also expect ethane demand to grow at a healthy 4.6 percent per year. Jet and kerosene demand also grow at a strong 2.9 percent per year (Exhibit 2.17).

Exhibit 2.15



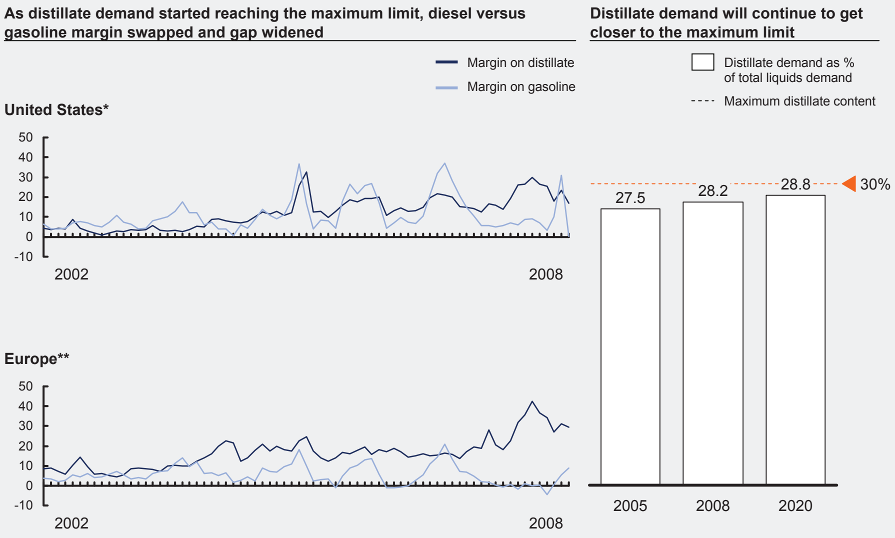
In the long term, diesel growth fundamentals are much stronger than gasoline in all scenarios

- **Biofuels growth primarily in motor gasoline pool**
- **New efficiency standards strongly impact gasoline; less so diesel**

Source: McKinsey Global Institute Global Energy Demand Model 2009

Exhibit 2.16

Relative tightness in distillates is expected to continue



* Based on WTI, Gasoline 89 USGC and Diesel USGC prices.

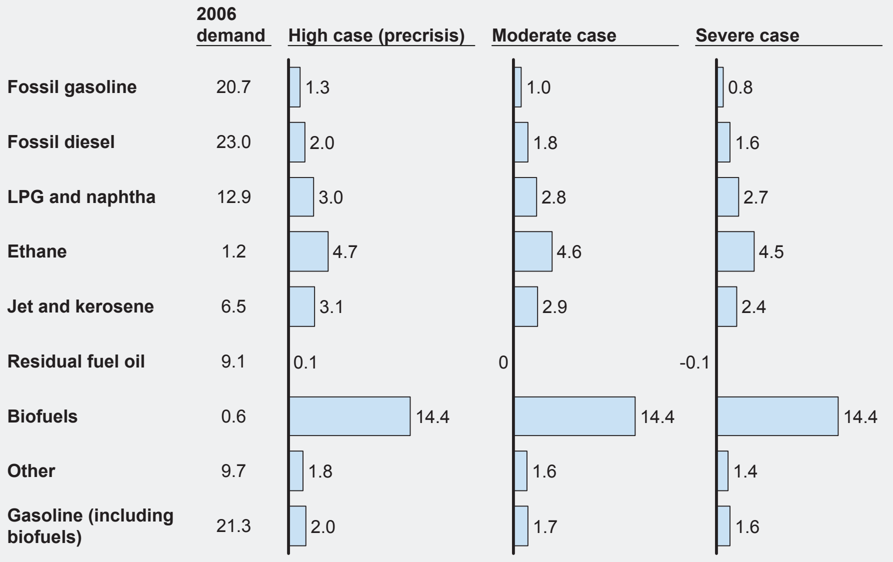
** Based on Brent, Gasoline 91 NWE and Diesel 10 pars per million NWE prices.

Source: McKinsey Global Institute Global Energy Demand Model 2009

Exhibit 2.17

Fossil gasoline growth is slower than fossil diesel across cases

Million barrels per day, compound annual growth rate, 2006–20, %



Source: McKinsey Global Institute Global Energy Demand Model 2009

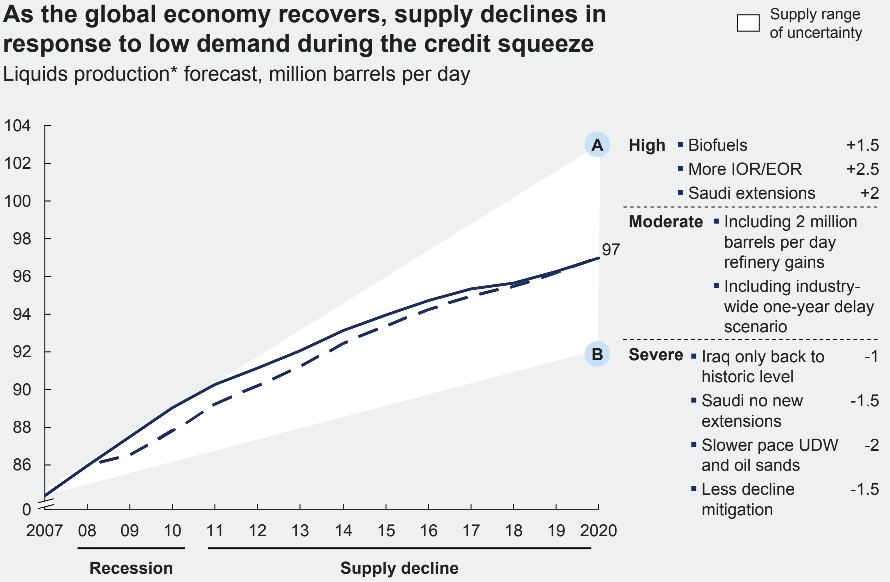
SUPPLY WILL CONSTRAIN DEMAND IN THE LONG TERM

In the medium term, as demand rebounds, McKinsey's GEM practice expects that growth in supply will experience declines of a greater magnitude (Exhibit 2.18). McKinsey projects that supply will grow by only 1.4 percent to 2010, meaning supply of 87.8 million barrels a day, or 161 QBTU, in 2010. After that, supply will grow at only a projected 1.0 percent a year to reach 97 million barrels a day in 2020, or 176 QBTU (95 million if one excludes refinery gains). Those projects delayed during the credit crisis will start to depress supply from 2010 onward, compounded by greater natural declines of global liquids fields. In addition, more effort and capital will be required to sustain supply growth, as increasingly deeper wells will be required in increasingly capital-intensive environments (Exhibit 2.19). Finally, shortages of skilled people and equipment in the industry have contributed to increasing the average project delay to 14 months, further depressing supply growth.

Exhibit 2.18

As the global economy recovers, supply declines in response to low demand during the credit squeeze

Liquids production* forecast, million barrels per day

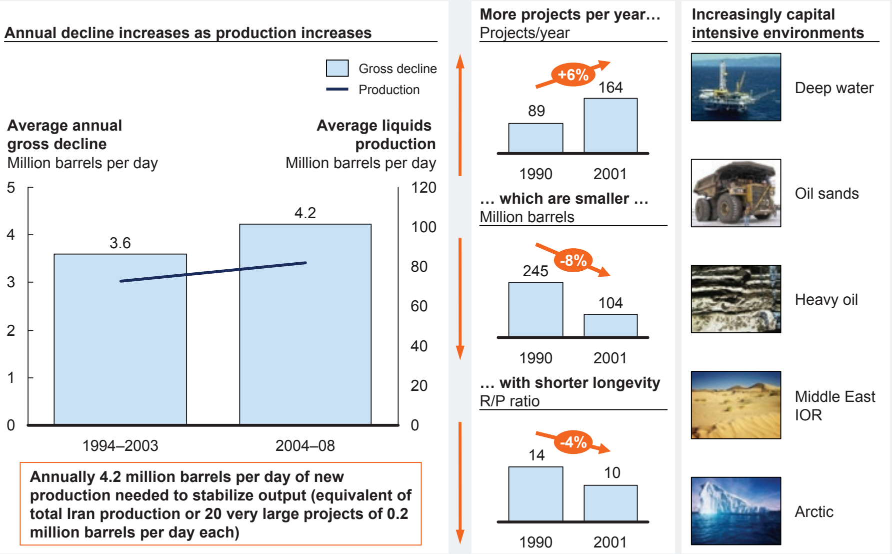


* Includes crude oil, condensate, natural gas liquids, bitumen, ultraheavy oil, coal-to-liquids, gas-to-liquids, biofuels and shale, and refinery gains.

Source: McKinsey Petroleum Supply Model; McKinsey GEM practice

Exhibit 2.19

Absolute natural field decline rises; more capital is needed for new fields



Annually 4.2 million barrels per day of new production needed to stabilize output (equivalent of total Iran production or 20 very large projects of 0.2 million barrels per day each)

* Includes biofuels, CTL, GTL; excludes refining gains.

** Based on gross historical decline rates.

Source: EIA; IEA; Wood Mackenzie; McKinsey GEM practice

In the long term, liquids supply is likely to constrain demand growth, growing at 1.0 percent per year until 2020 compared with moderate-case liquids-demand growth of 2.0 percent per year. Our estimates show that spare capacity levels could return to those seen in 2007 as soon as 2010 under our moderate case, or as late as 2013 under a our very severe GDP scenario. Since we project that liquids supply will grow more slowly than our demand path at $75 liquids, either price, policy, or a combination of the two will be needed to bring demand and supply in balance.

McKinsey's GEM practice projections are broadly in line with those of others, albeit at the lower end of the range (Exhibit 2.20). The IEA and OPEC are both more optimistic than MGI, projecting between 98 million and 104 million barrels per day of supply by the year 2020 (roughly 1.6 percent growth per year) compared with McKinsey's 97 million barrels per day and 1.1 percent growth per year estimates.

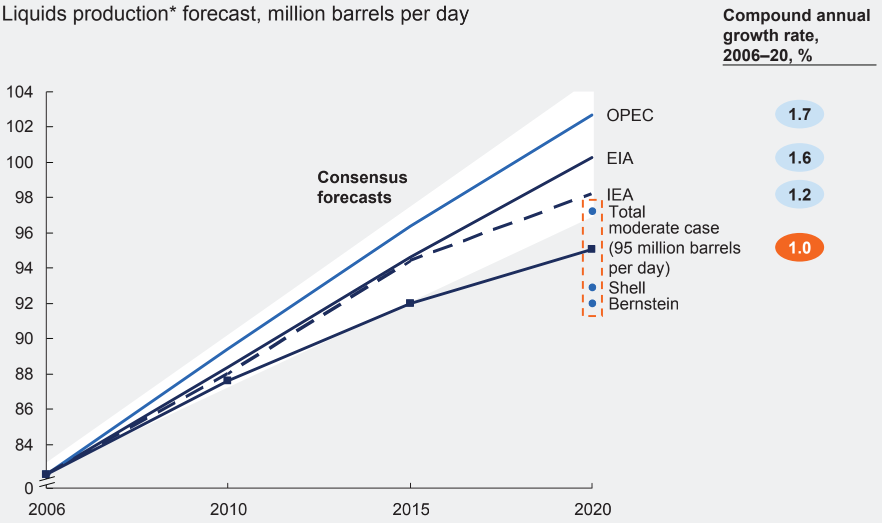
The EIA is in between IEA and OPEC, projecting about 100 million barrels per day of supply available in 2020 (1.3 percent growth per year). The supply projections of several large upstream companies align more closely with those of MGI. For instance, Total projects 98 million barrels per day of supply in 2020, while Shell projects a more pessimistic 94 million barrels per day. By contrast, Bernstein is even more pessimistic, estimating only 92 million barrels per day of supply (roughly 0.7 percent growth per year).

Exhibit 2.20

McKinsey's supply forecast is lower than those of the IEA, EIA, and OPEC

INCLUDING BIOFUELS

Liquids production* forecast, million barrels per day



* Includes crude oil, condensate, natural gas liquids, bitumen, ultra-heavy oil, coal-to-liquids, gas-to-liquids, biofuels and shale; does not include refinery processing gains.

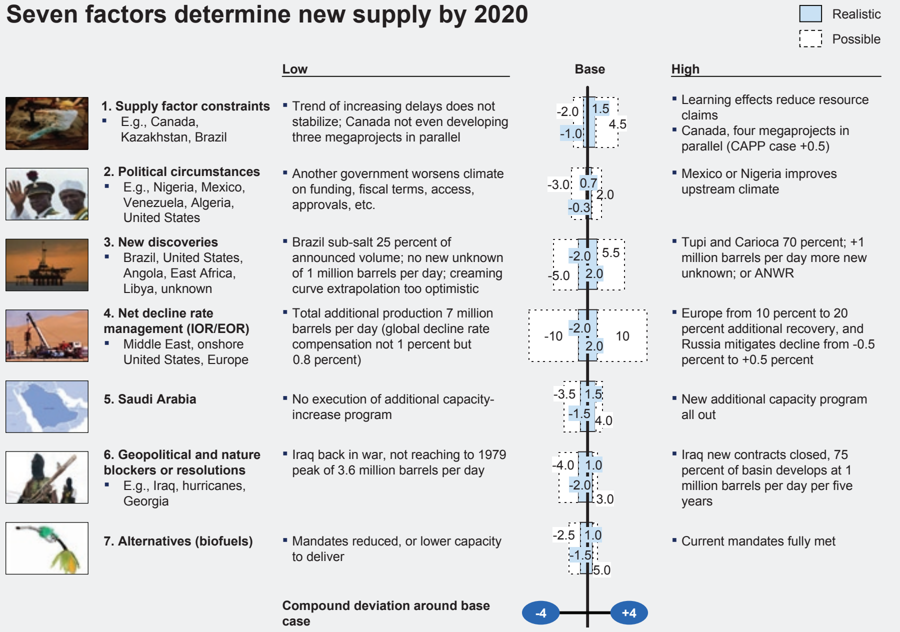
Source: IEA; OPEC; EIA; Total Oil Company; Shell; Bernstein; McKinsey Petroleum Supply Model

There are clearly significant uncertainties in trying to determine supply growth beyond the short term, and we identify seven major factors (Exhibit 2.21). First, it is hard to anticipate whether factors that are constraining supply in regions such as Brazil and Canada (where there is increasing evidence of project delays) will stabilize or whether learning effects that reduce resource claims could have a large impact on future supply. Second, political circumstances restrict access, foreign investment, economic returns, and so on, particularly in regions such as Nigeria, Mexico, Venezuela, and even in the United States (e.g., with the moratorium on the Arctic National Wildlife Refuge. Third, the uncertainties in recoverable volumes of new discoveries in regions such as Brazil (which has recently announced a large increase in sub-salt volume) can easily result in supply changes of plus or minus 1 million barrels per day in 2020.

Fourth, the success of decline rate management in mature basins is another uncertainty where trend changes could lead to significant changes in the forecast. Fifth, while Saudi Arabia—the largest producer of oil—probably has the opportunity to additionally increase supply and their current capacity increase program is well under way, any follow-up program would require significantly more effort and capabilities and is only likely be started if the Kingdom sees a clear and sustained demand gap. Sixth, geopolitical factors—notably the security issue in Iraq—can lock or unlock a significant portion of future supply. Finally, biofuels could very well be the largest source of new liquids supply growth. The 2020 biofuels number will depend on the compliance with the mandates and economic attractiveness. Overall, we estimate that these factors together give us a range of uncertainty of 4 million barrels a day either side of our moderate-case projection of supply by 2020.

Exhibit 2.21

Seven factors determine new supply by 2020



	Low	Base	High
1. Supply factor constraints ▪ E.g., Canada, Kazakhstan, Brazil	▪ Trend of increasing delays does not stabilize; Canada not even developing three megaprojects in parallel	-2.0 1.5 -1.0 4.5	▪ Learning effects reduce resource claims ▪ Canada, four megaprojects in parallel (CAPP case +0.5)
2. Political circumstances ▪ E.g., Nigeria, Mexico, Venezuela, Algeria, United States	▪ Another government worsens climate on funding, fiscal terms, access, approvals, etc.	-3.0 0.7 -0.3 2.0	▪ Mexico or Nigeria improves upstream climate
3. New discoveries ▪ Brazil, United States, Angola, East Africa, Libya, unknown	▪ Brazil sub-salt 25 percent of announced volume; no new unknown of 1 million barrels per day; creaming curve extrapolation too optimistic	-2.0 5.5 -5.0 2.0	▪ Tupi and Carioca 70 percent; +1 million barrels per day more new unknown; or ANWR
4. Net decline rate management (IOR/EOR) ▪ Middle East, onshore United States, Europe	▪ Total additional production 7 million barrels per day (global decline rate compensation not 1 percent but 0.8 percent)	-10 -2.0 2.0 10	▪ Europe from 10 percent to 20 percent additional recovery, and Russia mitigates decline from -0.5 percent to +0.5 percent
5. Saudi Arabia	▪ No execution of additional capacity-increase program	-3.5 1.5 -1.5 4.0	▪ New additional capacity program all out
6. Geopolitical and nature blockers or resolutions ▪ E.g., Iraq, hurricanes, Georgia	▪ Iraq back in war, not reaching to 1979 peak of 3.6 million barrels per day	-4.0 1.0 -2.0 3.0	▪ Iraq new contracts closed, 75 percent of basin develops at 1 million barrels per day per five years
7. Alternatives (biofuels)	▪ Mandates reduced, or lower capacity to deliver	-2.5 1.0 -1.5 5.0	▪ Current mandates fully met
	Compound deviation around base case		

Source: McKinsey GEM practice

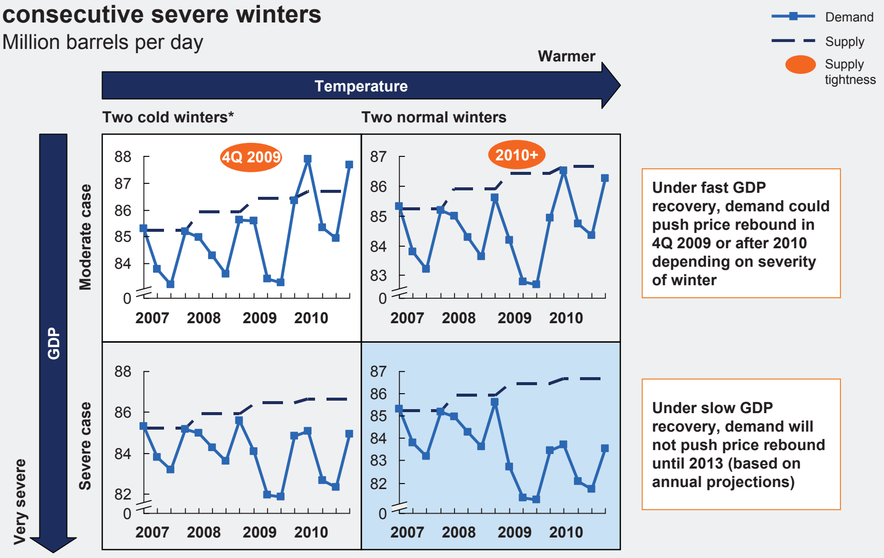
Although seasonal spikes in liquids demand may also play a factor in market tightness timing, only in the unlikely case of two consecutive severe winters coupled with a mild downturn would market tightness potentially return before 2010 (Exhibit 2.22).

Exhibit 2.22

Market tightness would return with less than two consecutive severe winters

Million barrels per day

WITH REFINING GAINS



Under fast GDP recovery, demand could push price rebound in 4Q 2009 or after 2010 depending on severity of winter

Under slow GDP recovery, demand will not push price rebound until 2013 (based on annual projections)

* Defined as Q1 and Q2 being –4 degrees Celsius colder than average.

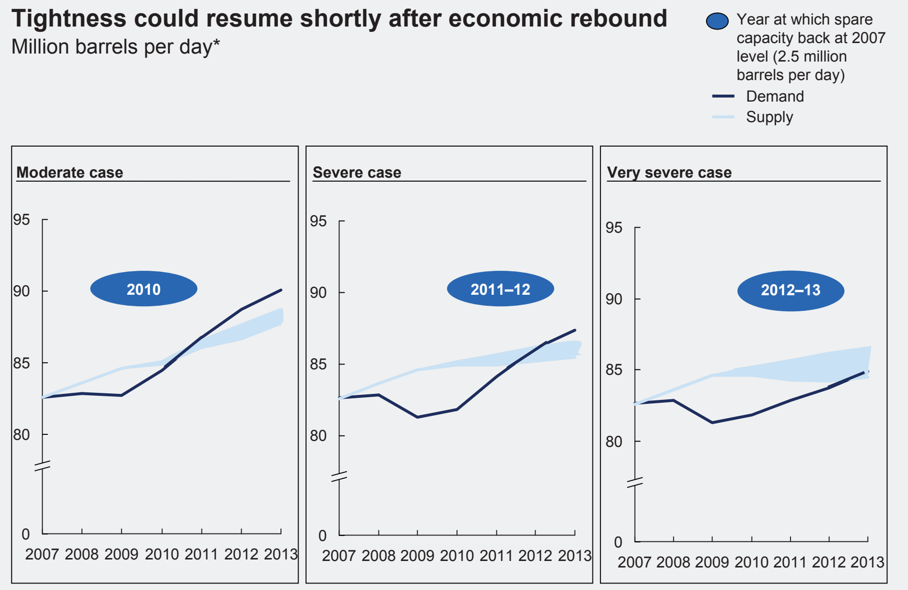
Source: IEA *Oil Market Report 2008*; local temperature sources; WeatherAmerica/Farmer's Almanac; McKinsey Global Institute Global Energy Demand Model 2009

In our moderate case, which assumes a moderate downturn with recovery beginning in late 2009, we could see market tightness return as soon as 2010, potentially leading to higher prices, just as the global economy begins to recover (Exhibit 2.23). In our severe case, enough spare capacity could be built to last for three to four years, delaying a resumption of price inflation until 2012. Under an even more severe downturn with recovery delayed beyond 2010, enough surplus capacity could be accumulated to last five to six years, delaying price inflation until 2013. Each path could see significant volatility as the market moves from a level at which production is marginal ($30–$40 a barrel), to a level at which that new investment is marginal ($60–$80 a barrel), to scarcity pricing (above $100 a barrel) in relatively short periods.

Exhibit 2.23

Tightness could resume shortly after economic rebound

Million barrels per day*



* Crude oil at the well head; includes biofuels and excludes refinery gains.

Source: McKinsey Global Institute Global Energy Demand Model 2009; McKinsey GEM practice

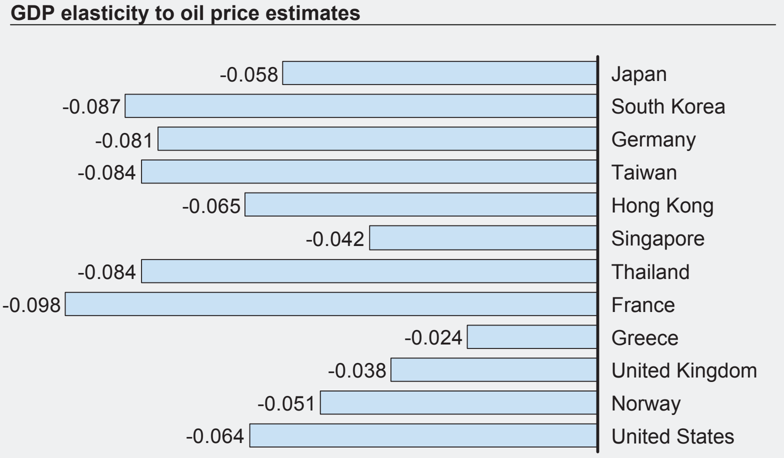
THERE IS A STRONG ECONOMIC CASE FOR ACTION TO PREEMPT A NEW SUPPLY SHOCK

Shouldn't policy makers simply let the market rebalance itself? After all, if demand outgrows supply, prices will go up and the markets will clear. While this is true, the fact is that oil demand and supply are both rather price inelastic, particularly in the short term and, given this, an imbalance between supply and demand could lead to a steep increase in the oil price. Such a spike in prices has significant economic consequences, causing costly shifts in consumption and production decisions and slowing GDP growth in oil-importing economies as they spend more on imported energy for the same level of output. The economic damage of such a situation also tends to fall most heavily on the poorer sections of these populations, as it is those with low incomes who spend a higher proportion of their income on energy. In addition, prices don't move linearly. We witnessed increased price volatility with prolonged periods of prices ratcheting up and steep falls. Such price patterns would not support investments in new supply nor efficiency improvements.

Academic studies have estimated that the GDP elasticity to the price of oil in the case of importing countries ranges from minus 0.05 to minus 0.10 (Exhibit 2.24). To illustrate the impact of this low elasticity, one needs to look no further than the oil shocks of the 1970s in which GDP dropped precipitously in the face of escalating oil prices (Exhibit 2.25). Today, GDP is less oil intensive than it was in the 1970s—we estimate the GDP elasticity of oil-importing countries at between minus 0.025 and minus 0.050, in line with recent academic research—and this goes some way toward mitigating the impact of rising oil prices on GDP (Exhibit 2.26). If oil prices were to double, this would have a one-off negative impact on the GDP of oil importers of between 3 and 5 percent. In 2020, estimates project that oil-importing countries will have a combined GDP of about $40 trillion, translating into a negative one-off impact on GDP from a doubling of oil prices of as much as $1.5 trillion.[6]

Exhibit 2.24

In aggregate, an oil price increase has a negative impact on oil-importing countries and on global GDP



Source: Among other articles, Donald W. Jones, Paul N. Leiby, Inja K. Paik, *Oil Price Shocks and the Macroeconomy: What Has Been Learned Since 1996*, 2004; Paul N. Leiby, "Impacts of oil supply disruption in the United States," *The Energy Journal*, 2004; *Oil supply disruption management issues*, presentation at the IEA/Asian workshop, Cambodia, April 2004

Exhibit 2.25

Global GDP growth dropped sharply during the last two oil shocks

Source: Global Insight

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[6] The math here is roughly $40 trillion times minus 0.05 elasticity times 100 percent price change. Using log elasticities makes it slightly less than the $2 trillion estimated by this equation.

Exhibit 2.26

Recent studies estimate US GDP elasticity to the oil price to be -0.02 to -0.07 taking monetary policy into account

	Bernanke, Gertler, and Watson, 2004	Carlstrom and Fuerst, 2005
With counter inflationary monetary policy	-0.07	-0.045
FED does not increase rates, and public **does not anticipate**	-0.04	-0.02
FED does not increase rates, and public **does anticipate**	N/A	-0.048

- **Tight monetary policy doubles the effect of an oil shock, and was used in the 1970s**
- **Pass-through of oil price to core inflation has declined—some theorize due to weaker labor union bargaining power—decreasing call for tight money during this oil price shock**

Source: Ben S. Bernanke, Mark Gertler, and Mark W. Watson, *Oil Shocks and Aggregate Macroeconomic Behavior;* Charles T. Carlstrom and Timothy S. Fuerst, *Oil Prices, Monetary Policy, and the Macro Economy, 2005*

In addition to the relative inelasticity of oil demand and supply to oil price changes, marginal differences in the levels of spare capacity in oil markets also have a tremendous impact on price when supply and demand balance is tight. Take for example the spare capacity of 2.5 million barrels per day that existed in late 2007 and the spare capacity of more than 5 million barrels per day in the early 1990s. The price difference between the two is dramatic at up to $100 a barrel. Put another way, a marginal 2.5 million barrels per day of demand reduction that takes the market from 2.5 million barrels per day to 5 million barrels per day of spare capacity would have a value to oil-importing countries of up to $1.5 trillion and even more if oil prices more than double.

On top of this energy-cost saving, there would also be lessened concern about equity and a decrease in economic volatility. Although these calculations are far from exact, they serve to demonstrate that in tight markets, there can be tremendous value in abating even 2.5 million barrels per day of oil demand.

However, in seeking to secure such demand abatement, there is a collective problem of inaction at work. No individual or single company can impact demand sufficiently to capture the overall benefit of $1.5 trillion; in any case, these players will tend to act in their own economic interests. As we have noted in this report, individuals tend to underinvest in energy efficiency even when such outlays have a net positive value.[7]

Although it is in the interests of oil exporters to create a sufficient, but not excessive, supply cushion, today's environment is characterized by the fact that the fundamentals that will underpin oil-demand growth to 2020 are very strong and substitute supplies are not coming on stream as quickly as they did after the twin oil shocks of the 1980s—when nuclear and natural gas came on heavily in the power sector and

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[7] We do not discuss other negative externalities associated with oil demand, including environmental impacts and increased national security cost. While these are certainly factors whose exclusion from price can lead to higher than socially optimal demand, this would be true whether oil production were projected to be abundant or scarce. This report does not seek to evaluate the cost of these externalities, focusing instead only on the economic consequences of demand and supply being out of balance and levers that could be pulled to alleviate this imbalance.

buildings and industrial substituted a large amount of petroleum for other fuels. In the medium term, therefore, McKinsey supply projections indicate that it will prove difficult to create enough supply to grow on top of the expected oil field decline rates. It is hard not to conclude that, while slowing investment in the supply infrastructure appears to make sense in the short term, in the medium to long term such a strategy may have the undesired effect of encouraging "peak demand" policies from major oil importers.

High oil prices bring large income increases and benefit oil-exporting countries at least in the short to medium term; from that standpoint, one possible response to the current economic downturn would be to hold back investment until prices go up again. However, high oil prices also come with some potential downsides for oil-exporting countries. First, high oil prices typically come with a significant degree of volatility, which makes government budgeting quite difficult. Second and more importantly, high oil prices motivate end users and policy makers to reduce demand—to the long-term detriment of oil exporters' customer base. Should oil prices escalate sharply again, one could envision a scenario in which policy makers and investors take broad actions to abate demand—a reaction seen from 1979 to 1989 when oil demand growth was virtually zero. One can imagine a world in which there is production of biofuels in massive volumes, EVs dominate the roads, and alternative energy sources such as natural gas replace oil almost completely in stationary applications. Such a "peak demand" world could even appear before peak supply (neither of which are projected before 2030 by the IEA, the EIA, or McKinsey) and have the potential to be a large lost opportunity for oil exporters. If a 15-year period of low oil prices and slow demand—akin to the period from 1979 to 1994—were to occur again, the cost to oil producers could be in excess of $10 trillion. This would be an extremely severe penalty for pushing the demand countries to peak demand policies.[8]

Addressing the issue of demand holds more promise for a coordinated response than supply given that demand is more concentrated than supply—Europe, the United States, and China represent 50 percent of demand in 2020, while the top three supply countries account for only 33 percent of supply. Policy plays a critical role in determining future demand for oil, offering scope for some mutually beneficial long-term tradeoffs between demand policy and supply installation.

Price can certainly be relied on to clear the market as well. Assuming a long-term oil-price elasticity of minus 0.15 as the IEA does, one can estimate a market-clearing price between a real $100 and $150 a barrel in 2020 (based only on demand elasticity to price), with the EIA projecting a market price of $110 per barrel by 2020 and IEA a market price of $100 per barrel by 2015. Our model considers only demand destruction through behavioral changes and improved capital-stock efficiency at higher prices, and demand for liquids would be 100 million barrels per day (not including refinery gains) at $200 a barrel. This in fact provides an upper bound for price, since our model does not consider the very important lever of substitution, particularly of natural gas for liquids in stationary applications. Since this should be a major factor that could relieve market tightness via high prices, prices significantly below $200 per barrel could be sufficient to clear markets in the medium term if our moderate demand case were realized and no additional demand reduction policies were enacted. In this case, short-term spikes above the medium- to long-term market-clearing price are also possible to clear temporary imbalances.

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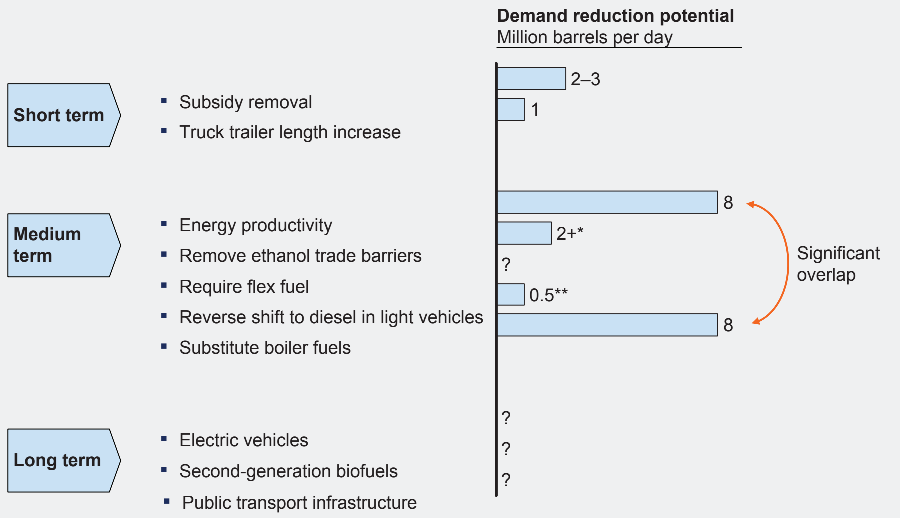
[8] Our calculation is as follows: reduction in demand growth to 0.5 percent per year (almost all/all biofuels) * $70/bbl = $1.8 trillion (this defers demand into the future instead of destroying it, but for all intents and purposes, the net-present value of demand deferred past 15 years is close to zero). Reduction of price from $70 to $40 for 15 years equals $10.2 trillion.

POLICY MAKERS WOULD NEED TO ABATE 6 MILLION TO 11 MILLION BARRELS OF OIL PER DAY TO BALANCE SUPPLY AND DEMAND

If policy makers opt to make proactive decisions aimed at heading off an oil crisis, we project that they need to abate between 6 million and 11 million barrels per day of 2020 energy demand. We have identified a series of options that policy makers could choose to employ as levers to abate oil demand in the short to medium term at low, or no, cost to the economy. In the longer term, new technologies such as EVs and second-generation biofuels could dramatically slow demand. Though investment in these could have large benefits, they are too nascent to have marked impact on demand by 2020 (Exhibit 2.27).

Exhibit 2.27

Significant levers are available to abate oil demand



* Includes only increase in Brazilian ethanol; other countries could also grow production but are excluded from estimate.

** Only represents diesel demand abatement as switching to gasoline keeps overall petroleum products demand unchanged.

Source: McKinsey Global Institute analysis

Short term: Low-cost levers could cut demand by 3 million to 4 million barrels per day

Short-term levers are limited as they depend mostly on behavioral changes of energy end users, which are often hard to induce due to low price elasticity. Eliminating oil subsidies is a large opportunity, but it depends mostly on the Middle East, where it is unlikely to happen. Increasing the maximum allowable size of trucks would provide up to 1 million barrels per day of demand reduction.

1. *Removing subsidies can reduce 2020 demand by 2 million to 3 million barrels per day—largely in the Middle East*

   A number of markets heavily subsidize gasoline prices, most notably Saudi Arabia, Iran, and Venezuela, and, to a lesser extent, China, Mexico, India, and Indonesia. If these economies were to remove all subsidies, we project that they could reduce demand by between 2 million and 3 million barrels per day in 2020. However, we should note that capturing the full abatement opportunity that could come from removing subsidies is not likely to be easy given that 60 percent of the potential would come from Saudi Arabia, Iran, and Venezuela where public support for subsidies—seen as a way of sharing those nations' oil wealth—is entrenched. That said, there are ways to remove such a subsidy that could be more tenable, including, for instance, giving lump-sum payments to consumers to replace some or all of the benefits of the subsidy.[9] In general this should lead to more optimal choice between consumption of oil and other goods and services they could use the lump sum payment to buy.

It seems likely that, if oil prices rise again, subsidies will be phased out progressively in a host of countries that are either oil importers or whose export volumes are dwindling. These countries might include India, China, Indonesia, Mexico, Vietnam, and Malaysia. In general, these countries subsidize oil prices much less than is seen in the Middle East. Because of this, removing subsidies in these countries offers the potential to abate at most 1 million barrels per day of 2020 demand.

2. *Increasing the size limit for trucks could save 1 million barrels per day*
   Regulators in both the United States and Europe are considering increasing the maximum allowable size for heavy trucks, potentially increasing the energy efficiency of trucks significantly. The US Department of Transportation reports a potential improvement in heavy truck VMT of between 10 and 25 percent, while the European Commission estimates a potential of 10 to 15 percent (see chapter 3.2 for more detail). These estimates imply an opportunity to reduce demand by roughly 0.5 million barrels per day to 1.0 million barrels.

   When analyzing the potential cost of such an abatement measure, we should note that increasing the size of trucks could increase the wear and tear of roads and bridges and therefore increase the cost of road maintenance and repairing and replacing bridges. In a 2008 report, the European Commission estimated that such costs might represent some 5 percent of today's annual spending on road and bridge infrastructure maintenance. In Europe, this would be equivalent to some $2 billion a year, while in the United States this same maintenance upkeep would represent some $3 billion. However, lengthening trucks with added trailers instead of increasing trailer size could mitigate these costs.

   Beyond these infrastructure costs, we see no additional safety costs. Megatrucks would have improved safety features using the latest technology that would offset the greater difficulty in maneuvering and reduced field of vision. Fewer trucks on the road due to improved efficiency would also mitigate safety concerns. Taking all of this into account, we estimate that it would take some $5 billion of capital per year to save around 1 million barrels of diesel—an implied cost of $15 per barrel. Given the expected tightness of the distillates market, this opportunity could be quite important.

Medium term: A second set of levers would focus on low or negative cost efficiency improvements and fuel substitution

In the medium term, additional levers are available for oil-demand abatement, many of which focus on shifting to fuels that are potentially more plentiful. While these shifts will be less rapid than our first set of levers, none of them depend on new technologies being developed, and most of them have IRRs potentially near or above 10 percent (depending on oil and diesel prices).

3. *Improving energy productivity offers a smaller opportunity to reduce oil demand than for other fuels*
   In our 2007 report, we identified a set of opportunities to boost energy produc-

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[9] For more information on policy scenarios to help improve developing-country energy productivity, see *Fueling sustainable development: The energy productivity solution*, McKinsey Global Institute, October 2008 (www.mckinsey.com/mgi).

tivity—the level of output we achieve with the energy we consume—using available technologies that would both reduce energy demand (usually via additional upfront capital expenditure) while at the same time having an IRR greater than 10 percent.[10] However, MGI's research also found that, despite the positive returns on offer, companies and individuals are far from capturing the full potential available to boost energy productivity because of a range of market imperfections. These include agency issues, distorted pricing, a lack of information, and the fact that the energy can often represent a small share of overall costs and therefore there is a lack of incentive to move toward a higher level of energy productivity. Even if we assume that there are no unmeasured costs associated with burning energy, boosting energy productivity opportunities would offer oil-importing countries the twin benefit of boosting the economic growth achievable for a given level of oil inputs at the same time as relieving supply tightness in oil markets, and therefore potentially holding down the oil price.[11]

While there are ample energy productivity opportunities across different energy sources, the potential is rather smaller in oil than is the case for other fuels. MGI estimates that there is an overall potential to boost energy productivity equivalent to 20 percent of energy demand in 2020. In oil, however, that opportunity is equivalent to slightly less than 10 percent of demand. This potential is by no means inconsequential—representing up to 8 million barrels per day, primarily concentrated in light vehicles (2 million barrels per day), buildings (2 million), and industry (4 million).

Within oil, four very large oil-consuming sectors—air transportation, trucking, petrochemicals, and power—represent nearly 40 percent of total 2020 petroleum-products demand but offer an energy productivity opportunity of close to zero. The reason for this is that the market imperfections that act as a hurdle to capturing higher energy productivity elsewhere are not in play. There are, for instance, no agency problems (the owner of the vehicle is also the fuel purchaser), no subsidies, and a very strong focus on fuel costs due to their high share in overall costs. Moreover, an end user such as petrochemicals, a fast-growing and heavy consumer of petroleum, has virtually no alternative way to lower its use of energy feedstock in the production process. Existing plants that burn petroleum in the power sector are typically in areas where no other fuel is readily available, are used only to serve peak demand, and thus are run only a few hours a day (instead of being retired), or arbitrage between burning natural gas and coal. For most of these power plants, there are no viable retrofit opportunities to improve energy efficiency, and these plants are unlikely to be replaced with more efficient units.

Light vehicles offer the most sizable energy productivity opportunity among oil end users with potential equal to 26 percent of petroleum products demand in 2020. Vehicle efficiency standards in the United States, the EU, and China lead to about half of the opportunity being captured, but further opportunities exist across several developing markets, including China and the Middle East.

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[10] *Curbing global energy-demand growth: The energy productivity opportunity*, McKinsey Global Institute, May 2007 (www.mckinsey.com/mgi).

[11] Many studies site measureable "externality costs" associated with using oil, such as higher national security budgets and environmental impacts such as pollution and global warming. Our energy productivity analysis does not consider these costs when determining whether an opportunity achieves the 10 percent IRR threshold.

The industrial sector represents 26 percent of petroleum demand; however, this demand is already growing quite slowly (or negatively in most developed countries) and is fragmented across countries and end users.[12] In the case of the pulp-and-paper sector, for instance, petroleum-product costs may represent only between 0.5 and 1.0 percent of overall costs; it is therefore rather difficult to get this industry to focus on boosting the energy productivity solely to reduce its petroleum usage. In light of this, it may be more effective to address the efficiency of petroleum-products consumption as part of a broader energy productivity program in the industrial sector to include other fuels such as power and natural gas. Furthermore, to the extent that the reduction of petroleum demand is a particular goal, it may be more practical to pursue the option of substitution (see later in this section for a more detailed discussion on substitution).

Finally, buildings represent 8 percent of petroleum demand, and, again, this sector's petroleum demand is growing slowly and is extremely fragmented. Energy productivity probably provides more leverage to abate petroleum demand in this sector because substitution is much more difficult. In buildings, users tend to be small and often located in rural locations, making such customers expensive to serve with other fuels. A combination of incentives for insulation and weatherization of petroleum-using dwellings could cut demand by 1 percent.

4. *Removing trade barriers to sugar- cane ethanol could help abate oil demand*
   Both the United States and the EU today place a prohibitive tariff on the import of sugar-cane-based ethanol from countries like Brazil. Yet sugar-cane ethanol has several advantages. Its carbon emissions are about 25 percent of those from burning gasoline (and about one-third of burning corn-based ethanol), and its price per equivalent barrel of oil is approximately $40, contingent on freight rates for chemical tankers as well as the crude-gasoline spread. Furthermore, ethanol can be blended up to a share of 15 to 20 percent with conventional gasoline and burned in conventional engines without requiring any changes in engine technology.

   In our projection scenarios, Brazil and Caribbean ethanol production increases from 0.2 million barrels per day produced in 2008 to 0.8 million barrels per day in 2020. However, if today's trade barriers against sugar-cane ethanol were to be removed, our analysis shows that Brazilian and Caribbean ethanol production could potentially ramp up as dramatically as 3.1 million barrels per day by 2020, which could help reach biofuel mandates and provide incremental supply.[13] Removing trade barriers could therefore help to reduce petroleum demand overall, although another impact of such a policy could be to increase the preponderance of diesel growth compared with that of gasoline.

5. *Requiring all vehicles to be flex-fuel capable would bring fleet flexibility*
   The additional production cost of adding flex-fuel burning capability to cars is quite small at less than an estimated $100 per unit—adding up to $0.5 billion to $1 billion per year in the United States between 2008 and 2020, for instance. Bearing this additional cost is worthwhile given the flexibility this gives the fleet and the potential for the diversification of supply. Given the potentially large supply of sugar-cane-based ethanol, this lever could be important.

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[12] Our definition of the industrial sector includes both nonenergy use (such as asphalt) and marine bunkers, each of which represents 6 percent of total 2020 petroleum demand.

[13] McKinsey Biomass Production model 2008.

6. *Reversing the shift to diesel in passenger vehicles*
   Our research shows that diesel will more than likely be in shorter supply than gasoline between 2010 and 2020 and that it is therefore worth considering a shift back to gasoline vehicles from diesel. Today, the power required for diesel-run passenger vehicles is less than that for cars run on gasoline; average diesel engine efficiency is roughly 45 percent, compared to 25 to 30 percent on average for gasoline engines. However, in the period ahead, gasoline engines should close most of the efficiency gap to diesel engines, with efficiency improvements of up to 40 to 45 percent. There are several reasons for this. First, turbo-charged gasoline vehicles will come onto the market over the next ten years. Second, the push for fuel economy and reduced CO_2 emissions, along with ultralow criteria emissions, is likely to result in a convergence of diesel- and gasoline-engine technology starting around 2015. By 2020, technologies that may have first appeared in diesel engines are likely to have migrated to gasoline engines; these include variable valve timing, transient boost devices, variable turbines, variable valve lift, low-pressure exhaust-gas recirculation (EGR), low-pressure EGR cooler, particulate trap, and nitrogen oxides trap.[14]

   The EU currently uses the majority of diesel in passenger vehicles. Given the current tax regime and wholesale gasoline-diesel spreads, end users pay 4 percent more for gasoline than diesel in Europe (average of Q1 to Q3 2008). Should diesel become more expensive than gasoline in Europe after taxes, based on diesel-gasoline fuel-efficiency convergence in vehicles by 2020 we project that gasoline cars will actually be equally or slightly more cost effective than diesel vehicles by 2020.

   However, it is possible to incentivize a more dramatic shift from diesel to gasoline passenger cars at a faster pace by altering the existing tax structure. In most European countries, diesel has a lower excise duty than gasoline—a policy originally driven by a desire to protect commercial trucking, and more recently by a concern for environmental effects, given the greater diesel-engine efficiency in the past. In total, the average percentage of end-use fuel price accounted for by tax is 46 percent for diesel and 56 percent for gasoline. Reversing this policy by taxing diesel more than gasoline could potentially have a large impact on incentivizing gasoline vehicles in Europe and at a more rapid pace than would be achieved through efficiency gains over time in gasoline engines alone.

   How much diesel demand reduction is possible in Europe from a shift to gasoline cars? Assuming the share of sales of diesel cars decreases gradually from 35 percent in 2008 to zero in 2020, cutting the stock of diesel vehicles from 36 percent to 17 percent over this period, this would produce a reduction in diesel demand by 2020 of approximately 0.5 million barrels per day out of a total diesel demand in 2020 of 2.6 million barrels a day in our moderate case. If we extrapolate this to global demand of 5.4 million barrels a day consumed by light vehicles, the result would be an opportunity to shift 1.0 million barrels a day from diesel to gasoline.

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[14] *Diesel Fuel News*, May 2008.

7. *Substituting boiler fuels could abate up to 8 million barrels per day*
   We project that some 12 million barrels of petroleum products a day—about 27 percent of total use in 2020—will be consumed in the industrial, power, and buildings sectors (excluding petrochemicals, where petroleum products are used for feedstock) Of this, more than 40 percent lies in regions that are self-sufficient in natural gas, and we estimate that, at a stretch, an additional 8 million barrels per day could be substituted out of petroleum products to natural gas by 2020. We already project a continued shift out of petroleum fuels in boiler applications to 2020; any shift to other applications must offer relatively higher value because such a shift is most likely to occur in places where the natural gas grid is not easily accessible. That said, substitution in boiler applications requires no additional technology improvement or breakthrough and could therefore be deployed in the near term more cost effectively.

   Furthermore, there are two potential pathways to capturing this opportunity: (1) building out the natural gas grid, or (2) building a small-scale liquefaction (LNG) infrastructure. Because the cost per MBTU for piping gas to a new location varies a great deal, depending on the distance from the grid and the daily volume of gas needed (smaller volumes tend to be less economical due to higher capital expenditure per MBTU), we use small-scale liquefaction to set an upper bound for costs to supply gas to facilities that are currently remotely situated. Our estimates show a full cost of between $2 and $3 per MBTU. At an oil price of $75 per barrel and a residual fuel oil pricing at 80 percent of crude, small-scale LNG would be more economical in all regions where local wholesale gas prices are less than $6.50 to $7.50 per MBTU. This includes all of the natural-gas-supply regions. Even more favorable economics apply to situations where diesel is being burned in these applications.

Long term: Options are available that could lead to peak demand or at least balance supply and demand to 2020

Another set of levers is available that will help to provide the next “marginal million barrels per day” of demand reduction that is crucial to keeping the oil market in balance. These measures are currently in their research phase or are nascent technologies that will take a long time to become fully viable. In short, these levers to abate petroleum demand will not be ready to roll out in time to head off the next potential energy crisis. Neglecting these measures for this reason would be shortsighted, however, given that they can play a vital role in balancing oil supply and demand, particularly in the 2020 to 2030 time frame.

8. *Investing in EVs research*
   Hybrid EVs are already a feature in the United States, holding 2.4 percent market share in 2008. Toyota and GM are planning to introduce plug-in hybrids (PHEV) by 2011. Fully battery-powered vehicles could be widely available within a few years after that. While EVs—particularly PHEVs and full battery EVs (BEV)—have a large impact on fuel consumption compared with traditional internal combustion engine (ICE) power trains—pure hybrids offer less of an advantage over ICE engines. This will particularly be true of the improved ICE engines that will be manufactured between 2010 and 2020. At the current cost per kilowatt for batteries, PHEVs and BEVs are too expensive. However, if battery costs continue to decline, these power trains will become more viable investments by 2015, we estimate.

For this reason, it makes sense to continue strong (perhaps government-supported) investment in battery technology in particular. Electric vehicles have the potential to provide the next wave of demand abatement to 2020 once the short- and medium-term levers that we have described have exhausted their potential. Should battery costs continue on their current path of 8 percent reduction or more per year, investing in a PHEV or BEV in 2020 will have a greater than 10 percent IRR for large segments of drivers.

9. *Investing in biofuels research*
Government regulations will be the primary determinant of the supply of biofuels in future years. These regulations might take the form of mandates to use biofuels in each country worldwide, as well as the availability of second-generation technologies that will allow production of biofuels to be cheaper than today's first-generation approaches based on food feedstocks. As with EVs, it makes sense for governments to encourage strong investment in biofuels to bring down production costs and therefore make second-generation biofuels viable. Our projections estimate 4 million barrels per day of biofuels in 2020 (3 million barrels of ethanol and 1 millions barrels per day of biodiesel. Diesel-replacement biofuels will likely be more valuable than gasoline replacements given our projections showing that diesel will likely continue to outgrow gasoline.

There are no commercial-scale cellulosic ethanol production facilities in the world today, but these are planned. In January 2009, Verenium Corporation announced the construction of the first large ethanol plant (a 36-million-gallon-a-year plant in Highlands, Florida), and POET Biorefining followed suit (a 25-million-gallon-per-year plant in Emetsburg, Iowa). The plant capital expenditure of these facilities is $7 to $8 per gallon of annual ethanol production capacity, significantly higher than the $2 per gallon capital spending on modern corn-ethanol plants in the United States. Other competing second-generation technologies that are set to be implemented include bacterial ethanol, thermochemical ethanol (Range Fuels plans to construct a 20-million-gallon-a-year ethanol plant in Soperton, Georgia in 2010) and biomass-to-liquids biofuels (e.g., Choren BTL).

10. *Investment in public-transportation infrastructure*
Investing in public-transportation infrastructure appears to be a logical element of any long-term plan to reduce oil demand. However, because of the huge existing stock of investment in road infrastructure, supply chains, suburban living arrangements, automobiles, and whole transportation systems, this is necessarily a slower and more expensive option compared with others. However, we note that in developing regions where transportation infrastructures are still developing—and rapidly—this sunk-cost argument does not hold as strongly. In these regions, the sooner this lever is employed, the more effective it will be in locking in a lower level of demand for the long term.

3. Sectoral outlooks

3.1. Light-duty vehicles

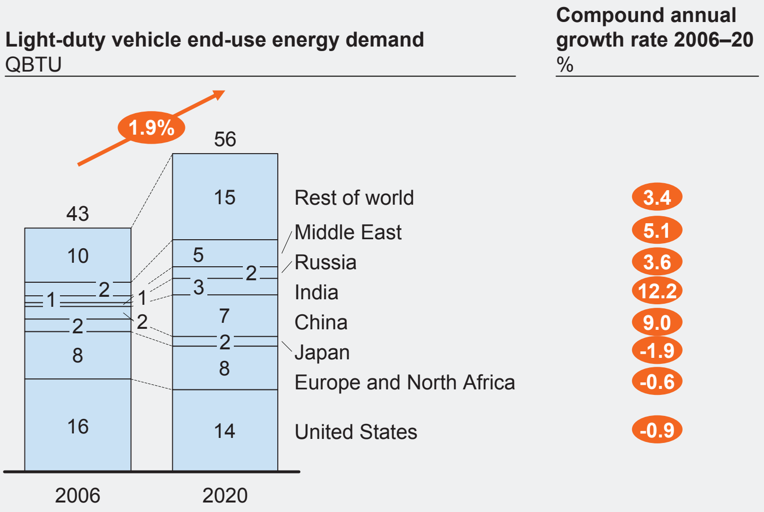
Road transport is crucial to gaining an understanding of the evolution of petroleum demand. The sector accounted for 41 percent of overall petroleum demand in 2006 and 14 percent of global energy demand. Light-duty vehicles consume more than 95 percent of gasoline, while light vehicles and trucks together burn 55 percent of diesel. Because of the importance of the light-vehicles sector, accounting for about 70 percent of the total road-transport sector, they are the focus of this chapter.

Energy demand from light vehicles is set to grow at 1.9 per annum to 2020, significantly less than overall global energy demand at 2.1 percent. Behind the aggregate figure, there are two opposing trends. Adding to energy demand is extremely rapid growth in the vehicle stock in China, the Middle East, and India. While the global vehicle stock will grow at an average of 3.3 percent per year, the stock in China and India, for instance, will expand at 11 and 12 percent per annum, respectively. However, robust new-vehicle efficiency standards—particularly but not exclusively in developed countries—offset this trend. The efficiency of the vehicle stock will improve at 1.5 percent per year, with the United States, the EU, and China leading the way at 1.5, 1.9, and 3.3 percent, respectively.[1]

Taking into account these two countervailing trends, MGI projects energy demand in the Middle East, China, and India will grow by 2.3 QBTU, 5.1 QBTU, and 2.2 QBTU, respectively, from 2006 to 2020. These three countries/regions will account for 75 percent of total global energy-demand growth (Exhibit 3.1.1).

Exhibit 3.1.1

India and China will see the fastest energy-demand growth from light-duty vehicles



Note: Numbers may not sum due to rounding.
Source:McKinsey Global Institute Global Energy Demand Model 2009

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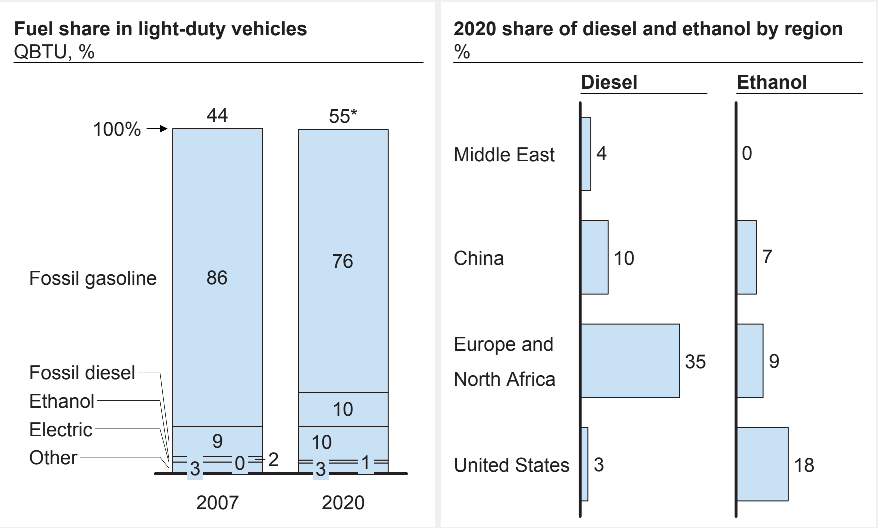
[1] We have only a rough estimate for China's 2006 vehicle stock efficiency, but this is largely irrelevant as growth in China's vehicle stock between 2006 and 2020 will dwarf the current stock.

While we consider all forms of EVs in our demand projections—full hybrids (HEVs), PHEVs, and BEVs their impact on average fuel economy by 2020 is small. We project global penetration of EVs of 8 percent by 2020, but about half of this is HEVs, and these offer a much smaller potential for incremental oil savings compared with ICEs than do PHEVs and BEVs. Although PHEVs and BEVs start to penetrate strongly into the vehicle stock by around 2015, stock turnover is not sufficient between 2015 and 2020 to make them a major factor. However, if the current trend in battery-technology improvements continues as we project, PHEVs and BEVs would become a major factor in 2020–30.

Energy demand—in particular for gasoline—in the light-vehicles sector will experience a significant supply-side impact from rapid growth of biofuels, which for the most part will replace gasoline in light vehicles. We project nearly three million barrels per day of blended ethanol by 2020, leaving global gasoline-demand growth at negligible levels (Exhibit 3.1.2). Diesel efficiency and substitutes do not grow proportionately—McKinsey projects only one million barrels per day of biodiesel by 2020—and this may lead to imbalances in the refining sector (see chapter 4.1 for more detail).

Exhibit 3.1.2

Ethanol grows its share sharply, while fossil gasoline share drops



* Does not match previous exhibit as power losses are excluded from this total.

Source: McKinsey Global Institute Global Energy Demand Model 2009

The light-vehicles sector is the most sensitive of all those studied in this analysis to oil price increases. We see the impact through reduced VMT, the increased penetration of EVs, and increased fuel economy in nonregulated markets. If the oil price were to increase to $150 between 2010 and 2020, we see energy demand in the sector 8.4 QBTU lower.

Despite the fact that energy-demand growth in the light-vehicles sector is already lower than in many other sectors, there are available levers that could reduce demand growth even further. Key among these is the removal of energy subsidies, particularly in Iran and Saudi Arabia, which could reduce demand by 4–5 QBTU. Furthermore, moves to slow the growth rate of vehicle stock in developing markets (including, for instance, high taxes on vehicle ownership and large public infrastructure investments) or policies or other factors that dramatically impact the rate of EV adoption, but that are subject to considerable uncertainty, could have a marked impact on the sector's demand path.

LIGHT-VEHICLES ENERGY-DEMAND GROWTH IS SET TO SLOW, REFLECTING DECLINING DEMAND IN DEVELOPED ECONOMIES

Short-term energy demand in the light-vehicles sector should react less strongly to weakening GDP than it does in other sectors. We project that the sector's energy demand will be virtually unchanged from 2007 to 2009 at 44 QBTU. Although this sector does not display the procyclicality of others, it remains the case that the GDP slowdown will slow growth in vehicle sales. More important, the impact of higher oil prices has also reduced demand growth in more price-exposed markets.

Looking further ahead, our moderate-case projection calls for 1.9 percent energy-demand growth in the sector globally to 2020, compared with 2.4 percent growth over the past decade. The developing regions of India, China, and the Middle East are responsible for almost all growth in demand to 2020, with energy demand increasing at annual rates of 12, 9, and 5 percent, respectively. The story in developed regions of the world is quite different. These regions have nearly reached a peak in their light-vehicles energy demand as the vehicle-stock growth slows and newer, more efficient technologies penetrate the vehicle fleet. Across developed regions, which accounted for the majority of the sector's energy demand in 2006, we expect to see that demand now decline and therefore rein back global energy-demand growth in the sector (see "MGI looks at four key levers to project light-vehicles energy demand").

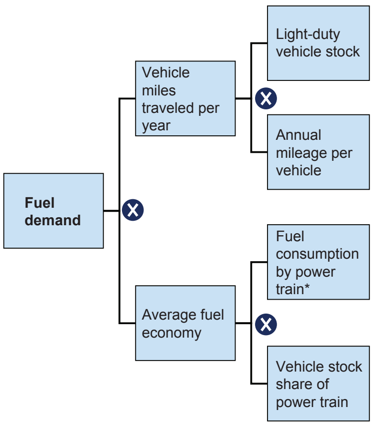
MGI looks at four key levers to project light-vehicles energy demand

To project energy demand in the sector, we look at four key levers and project them forward, taking into consideration current regulations and how they might change under different price scenarios (Exhibit 3.1.3):

Exhibit 3.1.3

Light-duty-vehicle fuel demand is driven by miles traveled and average fuel economy and is in turn linked to oil prices and GDP growth

Breakdown of light-vehicle fuel demand



	Mechanisms linking demand driver to MGI scenario variables		
	Oil price	**GDP**	**Regulation**
Light-duty vehicle stock	–	▪ Elasticity of vehicle sales or penetration to per capita GDP	▪ Vehicle ownership taxes
Annual mileage per vehicle	▪ Behavioral price-elasticity response	–	▪ Fuel taxes
Fuel consumption by power train*	▪ Breakeven point of fuel-saving technologies ▪ Shifts in vehicle-segment mix	–	▪ Efficiency regulations ▪ Fuel taxes
Vehicle stock share of power train	▪ Total cost of ownership by power train	–	▪ Electric vehicle mandates or subsidies ▪ Fuel taxes

* Fuel consumption is also weighted across light-vehicle segments (e.g., cars vs. light trucks in the United States).

Source: McKinsey Global Institute analysis

- **Vehicle sales.** We look at overall vehicle sales growth rates and sales share of each power train: ICE gasoline, ICE diesel, HEV, PHEV, BEV and compressed natural gas (CNG). We then translate these into vehicle stock using a vintage model for each region and power train (a total of 174 vintage models). We then use historical GDP-to-car sales correlations and cars per capita compared with GDP per capita intensity curves at PPP to project vehicle sales forward. Each region's retail fuel price determines the sales shares of HEVs, PHEVs, and BEVs (see "MGI-projected EV penetration and share using payback times for different drivers").

- **VMT.** We hold VMT per vehicle constant across regions. VMT per vehicle drops if the projected retail gasoline/diesel prices rise in a given region due to behavioral elasticity.

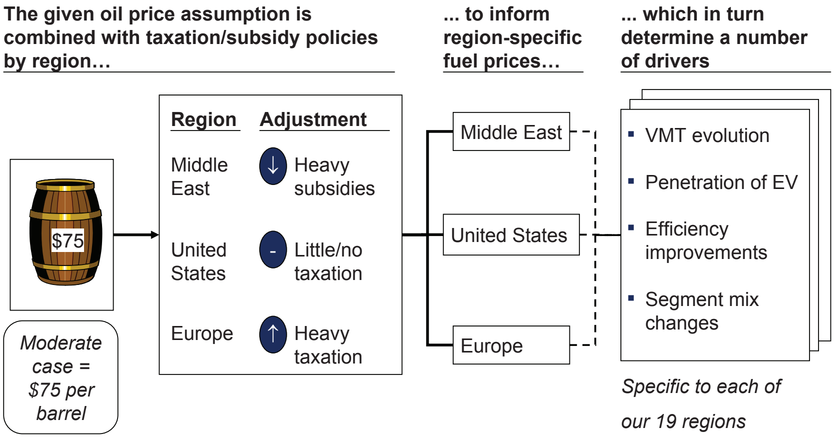
- **Fuel economy.** Each model year's average fuel economy is driven by prices and regulation—and we use whichever of these two factors implies the higher fuel economy in our projections. We assume that a consumer requires a five-year payback on fuel-economy investments, and that all fuel-economy investments that deliver this five-year payback are adopted. We base adoption on average miles driven per year rather than taking a distribution of drivers by miles driven per year per region (see "MGI-projected EV penetration and share using payback times for different drivers"). Should regulatory requirements be more stringent than economically driven improvements, we assume that the regulatory targets are achieved and disregard the lower level of efficiency called for by purely economically driven adoption.

- **Prices.** Pump gasoline and diesel prices are based on several scenarios for wholesale gasoline prices together with historical taxes, subsidies, and distribution margins for each region (Exhibits 3.1.4 and 3.1.5).

Combining these four factors into our vintage model allows us to calculate the vehicle stock per power train and average stock fuel economy in each year. Multiplying the vehicle stock per power train and average power train fuel economy with VMT then allows us to calculate total consumption by fuel.

Exhibit 3.1.4

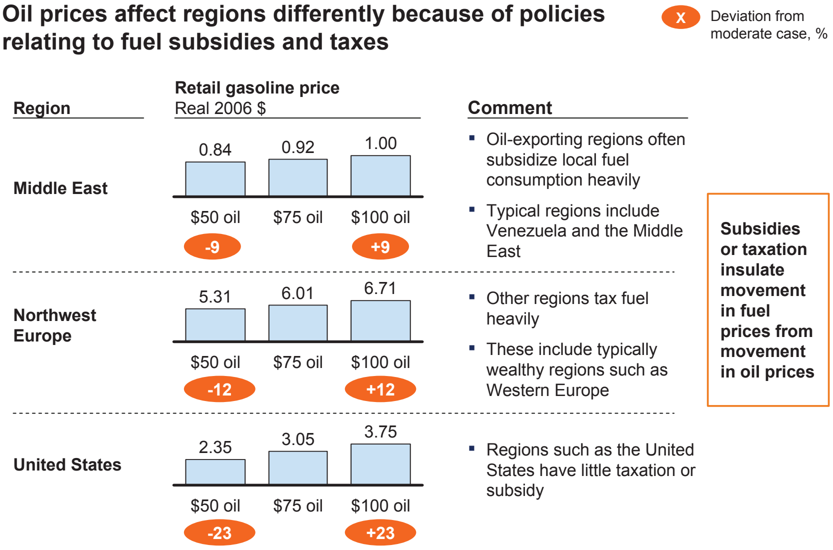
Oil price assumption informs region-specific fuel prices



Source: McKinsey Global Institute analysis

Exhibit 3.1.5

Oil prices affect regions differently because of policies relating to fuel subsidies and taxes



Comment

- Oil-exporting regions often subsidize local fuel consumption heavily
- Typical regions include Venezuela and the Middle East

- Other regions tax fuel heavily
- These include typically wealthy regions such as Western Europe

- Regions such as the United States have little taxation or subsidy

Subsidies or taxation insulate movement in fuel prices from movement in oil prices

Source: McKinsey Global Institute analysis

Fuel mix

The fuel mix in the sector will change markedly, although gasoline will remain the primary fuel for light-duty vehicles. We project diesel-demand growth for light-duty vehicles will remain strong at 2.7 percent per annum. If high diesel-gasoline spreads persist due to a shortage of diesel-producing capacity, we could easily see the trend toward dieselization reverse. While today diesel cars are 15 to 25 percent more efficient than gasoline cars on average, by 2020 that gap will have diminished significantly. Given the generally lighter power requirements of light vehicles compared with other diesel applications, it would therefore make sense to squeeze diesel out of light vehicles before other applications, although we should note that, because the light-vehicle stocks turn over only every 15 to 20 years, there will still be a significant number of diesel cars in 2020 under any scenario.

Biofuels are also a major factor, with around three million barrels per day of gasoline equivalent expected to be used mostly as blendstock by 2020. This will be a key factor in creating a potential gasoline-diesel imbalance, since we anticipate only one million barrels per day of diesel equivalent.

Although EVs could account for approximately 8 percent of vehicle stock by 2020, their overall power requirements will remain minor as HEVs, which account for nearly half of total EVs, require no external electrical power. We project demand of some 0.5 QBTU of electricity for EVs, equivalent to less than 1 percent of global electricity demand. We project Europe to be the largest market for EVs; the 0.1 QBTU of electricity in this region projected for 2020 represents 1.4 percent of total power demand.

Vehicle stock

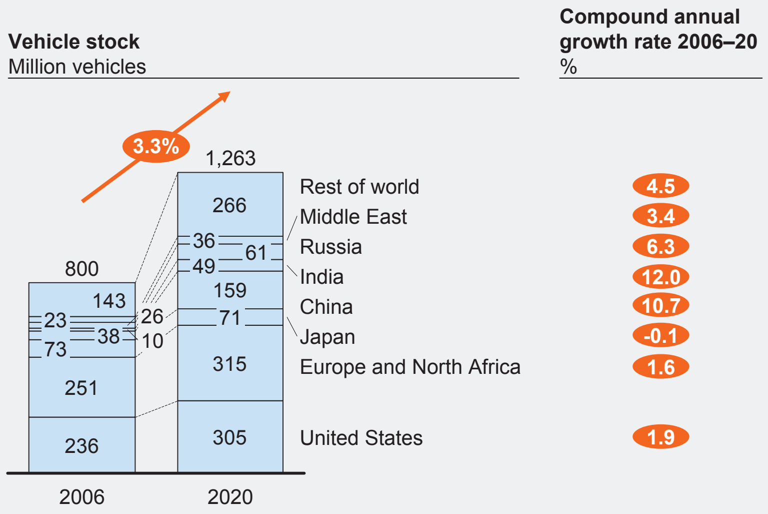
The global vehicle stock is projected to grow at 3.3 percent per annum, with China and India experiencing the strongest growth at 12.0 and 10.7 percent, respectively (Exhibit 3.1.6). It is interesting to note that, even if sales growth were to flatten to zero in 2010 and remain at that level until 2020, the vehicle stock in China and India would still grow at a compound annual rate of 9.0 and 6.4 percent, respectively, to 2020. The reason for this phenomenal growth is the low starting point of vehicle ownership in these countries; sales in the past five to seven years have been meteoric.

Looking at the sales share of different power trains, we see EVs penetrating most heavily in the EU—at nearly 18 percent by 2020—as high gasoline and diesel prices create very quick paybacks on battery investments. In stark contrast, we project no penetration of EVs in the Middle East by 2020 because the very low subsidized price of gasoline means that investing in them is not economic (see "MGI-projected EV penetration and share using payback times for different drivers") (Exhibit 3.1.7).

If oil prices were to jump to $200 per barrel in 2010 and maintain this level, we project EV penetration of up to 14 percent by 2020.

Exhibit 3.1.6

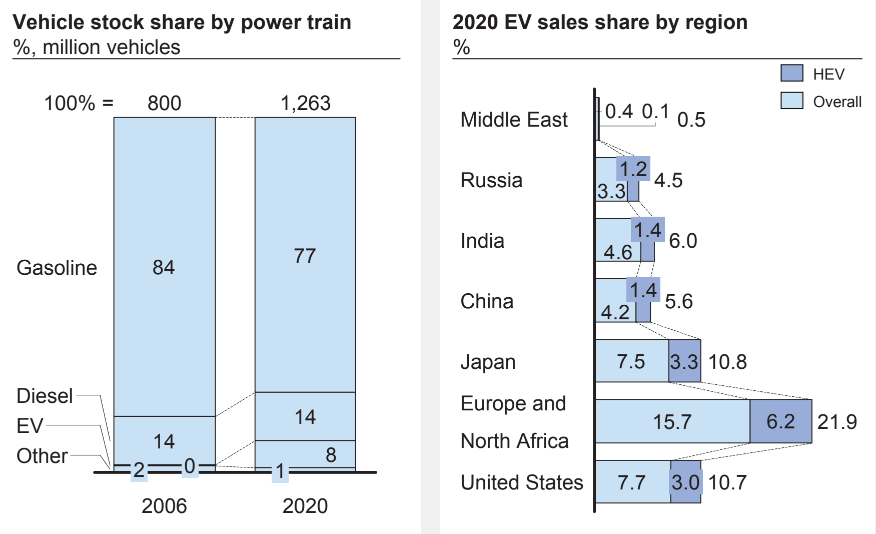
India and China both grow vehicle stock at more than 10 percent



Note: Numbers may not sum due to rounding.
Source: McKinsey Global Institute Global Energy Demand Model 2009

Exhibit 3.1.7

Electric vehicles gain a significant share, particularly in Europe where highly taxed fuel causes them to pay back quickly



Source: McKinsey Global Institute Global Energy Demand Model 2009

MGI-projected EV penetration and share using payback times for different drivers

Projections for EV penetration vary extremely widely. For example, Morgan Stanley projects that, in the United States, EVs will have around a 10 percent share of sales in 2020, while the Electric Power Research Institute (EPRI) projects nearly 65 percent. (Exhibit 3.1.8)

Exhibit 3.1.8

Plug-in hybrid electric vehicles would break even in five years for vehicles traveling more than 7,912 miles in MGI's US moderate case

Breakeven annual miles driven at various gasoline and electricity prices

Electricity	**Gas** $/gal								
$/kWh	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0.05	11,105	6,749	3,867	2,106	1,767	1,522	1,336	1,191	1,075
0.08	12,240	7,285	4,122	2,223	1,848	1,582	1,382	1,228	1,104
0.10	13,633	**7,912**	4,413	2,353	1,938	1,647	1,432	1,266	1,135
0.13	15,384	8,658	4,747	2,500	2,036	1,717	1,485	1,308	1,168
0.15	17,651	9,558	5,137	2,666	2,145	1,794	1,542	1,352	1,204
0.18	20,702	10,668	5,597	2,856	2,266	1,878	1,603	1,399	1,241
0.20	25,029	12,070	6,146	3,074	2,401	1,970	1,670	1,449	1,280
0.23	31,641	13,895	6,816	3,330	2,554	2,072	1,743	1,504	1,323
0.25	43,002	16,371	7,649	3,631	2,728	2,185	1,822	1,562	1,368

Source: McKinsey Global Institute analysis

MGI projected vehicle shares based on an economic model that takes into account the payback time for EVs for different segments of drivers. We built our model as follows:

- **Power train tradeoff model.** We created a model that calculated the breakeven miles driven per year at which a consumer would prefer to purchase an EV rather than a traditional ICE transmission (Exhibit 3.1.9). Drivers who drive more miles per year would be more likely to purchase an EV. We also took into account improvements to ICE engines likely in each region as well as likely reductions in the cost of car battery capacity. The result is a breakeven mileage in each region (which varies greatly based on local pump prices) at which a new car buyer would be equally happy to buy an improved ICE engine or an EV.

Exhibit 3.1.9

About 70 percent of US vehicles drive 8,000 or more miles a year

Histogram of annual miles per vehicle

	% of vehicles		**Cumulative %**	
	US	**NE***	**US**	**NE***
<1K miles	5.5	4.7	100.0	100.0
1–2K miles	4.3	3.9	94.5	95.3
2–4K miles	9.6	9.9	90.2	91.4
4–6K miles	10.8	11.1	80.6	81.5
6–8K miles	11.1	11.8	69.8	70.4
8–10K miles	10.6	11.5	58.7	58.6
10–12K miles	9.4	9.0	48.1	47.1
12–15K miles	11.6	11.7	38.7	38.1
15–20K miles	12.3	12.8	27.1	26.4
20–30K miles	10.0	9.7	14.8	13.6
>30K miles	4.8	3.9	4.8	3.9

* New England area.
Source: US Bureau of Transportation Statistics; McKinsey Global Institute analysis

- **Histogram of driving habits.** Using data from the US Bureau of Transportation Statistics' 2001 Household Transportation Survey, we created a histogram of vehicles in mileage per year bands (Exhibit 3.1.10).

Exhibit 3.1.10

About 27 percent of vehicles seem unlikely to be replaced by alternative power trains

	%	Rationale
Ⓐ Construction/agricultural workers using SUV/truck for work	5	▪ Alternative power train suitable for small cars; large vehicle batteries expensive
Ⓑ Vehicles with >20 percent of trips with five or more occupants	3	▪ Alternative power train suitable for small cars; large vehicle batteries expensive
Ⓒ Low-income households	13	▪ Unable to pay additional up-front cost of alternative power train ▪ Impact likely muted as this group purchases lower share of new cars
Ⓓ High-income households with two or more children currently owning SUV	1	▪ Will pay higher operating cost for convenience of large vehicle
Ⓔ Rural baby boomers	8	▪ Not traditional adopters of new technology
	~27	▪ Some double counting, but should not have much impact on overall effect size

Source: US Bureau of Transportation Statistics; McKinsey Global Institute analysis

- **Elimination of unlikely purchasers.** We eliminated drivers who were very unlikely to purchase EVs, including contractors who drive light trucks for work purposes and people who conduct 20 percent of their trips with five or more passengers (in which case the power requirement for EVs would be unjustifiably expensive) (Exhibits 3.1.11–3.1.12).

Exhibit 3.1.11

About 70 percent of US vehicles never or very infrequently travel more than 50 miles in a day and are thus good candidates for EV80* technology

	%	Description
Single-vehicle households with zero monthly long trips (>50 mile)	11	▪ Could replace current car with EV80
Multiple-vehicle households with zero monthly long trips	46	▪ Could replace all vehicles with EV80
Multiple-vehicle households with one to four monthly long trips	15	▪ Could replace 1.3 of current average 2.3 vehicles with EV80
	72	

* EV80 is an electric vehicle capable of traveling 80 km on one charge.

Source: US Bureau of Transportation Statistics; McKinsey Global Institute analysis

Exhibit 3.1.12

MGI assumes electric vehicle shares will reach the full addressable market size by 2030 in most cases

Share of alternative power trains in total sales at different gasoline prices

	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Share of alternatives %	10	25	40	50	60	60	60	60	60
Date achieved	2030	2030	2030	2030	2030	2030	2030	2025	2020

Share of total alternative power trains
%

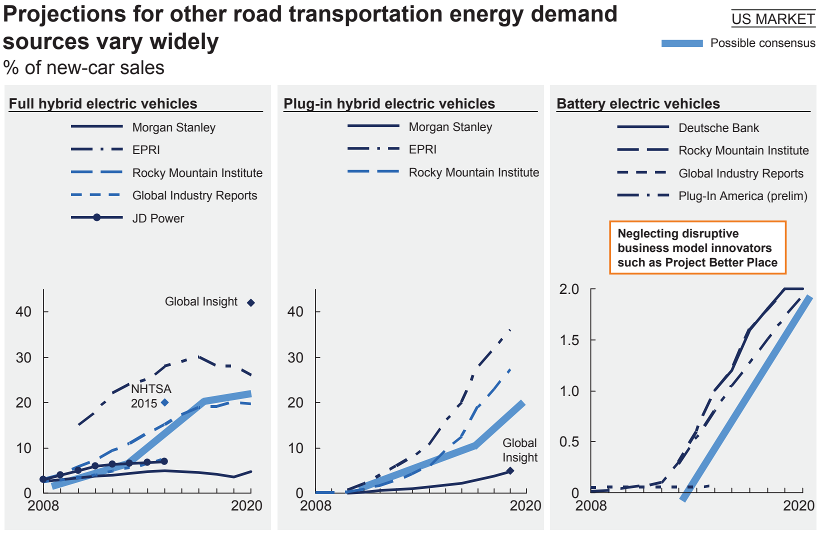
	2010	**2015**	**2020**
HEV	90	50	0
PHEV	5	40	50
EV80	0	10	50

Source: McKinsey Global Institute analysis

- We then combined these three components to create an "addressable market size" for each region and pump price. Last, we assumed that the sales share of EVs reaches full addressable market size by 2030 in most cases. In high-gas-price scenarios—i.e., at $9 or $10 per gallon—we assumed that the full sales share is reached by 2025 and 2020, respectively (Exhibit 3.1.13).[2]

Exhibit 3.1.13

Projections for other road transportation energy demand sources vary widely
% of new-car sales



Source: Deutsche Bank, *Electric cars—Plugged-in*, June 2008; EPRI; Global Industry Reports, Electric Vehicles, May 2008; Global Insight; JD Power, *Alternative power train light vehicle forecast*, April 2008; Morgan Stanley, *Plug-in hybrids—The next automotive revolution*, March 2008; NHTSA CAFE report, April 2008; Plug-In America; Rocky Mountain Institute

Finally, we split the EV share between HEVs, PHEVs, and BEVs, assuming that PHEVs surpass as 10 percent of all EVs in 2011 and BEVs in 2015. Our vintage model then calculates total stock shares of all EVs, and we multiply these vehicle stocks by VMT per vehicle and fuel consumption per kilometer to obtain overall fuel-demand estimates.

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[2] These gas price levels occur only when the oil price is assumed to be above $100 a barrel, not in our moderate-case, $75-a-barrel scenario.

Vehicle miles traveled

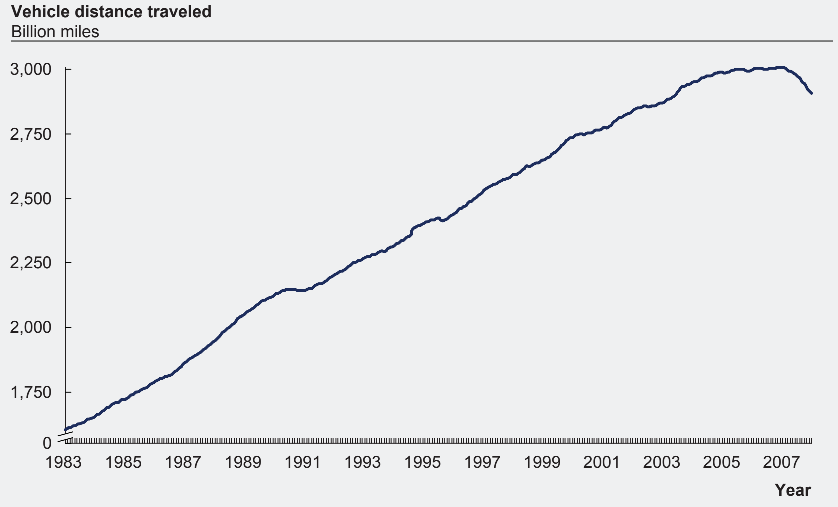
Current base-year assumptions show a wide variation in VMT based on historical data; Japan's figure is 9,000 km per vehicle, and VMT in the United States was 19,000 km per vehicle annually as of 2006. VMT is the source of behavioral price elasticity—i.e., when pump prices rise, drivers react by reducing the amount they travel by, for instance, "trip-chaining," carpooling, and reducing discretionary driving. Many studies have tried to assess the price elasticity of VMT and, although these produce a wide range of estimates, there is some consensus around an average elasticity of some minus 0.2.

Our moderate case for VMT per vehicle before price effects assumes a flat VMT rate across countries. However, in our estimate of the period from 2002 to 2007, we incorporate a price change that pushes VMT per vehicle lower by an average of 0.4 percent per annum in the period from 2006 to 2020. The actual effect of this price-induced fall in VMT is rather dramatic as it occurs entirely in the three years between 2006 and 2009. We can see a significant effect from US VMT data (which are aggregate, rather than per vehicle, data and therefore are even more striking) that flattened and then declined sharply in late 2007 to mid-2008 (Exhibit 3.1.14).

Exhibit 3.1.14

US vehicle miles traveled shows the short-term price impact most dramatically

Moving 12-month total on all roads



Source: US Federal Highway Administration

Fuel economy

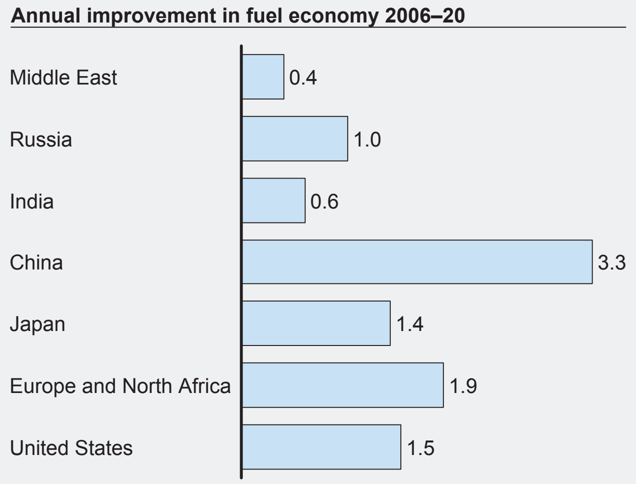
Growth in fuel economy varies widely from region to region, depending on the pricing and regulatory environment. Overall global vehicle efficiency is set to grow at 1.5 percent per year, led by the United States, the EU, and China. In the United States, CAFE standard regulations require the average fuel economy to reach a fleet average of 35 miles per gallon, leading to a 1.5 percent per annum improvement in the fuel economy of the US vehicle stock. In Europe, the average fuel economy of the stock improves by 1.9 percent per year. The increase in China is much larger at 3.3 percent per year, reflecting the low base and the fact that a very high percentage of the vehicle stock in 2020 is new (Exhibit 3.1.15).

Fuel-efficiency standards are an effective forcing mechanism toward higher energy efficiency (Exhibit 3.1.16). Countries where no regulations are in place to catalyze improvements in fuel economy progress at a much slower rate generally of between 0.5 and 1 percent per annum. Cases in point include the Middle East, India, and

Russia. Due to very high growth rates in vehicle stock, fuel-economy standards in these countries would have a more profound impact than equivalent standards in developed countries.

Exhibit 3.1.15

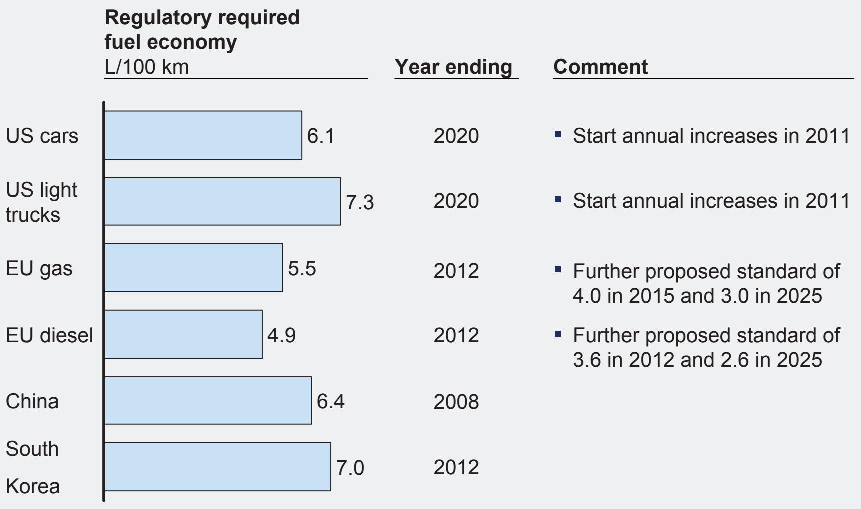
China's stock fuel efficiency improves the fastest, although efficiency in the United States, Japan, and Europe also increases significantly
%



Source: McKinsey Global Institute Global Energy Demand Model 2009

Exhibit 3.1.16

In several markets, fuel-economy standards imply much stronger efficiency improvements than if left to consumer choice



Source: Literature search

Prices

Prices impact the model in four ways.

- **Reducing VMT.** The shortest-term impact is reducing VMT through a behavioral change. As noted, we use a minus 0.2 price elasticity to pump prices.
- **Higher sales of efficient vehicles.** As pump fuel prices increase, more fuel-efficiency investments meet consumers' five-year payback requirement.

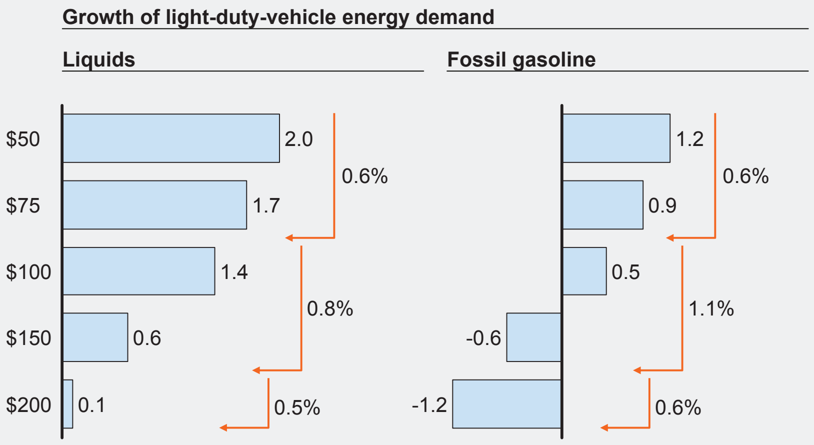
- **Smaller vehicles gain share.** As the price of fuel goes up, so the market share of smaller vehicles increases.

- **EVs gain share.** With higher pump prices, the percentage of consumers for whom EVs meet the five-year payback requirement increases.

As fuel prices rise, the projected growth of light-vehicles fuel demand slows, dropping to 1.4 percent per annum at $100 oil, 0.6 percent at $150 oil, and 0.1 percent at $200 oil. The sources of reduction at $200 oil are fairly evenly distributed between vehicle efficiency and VMT reductions. Interestingly, the impact of oil price accelerates. An oil price that moves from $50 to $100 per barrel reduces demand by only 0.6 percent per annum. If the oil price then increases from $100 to $150, the decline in demand accelerates to 0.8 percent. However, with oil between $150 and $200 a barrel, the impact weakens again. This nonlinearity is due to a number of factors. First, many fuel-economy improvements are already captured by regulation with oil between $50 and $100. At $100 to $150 oil, further price-driven fuel-economy improvements become viable, but not as many as become economic between $150 and $200. Second, VMT reductions are based on percentage changes in price, and these reductions decelerate as percentage price changes increase (i.e., $50 price increments are not equal on a percentage basis) (Exhibit 3.1.17).[3]

Exhibit 3.1.17

Overall light-duty-vehicle fuel demand would be flat at sustained $200 oil—but fossil gasoline would stabilize at lower prices
%



Source: McKinsey Global Institute Global Energy Demand Model 2009

Light vehicles' CO_2 emissions will grow more slowly than energy demand

While overall energy demand grows at 1.9 percent per year, CO_2 emissions increase by only 1.2 percent per year. This gap is due to the marked impact that biofuels are projected to have by 2020. We make the assumption that half of all biofuels by 2020 are either second generation or sugar-cane based, providing a much larger well-to-wheels reduction in greenhouse gases than corn-based ethanol. Should this assumption be incorrect, growth in emissions would be much closer to energy-demand growth in the sector (Exhibit 3.1.18). Japan, Europe, and the United States

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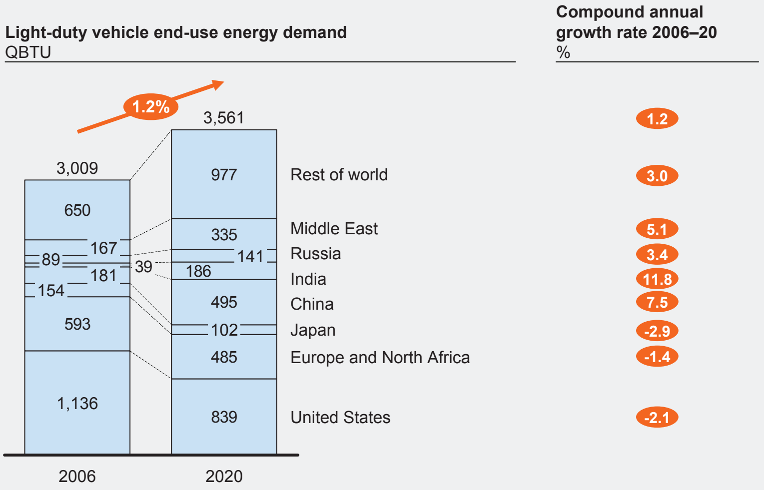
[3] The log price-elasticity function also dampens the impact of elasticity as the percentage increase grows.

all reduce CO_2 emissions in this sector by 1 percent per year or more. Meanwhile, emissions in India, China, and the Middle East grow quickly—in line with their overall energy demand.

Exhibit 3.1.18

CO_2 emissions grow slower than overall sector demand due to biofuels



Note: Numbers may not sum due to rounding.
Source: McKinsey Global Institute Global Energy Demand Model 2009

Removal of subsidies is the lowest-cost demand-abatement opportunity

Given that our projections show a potential mismatch between oil supply and demand and also an imbalance between diesel and gasoline in the refining sector, we reviewed the levers that could be pulled to reduce demand in each sector.

In the case of the light-vehicles sector, we have ranked several levers on the basis of their cost, and the least costly are opportunities to increase energy productivity. These measures include the removal of subsidies, particularly in Iran and Saudi Arabia, which we estimate could shave 4 QBTU off 2020 energy demand in the sector. There is also regulatory potential that would encourage the capture of investments in fuel economy that offer a positive payback; such regulations are today not present in countries such as India and the Middle East. Strengthening fuel-economy standards to capture energy productivity opportunities combined with removing fuel subsidies would provide a total of 8 QBTU of abatement. We should note that in our 2007 report we estimated an abatement opportunity of 13 QBTU; however, since that analysis, new regulations in several regions have been implemented, and the lead time to 2020 is shorter, leading to the revised opportunity estimate being about half.

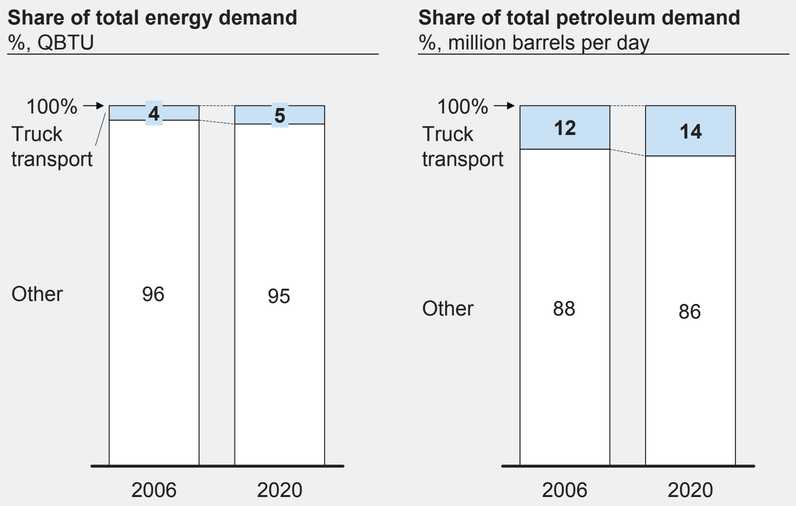
3.2. Trucks

OVERVIEW

In this section, we consider the energy demand of medium and heavy trucks, which correspond to classes 4 to 8 in the IEA's classification scheme (the IEA considers classes 1 to 3 as "light" trucks, and we include these in the light-duty vehicle section of this report). Truck transport accounted for 21.1 QBTU or 4.5 percent of 2006 global demand. However, because the sector's energy-demand growth will be more rapid than the increase in energy demand overall, its share of the total will rise to 4.9 percent—29.3 QBTU—of global demand in 2020. Although this is a small fraction of total energy demand, the truck-transport sector is important as a large source of petroleum demand, particularly diesel. Truck transport accounted for 12.5 percent of global petroleum demand and 45 percent of global diesel demand in 2006, and we project that these shares will grow to 13.7 percent of global petroleum demand and 46 percent of global diesel demand by 2020 (Exhibit 3.2.1).

Exhibit 3.2.1

Truck transport consumes some 4 percent of global energy and 12 percent of global petroleum – and its share will grow by 2020



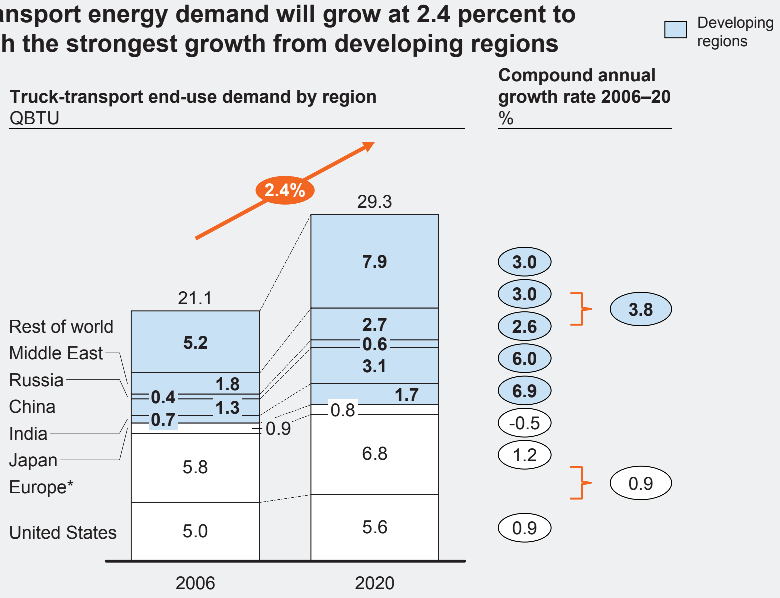
Source: IEA; McKinsey Global Institute Global Energy Demand Model 2009

Overall, truck-transport energy demand will grow at a rate of 2.4 percent a year with the strongest expansion in demand coming from developing regions. We project that demand from developing economies in this sector will grow at 3.8 percent a year to 2020 compared with a rate of 1.3 percent per year for developed regions (Exhibit 3.2.2).

Looking at the regional breakdown of demand, the United States and Europe and North Africa together currently consume 10.7 QBTU or 51 percent of global demand. Looking ahead, however, the story looks different with these three regions accounting for only 20 percent of the sector's energy-demand growth to 2020. At this point, these regions will consume 12.9 QBTU, but their share of total energy demand will have dropped to 43 percent. Instead, growth will shift to rapidly growing developing economies, most notably China and India, which will see their energy demand grow from 2.0 QBTU to 4.2 QBTU in 2020. By this time, these two economies alone will account for one-quarter of the sector's energy demand, reflecting not only their robust economic growth but also heavy investment in road infrastructure by their governments. We should note that, although truck-transport energy-demand growth tilts toward developing countries, this is much less the case than in other sectors (Exhibit 3.2.3).

Exhibit 3.2.2

Truck-transport energy demand will grow at 2.4 percent to 2020, with the strongest growth from developing regions



Note: Numbers may not sum due to rounding.

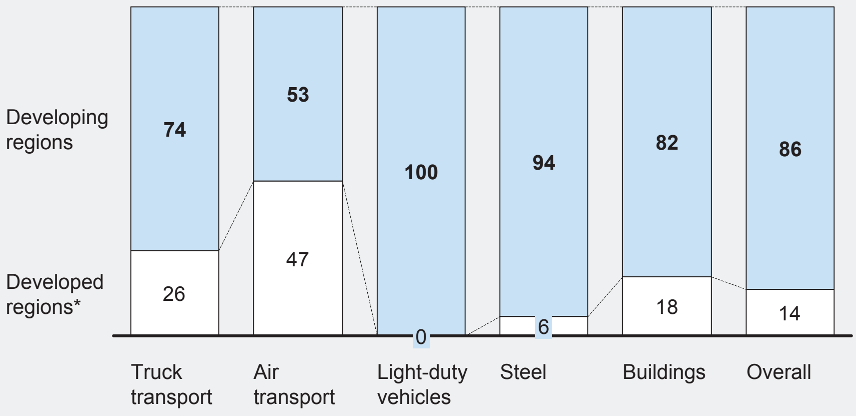
* Including Mediterranean Europe and North Africa and Baltic/Eastern Europe.

Source: IEA; McKinsey Global Institute Global Energy Demand Model 2009

Exhibit 3.2.3

Developing regions are not as dominant in energy-demand growth in trucks as in other sectors

% of overall demand growth by sector



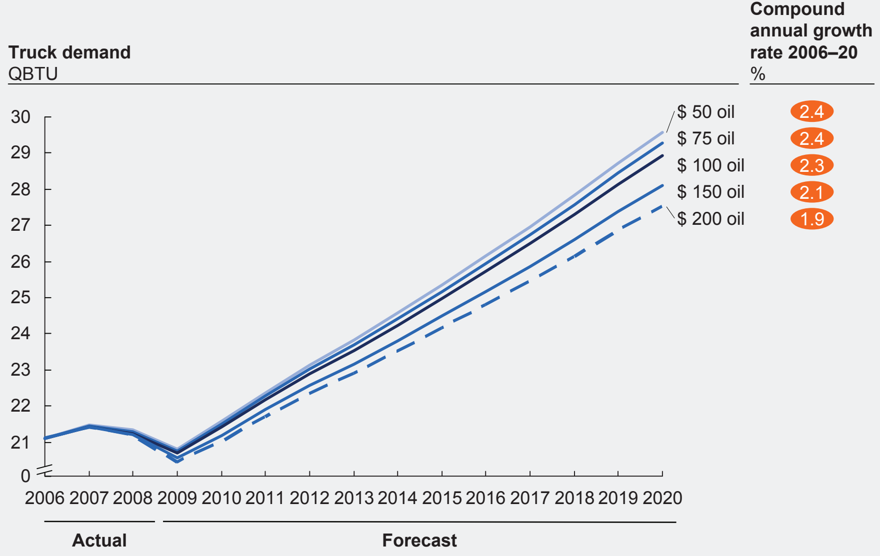
* Including Mediterranean Europe and North Africa, Baltic/Eastern Europe, United States, Canada, Japan, and South Korea.

Source: IEA; McKinsey Global Institute Global Energy Demand Model 2009

High energy prices will have some impact on truck-transport energy consumption in the period ahead. At a $50 a barrel oil price, energy-demand growth is 2.4 percent between 2006 and 2020; at $200 a barrel, energy-demand growth would shave back to 1.9 percent. We calculate this impact based on academic studies, which report a behavioral price elasticity of roughly half that of light-duty vehicles at around minus 0.1. While this is not extreme, a widening of diesel-gasoline prices in 2007 exacerbates the effect of prices. Overall, the price impact on truck energy demand is not as great as for light-duty vehicles because diesel-gas costs represent only a small portion of the cost of the total value chain, and it is difficult to reconfigure the fuel mix in response to oil prices, particularly in an uncertain price environment (Exhibit 3.2.4).

Exhibit 3.2.4

Higher diesel price scenarios depress truck-transport demand significantly

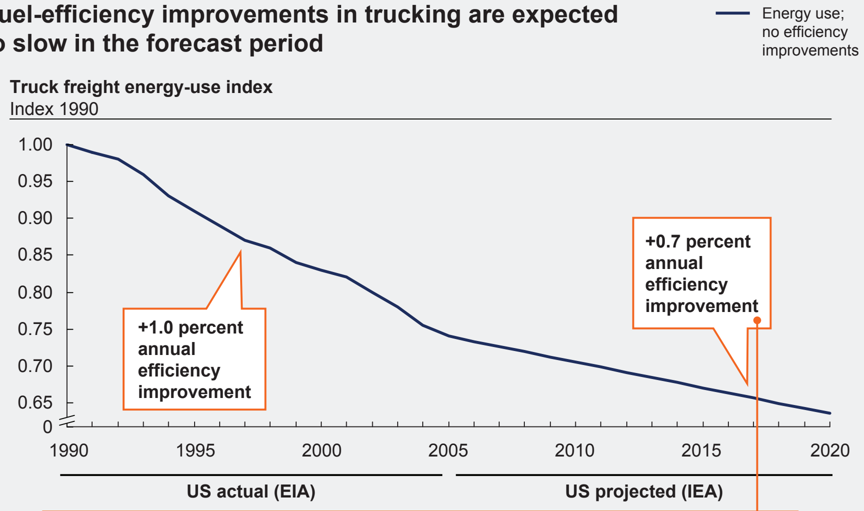


Source: IEA; McKinsey Global Institute Global Energy Demand Model 2009

Truck transport has historically been one of the fastest-growing sectors in terms of its energy consumption, which has been increasing at some 2.5 percent per year. In large part, this rapid growth in energy demand reflects the fact that the trucks sector, unlike light-duty vehicles, has limited efficiency-improvement opportunities for diesel engines (Exhibit 3.2.5). Moreover, efficiency improvements are likely to slow in the future as the focus of manufacturers turns toward meeting aggressive emissions standards for engines—and this can actually result in poorer efficiency. Finally, opportunities for switching to rail apply to only a small number of truck shipments (those that involve sufficiently large volumes and long distances), representing less than 4 percent of truck-transport volume in Europe, for instance.

Exhibit 3.2.5

Fuel-efficiency improvements in trucking are expected to slow in the forecast period



"For heavy trucks, my immediate view would be that efficiency opportunities are limited for the next eight years or so as meeting emissions regulations are OEMs' number one priority and this often reduces technical efficiency."

– McKinsey truck expert

Source: McKinsey Global Institute analysis

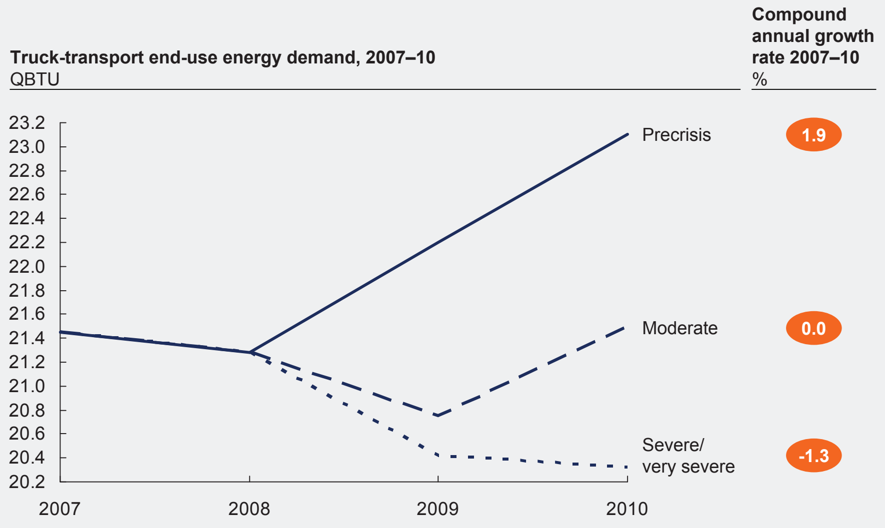
Although the scope for energy efficiency improvements is limited in the sector, there are nevertheless some levers available that could rein back energy-demand growth. As noted, switching to rail is a possibility, but the addressable market size is limited. The rail-transport market could expand through, for instance, the location of warehouses on railway lines, but the cost would be substantial. Other efficiency opportunities include adding trailers to trucks (determined by policy) and supply-chain shifts to improve VMT.

DEVELOPING COUNTRIES WILL DRIVE REBOUNDING ENERGY-DEMAND GROWTH WITH GLOBAL ECONOMIC RECOVERY

In the short term, energy-demand growth in truck transport will slow in our moderate case to 0.8 percent in 2008 and 2.5 percent in 2009 in response to the global economic slowdown, high energy prices in 2007, and the credit squeeze (Exhibit 3.2.6). In our severe scenario—implying a more severe downturn—energy demand would actually contract by 1.0 and 3.6 percent in 2008 and 2009 respectively. Truck-transport volumes actually slow to a greater extent than GDP as the sector has shown itself historically to be procyclical (see “MGI examines four levers in modeling truck-transport energy-demand growth”). In our very severe scenario—implying a severe downturn with a delayed recovery—energy demand would continue to contract in 2010 and 2011 at minus 0.1 percent per year.

Exhibit 3.2.6

Truck-transport energy demand will slow slightly in response to high energy prices in 2007 and the credit squeeze

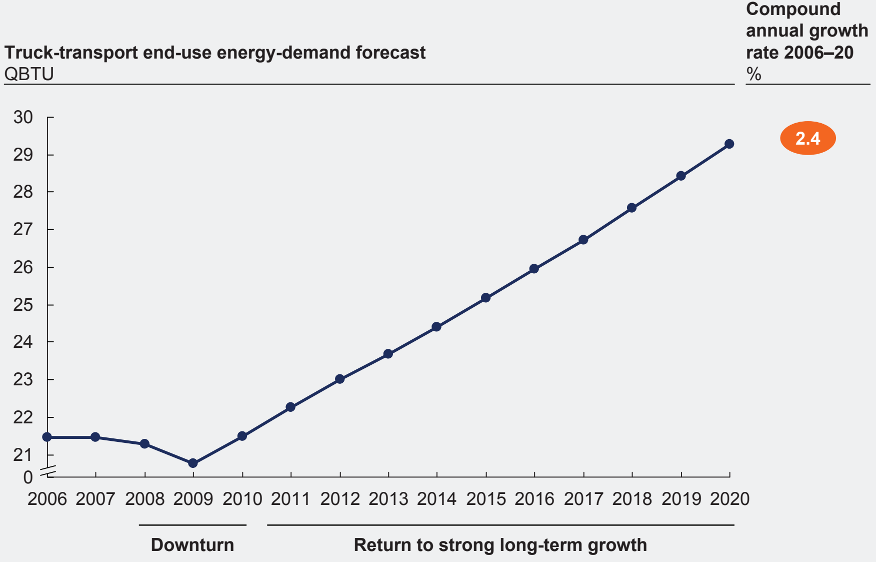


Source: McKinsey Global Institute Global Energy Demand Model 2009

In the longer term, strong growth in energy demand coming from truck transport will resume, driven by increasing energy consumption in developing regions. In our moderate case, energy demand will be growing at a pace of 2.9 percent a year by 1010, shading back somewhat to an annual 2.4 percent between 2011 and 2020 (Exhibit 3.2.7).

Exhibit 3.2.7

As the global economy recovers, energy-demand growth in trucks will rebound, reflecting strong fundamentals



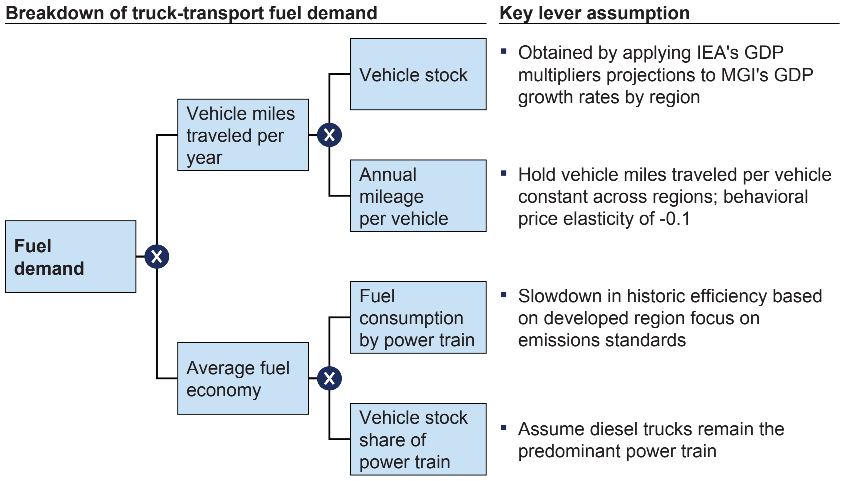
Source: McKinsey Global Institute Global Energy Demand Model 2009

MGI examines four levers in modeling truck-transport energy-demand growth

We base our methodology for projecting demand on estimating growth in the vehicle stock using our GDP-growth assumptions while holding constant three other levers—VMT, efficiency improvements, and fuel mix—contingent on prices and the current regulatory environment (Exhibit 3.2.8):

Exhibit 3.2.8

MGI examines four levers when modeling truck-transport energy-demand projections



- Obtained by applying IEA's GDP multipliers projections to MGI's GDP growth rates by region
- Hold vehicle miles traveled per vehicle constant across regions; behavioral price elasticity of -0.1
- Slowdown in historic efficiency based on developed region focus on emissions standards
- Assume diesel trucks remain the predominant power train

Source: McKinsey Global Institute analysis

- **Vehicle stock.** We take overall vehicle-stock growth rates and apply IEA GDP multipliers projections to our GDP growth rates by region.
- **VMT.** We hold VMT per vehicle constant across regions; VMT per vehicle drops if the projected retail diesel price rises in a given region due to a behavioral elasticity of minus 0.1.

- **Efficiency improvements.** We implement a slowdown in historic efficiency based on the focus on emissions standards in developed regions.

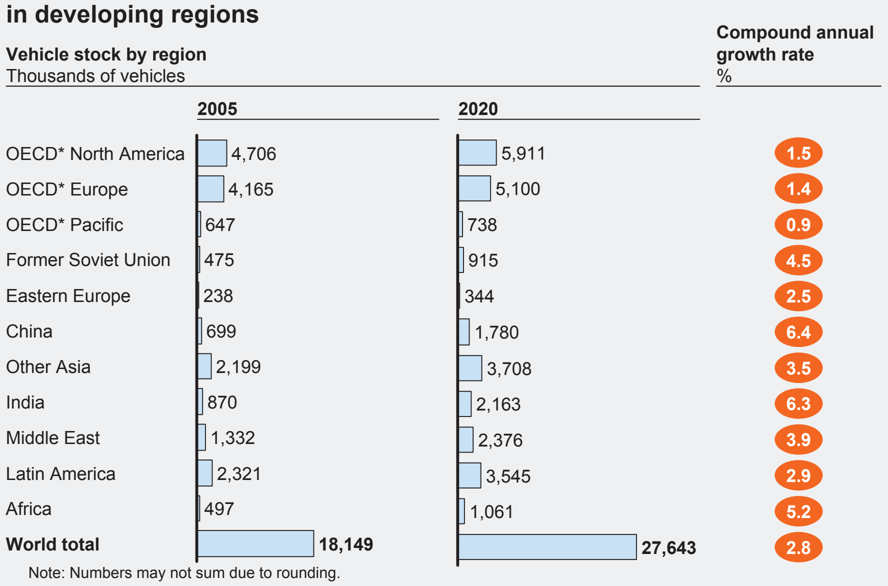
- **Fuel mix.** We assume diesel trucks remain the predominant power train.

Vehicle stock

We have modeled our vehicle stock assumption most intensively. The global truck fleet is projected to grow at 2.8 percent per annum—developing regions at 4.4 percent and developed regions at 1.3 percent. China and India experience the strongest annual growth with 6.4 and 6.3 percent, respectively, while Europe and Japan have the lowest rate of stock increase at 1.4 and 0.9 percent, respectively. The rate of increase in the United States is 2.1 percent (Exhibit 3.2.9).

Exhibit 3.2.9

The vehicle stock is expected to increase most rapidly in developing regions



Note: Numbers may not sum due to rounding.
* Organisation for Economic Co-operation and Development.
Source: McKinsey Global Institute Global Energy Demand Model 2009

Vehicle miles traveled

MGI's current base-year assumptions incorporate two VMT values—60,000 kilometers per year per vehicle for developed regions, and 50,000 kilometers a year per vehicle for developing regions. VMT is the transmission mechanism through which behavioral price elasticity operates. When pump prices rise, shippers react by reducing the amount they travel (i.e., through reconfiguring the supply chain so that the network is more distributed and minimizes the distance traveled). The best estimate of price elasticity that academic studies produce appears to be fairly low at about minus 0.1. The reason for this low elasticity is that reconfiguring the supply chain is both expensive and time-consuming. Especially in uncertain price environments, companies often decide not to react to price changes unless they appear to be structural.

Our moderate case for VMT per vehicle is flat between 2006 and 2020 across all countries assuming no change in energy prices. However, based on the change in energy prices we saw in 2007, VMT per vehicle actually declines by an average of 0.8 percent per annum from 2006 to 2010. The price effect is naturally greatest in regions that have witnessed the largest price increases. In the United States, for instance, VMT per vehicle decreases on average 0.9 percent per year from 2006 to 2010, but it declines by only 0.5 percent in Europe since taxes on diesel result in a smaller proportional price increase.

Efficiency improvements

Unlike light-duty vehicles, there are limited efficiency-improvement opportunities for diesel engines (Exhibit 3.2.10). In fact, as we have noted, efficiency improvements are likely to slow in the future. We project an annual improvement in energy efficiency in developed regions of 0.75 percent a year, slightly lower than the improvement of some 1.0 percent observed in the United States from 1990 to 2005, according to the EIA. Projected energy efficiency for developing regions is in line with this 1.0 percent annual improvement. However, the Middle East, which has little incentive to improve vehicle efficiency due to the abundance of petroleum, is an exception to this trend. The efficiency improvements in developing countries overall are much lower than the average 1.6 percent annual efficiency improvements in light-duty vehicles precipitated by stringent CAFE standards.

Exhibit 3.2.10

IEA data suggests that opportunities to improve the energy efficiency of heavy and medium trucks are limited

	Heavy-truck efficiency improvement Annual %	**Light-duty-vehicle efficiency improvement** Annual %
OECD North America	0.75	1.40
OECD Europe	0.75	2.40
OECD Pacific	0.75	2.00
Former Soviet Union	1.00	0.60
Eastern Europe	1.00	2.40
China	1.00	1.40
Other Asia	1.00	1.40
India	1.00	1.40
Middle East	0.00	0.00
Latin America	1.00	1.40
Africa	1.00	1.40

Source: IEA

Fuel mix

Fuel-mix shifts will be much smaller in truck transport than in other end-use sectors as it will continue to consume diesel almost exclusively. Growth in alternative power trains is not likely to be a significant factor. We currently project gasoline to continue accounting for only 0.1 percent of the truck stock, and we expect no share at all for hybrid vehicles. Although hybrid trucks are likely to become more common in the future, these alternative power trains will likely be smaller trucks that fall outside the IEA's 4 to 8 classification.

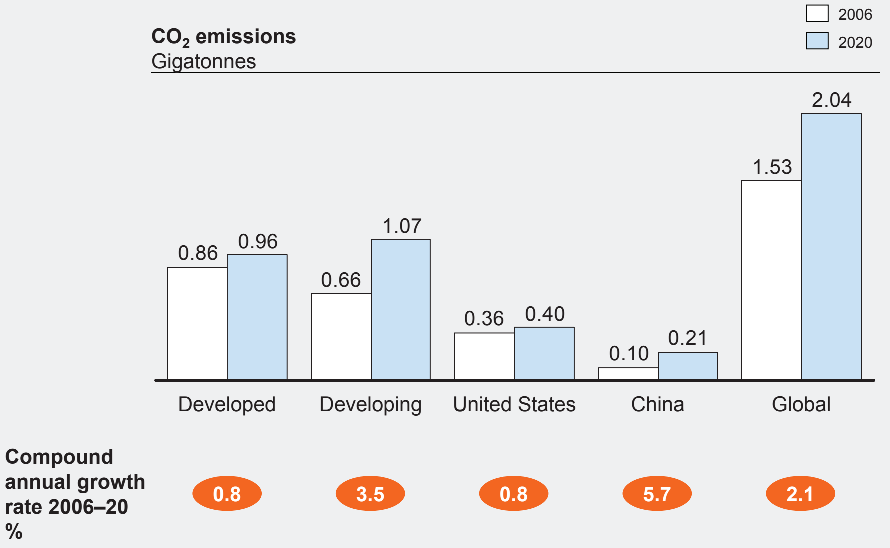
However, given that diesel may continue to be expensive relative to gasoline, it is possible that gasoline trucks may become more prevalent, especially on replacement of smaller-end medium trucks. The other major alternative is biodiesel, which could be a robust source of supply in periods of tension between supply and demand. We expect the trucks sector to use 1.0 million barrels per day of biodiesel (compared with the 3.8 million barrels per day of gasoline-equivalent biofuel expected to be used mostly as blendstock by 2020 in light-duty vehicles).

CO_2 EMISSIONS IN TRUCKS WILL GROW MORE STRONGLY THAN TOTAL EMISSIONS

The end-use CO_2 emissions of the truck-transport sector will grow strongly at a rate of 2.1 percent per annum, slightly faster than the 1.9 percent overall emissions growth rate that we project. From 1.5 gigatonnes in 2006, the truck sector's emissions will increase to 2.0 gigatonnes in 2020 and maintain a 6 percent overall share of emissions.[4] Truck-sector emissions in developing regions will grow at 3.5 percent per year compared with 0.8 percent per year for developed regions. China will see the most rapid growth in truck-sector emissions at 5.7 percent per year, accounting for 20 percent of the emissions growth in this sector between 2006 and 2020 (Exhibit 3.2.11).

Exhibit 3.2.11

Truck sector CO_2 emissions will increase strongly with China accounting for 20 percent of emissions growth to 2020



Source: IEA; Global Insight; McKinsey Global Institute Global Energy Demand Model 2009

MGI IDENTIFIES THREE POTENTIAL OPTIONS TO IMPROVE ENERGY PRODUCTIVITY IN TRUCKING

Boosting the energy productivity of truck transport is vital, given the sector's importance in global diesel and, more broadly, petroleum consumption; the strong growth of its diesel demand; and the fact that the sector faces challenging supply fundamentals. Our analysis identifies three broad opportunities that have the potential to increase the sector's energy productivity—switching from truck to rail transport; adding trailers to trucks; and reconfiguring supply chains.

- Switching from truck to rail transport. This intermodal opportunity is unlikely to be large. Using International Railroad Union (IRU) estimates of the split between road and rail shipping volumes and IEA estimates of rail and road shipping energy consumption, we estimate that rail is roughly twice as energy efficient as truck transport (Exhibit 3.2.12). This would imply that for every 1 percent of the heavy-truck volume shifting to rail, heavy trucks would reduce their energy consumption by 0.50 percent or some 0.06 million barrels per day. Thus, a reduction of 1 million barrels per day would require around a 15 percent shift from truck transport to rail. The problem is, as we have noted, that the address-

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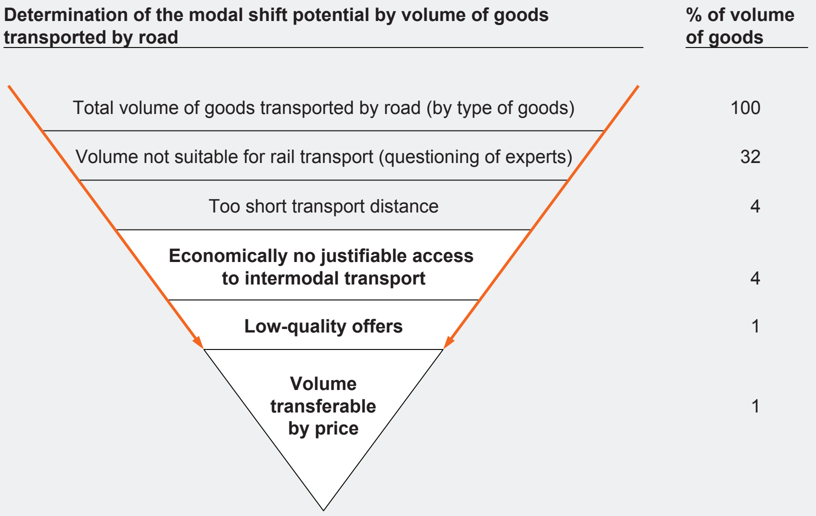
[4] In this report, we use tonnes, megatonnes, and gigatonnes, all metric figures.

able market size of truck shipments that can be shifted to rail is small. Based on a 2008 IRU study focused on Europe, an estimated 68 percent of trucking shipments are not of a sufficiently large volume to ship via rail, and an additional 28 percent involve distances that are too short to use rail.[5] Of the remaining 4 percent, some of the volume could be containerized in a way that would preclude any economic savings. That leaves only up to about 4 percent of shipments that could offer benefits from a shift to rail—implying an energy-savings opportunity of only 0.30 million barrels per day. MGI therefore expects the current trend toward road shipping to remain in place in the United States and in the EU25 (Exhibit 3.2.13). Neither do we anticipate that an intermodal shift is likely to be significant in developing economies (Exhibit 3.2.14).

Exhibit 3.2.12

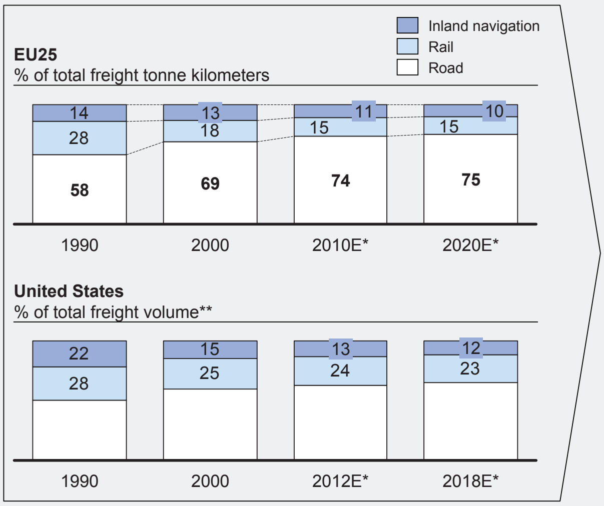
Road-to-rail shift has potential to increase energy productivity under the current transport infrastructure



Source: *The Influence of Road Tolls for Trucks on the Modal Split*; International Railroad Union; 2008

Exhibit 3.2.13

Past trends toward road transport are expected to continue in the United States and Europe



- **No significant shifts toward rail transport expected**
  - **$180 billion investment required until 2020 to shift more volume to rail in the United States**
  - **€145 billion investment required to make shifts toward rail more likely in the WEU**
- **Similar shifts within Japan**

* Estimated.
** Air and pipeline transport not included.
Source: Eurostat; Bundesamt für Gütertransport; American Trucking Association

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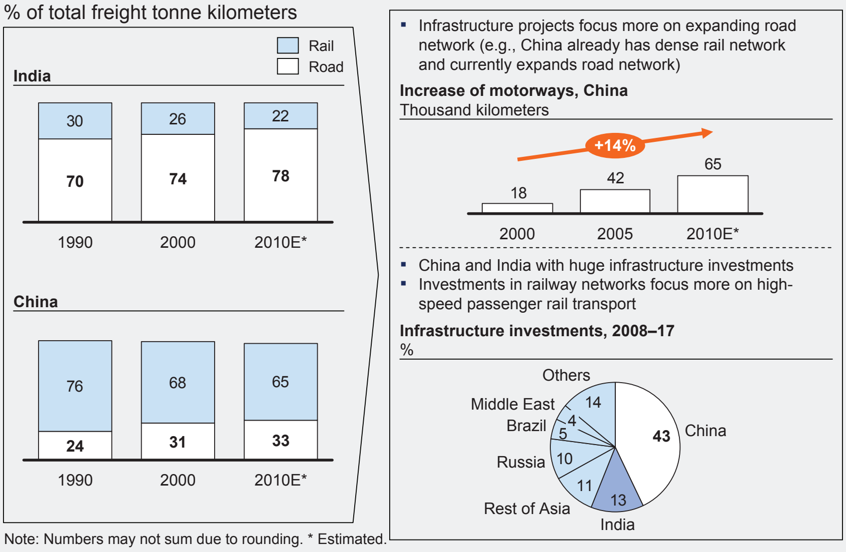
[5] *The Influence of Road Tolls for Trucks on the Modal Split*, IRU, 2008.

Exhibit 3.2.14

A modal shift from road to rail will not play an important role in emerging markets



- Infrastructure projects focus more on expanding road network (e.g., China already has dense rail network and currently expands road network)

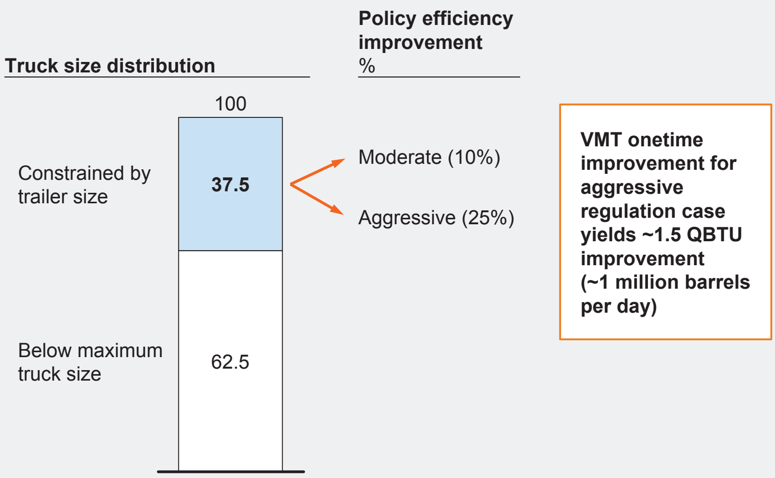
- China and India with huge infrastructure investments
- Investments in railway networks focus more on high-speed passenger rail transport

Note: Numbers may not sum due to rounding. * Estimated.
Source: BFAI; CLSA; ENAM; European Environmental Agency

- Adding trailers to trucks to increase average load. This lever for reducing truck-sector energy demand relies on policy as regulators set in the maximum size and number of truck trailers. Based on a US Vehicle Inventory survey in 2008, about 37.5 percent of heavy-truck trailers are constrained by size regulation in the United States (i.e., in a size class that would benefit from reconfiguration if requirements for truck sizes changed). Within this subset of heavy trucks, the US Department of Transport has estimated that a 10 percent improvement in VMT would be possible with a “moderate” regulation change and a 25 percent improvement achievable with “aggressive” regulation change (Exhibit 3.2.15). These improvements suggest an energy-demand reduction opportunity of around 0.5 million barrels per day in a moderate regulatory-change scenario, and some 1.0 million barrels per day in an aggressive case.

Exhibit 3.2.15

The energy efficiency gained from changing regulations on truck trailers has been estimated at 0.5 to 1.0 barrels per day



VMT onetime improvement for aggressive regulation case yields ~1.5 QBTU improvement (~1 million barrels per day)

Source: US Department of Transportation, 2007

- Reconfiguring supply-chains. Shifting the supply chain to minimize truck-transport distances could also reduce energy demand in the future. However, such reconfigurations are costly and require several years to implement. In an era of uncertain energy prices—over the past year alone, the oil price has ranged between above $150 to as low as $30—it is often difficult to justify investing in such a capital-intensive project without assured gains. For many companies, the optimal strategy for most is wait and see. In the near term, therefore, it is unlikely that this lever will deliver substantial demand reduction. In the future, however, if energy-price changes become perceived as permanent (e.g., there are several years of sustained prices, possibly precipitated by supply tightness during a demand recovery), supply-chain shifts would become more viable. If our projection of a resumption in oil price inflation between 2010 and 2012 turns out to be true, and given that most companies wait at least three years before considering an oil price increase as permanent, this would push a major decision to reconfigure a company's network out to at least 2013 to 2015. Taking into account normal speeds of adoption (and the entire market will not move simultaneously) and capital-stock turnover, we do not expect that network reconfiguration could have a major impact by 2020, even if high oil prices return.

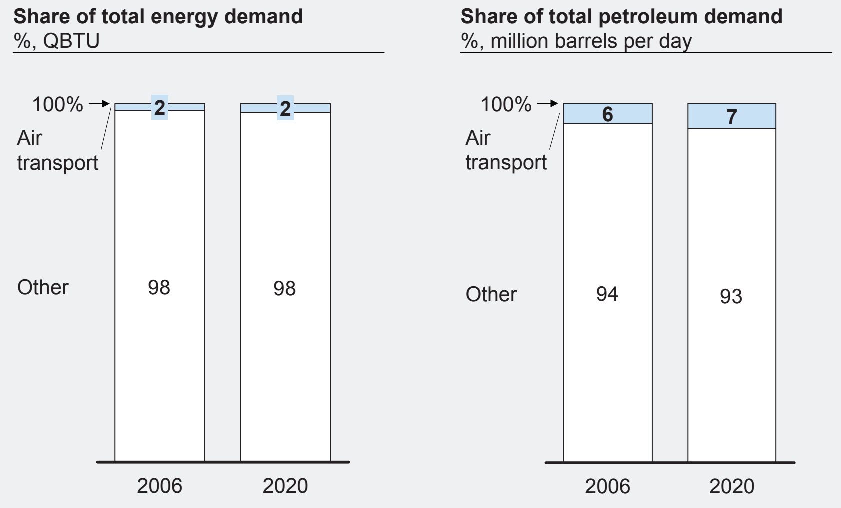
3.3. Air transport

OVERVIEW

Air transport accounted for 9.5 QBTU or 2.0 percent of global demand in 2006 but, as the fastest-growing energy end-use sector, will see its energy demand grow to 15.0 QBTU or 2.4 percent of global demand in 2020. While air transport accounts for a very small share of the world's total energy demand, it nevertheless bears analysis because this sector is a rapidly growing source of demand for petroleum. In 2006, the sector accounted for 5.7 percent of global petroleum demand, and we project that this share will rise to 7.1 percent in 2020 (Exhibit 3.3.1).

Exhibit 3.3.1

Air transport consumes 2 percent of global energy and 6 percent of global petroleum, and this share will increase to 2020



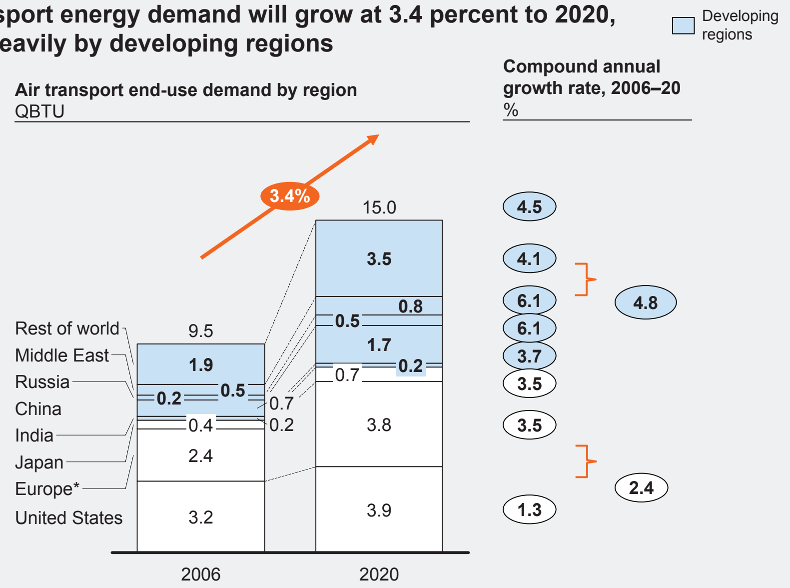
Source: IEA; McKinsey Global Institute Global Energy Demand Model 2009

Overall, air-transport energy demand will grow at 3.4 percent annually in the period to 2020, driven by both developing and developed regions. We project energy-demand growth from developing regions in air transport at 4.8 percent, considerably higher than the 2.4 percent we project for developed regions. China's energy demand in this sector will grow from a mere 0.7 QBTU today to 1.6 QBTU in 2020 as airlines add routes in response to rising prosperity among China's consumers that will boost air-travel volumes. Nevertheless, because today developing economies still represent a disproportionately small share of global air transport, even the rapid growth of an economy such as China does not act as the predominant driver of energy-demand growth in the sector overall, as it does in other end-use sectors.

The United States, Europe, and North Africa currently represent the vast majority of air-transport energy demand, consuming 5.6 QBTU or 64 percent of the global total in this sector. These three regions will also account for 40 percent of energy-demand growth in air transport to 2020, hitting 7.7 QBTU in demand at that stage and accounting for an increased 56 percent of global demand in this sector (Exhibit 3.3.2).

Exhibit 3.3.2

Air-transport energy demand will grow at 3.4 percent to 2020, driven heavily by developing regions



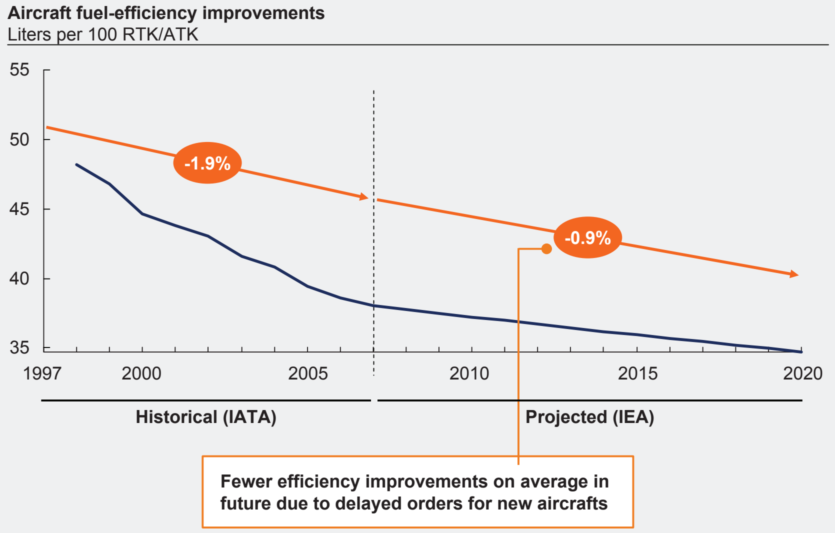
Note: Numbers may not sum due to rounding.
* Including Mediterranean Europe and North Africa and Baltic/Eastern Europe.
Source: IEA; McKinsey Global Institute Global Energy Demand Model 2009

Air transport has historically been one of the fastest-growing sectors in terms of energy consumption with a rate of some 3.2 percent per year. The main reason for this rapid growth is the fact that the industry has little scope to improve energy efficiency. There are a number of reasons for this. First, stock turnover is relatively slow, which limits the speed of annual efficiency improvements. Second, the sector has already captured most of the potential to boost fuel efficiency through, for instance, improving utilization. Indeed, annual efficiency improvements may actually slow as airlines delay orders of new aircraft in the face of the global financial and credit squeeze, decelerating stock turnover even further (Exhibit 3.3.3).

If high energy prices were to recover after their very sharp recent fall, they would have a significant impact on air-transport energy consumption. At a $50 per barrel oil price, we project energy-demand growth at 3.4 percent between 2006 and 2020; at $200 oil, we project 2.6 percent. While significant, this reaction may not be as large as expected since the oil price represents only part of an airline's costs and travelers may not feel its impact in full. Demand is often very inelastic on routes considered as "nonluxury." Overall, the elasticity of fuel price to air traffic is an estimated minus 0.2, calculated using a cross section of airlines from 1995 to 2005, controlling for airline ticket prices and economic growth. As oil prices increase, air traffic decreases as travelers purchase fewer airline tickets on luxury segments and airlines eliminate marginal routes. The decrease in demand projected is highly dependent on the consumer response to higher prices, which may behave in a nonlinear fashion in an environment with sustained oil prices as high as $200 a barrel (Exhibit 3.3.4).

Exhibit 3.3.3

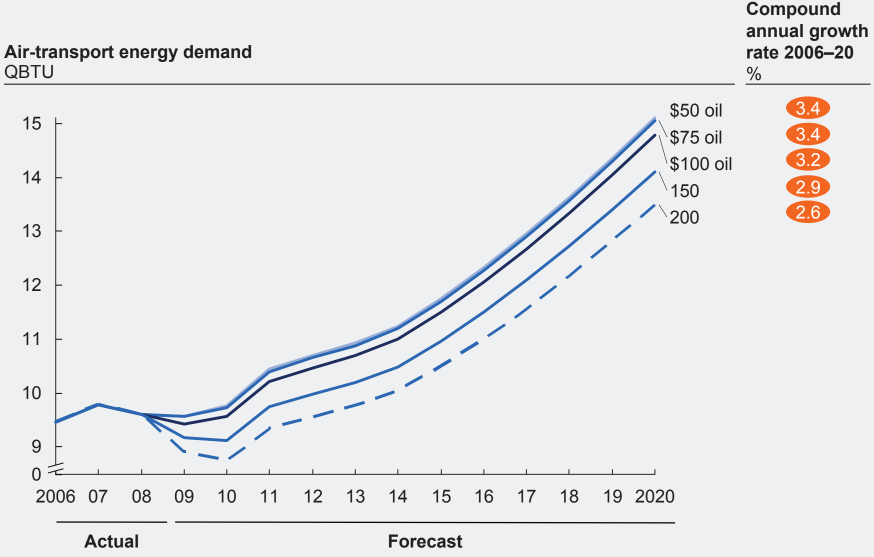
Fuel-efficiency improvements in air transport are expected to slow in the forecast period



Source: McKinsey Global Institute analysis

Exhibit 3.3.4

Higher jet-fuel price scenarios depress air-transport energy demand significantly



Source: IEA; McKinsey Global Institute Global Energy Demand Model 2009

While the fuel price is important to air-transport energy consumption, economic growth can have just as large an impact in a given year. In fact, a 1 percent decrease in GDP may precipitate a 3 percent contraction in air-transport energy demand in a particular year, the counterpart being that demand would rebound sharply when GDP later recovers.

Fuel mix

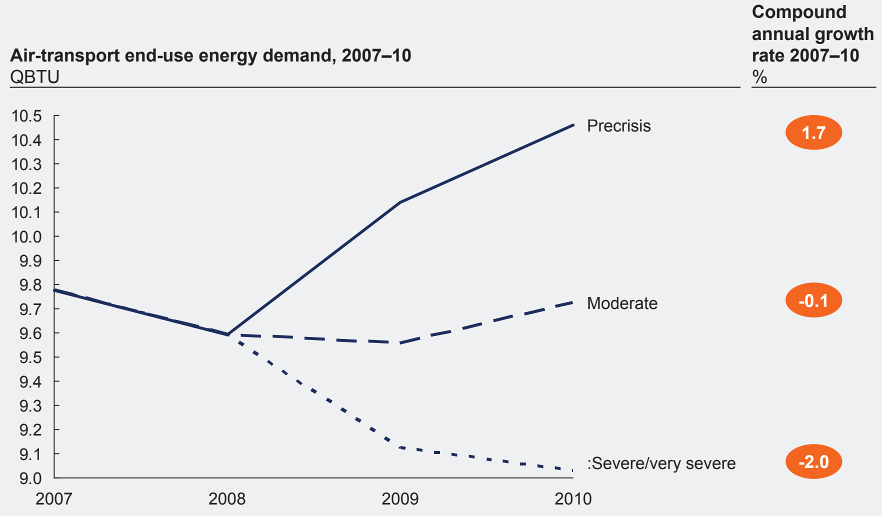
The fuel mix of the air transport will shift little as jet fuel accounts for 100 percent of energy consumption.

MGI'S MODERATE CASE SEES AIR-TRANSPORT ENERGY DEMAND REBOUNDING IN 2010

In response to the global downturn in the short term, air-transport energy-demand growth will slow to a projected 1.9 percent in 2008 and 0.4 percent in 2009. In our severe case, assuming severe downturn, energy demand would shrink by 1.9 percent in 2008 and by 5.2 percent in 2009. In our very severe scenario, assuming a severe downturn with a delayed recovery, energy demand would continue to contract in 2010 by 1.1 percent and increase only in 2011 by 2.3 percent. Air-transport volume slows down to a much greater extent than GDP, as the sector has shown itself historically to be "procyclical," declining faster than GDP during recessions. This is largely due to two factors: route destruction as the airline industry responds to recessions, and a reduction in the amount consumers travel on luxury air segments (Exhibit 3.3.5).

Exhibit 3.3.5

Air-transport energy-demand growth will slow slightly in the short term, due to high 2007 energy prices and GDP downturn

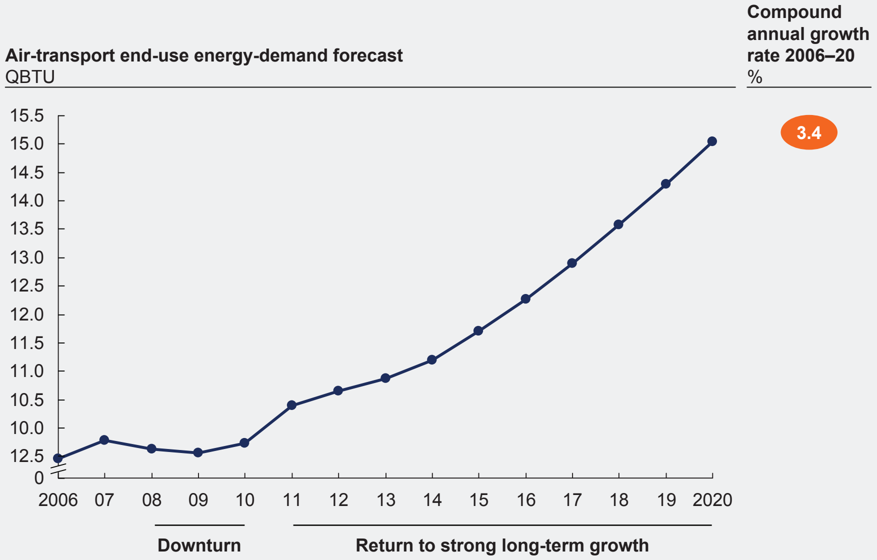


Source: McKinsey Global Institute Global Energy Demand Model 2009

In the long term, air-transport energy demand will return to its strong historical growth, led by developing regions. Nascent airlines will rapidly create new routes in regions such as Russia and China, increasing demand at an even faster pace than economic growth would appear to imply. In 2010, moderate-case demand growth will rebound at a pace of 1.8 percent and continue to grow 3.8 percent per year between 2011 and 2020. In the case of a prolonged, severe downturn, this rebound would be delayed. In this scenario, energy demand would decline at a rate of 1.1 percent in 2010 but would then jump by 6.7 percent the following year and continue to grow strongly at 3.7 percent annually thereafter. Net of route destruction or creation, air-transport demand growth will roughly track GDP growth at a regional level on average (Exhibit 3.3.6).

Exhibit 3.3.6

As GDP recovers, air-transport energy demand will rebound on strong fundamentals



Source: McKinsey Global Institute Global Energy Demand Model 2009

Forecasting air traffic

Based on the *Boeing Current Market Outlook 2007*, we expect the volume of air travel to grow by 5.1 percent a year between 2006 and 2020 from 4,000 to 8,000 RPKs. This is a downward revision from the 5.4 percent growth estimated on the basis of the *Boeing Current Market Outlook 2006*. This revision takes account of near-term global downturn but is still very much in line with the historic 5.2 percent growth a year observed between 1985 and 2000.

From 2006 to 2020, air traffic in developed regions grows by an average of 3.5 percent and by 7.4 percent on average in developing regions. China and India will see the highest projected growth at 8.1 and 9.6 percent, respectively. It is interesting that several developed regions still could experience relatively high growth in the future. Air traffic in Europe is projected to grow 4.2 percent per year during this period, buoyed by strong growth in the emerging Eastern European market. Likewise, air traffic in Japan is projected to grow 3.9 percent per year due to its proximity to rapidly expanding Asian neighbors. In comparison, US air traffic is projected to grow by only 2.5 percent per year during this period (Exhibit 3.3.7).

Rapid growth in demand for airplane fuel creates new logistical challenges for the refining industry. A standard refining configuration generally produces less than a 10 percent share of jet fuel today, although strong continued growth of air-transport demand will likely see several regions exceed this proportion. Ensuring that there is sufficient refining capacity to serve jet-fuel demand is most pressing in developed regions with large established airline markets such as the United States and Europe, where airlines represent 14.9 and 13.5 percent, respectively, of total petroleum demand in 2020.

Exhibit 3.3.7

Air travel will grow by between 4.5 and 9.1 percent to 2020, with the strongest expansion in China and India

%

Boeing air-travel growth forecasts, 2003–20		Adjusted* MGI growth forecasts		
Region	CAGR**	Region	CAGR**	Average annual GDP growth multipliers
Africa	5.8	▪ South/East	5.5	1.46
		▪ West Africa	6.3	1.39
Central America	5.0	▪ Mexico	4.9	1.21
		▪ Venezuela	5.2	1.48
China	8.1	▪ China	8.1	1.19
Former Soviet Union	5.1	▪ Eastern Europe	4.3	1.45
		▪ Black Sea/Caspian	7.4	3.38
		▪ Russia	5.7	1.93
Europe	4.2	▪ Mediterranean/North Africa	4.3	1.91
		▪ Northwest Europe	4.2	1.21
Middle East	6.8	▪ Middle East	6.8	2.16
North America	2.8	▪ Canada	4.0	1.29
		▪ United States	2.5	2.09
Northeast Asia	5.7	▪ Japan	5.3	1.89
		▪ South Korea	7.9	1.23
South America	8.0	▪ South America Atlantic	7.9	1.11
		▪ South America Pacific	8.7	1.39
Southeast Asia	5.2	▪ Southeast Asia/Australia	5.2	1.22
Southwest Asia	9.6	▪ India	9.6	1.20
Global	**5.1**			**1.65**

* Intraregional growth rates are adjusted to intraregional GDP growth forecasts.
** Compound annual growth rate.
Source: *Boeing Current Market Outlook, 2007*; McKinsey Global Institute analysis

Efficiency improvements

As we have noted, air-transport energy demand has tended to grow rapidly because of limited efficiency improvements. Going forward, we project that the sector will post energy efficiency improvements of 0.9 percent, somewhat weaker than the historical pace of 1.3 percent observed between 1995 and 2003. This is due to even slower stock turnover because of the impact of the current financial and capital squeeze on airlines.

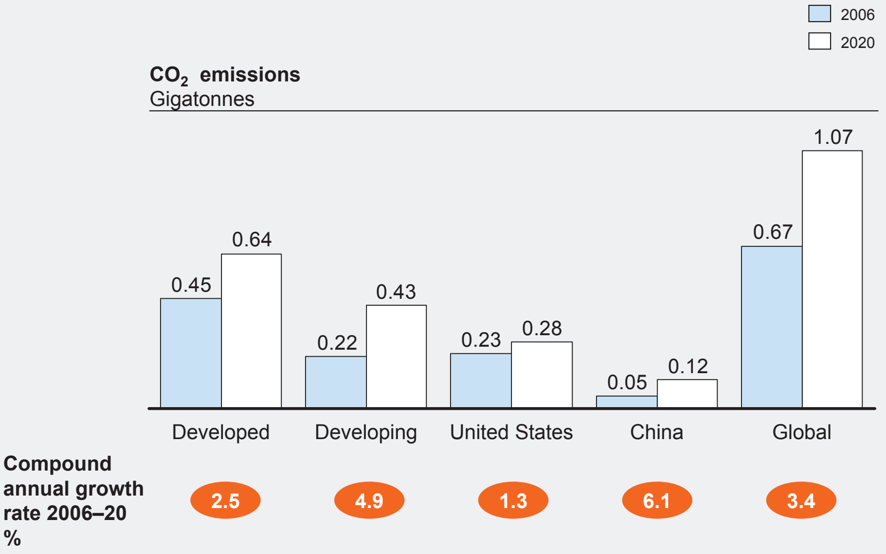
DEVELOPED AND DEVELOPING COUNTRIES WILL BE BROADLY EQUAL SOURCES OF CO_2 EMISSIONS

Air transport remains a small but fast-growing source of CO_2 emissions, accounting for 0.7 gigatonnes or 2.6 percent of total emissions in 2006. In the period to 2020, the sector's emissions will grow at a projected 3.4 percent a year, in line with increasing overall energy demand, due roughly equally to developed and developing economies. At the end of the period, the sector's emissions will have grown to 1.1 gigatonnes or 3.1 percent of total emissions.

Developing regions will see their emissions grow at 4.9 percent a year to 2020, nearly twice as fast as the 2.5 percent we project in developed regions. However, given the concentration of air transport in developed economies, growth in emissions from these regions is roughly equivalent to those from developing economies, despite the fact that the latter's emissions are increasing at a greater annual rate. China's emissions, which will grow at a projected 6.1 percent per year, will see its emissions more than double from 51 million tonnes in 2006 to 119 tonnes in 2020—accounting for 17 percent of global air-transport emissions growth. Europe and North Africa emissions, buoyed by an emerging Eastern European market, will grow at 3.5 percent per year from 167 million tonnes in 2006 to 273 million tonnes in 2020, accounting for 27 percent of global emissions growth. The United States—the single-largest emitter in air transport today—will see much slower growth in its emissions of 1.3 percent per year between 2006 and 2020, increasing from 229 million tonnes to 276 million tonnes and representing only 12 percent of global emissions growth (Exhibit 3.3.8).

Exhibit 3.3.8

Air-transport CO_2 emissions will increase at 3.4 percent per annum



Source: IEA; MEI; Global Insight; McKinsey Global Institute Global Energy Demand Model 2009

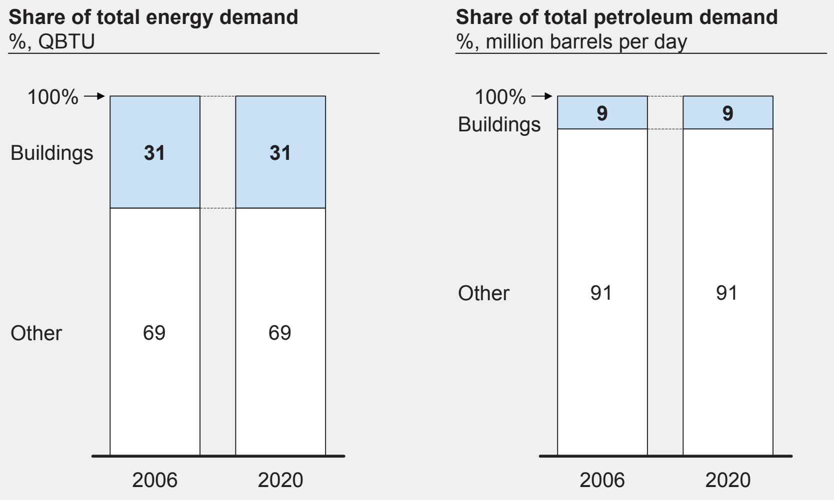
3.4. Buildings

OVERVIEW

The buildings sector, comprising residential and commercial buildings, represented 31 percent of global end-use energy demand in 2006 (146 QBTU)—making it the single-largest energy-consuming sector—and 9 percent of global petroleum demand (eight million barrels per day). MGI projects that these shares will remain steady at 31 percent of energy demand (194 QBTU) and 9 percent of petroleum demand (ten million barrels per day) by 2020 (Exhibit 3.4.1).

Exhibit 3.4.1

Buildings consume some 31 percent of global energy and 9 percent of global petroleum – and will maintain those shares by 2020



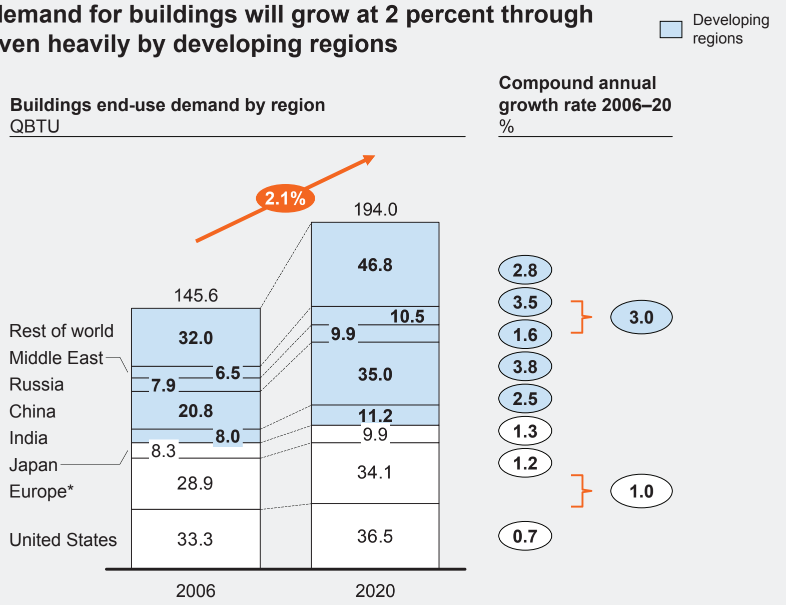
Source: IEA; McKinsey Global Institute Global Energy Demand Model 2009

The continued strength of energy-demand growth in developing regions will drive the overall growth rate of 2.0 percent per annum. On average, developing economies will see their energy demand grow by 3.0 percent, while the growth rate in developed regions will be only 0.4 percent.

Looking at energy demand in different regions, we find that the United States and Europe and North Africa currently account for the majority of buildings sector energy demand at 63.3 QBTU or 41 percent of the global total. When we look at growth rates in energy demand, however, it is a different story with these regions representing only 9 percent of global growth to 2020 when their energy demand will stand at 67.5 QBTU or 34 percent of global demand. China alone will account for 35 percent of global energy-demand growth in the sector, increasing from 24.4 QBTU to 40.7 QBTU in 2020. Strong continuing urbanization, robust commercial development in major cities, and a growing middle class that will live and work in larger spaces will drive China's energy demand (Exhibit 3.4.2).

Exhibit 3.4.2

Energy demand for buildings will grow at 2 percent through 2020, driven heavily by developing regions



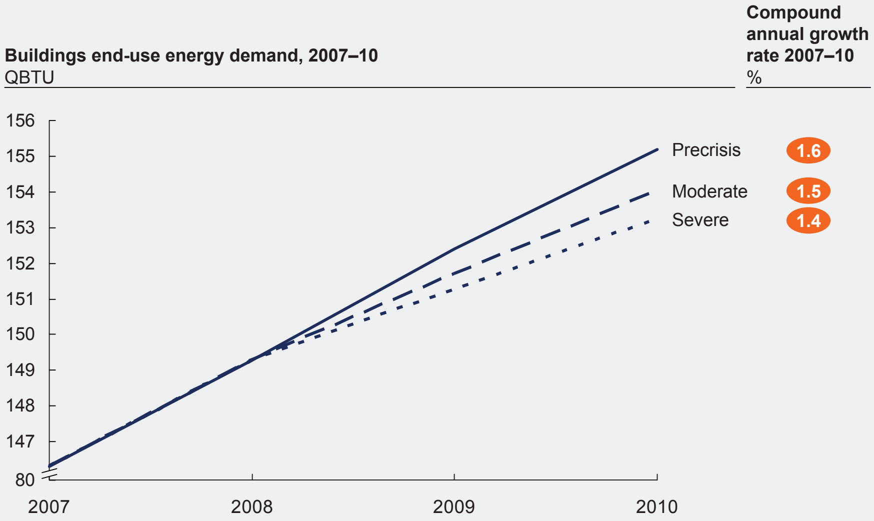
Note: Numbers may not sum due to rounding. * Including Mediterranean Europe and North Africa and Baltic/Eastern Europe.
Source: IEA; McKinsey Global Institute Global Energy Demand Model 2009

The 2.0 percent growth in energy demand we now project for the sector to 2020 is somewhat lower than the 2.2 percent we had forecast in 2007 due to the economic downturn and tightened energy efficiency regulations in developed regions (Exhibit 3.4.3). However, the response to weakening GDP is less marked in this sector than in others—because consumers do not respond particularly dramatically to swings in GDP—and will be short term. In the long run, energy-demand growth will return to predownturn levels (Exhibit 3.4.4).

Should the oil supply–demand balance become tight again, the buildings sector could help relieve pressure by substituting liquid petroleum gas (LPG) and kerosene, which is commonly used in buildings in regions including India and Japan, with natural gas. However, this switch would require a change in infrastructure; many residential and commercial users are generally isolated, low-volume users who do not have access to natural gas and/or electricity. As illustration, some 1.6 QBTU (0.9 million barrels per day) of LPG and kerosene consumption is in regions that are self-sufficient in natural gas.

Exhibit 3.4.3

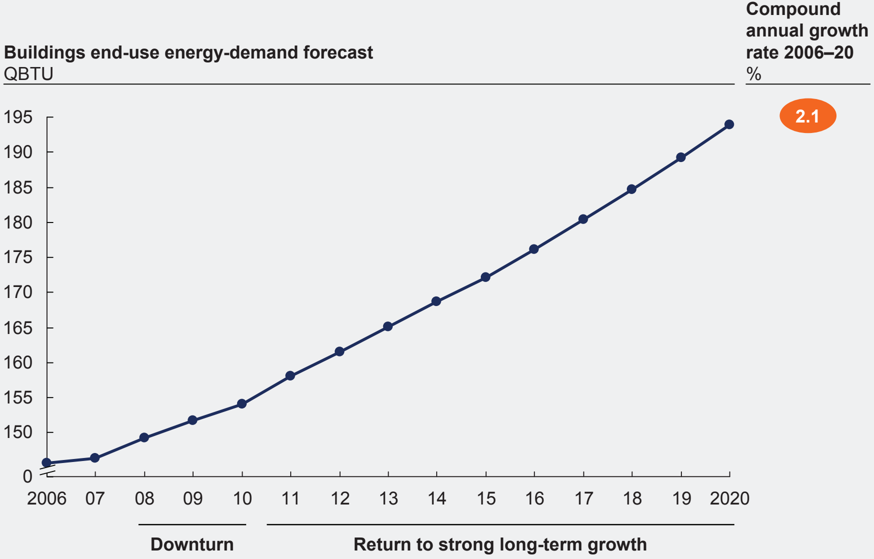
Buildings energy demand will slow slightly in the short term, reflecting high 2007 prices and the credit crunch



Source: McKinsey Global Institute Global Energy Demand Model 2009

Exhibit 3.4.4

Energy demand from buildings will rebound on strong fundamentals as the global economy recovers



Source: McKinsey Global Institute Global Energy Demand Model 2009

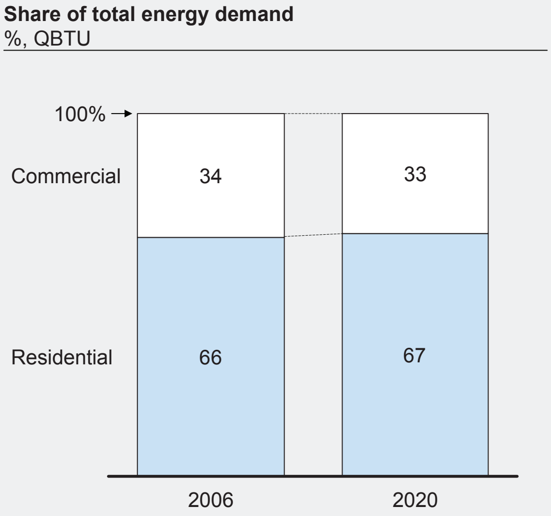
High energy prices will have very little impact on buildings sector energy consumption. At a $50 per barrel oil price, energy-demand growth is 2.1 percent between 2006 and 2020 and declines only marginally to 2.0 percent even at $200 oil. The reason for this anemic response to price is that oil represents only a small percentage of the sector's total energy consumption. Moreover, price has a minimal impact on end-user prices for electricity and natural gas due to the fact that taxes and subsidies insulate the market from the market price and to the fact that there are other fuels in the dispatch curve for electricity. In addition, a variety of market imperfections are in play that mitigate against a behavioral response from consumers; these include principal/agent problems between renters and owners as well as difficulties in measuring energy savings. This means that consumers will make energy efficiency investments only in buildings that offer very high returns.

A WEAK CONSUMER RESPONSE TO GDP WILL MUTE THE SHORT-TERM DOWNTURN IN BUILDINGS SECTOR ENERGY DEMAND

Residential buildings will account for 66 percent of the total sector's energy demand in 2020 compared with 32 percent for commercial buildings. Between 2006 and 2020, residential buildings energy demand will grow by 2.1 percent, accounting for 67 percent of total demand growth in this period compared with 33 percent for commercial buildings (Exhibit 3.4.5).

Exhibit 3.4.5

The residential segment accounts for around 70 percent of overall buildings energy demand



Source: IEA; McKinsey Global Institute Global Energy Demand Model 2009

In the short term, we expect the GDP slowdown to rein back the overall sector's energy-demand growth to 1.6 percent in 2008 and 0.4 percent in 2009 as the development of new buildings (both residential and commercial) decelerates. Unlike other industries that have inventory or durable-goods effects, buildings sector energy demand will not fluctuate more than overall economic growth because of the limited consumer response to GDP fluctuations. While overall energy demand grows at 1.9 percent from 2007 to 2009, buildings sector energy demand will also grow 3.7 percent.

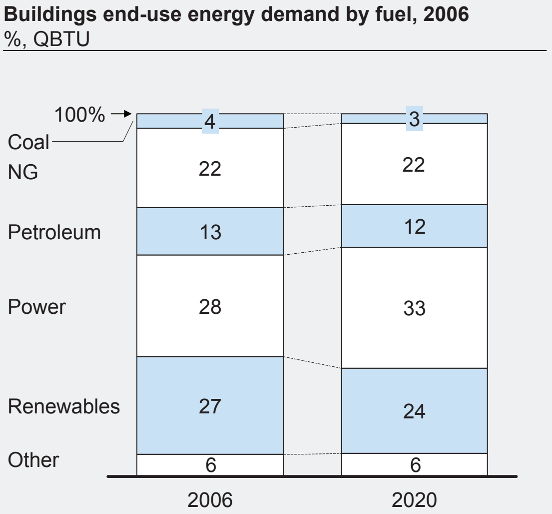
As the global economy rebounds, so will the sector's energy-demand growth. In 2010, as the downturn lifts in our moderate case, buildings sector demand will grow at 1.5 percent and thereafter at 2.3 percent to 2020.

THE FUEL MIX WILL SHIFT MORE DRAMATICALLY IN BUILDINGS THAN IN OTHER SECTORS

As developing regions shift away from traditional renewables such as wood and manure to power, there will be a more dramatic shift in the sector's fuel mix than we will witness in other end-use sectors. Power's share of energy demand will increase from 28 percent in 2006 to 33 percent in 2020, while traditional renewables will drop from 27 to 24 percent. The shares of other fuels such as coal, natural gas, and petroleum will change only marginally (Exhibit 3.4.6).

Exhibit 3.4.6

The fuel mix will shift from renewables to power as emerging economies develop



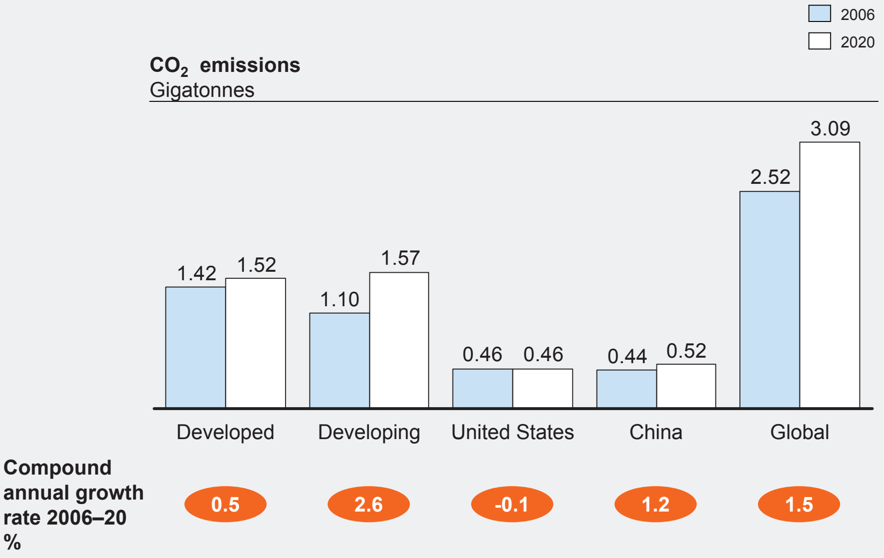
Source: McKinsey Global Institute Global Energy Demand Model 2009

BUILDINGS SECTOR CO_2 EMISSIONS WILL GROW MORE SLOWLY THAN GLOBAL EMISSIONS

The buildings sector's end-use CO_2 emissions will grow modestly from 2.5 to 3.1 gigatonnes from 2006 to 2020, so that the sector's share of global emissions falls slightly from 10 to 9 percent. Overall, emissions in the buildings sector grow at 1.5 percent per annum, somewhat slower than the 1.9 percent global projected growth rate (Exhibit 3.4.7).

Exhibit 3.4.7

CO_2 emissions from the building sector will increase



Source: IEA; Global Insight; McKinsey Global Institute Global Energy Demand Model 2009

Residential buildings represent about 72 percent of 2020 emissions at 2.2 gigatonnes and almost all of the growth in buildings emissions with an annual rate of 2.0 percent. Commercial buildings, which will represent the other 28 percent of the sector's emissions in 2020 with 0.9 gigatonnes, will see very slight growth of only 0.3 percent per year.

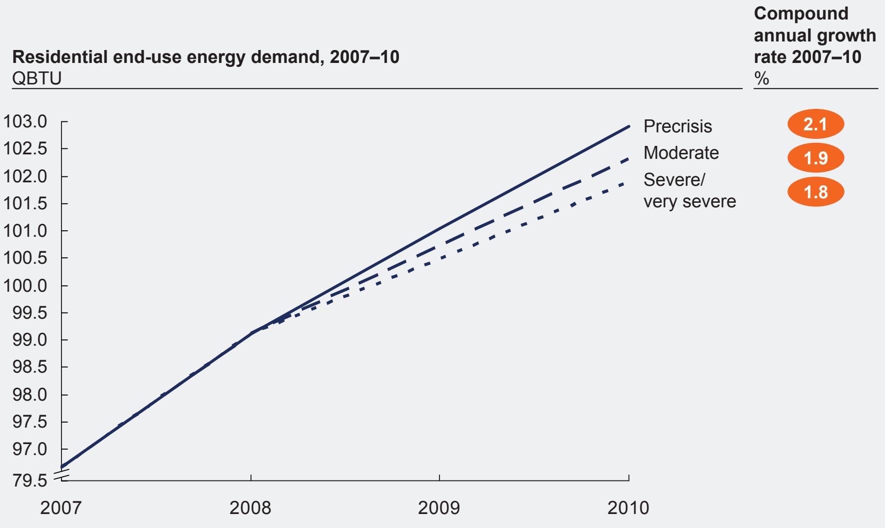
In 2006, developing regions represented 44 percent of buildings sector emissions, but their share will increase to 51 percent in 2020 as emissions grow at 2.6 percent per year compared with only 0.5 percent per year for developed regions. China will be the greatest source of buildings sector emissions growth with emissions increasing at 2.8 percent per year—accounting for 15 percent of the sector's total emissions growth between 2006 and 2020.

RESIDENTIAL

Residential buildings used 97 QBTU of energy in 2006, representing 21 percent of overall global energy demand, and this share will remain the same in 2020. Residential energy demand will weaken slightly in the short term due to the global economic slowdown (Exhibit 3.4.8). However, as the global economy recovers, there will be a rebound in the energy-demand growth from residential buildings to a rate of 2.1 percent between 2006 and 2020, which will match the rate of overall buildings of 2.1 percent per annum (Exhibit 3.4.9). China will be the main engine of residential energy-demand growth with its energy demand projected to increase 15 QBTU to 24 QBTU. The key factors driving increasing energy consumption in the residential sector are the expansion of floor space, the penetration of appliances, the fuel mix, and increased energy efficiency.

Exhibit 3.4.8

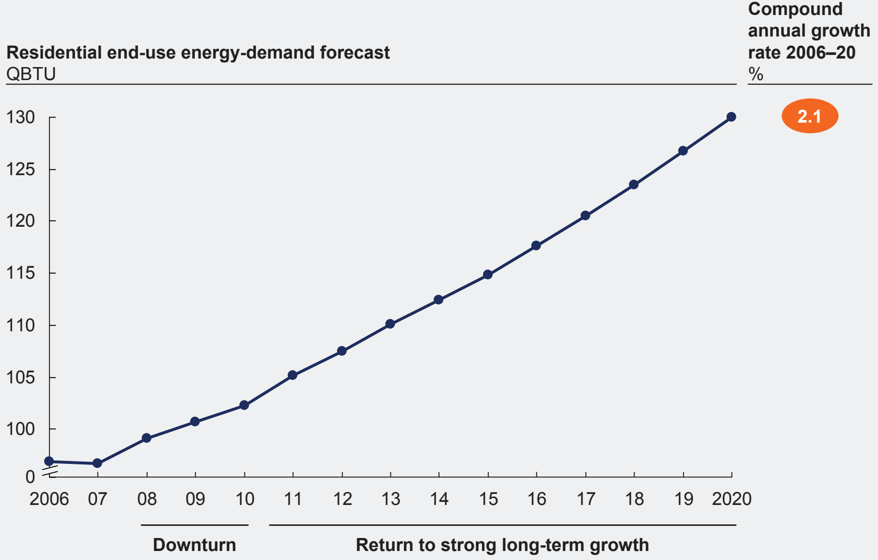
Residential energy demand will weaken moderately in the short term due to high 2007 prices and the credit squeeze



Source: IEA *Oil Market Report,* December 2008, Bernstein, October 2008; FACTS, October 2008; McKinsey Global Institute Global Energy Demand Model 2009

Exhibit 3.4.9

Strong fundamentals will ensure that residential building energy demand rebounds with economic recovery



Source: McKinsey Global Institute Global Energy Demand Model 2009

Floor space growth

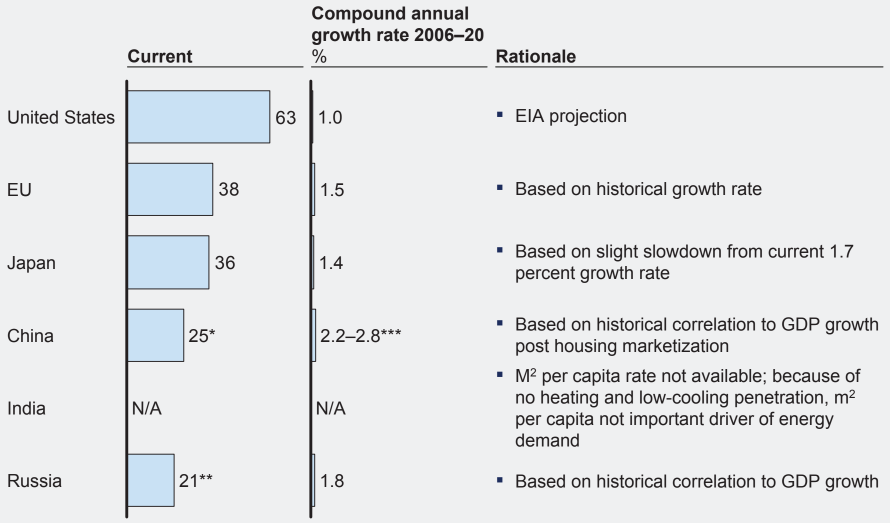
Floor space will grow as space per capita converges across countries between 2006 and 2020. In the United States, where per capita floor space is highest at 63 square meters, we project floor space will grow the most slowly of any region at 1.0 percent per year to 2020. Other developed regions such as Japan and Europe (which have much denser populations and where floor space averages 38 square meters and 36 square meters, respectively) are projected to grow at close to the historical pace at 1.5 and 1.4 percent respectively; as such, they will slowly converge with the United States. Developing regions will converge much more quickly as they develop. Floor space in China, for example, is projected to grow 2.2 percent per year in rural areas and 2.8 percent per year in urban areas, while floor space in Russia is projected to grow at a slightly slower pace of 1.8 percent per year (Exhibit 3.4.10).

Appliance penetration

Appliance penetration will be particularly important in driving residential energy-demand growth in countries such as India and China where rapid urbanization and growing middle classes mean many more households will be buying energy-intensive appliances such as refrigerators and air conditioners. In developed regions such as the United States and Japan, penetration is already almost 100 percent, although appliances per household still can grow slightly as second and third appliances are bought. Appliance penetration will affect energy usage the greatest in rural areas of India and China, where we project that refrigerator penetration will grow at 8.0 and 8.3 percent per year, respectively. The penetration of washing machines, the other key large appliance, will grow more slowly by around 3 percent per year because purchasing these requires a higher level of income (Exhibit 3.4.11).

Exhibit 3.4.10

MGI projects per capita growth in housing m² of 1 to 3 percent to 2020

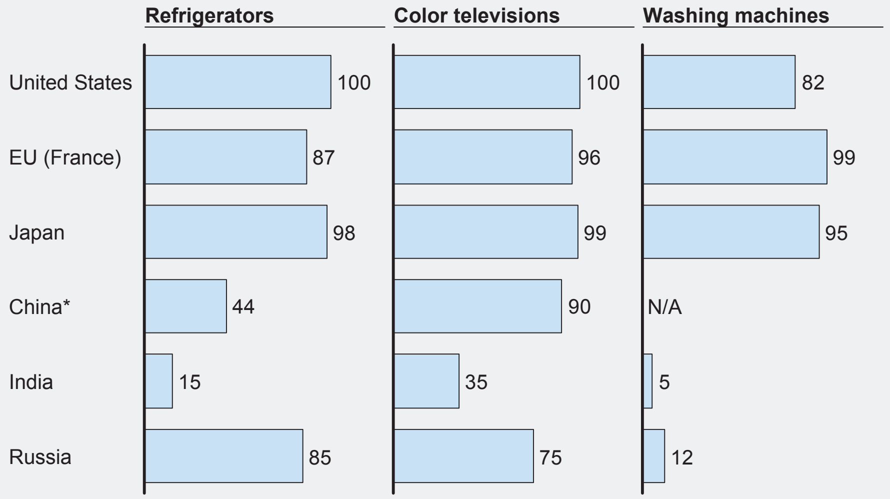


* 2003.
** 2004.
*** Rural 2.2 percent; urban 2.8 percent.
Source: McKinsey Global Institute Global Energy Demand Model 2009

Exhibit 3.4.11

Appliance penetration is expected to be a major demand-growth driver only in China and India

%, penetration of residential appliances by country, 2004



* China computed from Chinese National Statistics given large variances with Euromonitor data.
Source: Euromonitor; China National Statistics

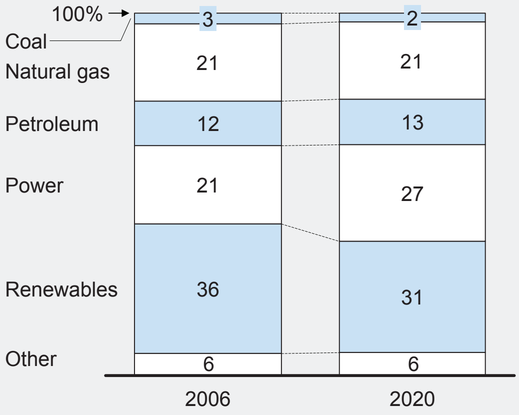
Fuel mix

The fuel mix varies significantly from region to region, depending on the availability of local resources. China and India, for instance, rely heavily on renewables, while the United States and Canada use a majority of power. Over the development cycle, residential fuel typically shifts from traditional energy sources to cleaner petroleum and natural gas (required for urban basic needs such as heating and cooking) and finally toward electricity (used for second-level necessities and luxuries). Overall, traditional biomass was the largest source of energy in the residential sector at 36 percent in 2006, but we expect this share to fall to 31 percent in 2020 due to a switch toward power, whose share increases from 21 to 27 percent in developing regions as incomes rise. This overall shift is in large part because of China, which is one of the fastest-growing regions and has one of the most dramatic shifts in fuel mix. China will see its share of renewables fall from 50 to 30 percent and power's share increase from 19 to 34 percent. Fuel mix in most developed regions such as the United States shift only marginally (Exhibit 3.4.12).

Exhibit 3.4.12

Residential buildings' fuel mix will shift from renewables to power as emerging economies develop

Residential final energy demand by fuel, 2006
%, QBTU



Note: Numbers may not sum due to rounding.
Source: McKinsey Global Institute Global Energy Demand Model 2009

Efficiency improvements

Policies that set minimum energy efficiency standards for appliances will potentially moderate a significant portion of residential demand growth. By and large, the United States lacks the standards required to improve efficiency further than achieved through policies implemented in the 1970s, and we therefore expect efficiency to improve by only 0.6 percent per year to 2020. Nevertheless, this is still an upward revision from the 0.2 percent annual efficiency improvements we projected in our 2007 report, due largely to the implementation of higher lighting standards.[6] Japan has put in place a more ambitious "voluntary" standards program, which may deliver higher efficiency improvements that we estimate could amount to 1.5 percent per year.[7] The energy efficiency opportunity is particularly high in developing regions such as China and India, which are expected to account for most of global demand growth and have traditionally lacked stringent appliance standards, especially those for heating. Based on aggressive government targets such as China's goal to reduce energy intensity by 20 percent by 2010, we expect improvements to be roughly 2.0 percent per year, although we note that a lack of comprehensive information makes this more challenging to assess (Exhibit 3.4.13).

Price elasticity

Changes in price are unlikely to have a strong direct impact on the residential sector for a variety of reasons. Petroleum accounts for only a very small percentage of residential end-user needs (concentrated mostly in Japan and China). In addition, residential price fluctuations are buffered by distribution costs as well as taxes and subsidies, which vary by region. Finally, price elasticity is quite low due to a lack of information available to consumers to help them make effective and energy efficient choices, principal/agent problems between renters and owners, and other mar-

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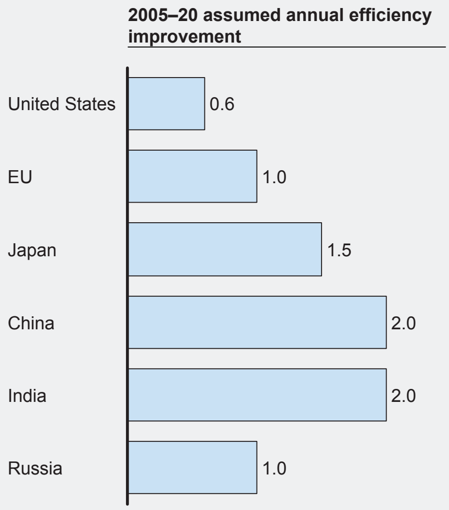
[6] We base this on the EIA's assessment of appliance-efficiency improvements due to EISA standards.

[7] We base this on analysis by Japan's Institute of Energy Economics.

ket imperfections that require very high return on investments to have an impact on behavior. Overall, we estimate that an increase in the oil price from $50 a barrel to $200 shaves back the growth of energy demand in residential buildings only marginally from 2.1 to 2.0 percent from 2006 to 2020 (Exhibit 3.4.14).

Exhibit 3.4.13

MGI's projections for efficiency improvement vary widely between regions
%



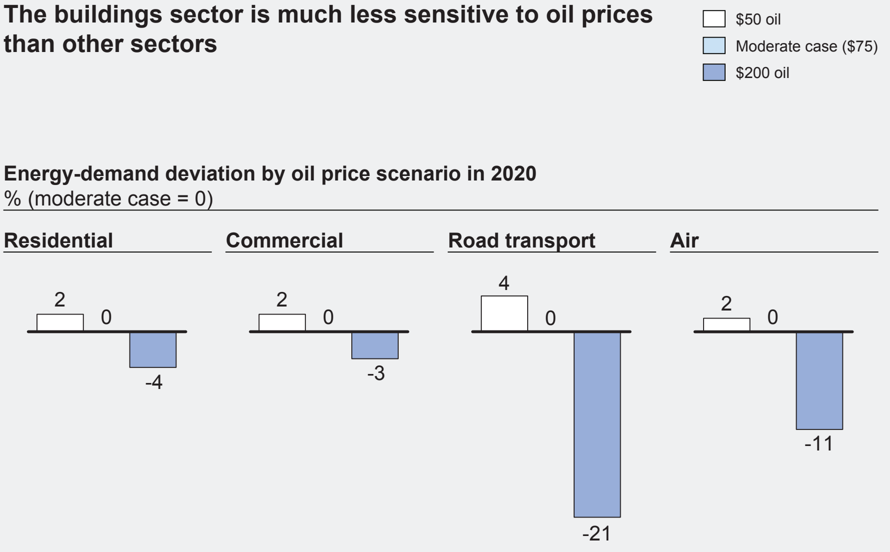
Rationale

- EIA base case
- Based on historical performance
- Japan IEEJ
- Based on moderate progress toward China's Five-Year Plan goal of reducing energy intensity by 20 percent by 2010
- Based on rolling out of state-level DSM programs similar to those in Kerala, Maharashtra, and Gujarat
- Based on historical EU average rate despite larger opportunity, because of limited policy focus on improved efficiency

Source: EIA; IEEJ; China 11th Five-Year Plan; literature search; McKinsey Global Institute analysis

Exhibit 3.4.14

The buildings sector is much less sensitive to oil prices than other sectors



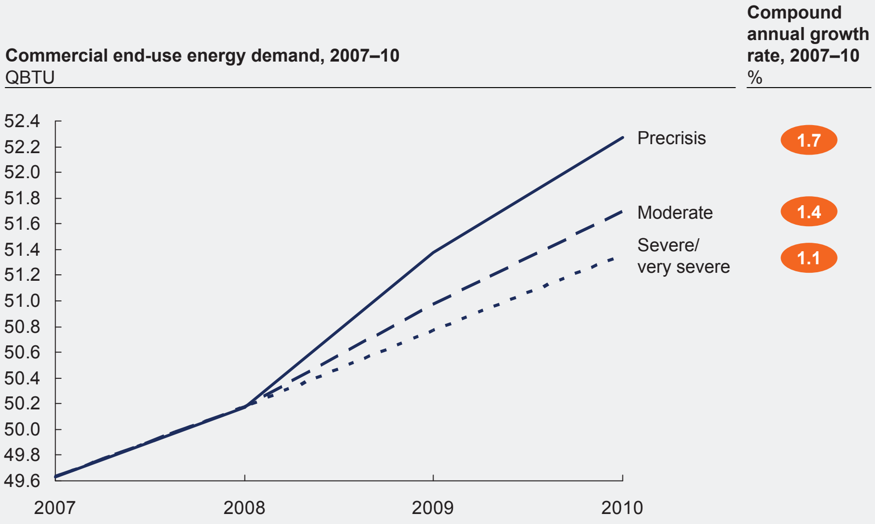
Source: IEA; McKinsey Global Institute Global Energy Demand Model 2009

COMMERCIAL

Commercial buildings used 49 QBTU of energy in 2006, representing 10 percent of overall global energy demand. MGI projects a slight near-term deceleration in this subsector's energy-demand growth due to the global economic slowdown (Exhibit 3.4.15). However, commercial buildings' energy-demand growth will rebound as the global recovery gets under way, and its share of global energy demand will remain unchanged in 2020 (Exhibit 3.4.16). Demand in this subsector will be slower than in the buildings sector overall at 1.9 percent per annum. China is the primary driver of energy-demand growth in commercial buildings, with demand expected to more than double from 5.5 QBTU to 10.8 QBTU. As in residential buildings, the key drivers of expanding energy demand from commercial buildings are floor space growth, appliance penetration, fuel mix, and efficiency growth.

Exhibit 3.4.15

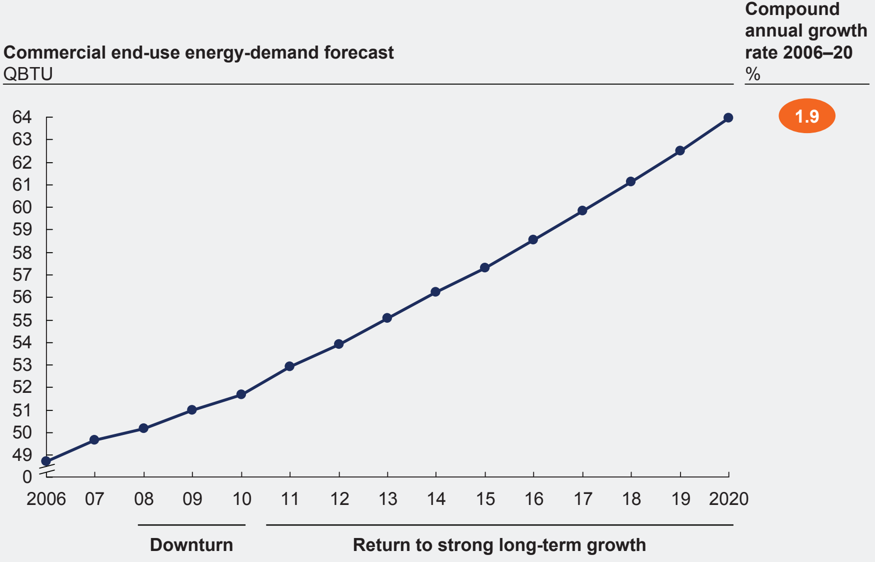
Commercial buildings' energy-demand growth will slow slightly in the short term due to the GDP slowdown and credit crunch



Source: McKinsey Global Institute Global Energy Demand Model 2009

Exhibit 3.4.16

Commercial buildings' energy-demand growth will rebound with GDP on strong fundamentals



Source: McKinsey Global Institute Global Energy Demand Model 2009

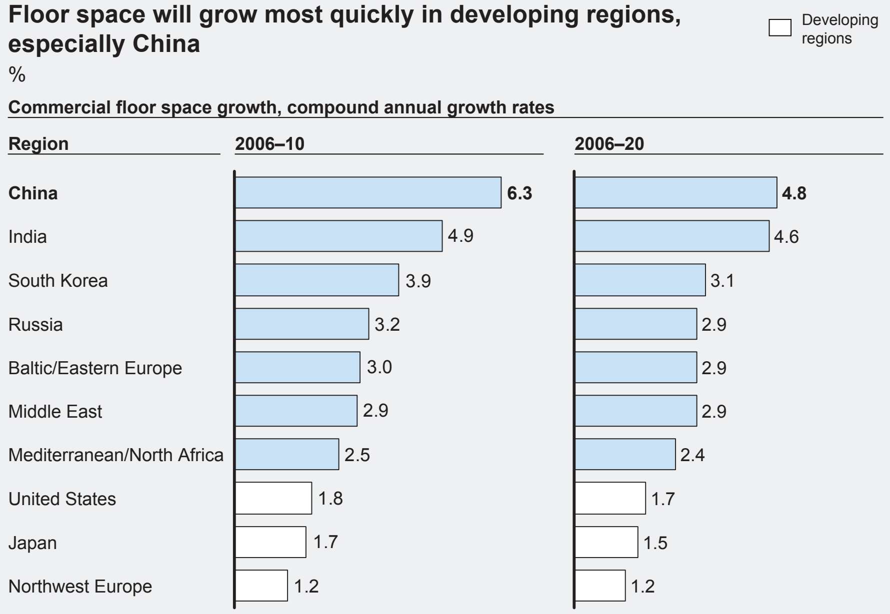
Floor space growth

Commercial floor space will grow roughly in line with the pace of overall GDP growth. We project that floor space in the United States—which has the greatest amount of any region—will grow by only 1.7 percent per year between 2006 and 2020. Japan, whose economic growth will be slow and which has a greater population density, will see growth of only 1.4 percent per year. In contrast, developing regions will see much more rapid growth in commercial floor space as their commercial sectors develop. In China, commercial floor space is projected to grow 4.8 percent per year, while the equivalent figure in India is slightly slower at 4.4 percent (Exhibit 3.4.17).

Exhibit 3.4.17

Floor space will grow most quickly in developing regions, especially China

%



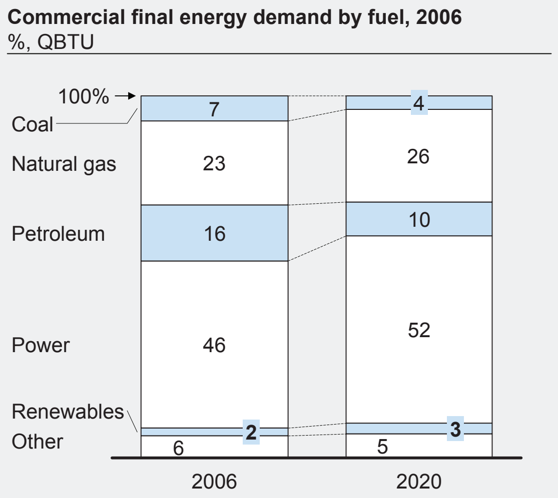
Source: McKinsey Global Institute analysis

Fuel mix

As in the case of residential buildings, the fuel mix depends on what energy sources are available locally. China, for instance, relies heavily on coal in their mix, while the United States uses a majority of power. Overall, power is by far the largest source of energy in the commercial sector at 46 percent in 2006, growing to 52 percent in 2020 as several developing regions switch to power. (Petroleum use drops from 16 to 10 percent.) The shift to power is in large part due to China, which will see a significant shift, dropping from 36 percent coal to 13 percent renewables and increasing power use from 18 to 41 percent. Fuel mix in most developed regions such as the United States shift only marginally. Japan decreases petroleum usage from 30 to 14 percent, substituting mostly with natural gas, which shifts from 22 to 33 percent (Exhibit 3.4.18).

Exhibit 3.4.18

The fuel mix in commercial buildings will shift from petroleum to power in developing economies



Note: Numbers may not sum due to rounding.
Source: McKinsey Global Institute Global Energy Demand Model 2009

Efficiency improvements

In the long term, overall energy efficiency improvements drive reductions in energy demand, especially in developed regions. We project improvement of 13 percent from 2006 to 2020 compared with 10 percent in developing regions. The United States and Europe, in particular, have recently made large strides in efficiency regulation. In December 2007, the United States passed the EISA in 2007, which includes a variety of new improved standards for lighting and for residential and commercial appliance equipment including residential refrigerators, freezers, metal halide lamps, and commercial walk-in coolers and freezers. In Europe, the European Commission has set a number of building-efficiency certification requirements for new buildings through the Energy Performance of Buildings Directive (EPBD) and set energy efficiency improvement targets for existing buildings in the Energy Services Directive (ESD). Overall, the commission targets a 20 percent savings in building energy use by 2020 (Exhibit 3.4.19).

Exhibit 3.4.19

Slow commercial buildings energy-demand growth is due to tighter regulation in the United States and the EU

Key provisions	Description	Impact
 **United States:** - **Energy efficiency equipment standards**	Include a variety of new standards for lighting and for residential and commercial appliance equipment. The equipment includes residential refrigerators, freezers, refrigerator-freezers, metal halide lamps, and commercial walk-in coolers and freezers	EIA revised efficiency improvements achieved by 2020 up from 8 to 14 percent
 **EU:** - **Energy Performance of Buildings Directive**	**For new buildings** - Estimated energy savings of 27 percent and CO_2 per year reduction of up to 30–45 Mt by 2010 - Energy-performance calculation - Energy certification (including advice on improvement measures) of buildings being built, sold, or rented - National building regulations regarding energy efficiency to be tightened every five years - Renovation requirements for buildings >1,000 m^2 when undergoing major renovation	Given projected growth of new buildings in the EU, weighted average energy efficiency for 2020 is up from 8 to 13 percent
 **EU:** - **Energy Services Directive**	**For existing buildings** - Goal: minimum 9 percent improvement in end-use energy efficiency in each member state over nine years (i.e., 1 percent per annum improvement) - Requirements within public procurement - New role for energy suppliers - Cofinancing of energy efficiency in buildings	

Source: europa.eu; EuroACE; ec.europa.eu/energy/demand/legislation/buildings_en.htm

Despite the advances made in energy efficiency regulation in developed regions, regulation in developing regions continues to be a critical question mark. China instituted the 2003 Energy Conservation Law for new buildings' efficiency, but compliance and enforcement have been low and certainly failing to keep pace with the rapid pace of building construction. Although the Chinese government reports an improvement in enforcement, it remains difficult to assess the extent of any efficiency gains given the challenging regulatory environment. Likewise in India, despite the passage in 2007 of the Energy Conservation Building Code setting minimum energy-performance requirements, there are shortcomings in compliance and enforcement. Russia currently lacks a centralized institution to regulate energy efficiency; moreover, entities involved in energy policy have not laid out any explicit building energy efficiency standards (Exhibit 3.4.20).

Price elasticity

As in the residential sector, changes in price are not likely to have a strong direct impact on commercial building energy demand for a variety of reasons. Petroleum accounts for only a very small percentage of commercial end-user needs (concentrated mostly in Japan and China). In addition, commercial prices correlate only very weakly to petroleum prices due to distribution costs as well as taxes and subsidies that vary by region. As a result, academic studies estimate that the behavioral response to higher prices is approximately minus 0.1 to minus 0.2. Thus, increasing the oil price from $50 a barrel to $200 decreases the overall energy-demand growth rate for commercial buildings only from 1.8 to 1.6 percent from 2006 to 2020.

Exhibit 3.4.20

Regulation in developing regions will have a mixed impact on buildings' energy efficiency

Region	Regulation	Impact
China	• Reported more stringent enforcement of 2003 Energy Conservation Law for new-building efficiency	• Compliance for new-building efficiency standards remains questionable given current regulatory environment
India	• Instituted the 2007 Energy Conservation Building Code, which sets minimum energy-performance requirements for new-building efficiency	• Targets for new-building efficiency based on pilots in government buildings, which report a 20–30 percent increase in new-building efficiency
Russia	• Lacks a centralized institution to regulate energy efficiency • Entities involved in energy policy have not laid out any explicit building energy efficiency standards (only loosely defined Energy Strategy for 2030, construction standards, and some local regulations) • Government pledged to raise gas prices to net-back by 2012	• Slowing of natural-gas-demand growth due to higher prices • No energy regulatory impact

Source: Literature search

3.5. Industrial sector

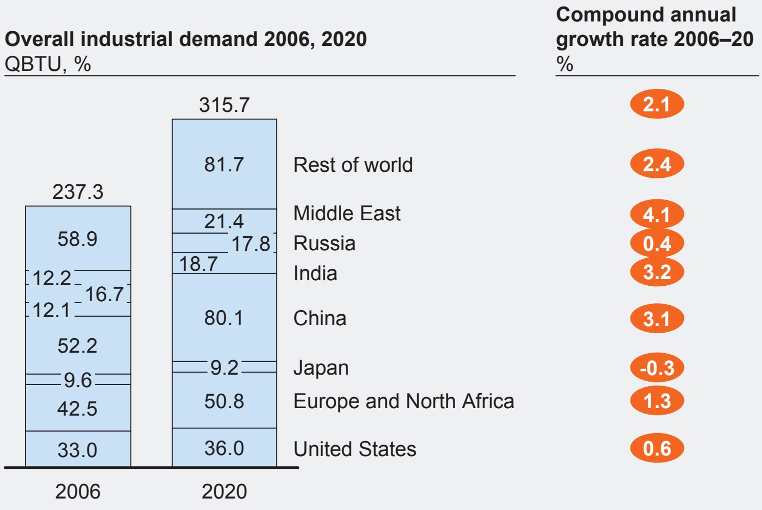
OVERVIEW

The industrial sector, which comprises industries such as steelmaking, chemicals, and pulp-and-paper production, represented 51 percent of global energy demand in 2006 (237 QBTU) and 29 percent of global petroleum demand. The industrial sector is expected to grow at 2.1 percent per annum—equal to the overall rate of energy-demand growth across sectors—and continue to account for 51 percent of global energy demand in 2020.

The continued strength of demand growth in developing regions will mostly drive strong growth in energy consumption. Industrial demand in China, India, and the Middle East will grow at 3.1, 3.2, and 4.1 percent per annum, respectively, to 2020 (Exhibit 3.5.1). Nevertheless, some major steps to increase energy efficiency in the industrial sector are being taken. One of the key initiatives is China's Top-1,000 program, which targets a 20 percent cut in the economy's energy-intensity improvement from 2005 to 2010 in China's 1,000 largest industrial sites. For example, in 2005 and 2006 alone, the steel sector's largest plants achieved an annual improvement of 3.7 percent. Overall we expect the energy efficiency of the pulp and paper and steel sectors to increase at 1.1 and 0.9 percent per annum, respectively. The installation of more modern plants in developing countries as well as the capture of energy efficiency opportunities within existing plants will drive this improvement. Meanwhile, petrochemicals, where fewer opportunities to improve energy efficiency exist, is projected to have minimal efficiency improvements.

Exhibit 3.5.1

India and China are showing the greatest industrial-sector growth



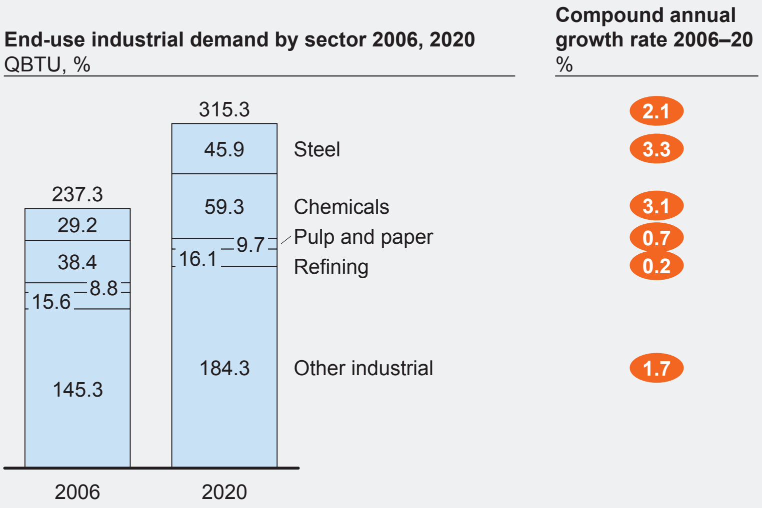
Note: Numbers may not sum due to rounding.
Source: McKinsey Global Institute Global Energy Demand Model 2009

Macroeconomic trends influencing energy demand include rapid income growth in, and urbanization of, developing regions (especially China), which drives demand in sectors such as steel (through infrastructure-capacity building) and petrochemicals (through increased consumer purchasing power). We project energy demand in steel and chemicals to grow at approximately 3.3 and 3.1 percent per annum, respectively. China will lead energy-demand growth in these two sectors with 4.5 and 5.8 percent, respectively.

Global energy demand in pulp and paper will grow more slowly at 0.7 percent per annum as the transition from print to digital media continues (Exhibit 3.5.2).

Exhibit 3.5.2

Within industry, steel and chemicals are set to grow at more than 3 percent per annum

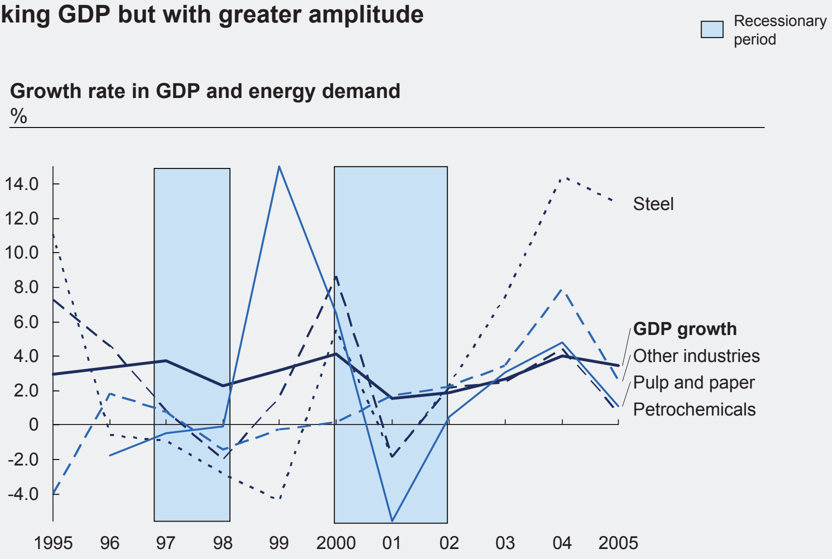


Source: McKinsey Global Institute Global Energy Demand Model 2009

Historically, industrial demand has been procyclical—i.e., moving in the same direction as GDP growth but with greater amplitude (Exhibits 3.5.3). The impact of the economic downturn in full swing at the time of writing in early 2009 is likely to have a strong impact on industrial energy demand in the short term. In the long run, however, we see energy demand in the industrial sector returning to predownturn levels.

Exhibit 3.5.3

Industrial energy demand has historically been procyclical, tracking GDP but with greater amplitude



Source: IEA; Global Insight; McKinsey Global Institute analysis

Should the oil supply–demand balance become tight again, the industrial sector could help relieve pressure by speeding up its rate of substitution of oil as a boiler fuel to natural gas. Roughly 12 QBTU (six million barrels per day) of residual fuel oil and diesel are used in regions that are self-sufficient in natural gas.

INDUSTRIAL ENERGY-DEMAND GROWTH WILL REBOUND AFTER A DRAMATIC SHORT-TERM DIP WITH GDP

In the short term, we expect the global GDP slowdown to reduce energy-demand growth in the industrial sector to a dramatic extent. This marked reaction to the worldwide economic decline is due to the fact that the industrial sector tends to be procyclical and fluctuate more strongly than GDP. The reason for this pronounced reaction to swings in GDP relates to inventory effects as well as the industrial sector's role as an input to infrastructure and durables.

We project overall energy demand to have grown at a rate of 0.8 percent in 2008 and 1.2 percent in 2009 in the moderate-case GDP scenario. In our severe-case GDP scenario, we project 2009 growth of 0.8 percent, while in our very severe–case GDP scenario we see a contraction of 0.6 percent. Many industrial subsectors will grow more slowly than these aggregate figures. Particularly hard hit will be steel. In this subsector, our moderate case projects that energy demand will have contracted by 3.9 percent in 2008 and will grow by 2.1 percent in 2009. In the severe GDP case, we would project contractions in energy demand of 3.9 and 6.9 percent in these two years, respectively.

However, the counterpart to the pronounced downturn in the industrial sector will be a smart rebound at a quicker rate than GDP. In steel, for example, we expect energy demand to grow at a robust 5.2 percent in 2010–15. This means that, even if the economic downturn is prolonged and deep, we will still see strong long-term growth in energy demand unless the global GDP trend changes. In general, each 2 percent aggregate reduction of global GDP from trend results in a 0.1 percent reduction in the compound annual growth rate of global industrial energy demand between 2006 and 2020. This leaves our lower case some 0.3 percent below the annual energy-demand growth we project in our moderate case.

If we look at different industrial subsectors, steel and petrochemicals will lead demand growth in the period to 2020, growing at 3.3 and 3.1 percent per annum, respectively, during this period. With growth of 16.7 QBTU and 20.8 QBTU between 2006 and 2020, these two subsectors account for 49 percent of total industrial-sector energy-demand growth.

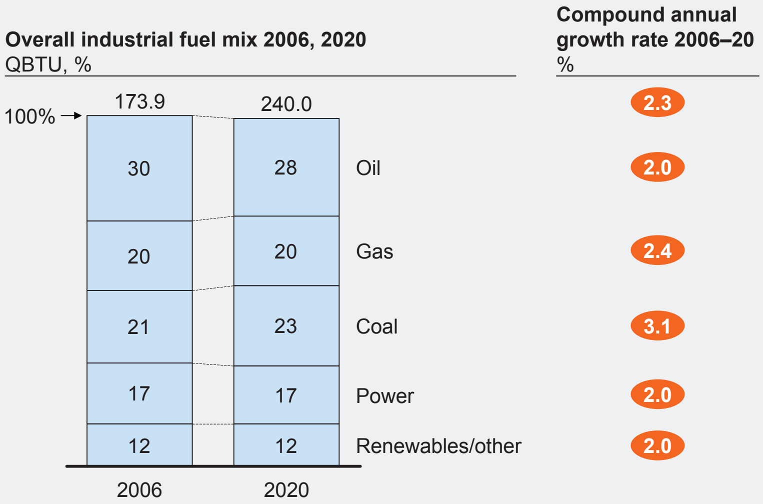
The regions that will see the most rapid industry energy-demand growth throughout the period of our analysis are India, China, and the Middle East at 3.2, 3.1, and 4.1 percent per annum, respectively—together accounting for 57 percent of the global total. The United States, Europe and North Africa, and Japan, by contrast, will grow more slowly. Indeed, industrial energy demand will actually shrink in Japan by 0.3 percent per annum. These three regions will account for only 12 percent of energy-demand growth to 2020. Should high oil prices return and transport costs increase substantially, we could see this trend change as some goods such as more steel could be produced domestically in markets such as the United States instead of being imported from overseas.

INDUSTRIAL SECTOR'S FUEL MIX IS NOT LIKELY TO CHANGE SUBSTANTIALLY TO 2020

Our analysis finds that the fuel mix in the industrial sector will likely remain broadly stable as relatively strong growth in petrochemicals boosts petroleum's share to 2020 but, at the same time, the share of petroleum as a boiler fuel continues to decline rapidly. We do not expect bioplastics to gain a significant share during this time frame (Exhibit 3.5.4).

Exhibit 3.5.4

Industrial fuel mix shifts only very slightly in MGI's moderate case



Source: McKinsey Global Institute Global Energy Demand Model 2009

The industrial sector provides a major potential opportunity for relieving any oil supply tightness that might develop. Some nine million barrels per day comprising mostly resid and diesel are used as boiler fuel in the industrial sector—of which six million barrels per day are in regions that supply most, or all, of their own natural gas needs. While our moderate case shows the industrial sector's fuel mix to be broadly stable, if supply tightness and/or high oil prices were to return, we could see a quicker migration out of petroleum products today used as boiler fuels. In such a case, there would be a shift away from oil and toward natural gas.

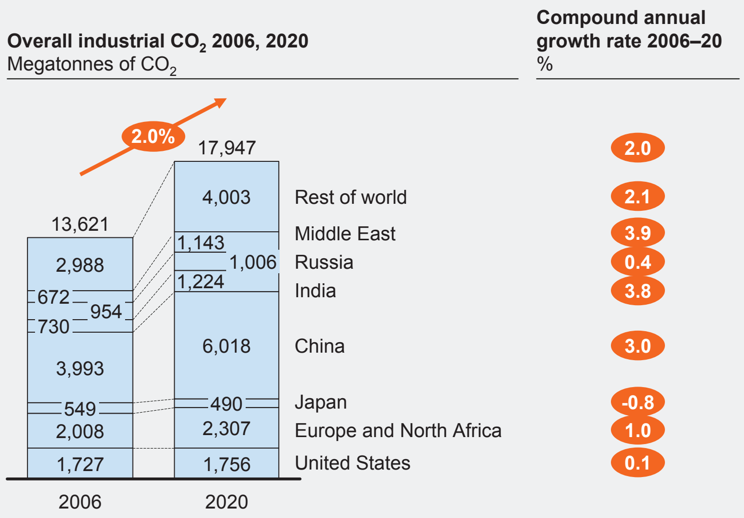
Because it is difficult to shift the industrial fuel mix away from coal (whose major industrial end use is steel, which uses coal as a reactant), the most likely effect of CO_2 regulations would be not on the mix but on the industrial sector's energy efficiency.

INDUSTRIAL SECTOR'S SHARE OF GLOBAL CO_2 EMISSIONS WILL REMAIN STABLE

The industrial sector's end-use CO_2 emissions will grow from 13.6 gigatonnes to 17.9 gigatonnes between 2006 and 2020, keeping its share of global emissions steady at 52 percent. Emissions in the industrial sector will keep pace with projected global emissions expansion of 2.0 percent a year (Exhibit 3.5.5). Breaking down industry into subsectors, we project that steel emissions will grow by 3.3 percent per year to reach nearly 4 gigatonnes of CO_2 in 2020—or some 20 percent of all industrial emissions. We see petrochemical emissions increasing at 2.9 percent per annum, reaching 2.4 gigatonnes by 2020.

Exhibit 3.5.5

CO_2 emissions grow slightly slower than overall sector demand



Source: McKinsey Global Institute Global Energy Demand Model 2009

CHEMICALS

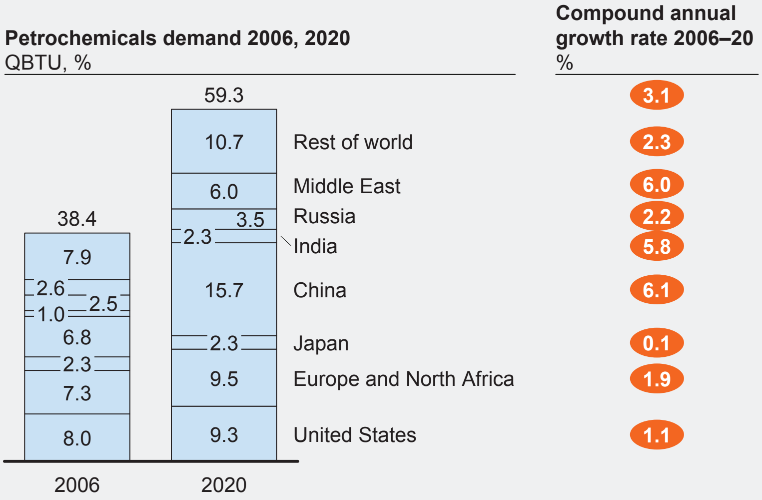
In 2006, chemicals represented 8 percent of overall global energy demand and 16 percent of industrial-sector energy demand; it consumed 11 percent of the world's petroleum products. We expect to see a short-term slowdown in petrochemicals growth in 2008 and 2009—in these years, we project that the subsector's energy demand will be static and grow at only 0.5 percent each year. Procyclicality plays a major role in this subsector, though its impact is not as pronounced as in steel.

From 2010 to 2015, we expect a strong return to growth, with energy demand growing at 3.6 percent per annum. Looking further out, we project chemicals energy demand to grow at a rate of 3.5 percent per annum. By 2020, the chemicals subsector will account for 10 percent of total energy demand and 14 percent of petroleum demand. Energy demand in this subsector will increasingly come from developing regions, with China alone projected to increase its chemicals energy demand by more than 9 QBTU to 2020—about half of total energy-demand growth in chemicals (Exhibit 3.5.6). The Middle East's rapid 6 percent growth depends on oil prices staying high, which provides investment dollars to build plants and provides advantage to their stranded gas over using petroleum-based feeds.

The chemicals subsector is highly fragmented with dozens of important products (Exhibit 3.5.7). We built our projections of energy demand in this subsector around three representative products—ethylene, chlorine, and ammonia—and then extrapolated these results across the subsector. Ethylene production is projected to grow at 3.9 percent annually to 2020, with growth concentrated heavily in China, the Middle East, and Russia (Exhibit 3.5.8). Meanwhile, we project that chlorine will grow by 3.6 percent annually and ammonia by 3.1 percent—the latter heavily concentrated in developing regions.

Exhibit 3.5.6

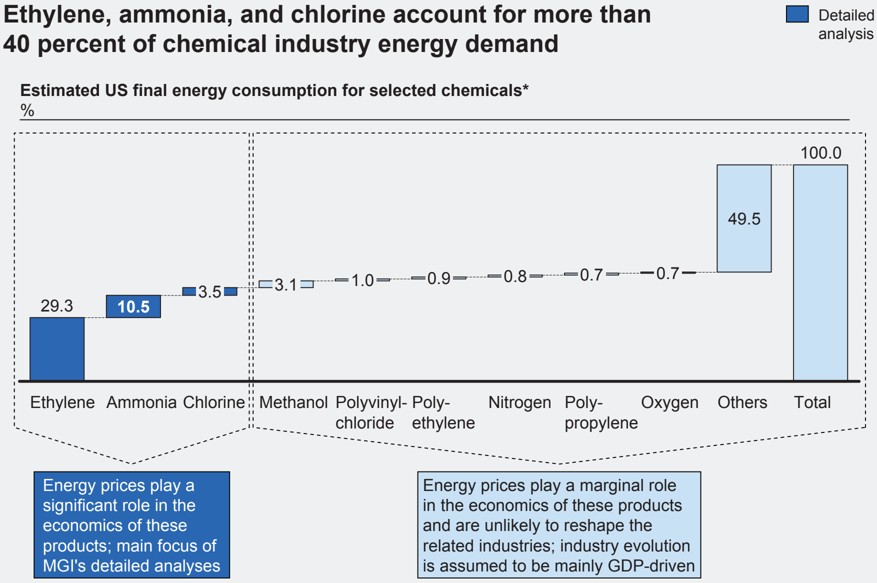
The Middle East, India, and China will see the fastest growth in petrochemicals demand



Source: McKinsey Global Institute Global Energy Demand Model 2009

Exhibit 3.5.7

Ethylene, ammonia, and chlorine account for more than 40 percent of chemical industry energy demand



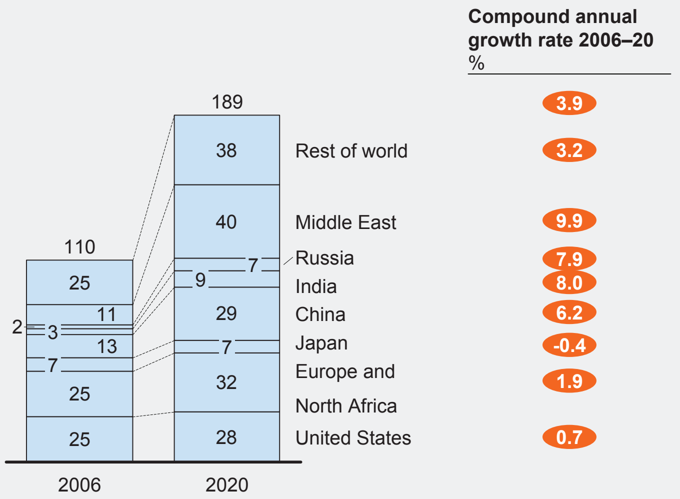
* Including feedback based on 1944 data.

Source: Warrell et al, 2000; McKinsey Global Institute analysis

Exhibit 3.5.8

Ethylene-production growth is greatest in developing regions

Million tonnes



Source:

Note: Numbers may not sum due to rounding.

Source: Tecnon; McKinsey Global Institute Global Energy Demand Model 2009

The majority of fuel for the chemicals industry serves as a feedstock, limiting the ability to increase efficiency or make substitutions. As a result, the mix will not change materially, natural gas and naphtha remaining the two largest fuels. Though petrochemicals feedstock demand grows at almost double the rate of crude demand, a shortage in feedstocks seems unlikely. Fossil gasoline demand grows substantially slower than crude, and many light fuels such as LPG and naphtha are currently converted to gasoline via isomerization, catalytic reforming, and alkylation. As less conversion to gasoline will be needed, these LPG and naphtha feeds can be redirected to petrochemicals instead of being converted to gasoline. Should this still not meet petrochemicals feedstock demand, coal-to-olefins and gas-to-olefins could come on more heavily, though we do not project this in our scenarios.

Because the energy efficiency potential in many segments is limited, the largest projected improvement in petrochemicals comes from the chlorine segment, driven primarily by the transition from mercury-cell to more efficient membrane-cell technology.

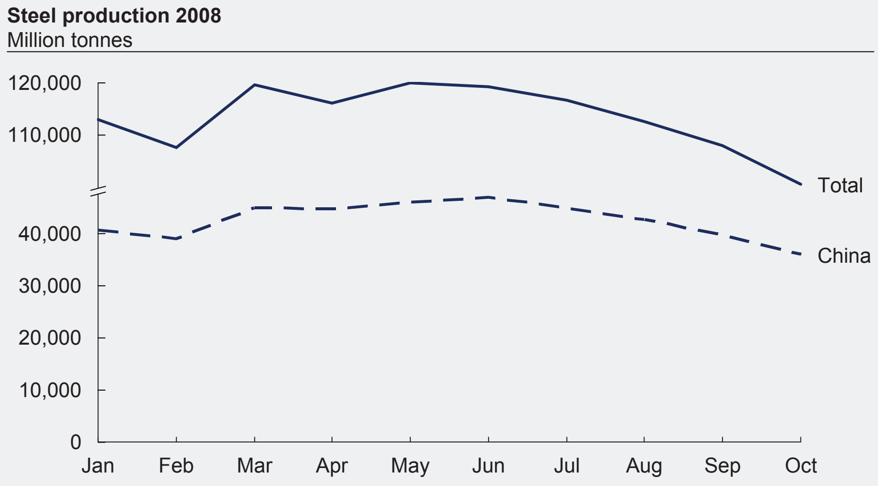
STEEL

Steel today accounts for 9 percent of global energy demand. In the short term, steel will experience the largest demand drop of any industrial subsector due to the economic downturn. In our moderate case, we project that steel energy demand will have contracted by 3.9 percent in 2008 and to grow at 2.2 percent in 2009. Steel is the most procyclical of the sectors we examined, evidenced by the sharp drop in production that we witnessed in autumn 2008. In October of that year alone, we saw steel production plunge by 8 percent globally and by 10 percent in China (Exhibit 3.5.9).

We project—true to the industry's procyclicality—that, as GDP recovers, steel demand will rebound strongly in the period from 2010 to 2015, with annual energy-demand growth of 5.2 percent. In the period to 2020, we project that steel energy demand will expand by 3.3 percent a year on average with more than 80 percent of that growth coming from China and India. Japan actually has negative energy-demand growth, while Europe and the United States grow slowly (Exhibit 3.5.10).[8] Steel's share of global energy demand will rise to 7 percent over this period to reach 45.9 QBTU.

Exhibit 3.5.9

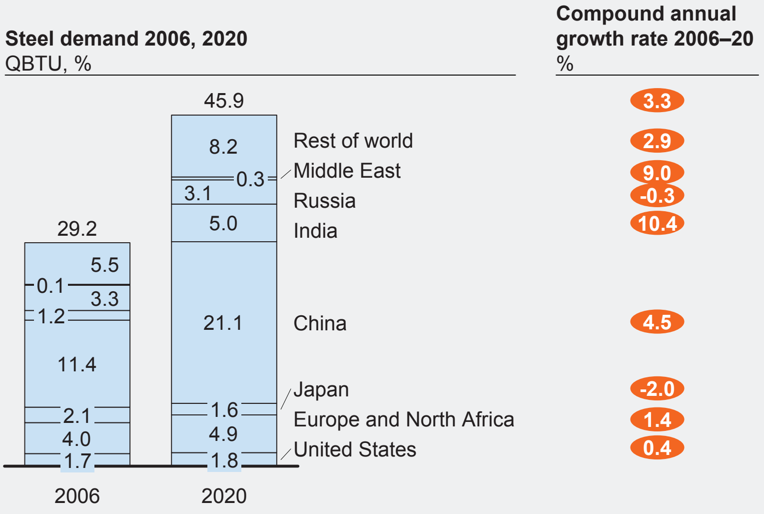
Global steel production dropped sharply in late 2008, impacting coal demand



Source: World Steel Association

Exhibit 3.5.10

Steel demand will grow fastest in India and the Middle East, but China's absolute growth will be half the total



Note: Numbers may not sum due to rounding.
Source: McKinsey Global Institute Global Energy Demand Model 2009

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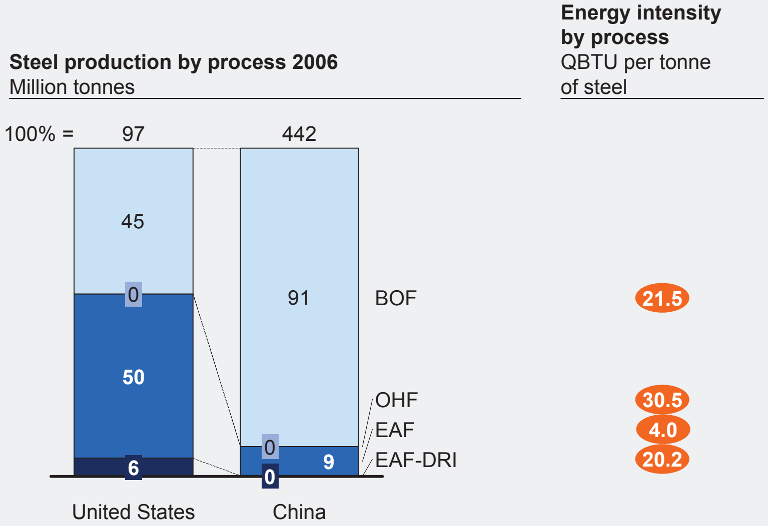
[8] Our estimate of the contribution of steel to energy demand is higher than in our 2007 report as we now include coke ovens and blast furnaces as part of the iron and steel subsector.

Projected growth in underlying steel production is 4.2 percent per annum from 2006 to 2020, with China and India representing almost 70 percent of the total. More carbon- and energy-intensive basic oxygen furnaces (BOF) dominate production in these two countries, which therefore account for approximately 80 percent of energy-demand growth to 2020 (Exhibit 3.5.11). This will lead to coal growing its share of sector energy demand from 75 to 77 percent at the expense of natural gas and power.

We expect energy efficiency to improve at a rate of 0.3 to 1 percent per year by region (Exhibit 3.5.12). China will outdo other regions in terms of improving energy efficiency—achieving a nearly 1 percent per annum cut in energy intensity due not only to regulatory intervention notably through the Top-1,000 program but also because of a less efficient starting point.

Exhibit 3.5.11

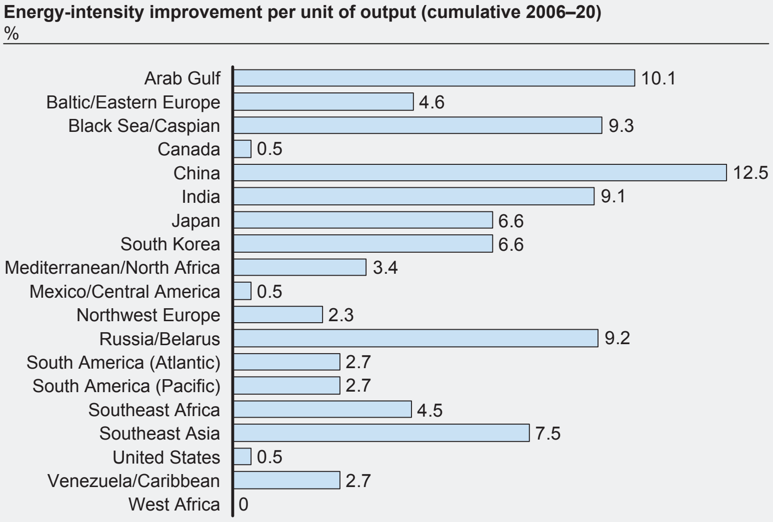
China's stronger share of global steel output will shift production into the energy- and carbon-intensive BOF process



Note: Numbers may not sum due to rounding.
Source: McKinsey Basic Materials practice; McKinsey Global Institute analysis

Exhibit 3.5.12

Energy demand is projected to decrease strongly for steel, particularly in China



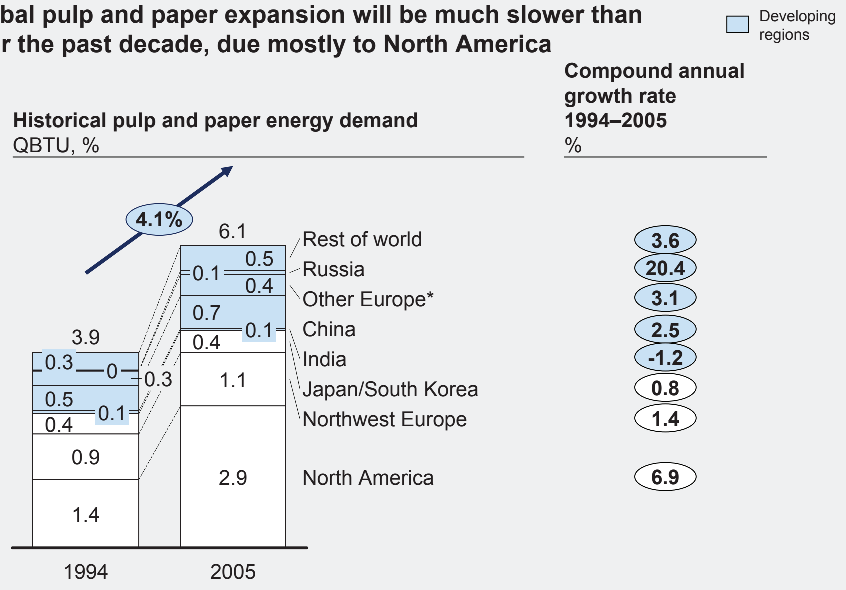
Source: McKinsey Basic Materials practice; McKinsey Global Institute analysis

PULP AND PAPER

The paper and pulp industry demanded 8.7 QBTU of energy in 2006, representing 1.9 percent of overall global energy demand. By 2020, the subsector's share of overall energy demand will have dropped to 1.6 percent, as the subsector's energy-demand growth will be slower than that of industrial sectors overall at 0.6 percent per annum. This rate is far less rapid than historical energy-demand growth of 4.1 percent over the past decade due to weaker production expansion and higher energy efficiency capture rates (Exhibit 3.5.13). What growth there is in this subsector will be driven primarily by China, whose demand is expected to double from 0.8 QBTU to 1.6 QBTU (Exhibit 3.5.14).

Exhibit 3.5.13

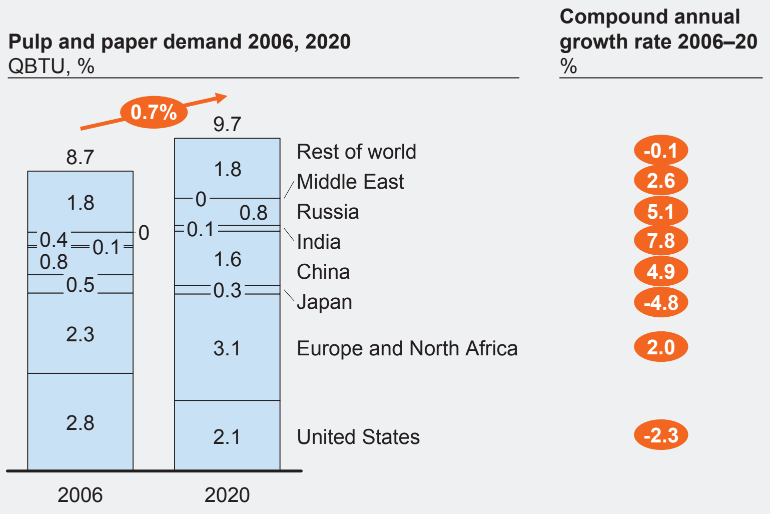
Global pulp and paper expansion will be much slower than over the past decade, due mostly to North America



Note: Numbers may not sum due to rounding.
* Including Mediterranean Europe and North Africa and Baltic/Eastern Europe.
Source: IEA; McKinsey Global Institute Global Energy Demand Model 2009

Exhibit 3.5.14

Pulp and paper energy demand will grow fastest in India and China

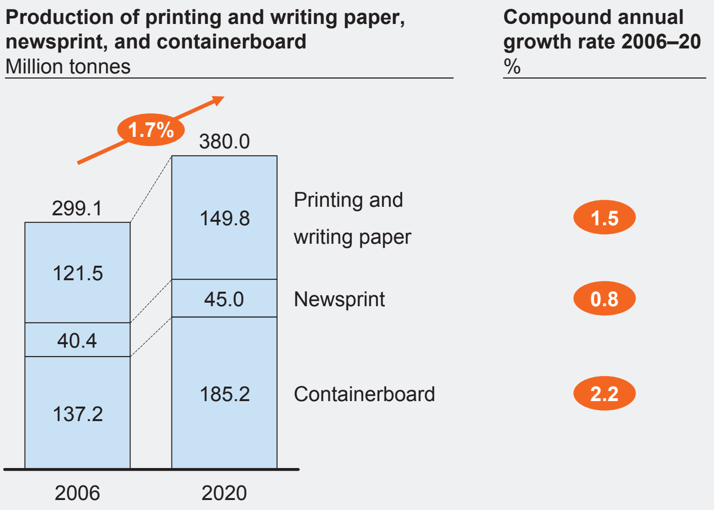


Note: Numbers may not sum due to rounding.
Source: McKinsey Global Institute Global Energy Demand Model 2009

Looking at the subsector's energy-demand growth at a greater level of detail, we see that an underlying cause of its slowdown compared with recent history is muted growth in the production of newsprint, paperboard, and printing and writing paper. Society's demand for paper products has receded as modern technology has provided substitutes such as digital media that reduce the need for paper (Exhibit 3.5.15).

Exhibit 3.5.15

Containerboard, which is less energy intensive than other products, will grow most quickly in the pulp and paper sector

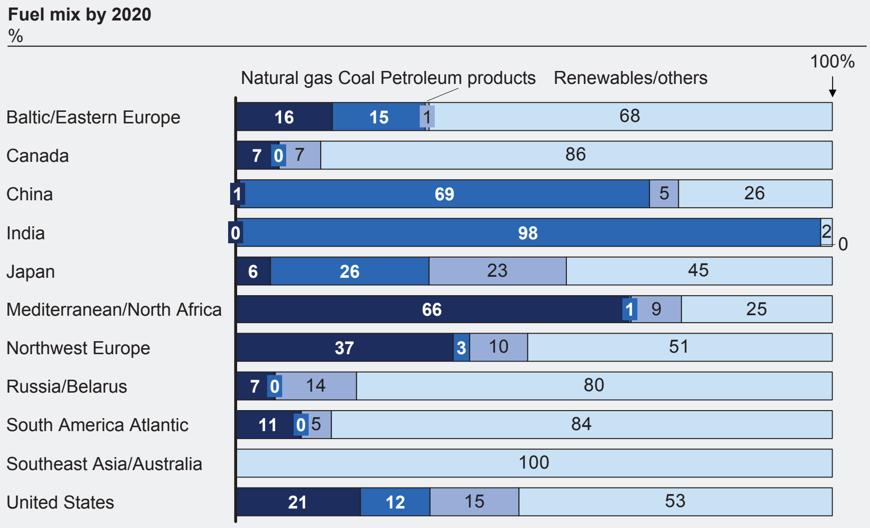


* Including Mediterranean Europe and North Africa and Baltic/Eastern Europe.
Source: IEA; McKinsey Global Institute Global Energy Demand Model

The fuel mix in this subsector depends very much on the region and what natural resources that region has. China and India rely heavily on coal, while the United States and Canada use a majority of renewables (such as wood bark). The fact that China represents the bulk of energy-demand growth in this subsector, while developed regions actually contract, leads to a shift toward coal as an energy source. Coal increases from 11 to 18 percent of the subsector's fuel demand by 2020, while natural gas declines from 16 to 12 percent (Exhibit 3.5.16-3.5.17).

Exhibit 3.5.16

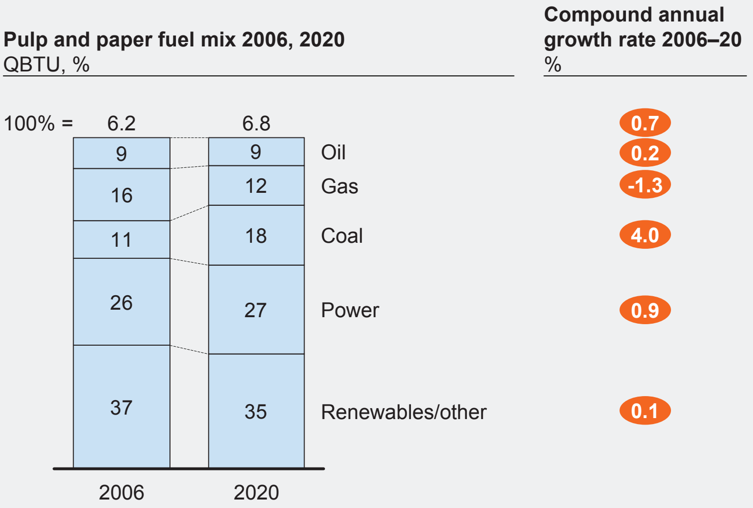
China, the fastest-growing region in the world economy, is heavily dependent on coal



Note: Numbers may not sum due to rounding.
Source: IEA; McKinsey Global Institute Global Energy Demand Model 2009

Exhibit 3.5.17

Due to China's strong growth, the pulp and paper fuel mix shifts toward coal



Note: Numbers may not sum due to rounding.
Source: McKinsey Global Institute Global Energy Demand Model 2009

3.6. Power

OVERVIEW

In this section, we discuss primary energy demand from the power sector, which is the sum of power losses from power generation and final electricity demand by end-use sectors. Primary energy from the power sector is today the largest source of primary-energy use and of CO_2 emissions. The power sector's primary demand represented 164 QBTU or 35 percent of global energy demand in 2006. We project that the sector's primary demand will grow at the same pace as global energy demand to 2020, reaching 219 QBTU or 35 percent of global demand at that date. The power sector's primary demand accounted for five million barrels a day (9 QBTU) or 6 percent of global petroleum demand in 2006, and we project it will decline to four million barrels a day (7 QBTU) or 4 percent of petroleum demand by 2020. The power sector represented 9.8 gigatonnes or 37 percent of total emissions in 2006 and will grow to a projected 12.8 gigatonnes or 37 percent of total emissions by 2020 (Exhibit 3.6.1).

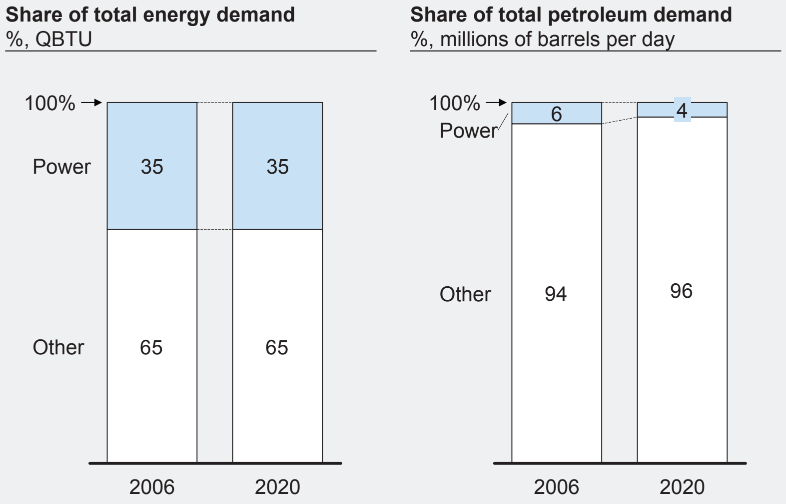
Energy-demand growth in the power sector overall will be 2.1 percent per annum to 2020, driven mostly by the continued strength of demand growth in developing regions. These regions will see their power-sector energy demand grow at an average 2.9 percent compared with 1.1 percent in developed regions (Exhibit 3.6.2).

Breaking overall power-sector primary energy demand down into different segments, we find that electricity demand from end-use sectors represents 59 QBTU or 13 percent of global energy demand in 2006 and will grow more rapidly than global energy demand to reach 85 QBTU or 14 percent of global demand in 2020.

As with power-sector primary demand, rapidly expanding developing regions will drive the overall growth rate of final electricity demand of 2.6 percent per annum. Electricity demand in these regions will increase at an average rate of 2.1 percent compared with 0.7 percent in developed regions. China, as in so many other sectors, plays a large role; its electricity demand will grow from 10 QBTU to 20 QBTU, representing 39 percent of power energy-demand growth. The drivers of this robust growth are rapid urbanization and a growing middle class as well as strong commercial development in its major cities. Currently the United States, Europe, and North Africa represent the largest segment of electricity demand, consuming 26 QBTU or 45 percent of the global total. These regions will account for 16 percent of growth in electricity demand, increasing to 31 QBTU or 36 percent of global demand by 2020. Electricity-demand growth remains positive due to the continued proliferation of electricity-using devices in developed countries (Exhibit 3.6.3).

Exhibit 3.6.1

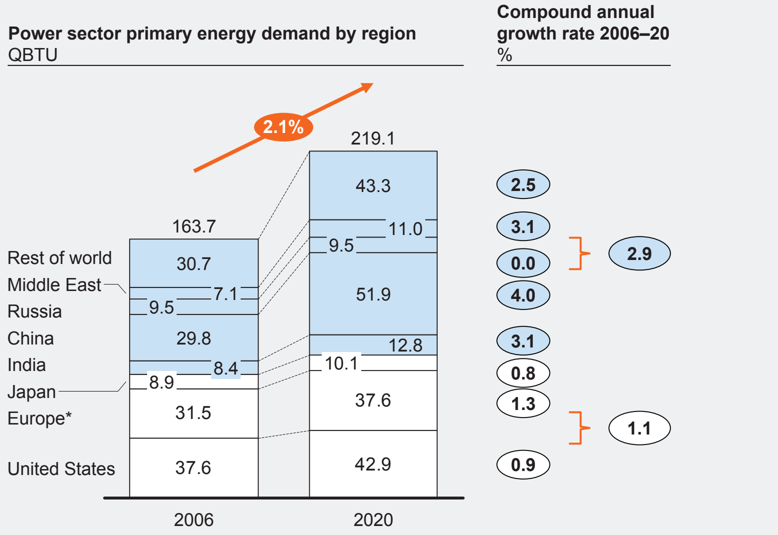
The power sector consumes 35 percent of global energy and 6 percent of global petroleum and will maintain shares by 2020



Source: IEA; McKinsey Global Institute Global Energy Demand Model 2009

Exhibit 3.6.2

Power-sector energy demand will grow at 2.1 percent a year through 2020, driven heavily by developing regions

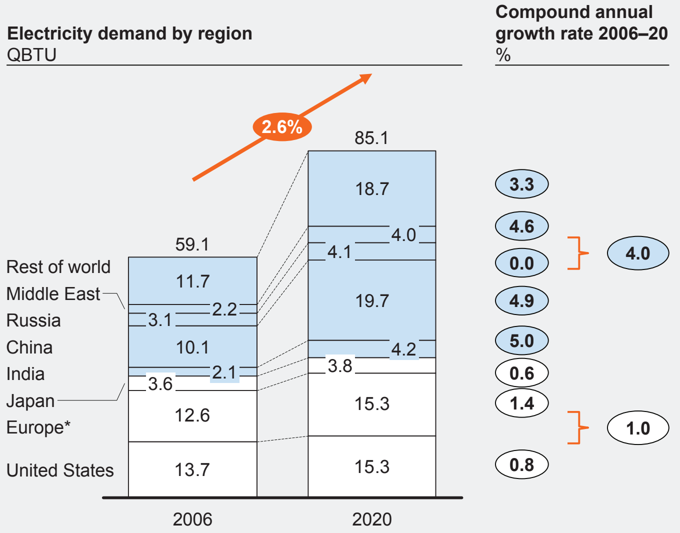


Note: Numbers may not sum due to rounding. * Including Mediterranean Europe and North Africa and Baltic/Eastern Europe.
Source: IEA; McKinsey Global Institute Global Energy Demand Model 2009

Exhibit 3.6.3

Electricity demand will grow more rapidly than overall energy demand at 2.6 percent

▭ Developing regions



Note: Numbers may not sum due to rounding. * Including Mediterranean Europe and North Africa and Baltic/Eastern Europe.
Source: IEA; McKinsey Global Institute Global Energy Demand Model 2009

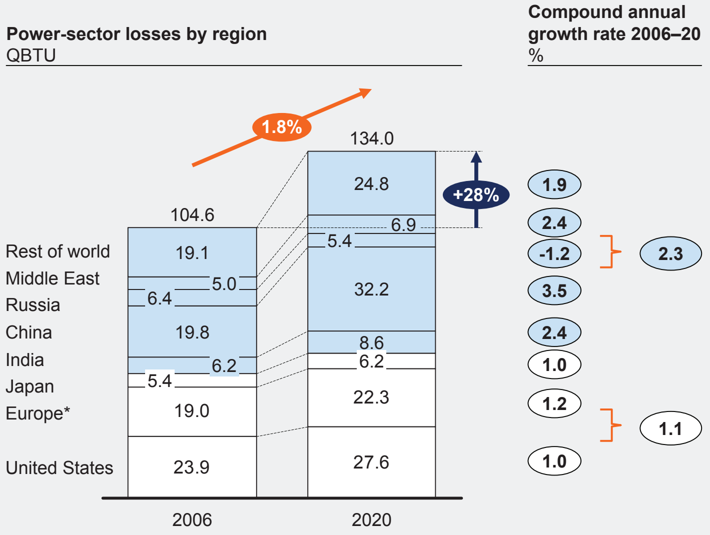
It is interesting to note that power losses—the amount of power not captured as energy during the generation process—account for 105 QBTU or 23 percent of global energy demand in 2006, but these losses will increase at a slightly slower rate than overall energy demand to 2020 when they will reach 134 QBTU or 22 percent of global demand in 2020. This is due to increasing efficiency in power generation, a product of the expanded use of more efficient gas plants (more detail follows).

Again, global growth in power losses at a rate of 1.8 percent per annum is driven mostly by the continued strength of demand growth in developing regions. Losses in developing regions on average will grow at 2.3 percent compared with 1.1 percent in developed regions (Exhibit 3.6.4).

Exhibit 3.6.4

Power losses will grow more slowly than overall energy at 1.8 percent

▭ Developing regions

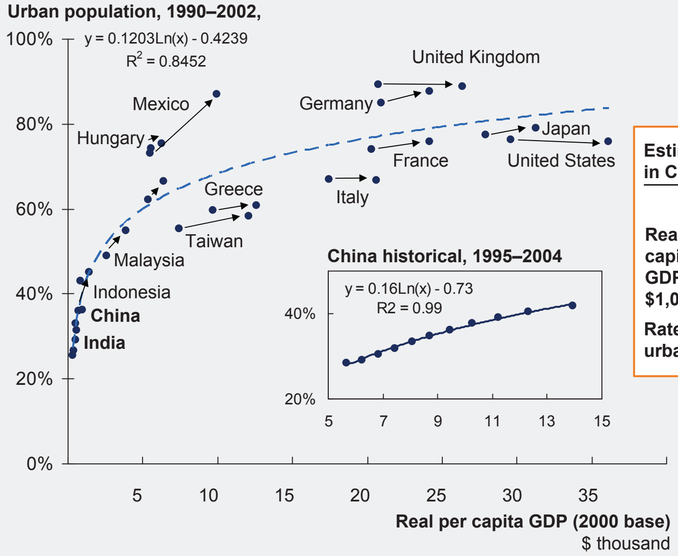


Note: Numbers may not sum due to rounding. * Including Mediterranean Europe and North Africa and Baltic/Eastern Europe.
Source: IEA; McKinsey Global Institute Global Energy Demand Model 2009

In contrast to the situation in electricity, the United States, Europe, and North Africa represent only 10 percent of power losses growth, consuming 43 QBTU or 41 percent of power losses, and growing to 50 QBTU or 37 percent of global power losses by 2020. This slow growth is due to greater efficiency measures mostly coming from a shift to natural gas and renewables as a source of power. By comparison, power losses in China will grow from 20 QBTU to 32 QBTU in 2020, at that date representing 46 percent of power losses growth in the sector. This is due to the fact that China will continue to be a heavy user of coal power plants—the technology of mass availability—as the country urbanizes rapidly (Exhibit 3.6.5). Therefore, as China develops and electricity demand grows, power losses grow in tandem.

Exhibit 3.6.5

Power-demand growth will be driven by strong urbanization rates in China and India



Estimated urbanization in China

	1990	2005	2020
Real per capita GDP, $1,000	0.4	1.6	5.4
Rate of urbanization	27%	42%	58%

Source: United Nations; McKinsey Global Institute analysis

Overall, we have revised down our 2007 projections for power-sector primary energy-demand growth for the period from 2006 to 2020 from 2.2 to 2.1 percent growth over the period. This revision reflects a combination of the downturn and more aggressive renewables targets in developed regions. The marked slowdown in GDP growth depresses power energy-demand growth as end-sector energy use decreases, particularly in sectors such as industrials and most notably in petrochemicals and steel. However, power energy demand slows to a lesser extent than other sectors. This is because consumers do not adjust their electricity demand dramatically in response to GDP swings, particularly in the buildings sector (see chapter 3.4).

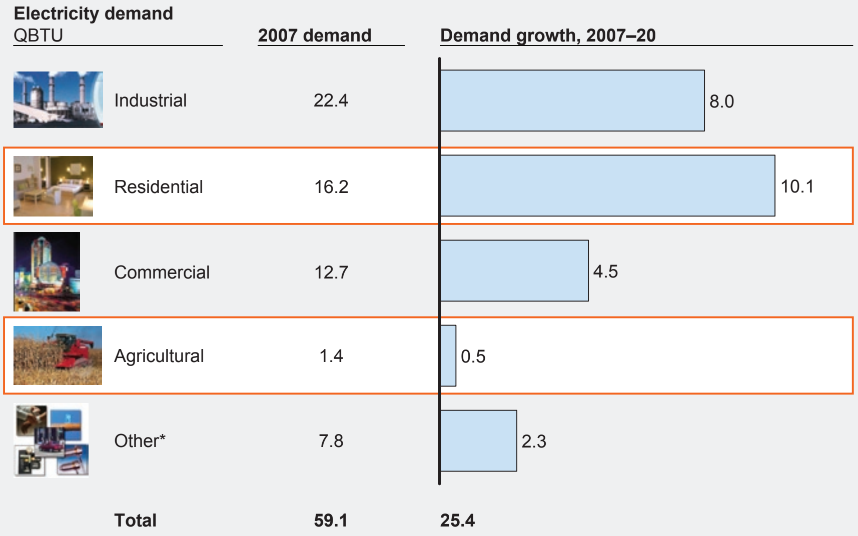
High energy prices would have very little impact on power energy consumption. At a $50 a barrel oil price, demand growth is a projected 2.1 percent between 2006 and 2020 and decreases only marginally at $200 oil. The reason for this demand inertia is that electricity prices do not change much in response to oil price fluctuations, especially in those regions where taxes and subsidies insulate end users from market prices. In addition, industrial sectors' power usage is only slightly price sensitive. Moreover, the bulk of power usage in buildings is very insensitive to price due to a range of market imperfections including subsidized pricing, principal/agent problems between renters and owners, and difficulties in measuring the importance of the power sector for CO_2 emissions (details of our modeling of both these factors follow).

POWER-SECTOR PRIMARY DEMAND WILL GROW RAPIDLY DUE TO RAPIDLY EXPANDING DEMAND IN DEVELOPING REGIONS

Of the various end-use sectors that consume power, buildings represent the bulk of power primary energy demand, and this sector's demand will grow at a projected 3.1 percent as developing regions shift to heavier power usage (Exhibit 3.6.6). Buildings represented 49 percent of power primary energy demand in 2006 (29 QBTU), and this share will rise to 52 percent (45 QBTU) in 2020. Between 2006 and 2020, buildings will account for 60 percent of global growth in electricity demand. Within the building sector, residential buildings account for the bulk of the demand—16 QBTU out of 29 QBTU in 2006—and outpace commercial buildings' power-demand growth at 3.6 percent per year compared with 2.5 percent. Most of the remaining growth comes from industrial sectors, which represent 31 percent of the power-demand growth. In these sectors, primary power demand will increase at a projected 2.2 percent per year between 2006 and 2020. In addition, the industrial sector accounted for the remaining 38 percent of electricity demand in 2006 (22 QBTU), but this sector's share of the global total will decline to 36 percent in 2020 (30 QBTU).

Exhibit 3.6.6

Buildings are the largest source of electricity demand



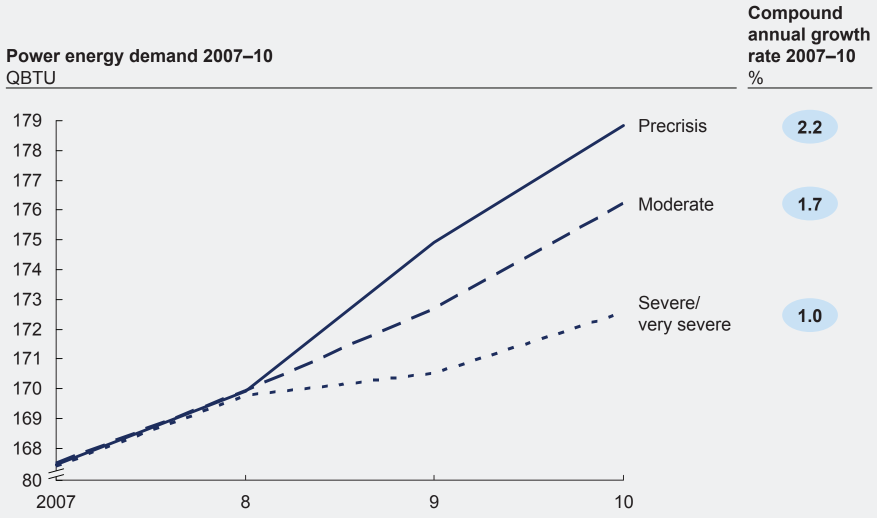
Note: Numbers may not sum due to rounding.
* Includes oil refining, rail transport, steel and iron, pulp and paper, and other industries.
Source: McKinsey Global Institute Global Energy Demand Model 2009

In the short term, primary energy demand from the power sector slows only slightly to 1.4 percent in 2008 and 1.6 percent in 2009 (Exhibit 3.6.7). If a more severe downturn were to unfold, these growth rates would slow to 1.4 and 0.3 percent in these two years. Power-sector primary demand slows only slightly in our moderate case because the bulk of power demand comes from residential and commercial buildings, and these segments, unlike other industries with inventory or durable-goods effects, do not fluctuate more than overall economic growth (in the same way as consumers do not tend to respond significantly to swings in GDP). In fact, while overall energy demand grows at 1.0 percent per year from 2007 to 2009, buildings power energy demand will grow at 1.7 percent per year, which is only slightly slower than the 2.0 percent long-term annual growth rate from 2007 to 2020. This counterbalances power demand from industrials, which is procyclical and which we project will slow to an annual rate of 0.6 percent of the global total in 2007 to 2009.

In the long term, power-sector primary-energy demand will remain strong. Power-sector primary demand will rebound along with global GDP and as the buildings sector becomes more power intensive (Exhibit 3.6.8). In 2010, the year when our moderate case assumes that the downturn will lift, buildings' demand for electricity will grow by 2.9 percent. Looking further out, buildings' demand for power will grow at a robust 3.4 percent between 2011 and 2020.

Exhibit 3.6.7

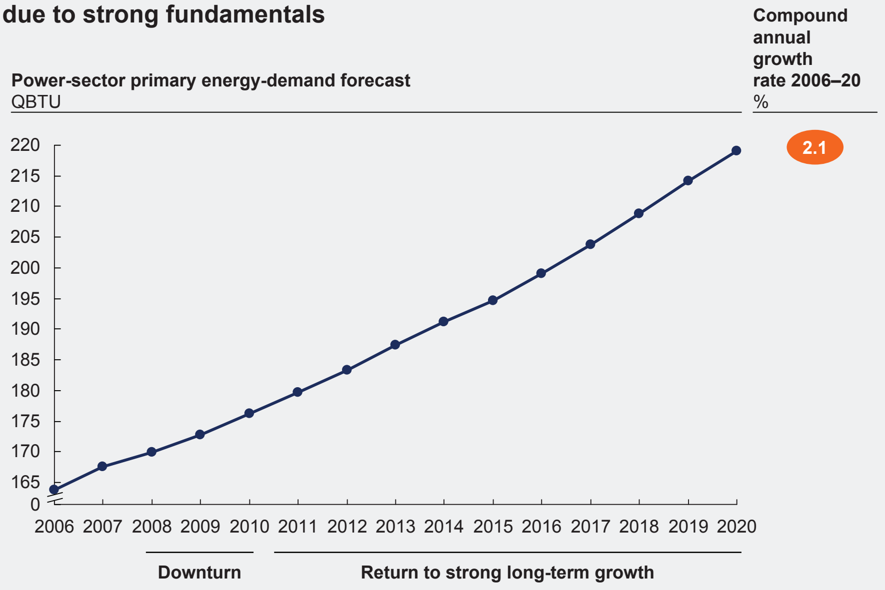
Power energy demand will grow only slightly in response to high 2007 prices and the credit crunch



Source: McKinsey Global Institute Global Energy Demand Model 2009

Exhibit 3.6.8

Power energy-demand growth rebounds along with GDP due to strong fundamentals



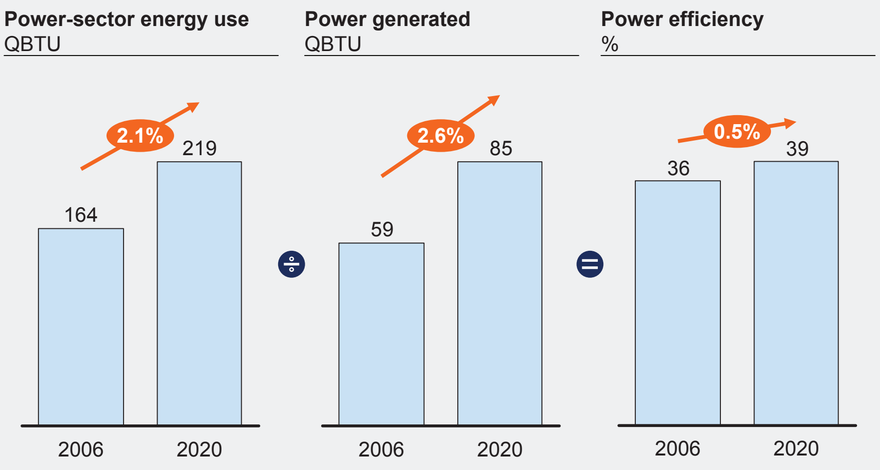
Source: McKinsey Global Institute Global Energy Demand Model 2009

Efficiency

In the long term, we project that the power sector's total primary-energy use will increase at a rate of 2.1 percent per year from 164 QBTU to 219 QBTU in 2020, while power-generated electricity demand will expand at 2.6 percent from 59 QBTU to 85 QBTU in 2020. Efficiency will increase significantly at an average annual rate of 0.5 percent between 2006 and 2020 (Exhibit 3.6.9). This improvement in efficiency is due to a shift toward natural gas plants especially in developed economies, which avoid power generation by less efficient coal plants.[9] In addition, the average efficiency of gas and coal generation will also be increasing rapidly as new plants are added, accounting for half the average annual improvement.

Exhibit 3.6.9

Despite strong growth in electricity demand, power efficiency will improve markedly by 2020



Source: McKinsey Global Institute Global Energy Demand Model 2009

Fuel mix

Globally, the power sector sees two important trends. The first is a dramatic shift from traditional coal, gas, and oil plants to renewables, which are becoming a significant source of electricity generation. The second is a shift from coal to gas plants due to the prohibitive capital cost of coal, the inefficiency of coal plants, and the price of coal relative to gas.

In the United States today, most states have now instituted portfolio standards, which imply meeting a target of a 10 percent renewables share by 2020 (Exhibit 3.6.10). This is a dramatic increase from the 3 percent renewables mix in 2006 and implies a tremendous 70 gigawatts of additional implemented renewables capacity. In Europe, the European Commission ratified a plan in October 2007 detailing a 20 percent renewables target in 2020, a very significant increase from the 5 percent renewables share of 2006. This increase would imply an additional 110 gigawatts of additional online renewables capacity, the majority of which will be offshore wind and biomass (Exhibit 3.6.11). In China and transition economies, targets of 5 percent shares for renewables by 2020 are reasonable based on government plans.

Also important for the evolution of the fuel mix will be baseload electricity shifts away from coal to natural gas in developed regions. This occurs for two reasons. First, the capital cost of coal in developed regions is roughly $2,000 per kilowatt—much more expensive than the $850 per kilowatt capital cost of gas plants (Exhibit 3.6.12). Second, the efficiency of new gas plants is about 53 percent, significantly greater than the efficiency of new coal plants of approximately 43 percent. These factors are borne out by planned capacity additions figures from the UDI World Electric Power

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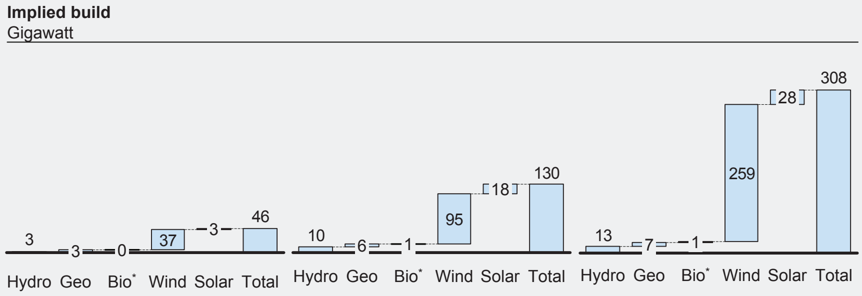
[9] New coal and gas plants average 43 and 53 percent efficiency, respectively, in our model.

Plants Database, which shows coal representing only 9 percent of planned new additions in Europe between 2008 and 2010 and 25 percent of planned new additions in the United States.

Other developing supply regions will not change behavior dramatically because they have no incentive to invest in infrastructure to burn cleaner fuels. Russia will continue to utilize its natural gas reserves; by 2020, renewables will not feature at all. Similarly, the Middle East will continue to use its gas reserves as well, with renewables having a zero share in power generation in 2020.

Exhibit 3.6.10

Most US states now have renewable portfolio standards



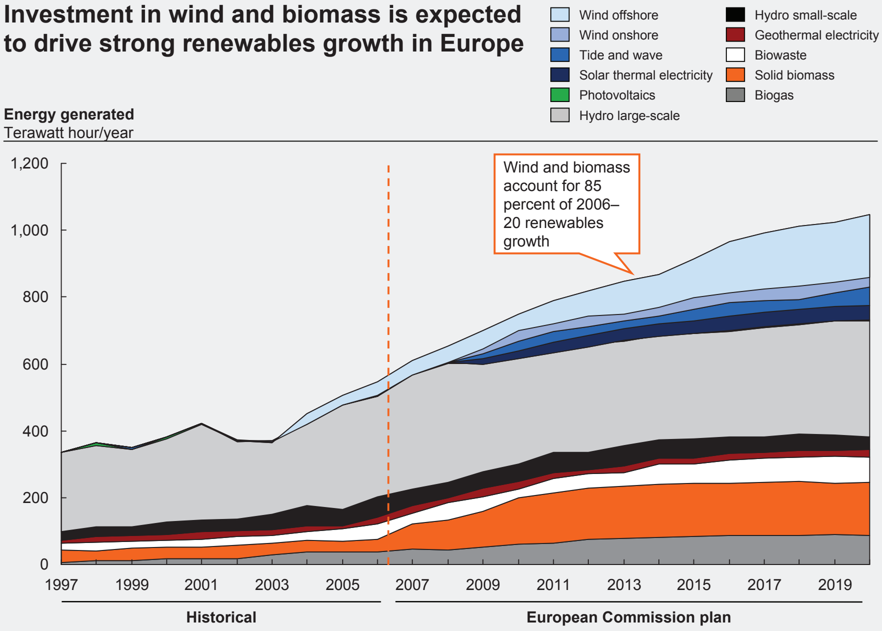
Current state RPS with tough enforcement	All current state RPS	State RPS plus a 15% federal RPS
• RPS targets met only in states with strong enforcement mechanisms (e.g., California) • 5 percent of national supply from RPS sources • $75 billion CapEx required	• All state RPS met, including 29 states with existing RPS and three more with proposed/not passed RPS • 9 percent of national supply from RPS sources • $188 billion CapEx required	• In addition to meeting all state RPS, a federal target of 15 percent by 2020 is imposed • 17 percent of national supply from RPS sources • $404 billion CapEx required

* Biomass is economically viable methane from landfill, manure management, and domestic wastewater.

Source: McKinsey Global Institute analysis

Exhibit 3.6.11

Investment in wind and biomass is expected to drive strong renewables growth in Europe



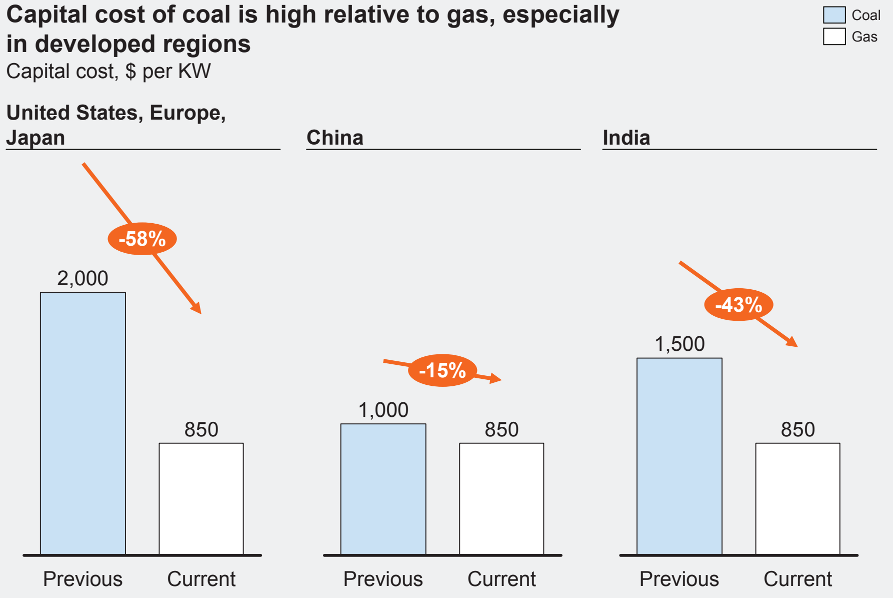
Wind and biomass account for 85 percent of 2006–20 renewables growth

Source: *Renewable Energy Roadmap*, European Commission, January 2007

Exhibit 3.6.12

Capital cost of coal is high relative to gas, especially in developed regions

Capital cost, $ per KW



Source: Expert interview

Besides renewables and the coal-to-gas shift, the other significant change in the power sector's fuel mix that also increases the efficiency of power generation is the fact that China and Japan are both investing heavily in nuclear power. In China, nuclear-power generation will grow from 2.2 to 4.7 percent of total power between 2006 and 2020 (some 27 gigawatts of additional capacity); in Japan, nuclear increases from 24 to 30 percent over the same time frame (about 15 gigawatts).

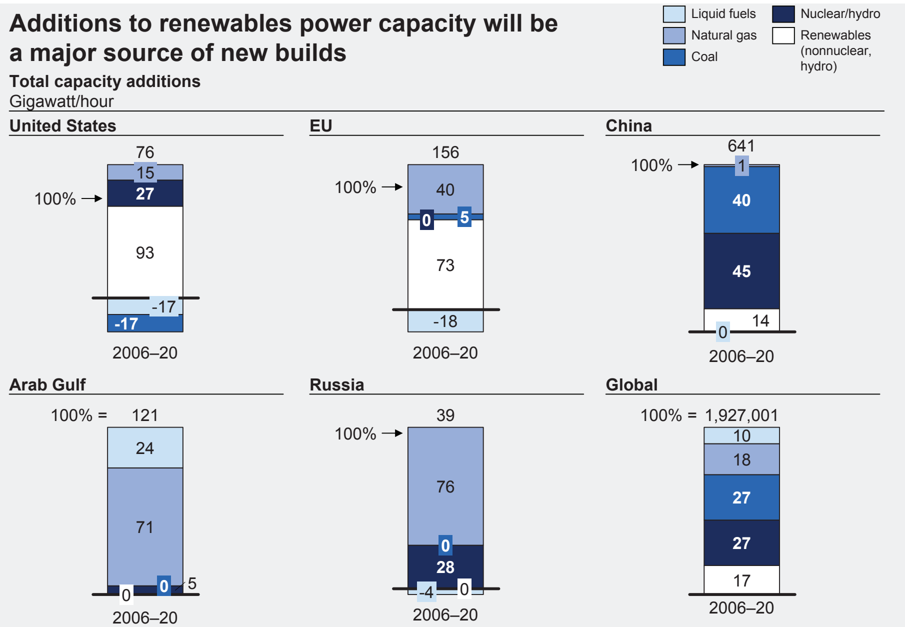
Because of aggressive renewables targets, renewables represent the large percentage of new capacity additions in our moderate case (Exhibit 3.6.13). Renewables is the third-largest source of new builds globally between 2006 and 2020, accounting for 17 percent of the total or 330 gigawatts. Nuclear and hydro together account for the largest source of new builds, representing 27 percent of new plants to 2020, along with coal, which also accounts for 27 percent. Natural gas accounts for 9 percent of new plants to 2020. Of the remaining new plants, natural gas accounts for 18 percent and liquid fuels account for 10 percent.

Breaking down additional renewables capacity by region, the United States will add an additional 70 gigawatts per hour, and Europe will add 110 gigawatts. Together, these will account for most of the global total of 330 gigawatts. In the United States, the majority of all new builds will have to utilize renewables in order to achieve the 10 percent renewables target. We also project a slight increase in natural gas plants and that some coal and liquid-fuel plants (which are often older and less efficient) will be retired. In Europe, renewables will account for 70 percent of all new builds, with the majority of remaining new builds being natural gas plants. As in the United States, a portion of liquid-oil plants will gradually be retired.

In other regions, renewables represent a smaller portion of new builds. To meet burgeoning electricity demand, China has invested heavily in nuclear and hydro plants that account for 40 percent of new builds, with the other 40 percent being coal plants given the abundance of this energy source. Renewables will account for only 14 percent of new capacity in China. In supply regions such as the Middle East and Russia, renewables additions are negligible.

Exhibit 3.6.12

Additions to renewables power capacity will be a major source of new builds



Note: Numbers may not sum due to rounding.

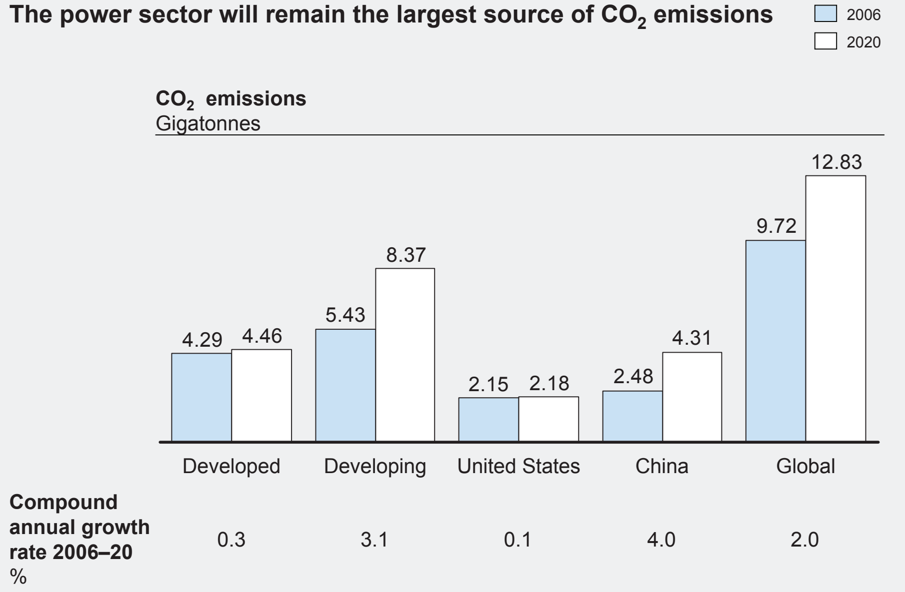
Source: McKinsey Global Institute Global Energy Demand Model 2009

POWER WILL REMAIN A LARGE SOURCE OF CO_2 EMISSIONS

Power remains the largest source of CO_2 emissions, accounting for 9.7 gigatonnes or 37 percent of total emissions in 2006 and growing to a projected 12.8 gigatonnes (still 37 percent of global emissions) by 2020 (Exhibit 3.6.14).[10] The 2.0 percent annual increase in emissions between 2006 and 2020 will be driven largely by developing regions, whose emissions will be increasing at a rate of 3.1 percent per year during this period, in contrast to a small 0.3 percent decline in the emissions of developed regions.

Exhibit 3.6.14

The power sector will remain the largest source of CO_2 emissions



Source: McKinsey Global Institute Global Energy Demand Model 2009

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[10] The MGI model captures only pure price elasticity in both electricity and primary-power demand. The implication is that many other opportunities to abate CO_2 emissions that might carry a cost of less than $40 per tonne to implement might not be captured without other enabling regulations. For a review of these opportunities, see *Pathways to a low- carbon economy*, Climate Change Special Initiative, McKinsey & Company, January 2009 (www.mckinsey.com).

China, today the single-largest emitter of CO_2 in power, will see its power-related emissions grow at 4.0 percent per year between 2006 and 2020. These emissions accounted for 2.5 gigatonnes or 25 percent of global power emissions in 2006 and will total 4.3 gigatonnes or 33 percent of the total by 2020. Although emissions per QBTU of power generated in China will fall due to a shift toward cleaner and more efficient renewables and nuclear power, strong income growth and power demand will still drive a large net increase in China's power-related CO_2 emissions.

The United States, currently the second-largest emitter in power, will actually reduce its power-related emissions at a rate of 0.4 percent per year. In 2006, US power-sector emissions totaled 2.2 gigatonnes or 22 percent of the global total in 2006. By 2020, emissions will be steady at 2.2 gigatonnes, but their share of the global total will fall to 16 percent. This trend is driven by a significant increase in renewables power generation, although there will also be some impact from switching from coal to gas plants. Our estimate is in line with other major sources, which project flat to slightly positive CO_2 growth in the power sector. The IEA projects a 0.1 percent increase per year between 2007 and 2020, while the EIA projects a 0.4 percent increase per annum between 2007 and 2030. These figures reflect a slightly less optimistic renewables new builds relative to our assumptions. Europe and North Africa is the other region that grows emissions slowly—at a rate of 0.4 percent per year from 2006 to 2020.

When we combine these three regions, their power-sector emissions represented 1.37 gigatonnes or 14 percent of the global total in 2006 and will total 1.45 gigatonnes or 11 percent by 2020. Again, the major impact is from increasing renewables power generation together with a contribution from switching from coal to gas.

Overall, MGI's estimate of growth in power sector CO_2 emissions is slightly lower than estimates from IEA, which projects a 1.6 percent annual increase in emissions between 2006 and 2020, compared with our projection of a 2.0 percent annual increase over the same time frame.

Due to a shift toward cleaner and more efficient power, global emissions relative to GDP decrease by 20 percent from 260 million metric tonnes per million dollars in 2006 to 210 million metric tonnes per million dollars in 2020. It is notable that China will actually make more significant progress than the United States in this respect, improving its emissions relative to GDP by 45 percent from 2006 to 2020 compared with 33 percent for the United States.

Given the importance of the power sector for CO_2 emissions, we looked at two factors that can have a marked impact on emissions growth—a scenario in which renewables growth is relatively modest and a scenario that takes into account different levels of emissions taxes.

Emissions taxes

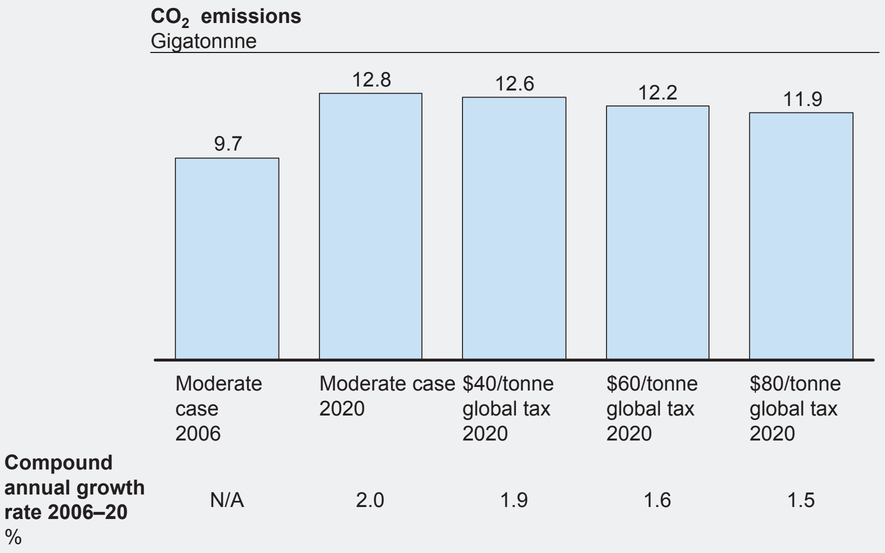
Different regions are looking at various emissions-tax schemes, and we have analyzed some different scenarios. In our high-tax scenarios, we extend the emissions tax of $40 per tonne in Europe and the United States of our moderate case to the rest of the world. We also look at the impact of higher global emissions taxes at $60 and $80 per tonne. We should note that our model may understate the impact of CO_2 taxes for two reasons. First, we model only the economically driven shift from gas to coal in new builds. If a high CO_2 tax were to cause the accelerated retirement of coal plants or a shift from coal to renewables instead of gas, our projections would not reflect this. Second, our estimated figures for the reduction of electricity demand represent a pure consumer response to prices; however, supporting regulations in addition to carbon taxes could capture additional abatement.[11]

A higher CO_2 emissions tax makes coal relatively more costly to burn for power, and this would result in more new builds of natural gas plants in several regions with cheap access to coal. Under a $40 per tonne global scenario, we would see 2020 CO_2 emissions decrease only from 12.8 gigatonnes in our moderate case to 12.6 gigatonnes and shade back growth in emissions from 2.0 to 1.9 percent between 2006 and 2020. This is because in China and India (which account for 65 percent of global coal plant new builds), coal in 2008 is roughly $3 per MBTU in both regions, compared to $12 per MBTU in China and $8 per MBTU in India for gas. This means it takes a more substantial tax than $40 per tonne to incentivize switching to gas plants.

Under a $60 per tonne global scenario, 2020 CO_2 emissions decrease to a much greater degree from 12.8 gigatonnes in our moderate case to 12.2 gigatonnes. This represents a decrease in annual CO_2 emissions growth between 2006 and 2020 from 2.0 percent in our moderate case to 1.6 percent. Finally, under an $80 per tonne global scenario, 2020 CO_2 emissions decrease from 12.8 gigatonnes in our moderate case to 11.9 gigatonnes, representing a decrease in annual CO_2 emissions growth between 2006 and 2020 from 2.0 percent in our moderate case to 1.5 percent (Exhibit 3.6.15).

Exhibit 3.6.15

CO_2 emissions drop significantly under higher global CO_2 emissions taxes



Source: McKinsey Global Institute Global Energy Demand Model 2009

On a global level, as a result of the $80 per tonne tax, coal new builds fall from 528 gigawatts to 367 gigawatts, while gas new builds increase from 349 gigawatts to 478 gigawatts. As a result, the power sector would demand an additional 2.7 QBTU of natural gas under a global $80 per tonne tax. This would certainly strain the LNG infrastructure, particularly if petroleum supply becomes tight and a significant amount of natural gas is necessary as a substitute (discussed in detail in chapter 2).

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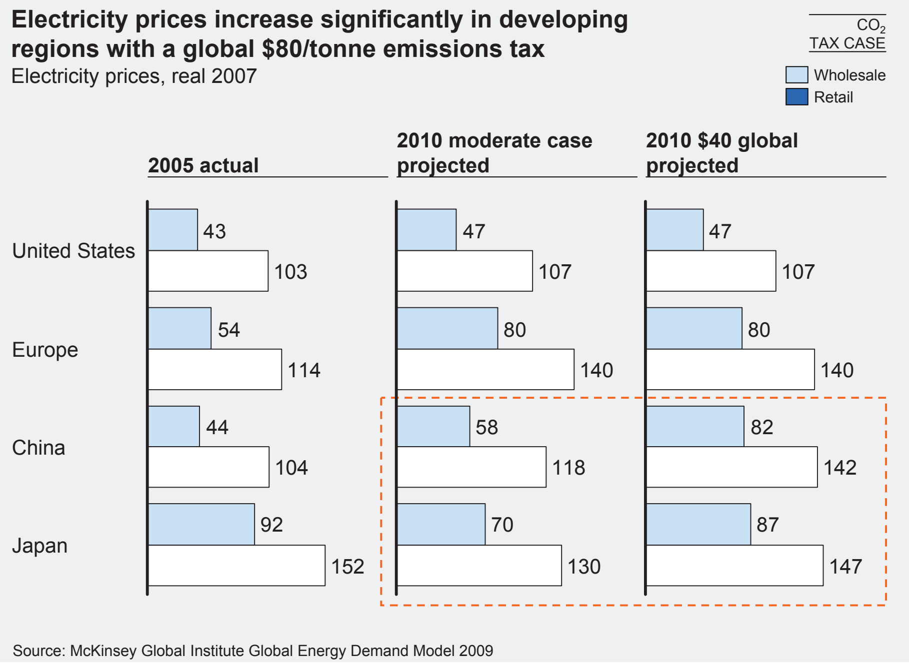
[11] As pointed out in McKinsey's report *Pathways to a low-carbon economy*, January 2009, many low and negative carbon-abatement opportunities exist; however, an emissions tax alone is not sufficient to capture these.

Overall, in this $80 per tonne scenario, China's emissions would decrease from 4.3 gigatonnes to 3.9 gigatonnes in 2020 and the annual growth rate of emissions decline to 4.0 to 3.5 percent. Emissions in India would drop from 1.0 gigatonnes to 0.9 gigatonnes in 2020 and their annual growth rate from 3.6 to 3.3 percent. Besides the shift to cleaner fuels already described, these emissions declines would also take place as a result of an increase in electricity prices due to the tax, which would depress electricity demand and the resulting primary demand for power generation.

Both wholesale and retail prices increase in developing regions as a result of CO_2 emissions taxes, but the magnitude of the increase would depend on how expensive electricity is in a given region. In China, projected wholesale electricity prices in 2010 would increase by 40 percent from $58 per megawatt hour to $82 per megawatt hour, while projected retail electricity prices would increase by 20 percent from $118 per megawatt hour to $142 per megawatt hour. In Japan, where electricity is more expensive, prices would increase less on a percentage basis; projected wholesale electricity prices in 2010 would rise 25 percent from $70 per megawatt hour to $87 per megawatt hour, while projected retail electricity prices in 2010 would increase 13 percent from $130 per megawatt hour to $147 per megawatt hour (Exhibit 3.6.16).

Exhibit 3.6.16



Electricity prices increase significantly in developing regions with a global $80/tonne emissions tax

Electricity prices, real 2007

Source: McKinsey Global Institute Global Energy Demand Model 2009

Due to these electricity-price increases, electricity demand would decline in developing regions. Globally, electricity demand in 2020 would decrease from 85 QBTU in our moderate case to 82 QBTU, reigning back annual growth from 2.6 to 2.4 percent. China's 2020 electricity demand would decrease from 19.7 QBTU to 19.3 QBTU, while Russia's would shade back from 4.2 QBTU to 3.6 QBTU.

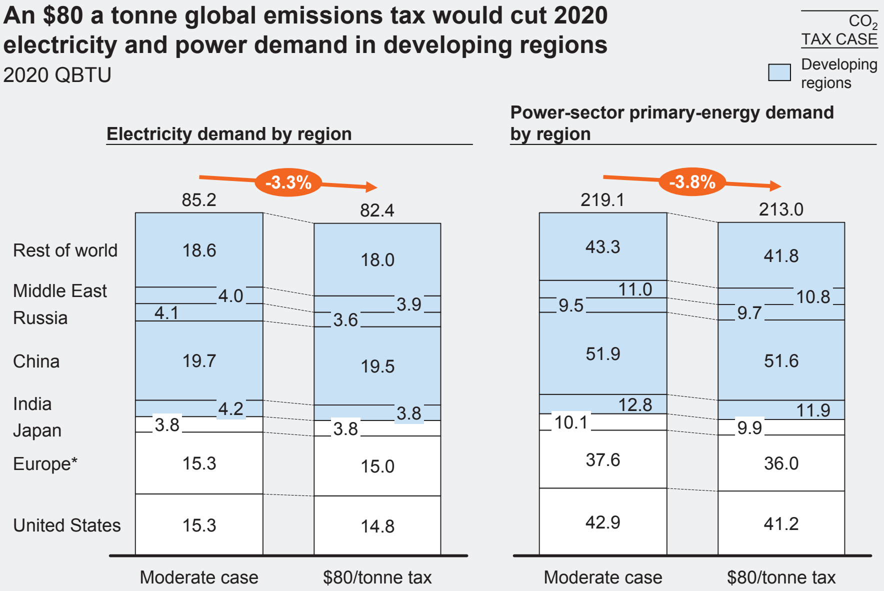
Overall primary demand from the power sector moves in line with electricity demand in developing regions. In our $80 per tonne CO_2 emissions tax scenario, total primary demand from power in 2020 decreases from 219 QBTU to 213 QBTU and the annual growth rate from 2.1 to 2.0 percent. In China, power-sector primary demand in 2020 would decrease from 52.6 QBTU to 52.2 QBTU and the rate of annual growth from 4.0 to 3.9 percent. In India, 2020 primary demand decreases from 13.1 QBTU to 12.2

QBTU and annual growth from 3.3 to 2.6 percent. This drop in power-sector primary demand would result in a decline in CO_2 emissions as the result of a global emissions tax inflating electricity prices (Exhibit 3.6.17).

Exhibit 3.6.17

An $80 a tonne global emissions tax would cut 2020 electricity and power demand in developing regions

2020 QBTU



Note: Numbers may not sum due to rounding. * Including Mediterranean Europe and North Africa and Baltic/Eastern Europe.
Source: IEA; McKinsey Global Institute Global Energy Demand Model 2009

In a scenario in which there are no emissions taxes, global power CO_2 emissions increase from 12.8 gigatonnes to 13.2 gigatonnes, boosting the annual growth rate in 2006 to 2020 from 2.0 to 2.1 percent. All of this increase occurs in the United States and Europe where, instead of increasing by 0.4 a year in 2006 to 2020, they would be increase by 1.2 percent a year.

However, this is due to demand reduction due to higher prices, and not efficiency gains from switching to cleaner-burning gas plants. Even with no emissions taxes, Europe and the United States build gas plants for both baseload and peak demand due to higher plant efficiency and the lower capital cost of gas.

Glossary of acronyms

ANWR Arctic National Wildlife Refuge

BEV Battery electric vehicles

BOF Basic oxygen furnace

BRIC Brazil, Russia, India, and China

CAFE Corporate average fuel economy

CAPP Canadian Association of Petroleum Producers

CNG Compressed natural gas

CTL Coal to liquid

DRI Direct reduced iron

DSM Demand-side management

DW Deep water

EAF Electric arc furnace

EGR Exhaust-gas recirculation

EIA Energy Information Administration

EISA Energy Independence and Security Act

EOR Enhanced oil recovery

EPBD Energy Performance of Buildings Directive

EPRI Electric Power Research Institute

ESD Energy Services Directive

EU European Union

EU25 25 member states of the EU

EV Electric vehicles

EV80 Electric vehicle capable of traveling 80 miles in one charge

FC Full-cost capacity

GEM global energy and material practice (McKinsey)

GoM Gulf of Mexico

GTL Gas to liquid

HEV Full hybrids

IATA International Air Transport Association

ICE Internal combustion engine

IEA International Energy Agency

IEEJ Institute of Energy Economics, Japan

IGO Industrial gas oil

IOR Improved oil recovery

IRR Internal rate of return

IRU International Railroad Union

KBD Thousand barrels a day

LNG Liquefied natural gas

LPG Liquid petroleum gas

LT Long term

MBTU Million British thermal units

MC Marginal-cost capacity

MEI Main economic indicators, OECD

NOC National Oil Corporation

NE New England area

NHTSA National Highway Traffic Safety Administration

OECD Organisation for Economic Co-operation and Development

OHF Open hearth furnace

OFSE Oil field services and equipment

OPEC Organization of Petroleum Exporting Countries

PHEV Plug-in hybrids

PPP Purchasing power parity

QBTU Quadrillion British thermal units

RPS Renewable portfolio standards

RPK Revenue passenger kilometers

RPM Revenue passenger miles

ST Short term

SUV Sport utility vehicle

UDW Ultra-deep water program

USGC US Gulf Coast

VMT Vehicle miles traveled

WEU Western European Union

WTI West Texas intermediate

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