McKinsey Global Institute

Productivity of growing global energy demand: A microeconomic perspective

November 2006

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Preface

This perspective is the product of a year-long effort by the McKinsey Global Institute (MGI) and McKinsey's Global Energy and Materials (GEM) Practice to understand the microeconomic underpinnings of global energy demand. It is the first of a two-part series to introduce microeconomic analysis of end-use segments to the global energy debate. The second part, to be published in early 2007, provides more detailed analyses by sector and fuel mix; and elaborates on implications to businesses and policymakers.

A group of leaders in McKinsey's Global Energy and Materials Practice, Pedro Haas, Scott Nyquist, Matt Rogers, and Jonathan Woetzel, provided strong leadership to our project throughout. The project team was led by Jaana Remes and Jaeson Rosenfeld, Senior Fellows at MGI. Our project has benefited from support from many colleagues around the world, and we would particularly like to thank Ivo Bozon, Odd Christopher Hansen, Scott Andre, Warren Campbell, Tim Fitzgibbon, Morten Jorgensen, Mike Juden, Allen Martin, Augusto Moreno, Greg Terzian, and Jin Yu. We also benefited from valuable input from our senior external advisors Adrian Lajous and Robert Mabro. The project team included Arpit Agarwal, Florian Bressand, Rahul Gupta Anders Havneraas, Maya Jolles, Paul Langley, Shawn Liu, Fabrice Morin, Laurent Poncet, Sebastian Roemer, Erin Tavgac, and Peter Yeung.

MGI combines McKinsey's business experience with the rigor of academic discipline. 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 perspective is independent and has not been commissioned or sponsored in anyway by any business, government or other institution.

Diana Farrell
November 2006
San Francisco

Productivity of growing global energy demand: A microeconomic perspective

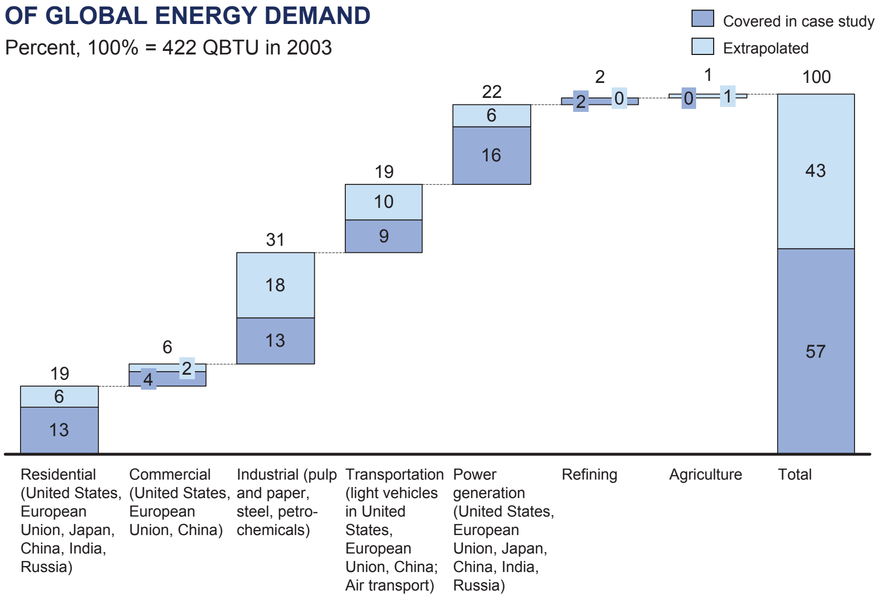
Energy is again in the headlines. Higher oil, gas, coal, and uranium prices have brought back age-old concerns about whether the physical resources of the globe can meet the rapidly growing demand from developing economies. To provide a fact base to inform the debate, the McKinsey Global Institute (MGI) and McKinsey's Global Energy and Materials Practice launched a year-long effort to understand the microeconomic underpinnings of global energy demand.

Our focus has been on energy productivity—how the growing demand for energy can be met most productively. Together with labor and capital productivity, energy productivity is critical to economic growth and well-being, and should therefore be a much higher priority in national policy agendas (see Box 1: What is energy productivity?). We took a detailed look at each of the main end-use segments in the largest economies globally; identified the key microeconomic, behavioral, and policy relationships, explaining energy demand in each sector; and aggregated across countries and end-user segments to produce an integrated, dynamic perspective on global energy demand and productivity (see Box 2 and Exhibit 1 for a further description of our energy-demand model).

Exhibit 1

THE MGI SECTOR CASES COVER 57 PERCENT OF GLOBAL ENERGY DEMAND

Percent, 100% = 422 QBTU in 2003



Source: IEA, MGI

BOX 1: WHAT IS ENERGY PRODUCTIVITY?

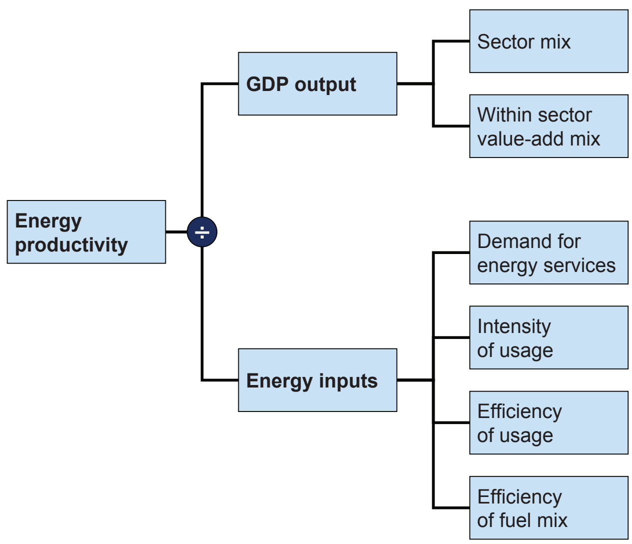
Like labor or capital productivity, energy productivity measures the output and quality of goods and services generated with a given set of inputs. We measure energy productivity as the ratio of value added to energy inputs, which today is $79 billion of GDP per QBTU of energy inputs. This is the inverse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

Energy productivity is a useful tool with which to analyze the public-policy aims of demand abatement and energy-efficiency because it encapsulates both. By looking merely in terms of shrinking demand, we are in danger of denying opportunities to consumers—particularly those in developing economies who are an increasingly dominant force in global energy-demand growth. Rather than seeking to reduce end-user demand—and thus the level of comfort, convenience, and economic welfare demanded by consumers—we should focus on using the benefits of energy most productively.

The concept of energy productivity provides an overarching framework for understanding the evolving relationship between energy demand and economic growth. Energy-productivity improvements can come either from reducing the energy inputs required to produce the same level of energy services, or from increasing the quantity or quality of economic output. Within each of these, there are multiple components that can change over time (Exhibit 2). The same level of energy services can be produced with fewer inputs if use is less intensive (e.g., smaller appliances); if technical efficiency improves (e.g., higher-mileage-car engines); or if fuel-mix shifts, say, from biomass to more efficient electricity. In turn, output can grow more quickly than demand for energy services because of sectoral shifts—say, from energy-intensive industrial sectors to services—or from an increasing share of growth taken by non-energy-intensive, high value-added activities within a sector (e.g., increasing share of investment banking versus retail banking). By being explicit about the relative importance of each, energy productivity acts as a useful tool to enable us better to understand the nature and source of change and more effectively seek to improve growth and energy outcomes.

Exhibit 2

DECOMPOSITION OF ENERGY PRODUCTIVITY



When identifying opportunities for energy improvements, we focus on changes that rely on currently existing technologies and have an internal rate of return (IRR) of 10 percent or more, without reducing the comfort or convenience valued by consumers. This marginal focus on economically viable opportunities only means that making these investments would benefit the economy by freeing up resources either to increase consumption elsewhere—or invest for faster growth.

Our main finding is that, while energy demand will continue to grow rapidly, there are sufficient economically viable opportunities for energy-productivity improvements that could keep global energy-demand growth at less than 1 percent per annum—or less than half of the 2.2 percent average growth to 2020 anticitated in our base-case scenario.

However, market-distorting subsidies, information gaps, agency issues, and other market inefficiencies all work against energy productivity. Furthermore, the small share of energy costs for most businesses and consumers reduces end-use response to energy-price signals. Therefore, shifting global energy demand from its current rapid growth trajectory will require the removal of existing policy distortions; improving transparency in the usage of energy; and the selective deployment of energy policies, such as standards.

CURRENT GLOBAL ENERGY DEMAND

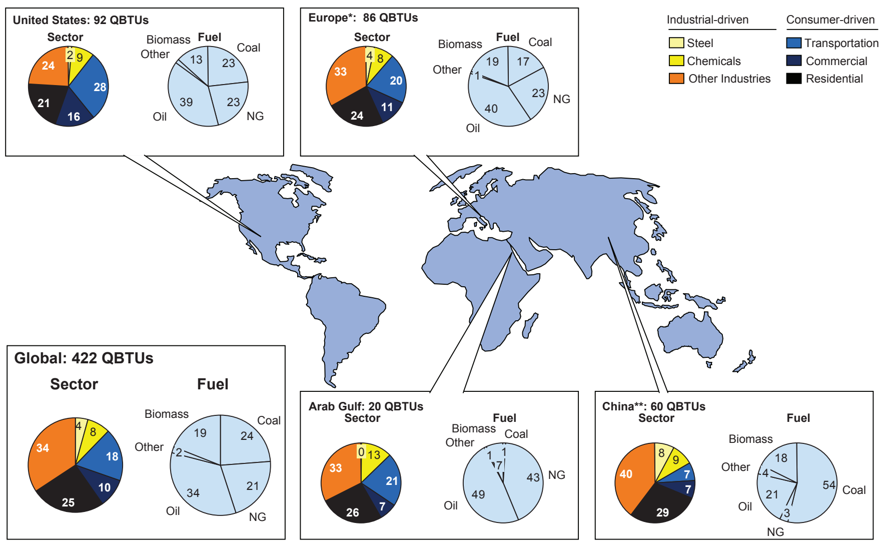
In 2003, the world used 422 QBTUs of energy annually, the energy equivalent of 222 million barrels of oil per day. Petroleum products account for a third of this demand (about 76 million barrels per day; or 145 QBTUs in 2003); coal and natural gas contribute 100 and 90 QBTUs each; and the remainder is split among myriad fuels, including biomass. The largest energy consumers are the United States with 92 QBTUs (or 22 percent of the global total), and China with 60 QBTUs (Exhibit 3). These two countries are also responsible for four of the largest end-use energy-demand sectors globally: US road transport with a 5.4 percent share; Residential in both countries (4.0 percent and 4.5 percent respectively); and Commercial in the United States (3.5 percent).

An end-use perspective shows that consumers drive more than half of global energy demand. After allocating power-sector-energy consumption and losses to end-use sectors, we show that 50 percent of total energy demand and 60 percent of developed world demand currently comes from sectors with the key characteristics of consumer goods—residential (25 percent of total demand); road transport (16 percent); commercial (10 percent); and air transport (2 percent). The share of industrial demand has declined with the shift to less energy-intensive services, particularly in developed economies.

Exhibit 3

US ENERGY DEMAND IS 92 QBTUS COMPARED WITH CHINA'S 60 QBTUS

End-use energy demand by sector, primary demand by fuel, QBTU 2003



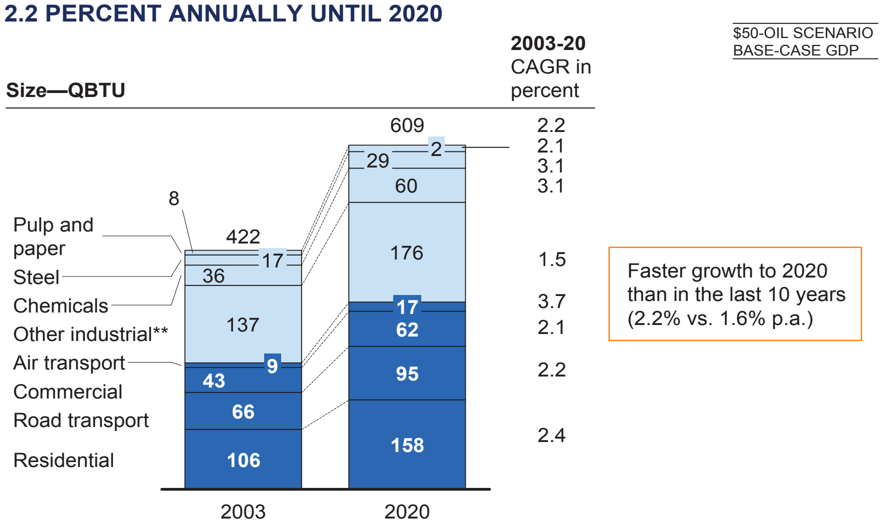
* Includes Northwestern Europe, Mediterranean, North Africa, Baltic and Eastern Europe
** Greater China region, includes Hong Kong and Taiwan
Source: MGI

ACCELERATING ENERGY-DEMAND GROWTH

Across all of our scenarios, global energy demand will grow more quickly over the next 15 years than in the past 15. Our base scenario—a $50 oil price and global GDP growth of 3.2 percent per annum—foresees 2.2 percent annual growth in global energy demand, growing from 422 QBTUs in 2003 to 610 QBTUs in 2020 (Exhibit 4). In this base scenario, global oil demand will grow to 89 million barrels per day by 2010, and 110 million barrels per day by 2020. The low- and high-GDP growth scenarios range from 1.7 percent to 2.7 percent energy demand growth annually—all higher than the 1.6 percent growth seen since 1994. The swing between $30 and $70 oil prices at the base-case growth rate is not as large—energy demand increases by 1 QBTU in the $30 oil case and decreases by 7 QBTUs in the $70 oil case.

Exhibit 4

WE FORESEE GLOBAL ENERGY END-USE DEMAND* GROWTH BY 2.2 PERCENT ANNUALLY UNTIL 2020



* Electricity-generation losses allocated to end-use segments
** Including refining
Source: MGI

Our base-case projections are approximately 0.5 percent higher across all end-use sectors than comparable IEA WEO 2006 energy-demand projections. The additional growth we predict comes particularly from the expectation—emerging from our microeconomic perspective—of more rapid growth in transportation demand in China, the Middle East, and middle-income Europe. Meanwhile, in our base case, CO_2 emissions will grow at a robust rate of 2.3 percent per annum, reaching 34 gigatons by 2020.

Developing countries represent 84 percent of energy-demand growth to 2020 (Exhibit 5). With six of the top ten global-growth sectors, China alone represents 32 percent of overall energy-demand growth. Chinese car penetration grows more quickly than previously expected over the next 15 years, as the Chinese middle class continues to expand and car prices continue to decline.[1] Chinese industrial-energy demand will also continue to grow rapidly, as the country is still at an early stage in its industrialization. Chinese steel production is expected to grow by 4.5 percent annually and represent over 40 percent of global steel

1 "From 'Made in China' to 'Sold in China': The rise of the Chinese urban consumer," MGI, November 2006.

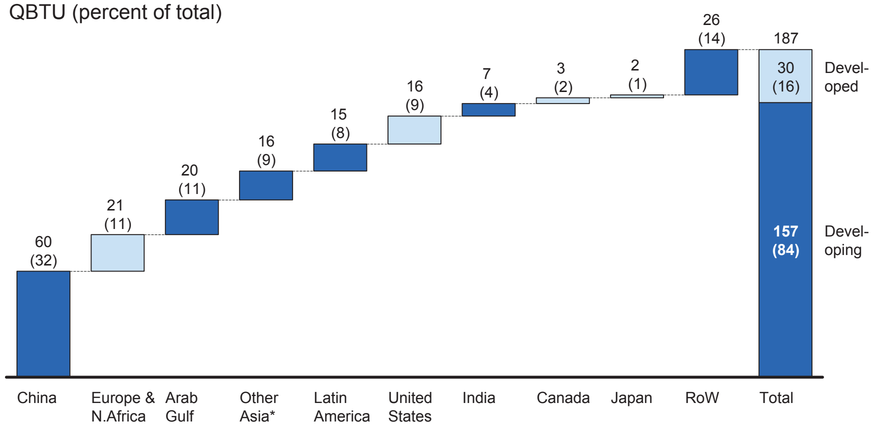
demand by 2020. The Arab Gulf is another fast-growing region, contributing more than 10 percent of total energy-demand growth in our base scenario and an even higher share in our $70-oil scenario which boosts the region's GDP growth and energy-demand growth, especially for subsidized petroleum products.

Exhibit 5

DEVELOPING COUNTRIES—PARTICULARLY CHINA AND THE ARAB GULF—WILL DRIVE ENERGY-DEMAND GROWTH TO 2020

$50-OIL SCENARIO
BASE-CASE GDP

End-use energy-demand growth 2003-2020 by region
QBTU (percent of total)



* Includes Australia and Japan
Source: MGI Energy Demand Model

BASE ENERGY-PRODUCTIVITY GROWTH IS NOT SUFFICIENT TO STOP ENERGY DEMAND ACCELERATING

The energy productivity of today's global economy is 12,600 BTUs of energy consumed per dollar of output produced—or $79 billion of GDP per QBTU of energy inputs.[2] This represents a 25 percent productivity increase since 1980. There is wide variance around the mean across regions—often directly as a result of differences in energy prices and/or policies. Japan leads the world in energy productivity overall, as a result of consistently high energy prices and strict energy-efficiency standards set by industry best practice; the Arab Gulf is among the least productive as a result of large, sustained energy subsidies and energy-intensive growth model. We see many examples of gaps in energy productivity at the sector level. Japanese gas and coal power plants are more than 70 percent more energy productive than Russian plants; and the 2007 standards for room air conditioners in Japan will be nearly 50 percent stricter than the Chinese equivalent. In the transportation sector, European gasoline taxes are roughly seven times the US tax level—and cars are 15 percent more energy-efficient than US cars in the same class.

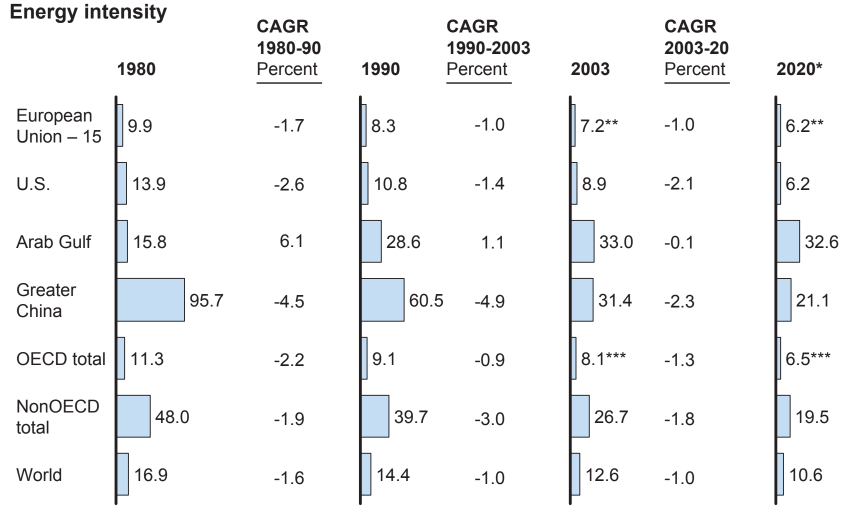
Global energy productivity will continue to improve by 1.0 percent per year. We predict a 19 percent increase in global energy productivity by 2020—or a shift from today's 12,600 BTU/$ to 10,600 BTU/$. This is the result of continuing shifts in most economies to less energy-intensive services, to higher-value-added products, and to more efficient technologies (Exhibit 6). In developed countries, we expect these trends to accelerate slightly from moderate historical trends. Energy productivity will continue to grow fastest in developing countries at 1.8 percent a year. More rapid GDP growth in these regions, as well as the introduction of new, more energy-efficient capital stock—both buildings and equipment—will drive much of the higher productivity increase and help close productivity gaps. While Chinese coal-power plants, with a large installed base, are likely to improve sector energy productivity by only 1.1 percent per year to 2020, we expect the sector energy productivity of residential buildings to improve by 2.0 percent per annum because of rapid growth in urban housing and the Chinese government's current 20 percent energy-intensity-reduction target.

2 Global GDP of $37 trillion in 2003, measured at market prices.

Exhibit 6

ALL REGIONS CONTINUE ON LESS INTENSIVE PATH, HOWEVER INTENSITY DECLINE IN ARAB GULF IS LOWEST

Energy intensity



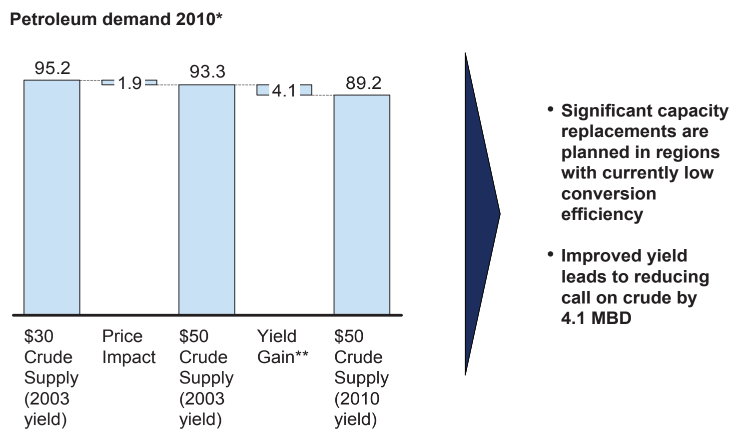
* Base case growth in $50 scenario
** North Western Europe
*** Including Northern Africa
Source: IEA; MEI; Global Insight, MGI analysis

Conversion economics in the refining sector will boost productivity by 4 million barrels per day, or 8 QBTUs, by 2010. Energy prices impact energy-transforming businesses more than other business sectors and consumers because energy feedstock is a very large share of total costs. There is currently a wide variance in conversion efficiency across power plants and refining operations. As capacity utilization rises, each incremental unit of new demand requires an ever-larger increase in feedstock energy as production moves to the least-efficient conversion capacity. For instance, the cost to refineries of producing the last unit of gasoline may require 50 percent more crude oil per barrel when they are operating at 95 percent capacity utilization than at 85 percent. This amplifying effect simultaneously creates more demand and increases incentives for suppliers to expand into new, high-conversion capacity when capacity utilization is high—a process which boosts energy productivity both by directly increasing average efficiency, and by taking less-efficient production out of use altogether. We estimate that the planned additions of refining capacity to 2010 will cause a 4 million barrels a day (equivalent to 8 QBTUs) reduction in refining crude oil demand by 2010 (Exhibit 7). Thus, the call on crude is contained, while the energy needs are still fully met, resulting in higher energy productivity.

Exhibit 7

REFINING CONFIGURATION IMPROVEMENTS WILL REDUCE CALL ON CRUDE BY 4.1 MBDs BY 2010

Millions of barrels per day



* MGI base case GDP growth scenario

** Increase in transportation fuel yield from 78% (2003) to 82% (2010) by volume

Source: EIA, IEA, Petrosims

Current energy-productivity growth is not sufficient to stop energy demand accelerating. With faster projected global GDP growth, a 1.0 percent rate of annual energy-productivity growth is not sufficient to keep global energy demand from accelerating from the rates that have prevailed historically.

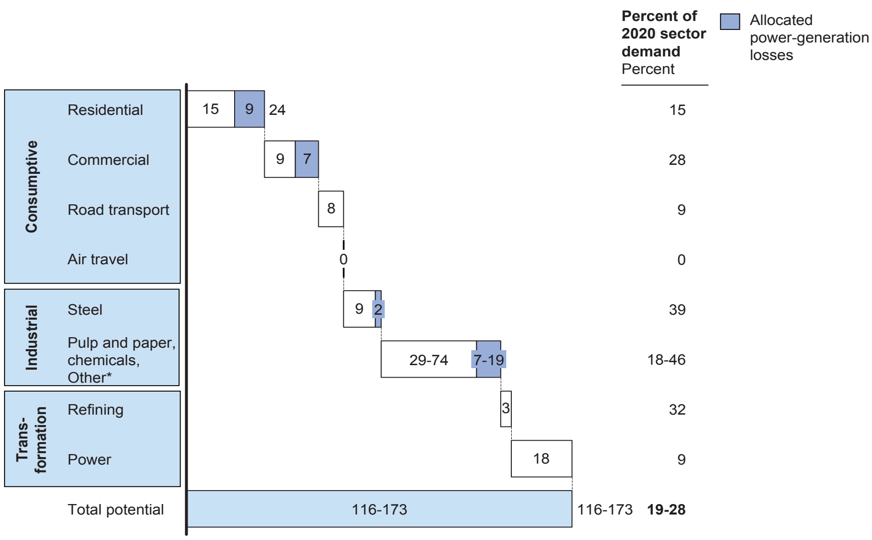
CAPTURING ENERGY-PRODUCTIVITY OPPORTUNITIES COULD REDUCE ENERGY-DEMAND GROWTH TO 0.6 PERCENT A YEAR

Energy productivity could be boosted by another 150 QBTUs—with largest untapped potential in the residential, power-generation, and industrial sectors. Conventional technologies with an Internal Rate of Return (IRR) of 10 percent or more provide large opportunities for additional productivity improvements in a broad range of end-use segments. Taken together, we estimate that these opportunities represent 150 QBTUs, or an additional 15 to 25 percent of projected 2020 end-use demand (Exhibit 8). Capturing these opportunities would reduce global-energy demand growth to 0.6 percent annually—from 2.2 percent in our base scenario.

The global residential sector currently represents 27 percent of global energy demand. By implementing technologies such as high-efficiency building shells,

Exhibit 8

CURRENT TECHNOLOGY FOR ENERGY PRODUCTIVITY IMPROVEMENT OF 19-28 PERCENT AT 10+ PERCENT IRR



Source: MGI

compact fluorescent lighting, and high-efficiency water heating—all of which are currently available—we estimate that residential-energy-demand growth would slow down from 1.4 percent per year to 0.5 percent per year, reducing 2020 energy demand by 24 QBTUs when the associated power generation losses are included (or 4 percent of the total).[3]

Reducing electricity generation and distribution losses is another large opportunity. Power generation used 129 QBTUs (30 percent of global energy use) to generate 57 QBTUs of delivered electricity in 2003—a loss of more than half of the energy initially used. Some of this is unavoidable, but, even today, conversion rates (energy delivered divided by energy used) range from only 30 percent in older coal plants to 55 percent plus in Advanced Combined Cycle Gas Turbine (CCGT) technology. We estimate that implementing changes with 10 percent or more IRR would reduce demand by 18 QBTUs by 2020. Growth in the power sector would decline from 2.2 percent to 1.7 percent per annum.

3 These technologies would include installing the tightest building shells in new homes, including chemically treated windows, and the highest-grade insulation. Furthermore, compact fluorescent lighting, reductions in standby power requirements, and driving ever-improving appliance-efficiency standards would all be part of the package. Solar water heaters (with appropriate backup when necessary) also show a positive return, at the same time as reducing energy demand.

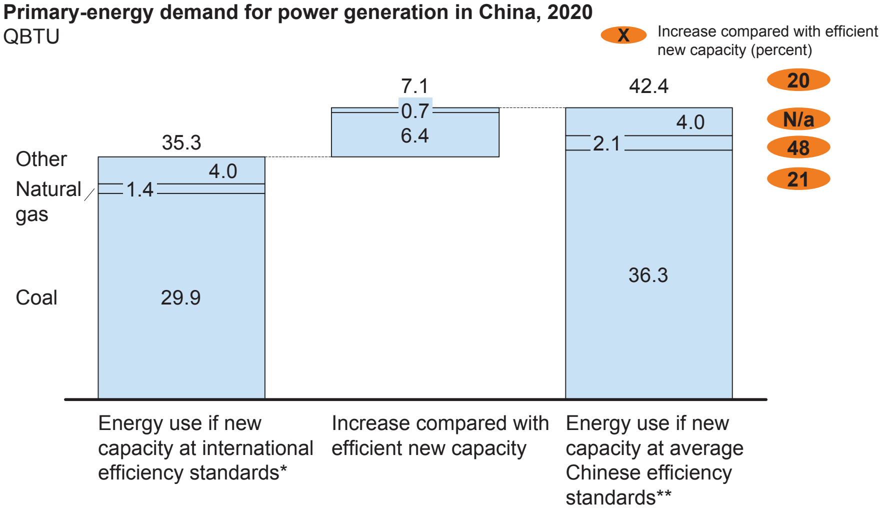
Finally, industrial sectors offer an approximately 40 percent, or 65 QBTUs, of additional energy-improvement opportunity. Within this total, we estimate that refining could raise productivity by 30 percent, steel by 40 percent, and other industries by 20-40 percent, with developing countries contributing more than developed countries due to lagging current energy productivity.

The energy-productivity path that developing economies choose will have a large impact on global energy demand. Given its share of the growth, the choices China makes are particularly critical. The growth in China's power sector alone represents 13 percent of global energy demand growth by 2020. Whether this new demand is met by power plants at current efficiency levels, or through the installation of new, high-efficiency coal plants, will swing Chinese energy demand by 7.1 QBTUs—or 1.2 percent of the global total—by 2020 (Exhibit 9). In the residential sector, the energy-efficiency standards in Chinese building codes are significantly below global benchmarks—for example, Chinese building-shell standards allow double the leakage of developed-country standards in similar climates (Exhibit 10). Action to raise these standards could reduce demand by 2 QBTUs.

Exhibit 9

FUTURE CHINESE ENERGY DEMAND COULD EXCEED OUR FORECASTS IF THE POWER SECTOR DOESN'T INSTALL EFFICIENT NEW CAPACITY

Primary-energy demand for power generation in China, 2020
QBTU

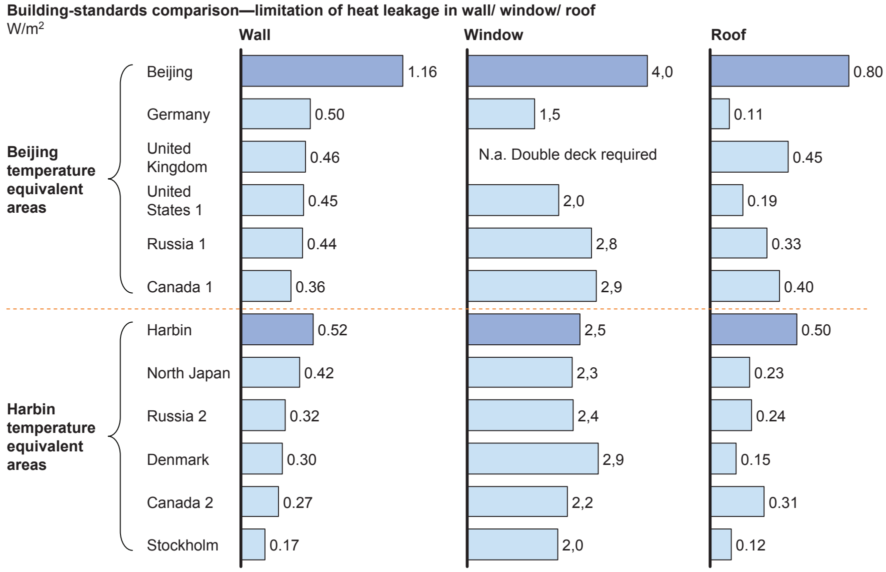


* Natural gas (53%); coal (43%)
** Natural gas (44%); coal (36.4%)
Source: MGI; UDI

Exhibit 10

CHINA HAS SIGNIFICANT POTENTIAL TO IMPROVE HEATING EFFICIENCY FROM EQUIPMENT AND HEATING CENTRALIZATION

Building-standards comparison—limitation of heat leakage in wall/ window/ roof



Source: ERI; Literature search

MARKET FAILURES PREVENT VIABLE ENERGY-PRODUCTIVITY IMPROVEMENTS BEING CAPTURED

Demand response to high prices is limited, even with sustained $70 oil prices. Our $70-oil case shows demand that is only 8 QBTUs below the $30-oil case projections, with almost all of that reduction coming from the road and air-transportation sectors. In general, energy-demand price-elasticity is quite low, and can take several years to take hold. Some sectors will not reduce overall energy demand—but will instead shift fuel sources in response to changes in relative fuel prices. For instance, we see a 13 QBTU shift from gas to coal between our high and low scenarios and an up to 4 QBTU shift from petroleum-based transportation fuels to biofuels. Further limiting the energy-demand response is the fact that high oil prices boost GDP growth in the unproductive Arab Gulf region, which offsets the reduction in GDP and energy demand in more efficient, importing regions.

Consumers lack the information and capital needed to improve energy productivity; and their price response is further muted by the priority given to convenience, comfort, style, or safety. Most consumers lack information on the range of energy-productivity-improvement opportunities available to them, despite the fact that these would be in their economic interest. They may also lack the capital, or desire to invest it, to fund the upfront capital investment often required to capitalize on these opportunities. The motivation to do so is also reduced, in developed economies, by the minor impact of fragmented energy savings on individual household expenditures. In reality, consumers are far more interested in using more energy for comfort (e.g., larger houses and apartments), convenience (e.g., more and larger appliances), style (e.g., more and larger vehicles), and health/safety (e.g., gas and electricity rather than coal for heating or dung and straw for cooking). Lastly, retail prices often include high distribution margins and taxes, which shelter end-users from fluctuations in global fuel prices. As a result, consumer standards and supplier-incentive programs are often more effective in improving consumer-energy productivity than price alone.

Businesses also forego viable energy-productivity investments because of small and fragmented energy costs—and further reduce consumer incentives to react to price. Increases in energy productivity that have been achieved thus far mean that total energy costs in the United States[4] now represent less than 10 percent of output value in all non-energy sectors, and less than half of that for most economic activities. On new capital-purchase decisions (e.g., automated manufacturing or IT hardware), energy efficiency is typically a minor factor at best. Many high-return investments to improve the energy productivity of existing operations are left on the table, as users often require three-year or less payback times—or more than a 30 percent IRR—for capital expenditures that reduce energy consumption. In addition, energy-transforming and energy-intensive industrial sectors continue to be publicly-owned in many developing economies, reducing the competitive pressure on managers to improve their performance.[5]

Meanwhile, manufacturers of energy-consuming equipment may also dampen the response to high energy prices in the short-term by temporarily delaying the migration to higher-efficiency equipment in response to energy-price increases.

4 Based on the United States, we include both the direct energy consumption in a sector, as well as all indirect energy consumed through goods and services used as inputs from other sectors.

5 Productivity in the electric utility industry, MGI, 1996, http://www.mckinsey.com/mgi/reports/pdfs/capital_productivity/Electrical_util.pdf)

We saw this in the US automotive sector, where local manufacturers compensated buyers of less fuel-efficient vehicles, notably SUVs, with incentives and rebates during the first two years of high oil prices in order to move inventory. Only when their losses mounted did manufacturers recently start to retool and shift their emphasis towards higher fuel-efficiency vehicles.

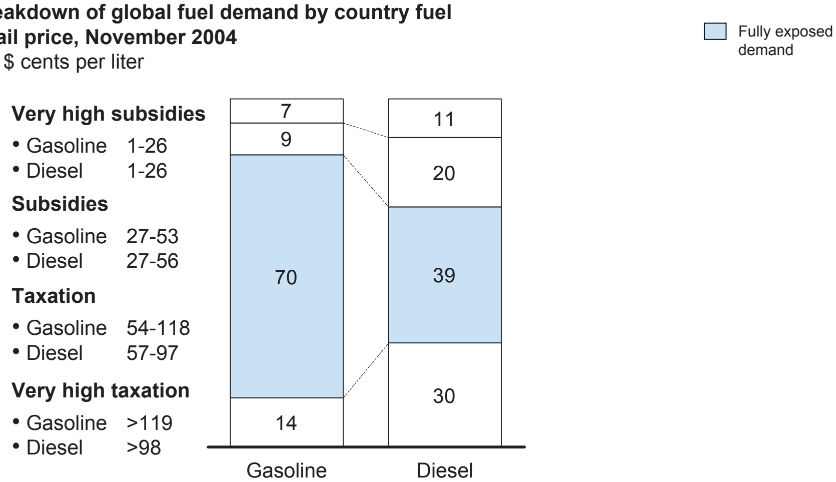
Moreover, widespread energy-price policies reduce incentives to end-users to adopt viable energy-productivity improvements and dampen market price signals. At least 20 percent of current global-energy demand is subject to energy subsidies or non-marginal pricing, which reduce, or eliminate, the incentive to use energy most productively. These distorting energy policies include fuel subsidies in oil-exporting Middle-Eastern countries; lack of metering in Russian residential gas usage that sets the marginal cost of energy at zero; and widespread prevalent energy subsidies to state-owned enterprises. It is not surprising that energy efficiency in these areas lags dramatically behind global best practice.

Taxes on energy may encourage energy productivity, but—like subsidies and non-marginal prices—they also prevent end-users from feeling the full impact of changes in energy-market prices. When oil prices climbed after 2002, more than 40 percent of global transportation-fuel demand—the largest oil end-use segment with 50 percent of global oil consumption—was insulated from the full price increase in global oil markets because of the buffer provided by local taxes or subsidies (Exhibit 11). This reduced the incentives for drivers to respond by reducing miles traveled. In oil-importing countries, such as Indonesia and Thailand, energy subsidies proved unsustainable because of their significant fiscal implications and had to be reduced.

Exhibit 11

TRANSPORTATION FUELS ARE "INSULATED" FROM MARKET OIL PRICE

Breakdown of global fuel demand by country fuel retail price, November 2004
US $ cents per liter



* Weighted first according to retail-price distribution within diesel and gasoline, then according to distribution of global demand between gasoline and diesel, assuming that it is the same for light vehicles as for total road transportation

Source: GTZ International Fuel prices 2005; MGI

TARGETED POLICIES TO REMOVE MARKET FAILURES AND INEFFICIENCIES ARE NEEDED TO DRIVE ENERGY PRODUCTIVITY

Our microeconomic analysis shows that even higher energy prices will not lead, by themselves, to more rapid energy-productivity growth, or to keep energy-demand from accelerating from historic levels. Higher prices (and different relative prices) will drive significant fuel switching, but relatively little aggregate decline in BTU consumption. Instead, targeted policy intervention to remove market failures are needed to achieve significant change in both. To motivate the framing of effective policies, policy makers need to make energy productivity an explicit indicator of national economic success—much like labor and capital productivity.

The first step is to remove policies that discourage the productive use of energy—typically the unintended consequence of price subsidies. Beyond that, optimal policies will need to reflect the microeconomic dynamics of end-user segments, which vary both by sector and region. In the residential and commercial sector, building codes and appliance-efficiency standards have a role because of the costs of overcoming informational and agency barriers. In the transportation sector, CAFÉ standards would be most appropriate for a place like China, where new vehicle purchases over the next 15 years will represent the majority of the vehicle stock; in the United States, taxes could have a more immediate impact as the vehicle stock will turn over more slowly.

The precise calibration of any policy will depend on the specific objectives for changing energy demand, prime among them the aim of increasing energy productivity, but also reducing CO_2 emissions, reducing geopolitical risks and dependency on imported energy; and earning a higher return on energy investments. The fact base that emerges from our model is designed to help policy makers, business, and consumers, prioritize the best opportunities for delivery of their respective aims.

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This report, "Productivity of Growing Energy Demand: A Microeconomic Perspective", is the fi rst of a two-stage series by MGI to introduce microeconomic analysis of end-use segments to the global-energy debate. Building on detailed global case-sector studies, it provides a useful context for discussing global energy demand and its complex dynamics. A further report, which we will publish in early 2007, will elaborate on our findings – particularly those at the sectoral and fuel mix levels– and on their broader implications to the global economy.

BOX 2: MGI'S BOTTOM-UP ENERGY-DEMAND MODEL

Analysts typically forecast energy demand at a global level using top-down correlations to GDP growth. They pair historical year-on-year GDP growth figures with corresponding energy-demand-growth numbers at both the country and fuel level—for example, oil demand in Japan—and then determine long-term correlations.

To complement these projections, the McKinsey Global Institute and McKinsey's Global Energy and Materials Practice decided to approach the energy-demand problem from a different angle—using a micro-, rather than macro-based, approach. Global energy demand is really nothing more than the sum of demand from hundreds of micro-economic sectors—such as China's road-transportation sector and Russia's steel sector. MGI's bottom-up global model builds on detailed microeconomic case-sector studies—a methodology that MGI has nearly 15 years' of experience applying to such diverse areas as productivity, offshoring, foreign-direct investment and capital markets. We cover nearly 60 percent of global energy demand across our nine micro-economic sectors, and use extrapolation techniques for the other 40 percent of global demand.[6]

In our bottom-up approach, we take global end-use energy demand as the basis of analysis. Our end-use demand equals primary demand, but allocates all generation and distribution losses to the corresponding end-use segments. This enables us to focus on a single global demand number and capture the full implications of behavioral and policy factors affecting each end-use segment. We believe that this is a more appropriate way of thinking about total energy demand and its drivers than the standard division between primary and delivered energy demand.

6 These are the two standard definitions used for overall energy demand, only one of which includes energy losses in generation and distribution. Primary energy demand includes both final energy end-consumption and the energy lost in generation, transmission, and distribution. This measure is typically used when looking at energy demand by type of fuel, as well as for supply decisions. Delivered energy demand includes only energy end-consumption, a measure typically used when assessing energy consumption by sector—or energy intensity in specific sectors. In 2003, the two measures were 422 QBTUs and 319 QBTUs—a difference of more than 30 percent.

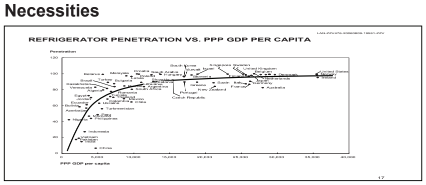
In each sector case, we start by breaking down energy demand into its key components: demand for energy services—how many refrigerators or cars?; intensity of usage—how large and what frequency?; efficiency of usage—what gas mileage or how many kilowatt-hours per cubic meter?; and the fuel-mix—how much gasoline versus diesel?. Countries may have significantly different outcomes in the same sector due to varied levels of development, urbanization rates, policy environments, and many other factors more easily observed at the micro-level. We then developed dynamic scenarios, which model how these factors might respond to different price and policy environments.

For example, in the residential sector we see very clear patterns of appliance-adoption based upon the level of GDP per capita in the country. From this standpoint, the current and future position of China along the penetration curves will make a real difference to forecasting global-energy demand (Exhibit 12). While urban areas of China have been traveling along the fast slope of the curve for refrigerator penetration over the last 15 years, they will reach

Exhibit 12

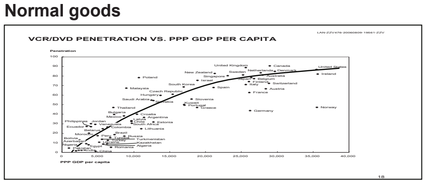
FOR EXAMPLE, WE MODEL FUTURE PENETRATION USING REGRESSIONS OF INTERNATIONAL APPLIANCE PENETRATION VS. PPP GDP/CAPITA

Necessities



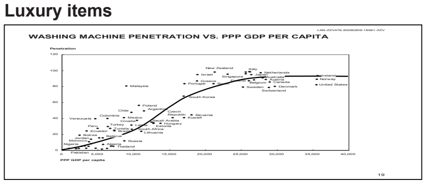
Steep log-curve
- Refrigerator
- Color TV

Normal goods



Gradual log-curve or linear
- Personal computer
- VCR/DVD player
- Vacuum cleaner
- Air conditioner

Luxury items



S-curve/logistic function
- Microwave oven
- Washing machine
- Dishwasher
- Clothes dryer

the saturation point of 100 percent penetration in urban areas in the next 15 years. So, while penetration has driven past refrigerator energy-demand growth, future growth will be motivated more by continued urbanization and by size increases in refrigerators.

Similarly, in industrial sectors we see micro-observable trends that will have real impact both on the location and size of industrial-energy demand going forward. For example, in the steel sector, two interesting trends are scrap availability and the European Union's adoption of the Kyoto protocol. Our projections show a shortage of scrap over the next five to ten years, resulting in a higher dependency on energy-intensive production methods, which drives energy demand up over the medium term. In the case of the EU and the Kyoto protocol, the Union could actually put at risk the highest-cost production in Europe, as full-cost mills could be built in Russia or China to displace them, thus shifting the location of energy demand.

We have aggregated such sector-level insights into our global energy-demand model which combines nine sector cases and extrapolates them into a single model that forecasts energy demand by country, fuel, and region. The model provides a unique tool to test different price, policy, global GDP, and other variables, and then state their respective impacts on energy demand.