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McKinsey Sustainability & Resource Productivity Practice




November 2011

Resource Revolution: Meeting the world's energy, materials, food, and water needs

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Resource Revolution: Meeting the world's energy, materials, food, and water needs

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3 billion more middle-class consumers expected to be in the global economy by 2030

80% rise in steel demand projected from 2010 to 2030

147% increase in real commodity prices since the turn of the century

44 million people driven into poverty by rising food prices in the second half of 2010, according to the World Bank

100% increase in the average cost to bring a new oil well on line over the past decade

Up to **$1.1 trillion** spent annually on resource subsidies

The challenge

$2.9 trillion

of savings in 2030 from capturing the resource productivity potential…

rising to **$3.7 trillion**

if carbon is priced at $30 per tonne, subsidies on water, energy, and agriculture are eliminated, and energy taxes are removed

70% of productivity opportunities have an internal rate of return of more than 10% at current prices…

rising to **90%**

if adjusted for subsidies, carbon pricing, energy taxes, and a societal discount rate of 4%

At least $1 trillion

more investment in the resource system needed each year to meet future resource demands

15 opportunities

deliver about 75% of total resource productivity benefits

The opportunity

Executive summary

During most of the 20th century, the prices of natural resources such as energy, food, water, and materials such as steel all fell, supporting economic growth in the process. But that benign era appears to have come to an end. The past ten years have wiped out all of the price declines that occurred in the previous century. As the resource landscape shifts, many are asking whether an era of sustained high resource prices and increased economic, social, and environmental risk is likely to emerge.

Similar concerns have appeared many times in the past, but, with hindsight, the perceived risks have proved unfounded. In 1798, land was at the center of popular worries. In his famous *An essay on the principle of population*, Thomas Malthus expressed concern that the human population was growing too rapidly to be absorbed by available arable land and that this would lead to poverty and famine.[1] But the dire vision he outlined did not come to fruition as the agro-industrial revolution swept across Britain and then the rest of Europe and North America, breaking the link between the availability of land and economic development. Malthusian theories have enjoyed brief revivals, notably in the Club of Rome's report on the limits to growth in the early 1970s. But the dominant thesis of the 20th century was that the market would ride to the rescue by providing sufficient supply and productivity.

This thesis—and hope—has largely proved correct. Driven by a combination of technological progress and the discovery of, and expansion into, new, low-cost sources of supply, the McKinsey Global Institute's (MGI) commodity price index fell by almost half during the 20th century when measured in real terms. This was astonishing given that the global population quadrupled in this century and that global economic output expanded roughly 20-fold, resulting in a jump in demand for different resources of anywhere between 600 and 2,000 percent.

The rise in resource prices over the past decade and the scale and pace of economic development sweeping across emerging markets have revived the debate about resources. The market and the innovation it sparks may once again ride to the rescue and will clearly be an important part of the answer. The ability to generate, communicate, share, and access data has been revolutionized by the increasing number of people, devices, and sensors that are now connected by digital networks. These networks can help to transform the productivity of resource systems, creating smarter electricity grids, supporting more intelligent building, and enabling 3D and 4D seismic technology for energy exploration. Digital networks could potentially have an impact on even small-scale farmers in sub-Saharan Africa. Techniques from the aerospace industry are transforming the performance of wind-turbine power generation. Developments in materials science are dramatically improving the performance of batteries, changing the potential for electricity storage, and, over time, will diversify energy choices for

1 Thomas Malthus, *An essay on the principle of population* (New York: Penguin, 1970; originally published in 1798).

the transport sector. Organic chemistry and genetic engineering may help to foster the next green revolution, transforming agricultural productivity, bio-energy provision, and terrestrial carbon sequestration. In short, there is no shortage of resource technology, and higher resource prices are likely to accelerate the pace of innovation.

However, the size of today's challenge should not be underestimated; nor should the obstacles to diffusing more resource-efficient technologies throughout the global economy. The next 20 years appear likely to be quite different from the resource-related shocks that have periodically erupted in history. Up to three billion more middle-class consumers will emerge in the next 20 years compared with 1.8 billion today, driving up demand for a range of different resources. This soaring demand will occur at a time when finding new sources of supply and extracting them is becoming increasingly challenging and expensive, notwithstanding technological improvement in the main resource sectors. Compounding the challenge are stronger links between resources, which increase the risk that shortages and price changes in one resource can rapidly spread to others. The deterioration in the environment, itself driven by growth in resource consumption, also appears to be increasing the vulnerability of resource supply systems. Food is the most obvious area of vulnerability, but there are others. For example, changes in rainfall patterns and greater water use could have a significant impact on the 17 percent of electricity supplied by hydropower, as well as fossil fuel power plants and water-intensive methods of energy extraction. Finally, concern is growing that a large share of the global population lacks access to basic needs such as energy, water, and food, not least due to the rapid diffusion of technologies such as mobile phones to low-income consumers, which has increased their political voice and demonstrated the potential to provide universal access to basic services.

This research has established that both an increase in the supply of resources and a step change in the productivity of how resources are extracted, converted, and used would be required to head off potential resource constraints over the next 20 years. The good news is that this research has identified sufficient opportunities to expand supply and improve productivity to address the resource challenge. The open question is whether the private sector and governments can implement the steps needed to deliver these opportunities sufficiently quickly to avoid a period of even higher resource prices, increased volatility, and potentially irreversible environmental damage.

Our analysis shows that there are resource productivity improvements available that would meet nearly 30 percent of demand for resources in 2030. Successful implementation of these productivity opportunities could more than offset the expected increase in land demand over the next 20 years in our base case. Their implementation would also address more than 80 percent of expected growth in demand for energy, 60 percent of anticipated growth in demand for water, and one-quarter of expected growth in demand for steel. We estimate the total value to society associated with these productivity improvement opportunities—including the market value of resources saved—to be $2.9 trillion in 2030, at current prices before accounting for environmental benefits and subsidies. The value of the opportunity would increase to $3.7 trillion assuming a $30 per tonne price for carbon as well as the removal of energy, agriculture, and water subsidies, as well as the removal of energy taxes. Just 15 opportunity areas, from improving the energy efficiency of buildings to moving to more efficient irrigation, represent roughly 75 percent of this productivity prize. There is an opportunity to achieve a resource productivity revolution comparable with the progress made on labor productivity during the 20th century. However, capturing these productivity opportunities will not be easy. We estimate that only 20 percent are readily achievable and about 40 percent are difficult to capture, facing many barriers to their implementation. Of course, if resource prices were to increase significantly, market forces would naturally drive greater resource productivity.

Boosting productivity alone would not be enough to meet likely demand requirements over the next 20 years. Supply would also need to grow. In the case of energy, a sizable proportion of the supply increase could come from the rapid development of unconventional gas supplies, such as shale gas. However, growing the supply of other fossil-fuel energy sources is more challenging, and the overall supply of energy would still need to expand by 420 quadrillion British thermal units (QBTU) from 2010 to 2030, almost entirely to replace the decline in existing sources of supply. For example, many of the world's giant oil fields, especially outside the Middle East, are mature and, absent a major improvement in recovery rates, are likely to experience significant declines over this period.

While increasing supply and resource productivity would meet projected global resource demand, it would likely not be sufficient to prevent further global warming above the two degrees Celsius that may already be inevitable, or to alleviate the resource poverty that affects so many citizens. Further changes in the mix of resource supply sources and additional investment would be required to meet the challenges of climate change and resource poverty. This investment could in itself result in a step change in cost. For example, our research suggests that a much more rapid scaling up of renewable energy technologies could lead to rapid declines in cost. Solar power capacity could become available at around $1 per watt by 2020, down from more than $8 per watt in 2007 and $4 per watt in 2010.

Delivering the required productivity improvements and supply growth required is a very large and complex agenda. Putting it into practice will be far from easy because there are hurdles to all the major opportunities. Overcoming these obstacles would require action at the local, national, regional, and global levels. Tackling the resource agenda must start with new institutional mind-sets and mechanisms that can develop more coordinated approaches to the challenge of resources, reflecting stronger interconnectedness of resource systems. Beyond this shift to a more integrated approach to resource management, policy makers might consider taking action on three broad fronts to address the resource challenge. First, they should look to history, which shows that stronger, sustained price signals are a key driver of improved performance in resource systems. Governments need to consider unwinding the more than $1 trillion of subsidies on resources, including energy and water, that today keep prices artificially low and encourage the inefficient use of these commodities. To address climate change, governments would also need to ensure, through mechanisms such as carbon pricing, that resource prices capture the cost of their impact on the environment.

Second, although getting prices right would go a long way toward addressing the resource challenge, action would also be necessary to ensure that sufficient capital is available and to address market failures associated with property rights, incentive issues, and innovation. Third, public policy can play a useful role in bolstering the long-term resilience of society in the face of the resource challenge, including taking measures to raise awareness about resource-related risks and opportunities, creating appropriate safety nets to mitigate the impact of these risks on the poorest members of society, educating consumers and businesses to adapt their behavior to the realities of today's resource-constrained world, and increasing access to modern energy, so improving the economic capacity of the most vulnerable communities.

This new era presents opportunities and risks for business. Companies in most sectors were able to benefit from declining resource prices over the past century. This allowed management to focus attention primarily on capital and labor productivity. But resource-related trends will shape the competitive dynamics of a range of sectors in the two decades ahead. Many companies need to pay greater attention to resource-related issues in their business strategies and adopt a more joined-up approach toward understanding how resources might shape their profits, produce new growth and disruptive innovation opportunities, create new risks to the supply of resources, generate competitive asymmetries, and change the regulatory context.

We now summarize the main findings of the seven chapters in this report.

1. Progressively cheaper resources underpinned global economic growth during the 20th century

During the 20th century, the price of key resources, as measured by MGI's index, fell by almost half in real terms. This was astounding given that the global population quadrupled in this era and global economic output increased by approximately 20-fold, together resulting in a jump in demand for different resources of between 600 and 2,000 percent. Resource prices declined because of faster technological progress and the discovery of new, low-cost sources of supply. Moreover, in some cases resources were not priced in a way that reflected the full cost of their production (e.g., energy subsidies or unpriced water) and externalities associated with their use (e.g., carbon emissions).

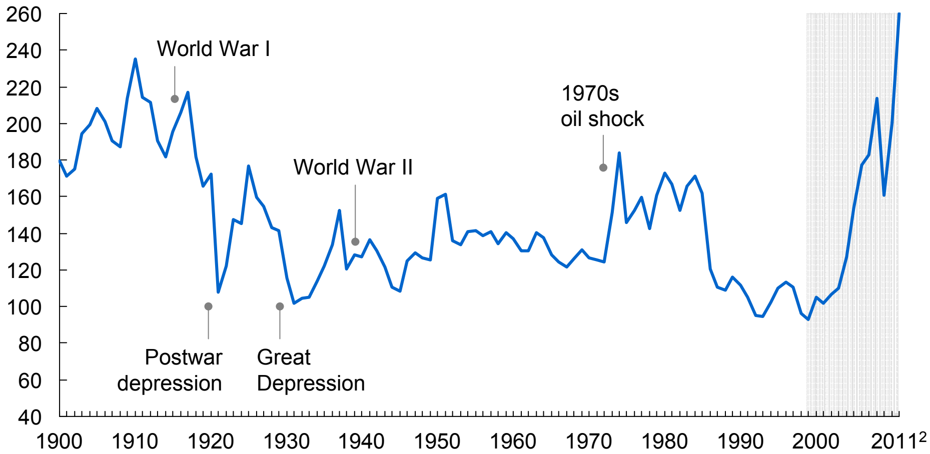
2. The world could be entering an era of high and volatile resource prices

The past decade alone has reversed a 100-year decline in resource prices as demand for these commodities has surged (Exhibit E1). With the exception of energy in the 1970s, the volatility of resource prices today is at an all-time high.

Exhibit E1

Commodity prices have increased sharply since 2000, erasing all the declines of the 20th century

MGI Commodity Price Index (years 1999–2001 = 100)[1]



1 See the methodology appendix for details of the MGI Commodity Price Index.
2 2011 prices are based on average of the first eight months of 2011.
SOURCE: Grilli and Yang; Stephan Pfaffenzeller; World Bank; International Monetary Fund (IMF); Organisation for Economic Co-operation and Development (OECD); UN Food and Agriculture Organization (FAO); UN Comtrade; McKinsey analysis

The resource challenge of the next 20 years will be quite different from any we have seen in the past in five main ways:

- **Up to three billion more middle-class consumers will emerge in the next 20 years.** The rapid economic development in emerging markets, especially China and India, could result in up to three billion more middle-class consumers in the global economy over the next 20 years.[2] The growth of India and China is historically unprecedented and is happening at about ten times the speed at which the United Kingdom improved average incomes during the Industrial Revolution—and on around 200 times the scale. These citizens will escalate demand for cars—we expect the global car fleet to double to 1.7 billion by 2030. They will be able to afford higher levels of nutrition. In India, we expect calorie intake per person to rise by 20 percent over the next 20 years, and China's per capita meat consumption could increase by 40 percent to 75 kilograms (165 pounds) a year (and still be well below US consumption levels). Demand from the new middle classes will also trigger a dramatic expansion in the global urban infrastructure, particularly in developing economies. China could every year add floor space totaling 2.5 times the entire residential and commercial square footage of the city of Chicago. India could add floor space equal to another Chicago annually.

- **Demand is soaring at a time when finding new sources of supply, and extracting them, is becoming increasingly challenging and expensive.** Our analysis suggests that, within the next 20 years, there are unlikely to be absolute shortages in most resources. In any case, history shows us that the mere expectation by governments, companies, and consumers of a material risk that shortages might develop has been an effective catalyst for innovation. However, demand for many resources today has already moved to the limits

2 Homi Kharas, *The emerging middle class in developing countries*, OECD Development Centre Working Paper No. 285, January 2010. This research defines "middle class" as having daily per capita spending of $10 to $100 in purchasing parity terms.

of short-run supply curves where supply is increasingly inelastic—in other words, a point at which it is more difficult for supply to react quickly to meet rising demand. This means that even small shifts in demand can drive greater volatility. We believe that this trend will persist because long-run marginal costs are also increasing for many resources. This is due to the fact that the depletion of supply is accelerating and, with the notable exception of natural gas and renewable energy, new sources of supply are often in more difficult, less productive locations. Feasible oil projects are mostly smaller than they were in the past, and more expensive. The average real cost per oil well has doubled over the past decade. New mining discoveries have been broadly flat despite a quadrupling in spending on exploration. Increasing demand for water could mean that some countries will face significantly higher marginal costs for adding new supply from sources such as gravity transfers or even desalination. As urbanization proceeds on an unprecedented scale, new and expanding cities could displace up to 30 million hectares of the highest-quality agricultural land by 2030—roughly 2 percent of land currently under cultivation.

- **Resources are increasingly linked.** The price and volatility of different resources have developed increasingly tight links over the past ten years. Shortages and price changes in one resource can rapidly impact other resources. The correlation between resource prices is now higher than at any point over the past century, and a number of factors are driving a further increase. The energy intensity of water, for instance, has been rising due to the lowering of the groundwater table, the increasing use of desalination processes, and the development of mega-projects for the surface transfer of water (such as China's South-North Water Transfer project, designed to move 45 billion cubic meters of water per year). Unconventional energy sources will require more inputs of resources such as steel. Industry data show that unconventional methods such as horizontal drilling use more than four times as much steel as traditional vertical drilling.[3] Future developments could further increase these linkages. For example, if carbon had a price of $30 per tonne, products produced or transported with energy would have a higher share of energy in their total costs.

- **Environmental factors constrain production.** Increased soil erosion, the excessive extraction of groundwater reserves, ocean acidification, deforestation, declining fish stocks, the unpredictable risk-multiplying effects of climate change, and other environmental effects are creating increasing constraints on the production of resources and on economic activity more broadly. Fish stocks are an example. The UN Food and Agriculture Organization (FAO) estimates that 25 percent of fish stocks are overexploited today and an additional 50 percent fully exploited. A recent study by the Economics of Climate Adaptation Working Group focused on the economic impact of current climate patterns and potential scenarios of climate change in 2030. This study found that some regions were at risk of losing 1 to 12 percent of their GDP annually as a result of existing climate patterns. A study by The Economics of Ecosystems and Biodiversity (TEEB) estimates that 11 percent of the world's remaining natural areas could be lost by 2050 due particularly

3 Colin P. Fenton and Jonah Waxman, "Fundamentals or fads? Pipes, not punting, explain commodity prices and volatility," J. P. Morgan Global Commodities Research, *Commodity markets outlook and strategy*, August 2011.

to the conversion of land for agricultural use.[4] This could have economic implications for many sectors. One example is health care. The pharmaceutical industry makes heavy use of biodiversity. Of all the anti-cancer drugs available today, 42 percent are natural and 34 percent are semi-natural.

- **Growing concern about inequality might also require action.** An estimated 1.3 billion people lack access to electricity and 2.7 billion people still rely on traditional biomass for cooking food. Roughly 925 million people are undernourished in the world, and about 884 million people lack access to safe water. Concern is growing that such a large share of the global population lacks access to basic needs such as energy, water, and food. The rapid diffusion of technologies such as mobile phones to low-income consumers has given these people a stronger political voice and demonstrated the potential to provide them with universal access to basic services.

Tighter markets, rising prices, and growing demand for key resources could slow economic growth, damage the welfare of citizens (particularly those on low incomes), strain public finances, and raise geopolitical tensions.

Rising commodity prices increase manufacturers' input costs and reduce discretionary consumption by households. Of course, countries that export key resources will receive an economic boost from higher prices, but this would be unlikely to offset fully the negative impact in commodity-importing countries. Overall, increasing commodity prices could have a negative impact on short-run global economic growth as consumers and businesses adjust to those higher prices. High prices are one issue; their volatility is another. Higher volatility in resource prices can dampen economic growth by increasing uncertainty, and this may discourage businesses from investing—or prompt them to delay investment—and increase the costs of hedging against resource-related risks.

Rising resource prices also hit the (urban and rural) poor disproportionately because they spend a larger share of their income on energy and food. India's rural poor, for instance, devote around 60 percent of household income to food and an additional 12 percent to energy. The World Bank estimates that recent increases in food prices pushed 44 million people into poverty in the second half of 2010 (although some farmers, typically the larger ones, benefited from higher food prices). It is important to note that the three billion additional middle-class consumers that could emerge over the next 20 years are also likely to be susceptible to price increases in food and energy. At $10 per day in purchasing power parity (PPP) terms, 35 percent of expenditure goes to food and at least 10 percent to energy.[5] An increase in food and energy costs of just 20 percent implies a 16 percent reduction in remaining income available to be spent on other goods and services. Many academic studies have linked sudden food price hikes

4 The Economics of Ecosystems and Biodiversity (TEEB) study is an international initiative aimed at drawing together expertise from the fields of science, economics, and policy to enable practical action to mitigate the growing costs of lost biodiversity and degradation of the ecosystem.

5 Using India as a proxy, see *Key indicators of household consumer expenditure in India, 2000–10,* National Sample Survey Organization, Government of India, 2011. Purchasing power parity measures long-term equilibrium exchange rates based on relative prices across countries. It is best used to understand the relative purchasing power of currencies in their local context.

to civil unrest.[6] In 2007 and 2008, increases in food prices triggered protests and riots in 48 countries, and similar bouts of unrest have occurred in 2011.

Many countries are heavily reliant on some resources, and today's concerns about how to secure sufficient supplies could intensify. From October 2010 to April 2011, China, India, and Vietnam, among other countries, imposed at least 30 export curbs on mineral resources, up from 25 during the previous 12 months, according to the World Trade Organization (WTO).

Many governments, particularly those in developing countries, could find their already pressed public finances exacerbated by rising demand for resources and their higher prices. The budget position of governments in many countries would take a direct hit from rising prices because they currently subsidize resources. Today, governments are subsidizing the consumption of resources by up to $1.1 trillion. Many countries commit 5 percent or more of their GDP to energy subsidies.

3. Meeting future demand would require a large expansion of supply

In this research, we discuss three illustrative cases for how the global economy might address its expanding resource requirements. The first of these scenarios is a supply expansion case. This assumes that resource productivity does not grow any faster than our base-case projections and leaves the remaining strain of meeting demand on expanding supply.[7] In this scenario, the supply of key resources expands to meet rising global demand at the same time as compensating for the depletion of existing supply. It is important to stress in this, and all our cases, that we do not allow for dynamic effects such as price rises in response to higher demand, helping to dampen demand.

Water and land are likely to present the largest challenges on the supply side. We estimate that the annual pace at which supply is added over the next 20 years in water and land would have to increase by 140 percent and up to 250 percent, respectively, compared with the rate at which supply expanded over the past two decades. This expansion of supply could have a wide range of potentially negative effects on the environment. In this case, there would be an additional 1,850 cubic kilometers of water consumption by 2030, 30 percent higher than today's levels; 140 million to 175 million hectares of added deforestation;[8] and carbon dioxide emissions of 66 gigatonnes in 2030 that could, according to some

6 Rabah Arezki and Markus Brückner, *Food prices and political instability*, International Monetary Fund Working Paper No. 11/62, March 2011.

7 Our base-case assumptions allow for productivity improvements consistent with current policy approaches and projected economic development. In agriculture, we assume that yields per hectare improve at 1 percent per annum. In water, we assume that agriculture water productivity (i.e., crop-per-drop) increases at 0.8 percent per annum, and industrial water use at around 0.5 percent a year (i.e., water withdrawals relative to the economic output of these sectors measured by gross dollar value added). In energy, the main productivity opportunities include a base-case productivity improvement. In transport, for example, we expect the fuel economy of the average new passenger vehicle to increase from 33 miles per gallon today to 48 miles per gallon in 2030 on the basis of current policy and anticipated technology improvements. If these base-case productivity improvements were not achieved, the strain on resource systems would be correspondingly greater.

8 Assuming that 80 percent of cropland expansion leads to deforestation.

estimates, lead to a rise in global average temperatures of more than five degrees Celsius by the end of the century.[9]

Expanding supply at this rate could also face capital, infrastructure, and geopolitical challenges. Meeting future demand for steel, water, agricultural products, and energy would require roughly $3 trillion average capital investment per year, assuming no exceptional sector-specific inflation. This is $1 trillion more than spent in recent history and will be at a time when global capital is likely to become increasingly expensive. Additional investment will also be necessary to help populations adapt to the potential effects of climate change. Such investment could include addressing the risk of flooding and desertification. Estimates of the annual costs of such efforts vary widely from less than $50 billion a year to more than $150 billion.[10] In addition to the considerable extra capital required, there are practical and political difficulties in expanding supply. For example, almost half of new copper projects are in countries with a high degree of political risk. More than 80 percent of the remaining unused available arable land is in countries with insufficient infrastructure or political issues. There is also a significant risk that supply-chain bottlenecks could increase the cost of expanding supply as well as prolong the effort, creating significant lags and increased risks for investors.

However, there is also considerable scope for innovation to generate new sources of supply. Shale gas is an example. Advancements in horizontal drilling techniques, combined with hydraulic fracturing, have led to the rapid development of shale gas in the United States. Its share of the overall US natural gas supply has increased from just 2 percent in 2000 to 16 percent in 2009. This development has supported lower electricity prices and created 260,000 jobs in four major shale production sites.[11] Shale gas could play a more significant role in the global primary energy mix of the future, with the contribution of natural gas to the primary energy mix rising from 22 percent today to 25 percent in 2030, according to the International Energy Agency's (IEA) "golden age of gas" scenario. There are, however, risks related to the potential environmental impact of shale gas production on air, water, and land that have not yet been fully understood. These risks have led to moratoriums on shale gas production in five countries.[12]

A rapid expansion of supply could create both economic opportunities and challenges. If used wisely, demand for resources could potentially transform those countries with rich resource endowments. The countries most likely to feel an adverse impact in this scenario would be those that import a high proportion of their resources and whose economies are resource-intensive—notably China and India and other countries whose economic development is in the industrialization phase. China and India may need to import 5 and 15 percent of their 2030 cereal demand, respectively, having been modest net exporters of this commodity in 2010.

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9 *The emissions gap report: Are the Copenhagen Accord measures sufficient to limit global warming to 2 degrees Celsius or 1.5 degrees Celsius? A preliminary assessment*, UN Environment Program, November 2010.

10 *Farewell to cheap capital? The implications of long-term shifts in global investment and saving*, McKinsey Global Institute, December 2010 (www.mckinsey.com/mgi).

11 Timothy J. Considine, et al., "The economic opportunities of shale energy development," *Energy policy and the environment report*, Manhattan Institute, May 2011.

12 "Are we entering a golden age of gas?" *World energy outlook*, International Energy Agency Special Report, 2011.

4. A step change in resource productivity is possible

A range of opportunities to boost the productivity of resource extraction, conversion, and end use can be tapped. Our second case—the productivity response—takes the base-case productivity growth assumed in our first scenario and adds a range of opportunities to boost resource productivity, filling the remaining gap with supply. There are opportunities in energy, land, water, and materials that could address up to 30 percent of total 2030 demand (Exhibit E2).[13]

The envisaged efficiency improvements do not allow for dynamic behavioral impacts that could at least partially offset productivity gains—a "rebound effect." Lower resource prices and therefore more spending power could lead to increased consumption, eventually boosting prices and compromising consumption. Policy would need to be designed to mitigate the impact of such an effect.

Capturing the total resource productivity opportunity—including the more difficult levers—could amass annual savings to society of $2.9 trillion a year in 2030, at current market prices. The value of the opportunity would increase to $3.7 trillion if we assume a $30 per tonne price for carbon as well as the removal of energy, agriculture, and water subsidies, and the removal of energy taxes. Today, governments rarely price water at its true cost, there are large energy and agriculture subsidies, and there is no global carbon price. The value of the benefits would be even greater if market resource prices were to be higher than they are today. Of the opportunities that are available, 70 percent have an internal rate of return of more than 10 percent at current prices. This proportion would rise to 80 percent if the externalities of resource use and subsidies were included in prices. This share reaches 90 percent if we exclude energy taxes and assume a societal discount rate of 4 percent.

Delivering on resource productivity reduces the need to expand supply but does not eliminate it. In the case of energy, improving productivity could cut incremental demand to only 20 QBTU. However, 400 QBTU of new supply would still be necessary due to declining sources of existing supply. The output of oil and natural gas could fall by approximately 6 percent per annum. The decline in coal output could be 3 percent a year. To put this in perspective, 1 QBTU is enough energy to power all of the cars, trucks, buildings, homes, infrastructure, and industry of New York State for more than three months.

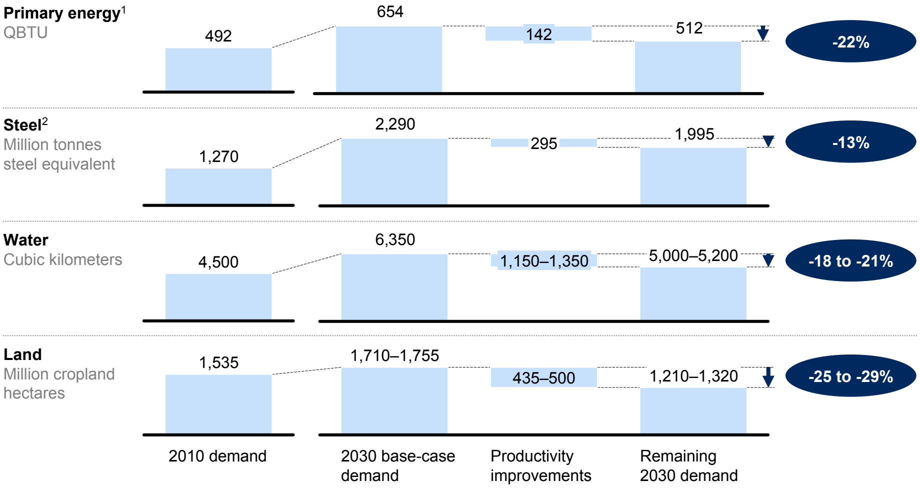
Despite these potentially high returns, this scenario requires more capital than the supply expansion scenario. The capital required to implement the resource productivity opportunity in full could be an additional $900 billion a year. However, the capital required to expand supply would fall to $2.3 trillion (from $3 trillion in a supply expansion case). Overall, this implies that the capital costs could be roughly $100 billion per annum higher than the supply expansion case—$1.2 trillion a year above historical expenditure. The institutional and managerial challenges of delivering on a productivity response approach are likely to be as

13 Given steel's importance to the global economy and its linkages with other resources, we focus on it as a proxy for materials overall (see Box 2, "Why steel matters"). For all resources, we reviewed levers across the whole value chain including extraction efficiency (i.e., more output from the same source), conversion efficiency (i.e., transformation of a raw material into another usable form such as coal to electricity), and end-use efficiency (i.e., lower end-use consumption through measures such as building efficiency or reducing food waste).

high as, or even higher than, the supply response case due to the fragmented nature of the opportunities.

Exhibit E2

In a productivity response case, opportunities could meet 13 to 29 percent of resource demand



1 Productivity improvements include supply-side measures, such as enhanced oil recovery, that lower effective remaining demand.
2 Supply-side levers such as improving recovery rates and the conversion rate in mining and coke do not save steel and are not reflected in this exhibit. We have included effective steel savings from higher scrap recycling.
SOURCE: McKinsey analysis

Concerns about energy security would potentially diminish somewhat in the productivity response case. Chatham House research finds that the Asia-Pacific region and Europe today could need imports to meet about 80 percent of their oil demand by 2030.[14] However, in a productivity response case, oil demand would be 20 percent lower than it would otherwise have been (83 million barrels per day versus 103 million). Oil would still account for 79 percent of fuel demand for road transport in 2030 (compared with 96 percent today). Oil demand could drop by an additional seven million barrels per day, from 83 million barrels to 76 million, if there were to be an aggressive move to ramp up the production and use of second-generation biofuels and if the power-sector mix shifted sufficiently to nearly eliminate oil-fired power by 2030. This would reduce oil's share of the energy used by road transport to 63 percent, with the remaining energy provided by biofuels (23 percent), electricity (13 percent), and other fuels (1 percent).

Carbon emissions would decline to 48 gigatonnes per annum in 2030, getting halfway to a 450 parts per million (ppm) pathway, which would require carbon emissions of only 35 gigatonnes by 2030. Higher yields on smallholder farms and large-scale farms, in addition to other productivity opportunities such as reducing food waste, would mean a net reduction of 215 million to 325 million hectares, from today's levels, in the land needed for cultivation of crops. This would have broader benefits for biodiversity and mean significantly lower water consumption as the productivity of rain-fed land and crop-per-drop where irrigation is in use would both increase. Reduced demand for food and energy due to higher productivity in their conversion and end use could lower prices, creating a range of economic and welfare benefits. The requirement for investment in climate adaptation could also be somewhat reduced.

14 John V. Mitchell, *More for Asia: Rebalancing world oil and gas*, Chatham House, December 2010.

The $900 billion of investment needed in a productivity response case could potentially create 9 million to 25 million jobs. Over the longer term, this investment could result in reduced resource price volatility that would reduce uncertainty, encourage investment, and also potentially spur a new wave of long-term innovation.[15] By reducing expenditure on imported resources and improving the cost competitiveness of businesses, these productivity opportunities could also strengthen trade balances in many net resource-importing economies.

To help prioritize the resource productivity initiatives that are available, we have developed an integrated resource productivity cost curve (Exhibit E3).[16] In this curve, we have grouped more than 130 potential resource productivity measures into areas of opportunity, prioritizing the top 15 that account for roughly 75 percent of the total resource productivity prize (Exhibit E4). The top three opportunities would deliver roughly one-third of the total potential. While each opportunity has one resource as its primary benefit, there are often important spillover benefits across multiple resources, including carbon.

These 15 opportunities are:

1. Building energy efficiency
2. Increasing yields on large-scale farms
3. Reducing food waste
4. Reducing municipal water leakage
5. Urban densification (leading to major transport efficiency gains)
6. Higher energy efficiency in the iron and steel industry
7. Increasing yields on smallholder farms
8. Increasing transport fuel efficiency
9. Increasing the penetration of electric and hybrid vehicles
10. Reducing land degradation
11. Improving end-use steel efficiency
12. Increasing oil and coal recovery
13. Improving irrigation techniques
14. Shifting road freight to rail and barge
15. Improving power plant efficiency

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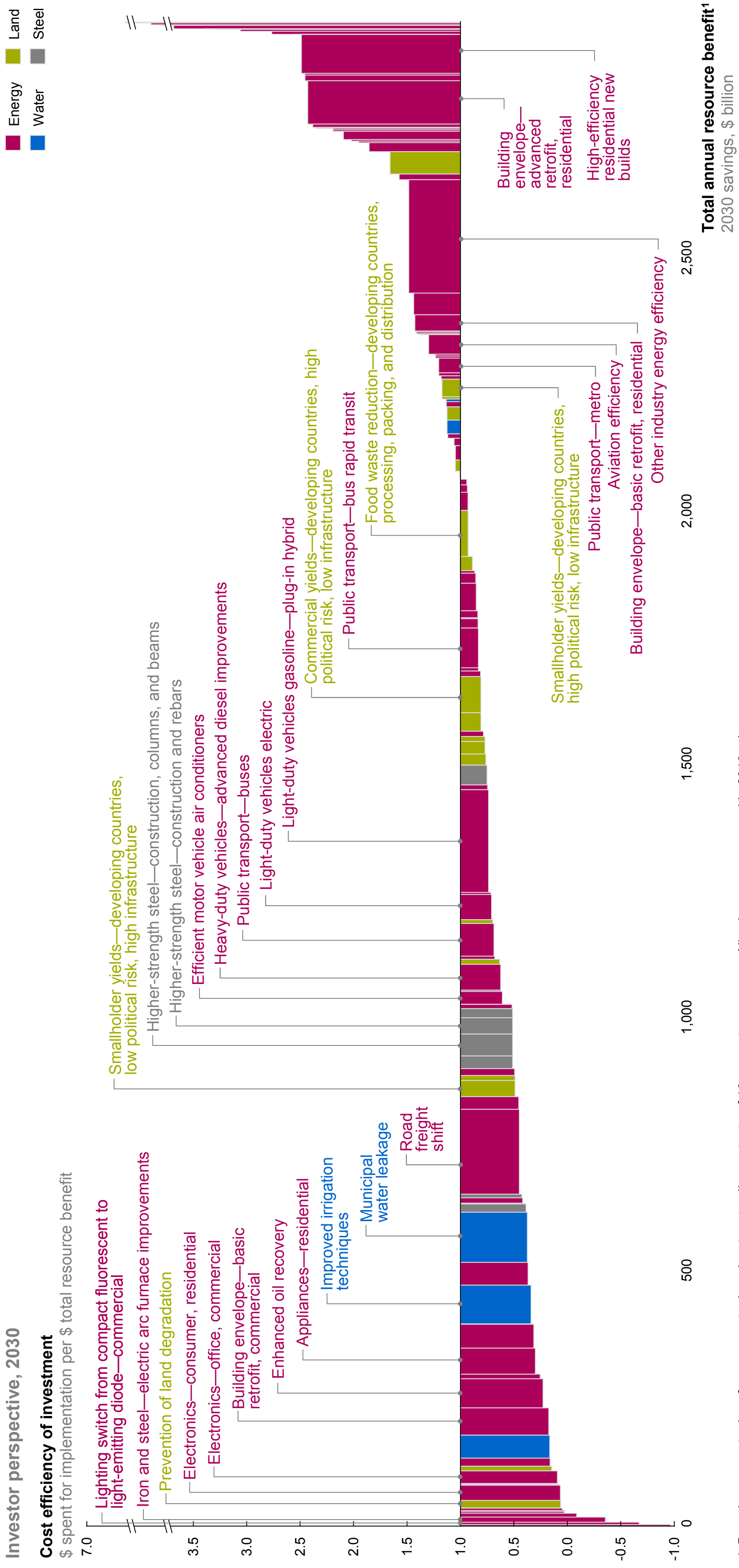
15 Some academics have discussed the possibility that resource productivity opportunities could create a new Kondratiev cycle—a long-term growth cycle typically lasting 30 to 50 years that can be attributed to major technological innovations such as the invention of steam power, railroads, and software information technology. For further details, see Ernst Von Weizsäcker, et al., *Factor five: Transforming the global economy through 80% improvements in resource productivity* (London: Earthscan, November 2009).

16 The integrated resource productivity cost curve shows the resource benefits and costs associated with productivity opportunities in energy, land use, steel, and water (see Box 10, "The integrated resource cost curve").

Exhibit E3

The productivity opportunity totals $2.9 trillion in 2030 from an investor perspective

Investor perspective, 2030

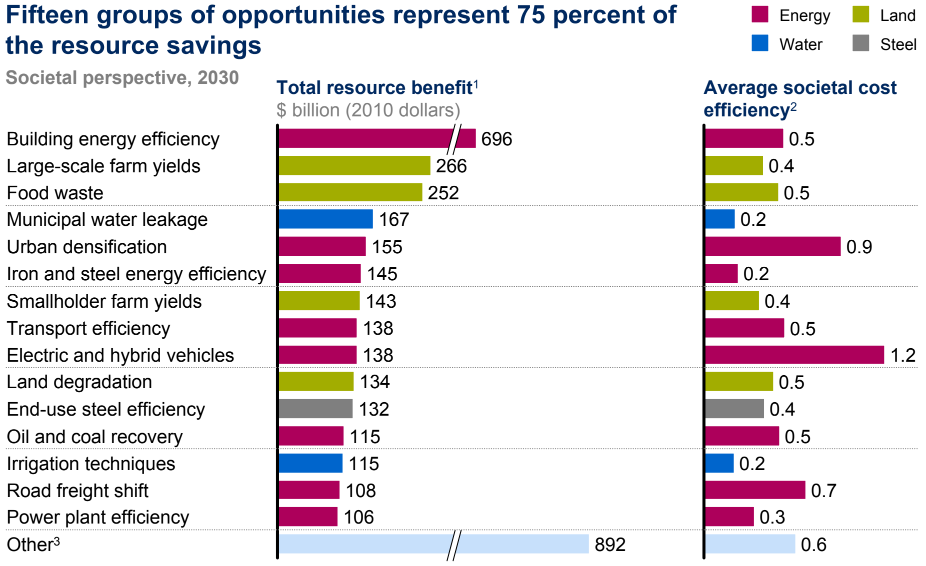


1 Based on current prices for energy, steel, and water at a discount rate of 10 percent per annum. All values are expressed in 2010 prices.
SOURCE: McKinsey analysis

Exhibit E4

Fifteen groups of opportunities represent 75 percent of the resource savings

Societal perspective, 2030



1 Based on current prices for energy, steel, and food plus unsubsidized water prices and a shadow cost for carbon.
2 Annualized cost of implementation divided by annual total resource benefit.
3 Includes other opportunities such as feed efficiency, industrial water efficiency, air transport, municipal water, steel recycling, wastewater reuse, and other industrial energy efficiency.

SOURCE: McKinsey analysis

We have excluded shale gas and renewable energy from this analysis, treating them as sources of new supply rather than as opportunities to improve the extraction, conversion, or end use of energy resources. While there is considerable uncertainty on the potential resource benefits of unconventional gas (including shale gas) and renewable energy, a rough sizing suggests that these could be in the top ten opportunities. In the case of unconventional gas, lower natural gas prices as well as some additional carbon benefits could mean savings as high as $500 billion per annum in 2030. In renewable energy, the scaling up of wind, solar, and geothermal could be worth $135 billion per annum from reductions in carbon alone (assuming a carbon price of $30 per tonne). There are other benefits that are difficult to quantify such as providing a hedge for volatile fuel prices and lower health costs than would be the case with today's levels of use of fossil fuels. Finally, if there were technological breakthroughs in renewables, total savings could increase by another $75 billion.

To accompany the cost curve, we have also begun to compile metrics to assess how different countries perform on resource productivity. From the evidence thus far, performance varies very widely. No one country outperforms others on all of the opportunities. This suggests that every country has scope to make further progress on resource productivity, learning from others how best to go about it.

5. Additional efforts would be necessary to address climate change and universal access to energy

A productivity response case would not be sufficient to achieve a 450-ppm carbon dioxide equivalent pathway that, according to the Intergovernmental Panel on Climate Change (IPCC), is consistent with limiting global warming to no more than two degrees Celsius in a median case. This report therefore presents a third scenario—a climate response case.[17] To achieve a 450-ppm pathway, carbon emissions would need to be reduced from 48 gigatonnes a year in the productivity response case to 35 gigatonnes in 2030. There would have to be a greater shift from high-carbon power such as coal to low-carbon power delivered through renewables and the incremental production of biofuels for use in road transport. There would also need to be further abatement of carbon emissions in land use through the reforestation of degraded land resources (estimated at more than two billion hectares globally today), the improved management of timberland, and measures to increase the productivity of pastureland.

Depending on the rate of technological advance in renewable energy, an additional $260 billion to $370 billion a year would need to be invested over the next two decades to put this plan into action, compared with the productivity response case. This would be only 60 to 90 percent of current fossil fuel subsidies and could also allow for reductions in adaptation investments. Universal energy access—providing all people with access to clean, reliable, and affordable energy services for cooking and heating, lighting, communications, and productive uses)—at an "entry level" of 250 to 500 kilowatt hours per person per year would cost around $50 billion a year over the next two decades.[18] The welfare benefits from such an investment could make a substantial contribution to economic growth and education (e.g., making it possible to read at night), and accelerate the diffusion of technology into poorer rural communities. Yet the increased demand for energy resulting from universal access would increase carbon emissions by less than 1 percent.

6. Tackling this resource agenda must start with a shift in institutional mind-sets and mechanisms

How might policy makers find their way through this complex maze? Overcoming barriers will require new institutional mind-sets and mechanisms that can develop crosscutting systemic approaches to the management of resources, incorporated into broader economic policy making. The relevant core ministries—energy, water, agriculture—may need additional resources to help them deal with the challenges they face.

Many governments tend not to take an integrated approach to resources. For example, issues related to water often fall between the ministries for water, agriculture, urban development, and the environment (e.g., on river quality). Land-use issues often fall between agriculture, forestry, and environment at the national level, with many other stakeholders at provincial and district levels. In the case of land use, many countries are struggling to put in place the right coordination mechanisms to tackle sustainable rural and agriculture development, reduce deforestation, and enhance food security in a single integrated agenda. At times, the international system for official development assistance can contribute to this fragmentation, since it has its own parallel set of international agencies, each

17 A 450-ppm pathway describes a long-term stabilization of emissions at 450-ppm carbon dioxide equivalent, which is estimated to have a 40 to 60 percent chance of containing global warming below the two degrees Celsius threshold by the end of the 21st century.

18 Our definition draws on *Energy for a sustainable future: Summary report and recommendations*, The Secretary-General's Advisory Group on Energy and Climate Change, United Nations, April 28, 2010.

focused on its own part of the agenda. Bilateral aid agencies, which tend to reflect different institutional interests in their own funding countries, can further complicate the picture.

This fragmented institutional approach runs the risk of governments failing to prioritize opportunities effectively. Indeed, public discourse does not seem to reflect the 15 priorities that we have highlighted in this report. A media review suggests that there is limited awareness of the full set of resource productivity opportunities. The energy efficiency of buildings, the largest opportunity identified in this analysis, attracts many column inches, while other areas such as food waste and improving the yields on large-scale farms receive little attention compared with their potential impact.

Beyond transforming institutional mind-sets and mechanisms, governments should consider action on three fronts. First and foremost, market signals would need to be strengthened, not dampened. Second, a range of other non-price market failures need to be corrected. Third, the long-term resilience of society needs bolstering.

A. STRENGTHEN PRICE SIGNALS

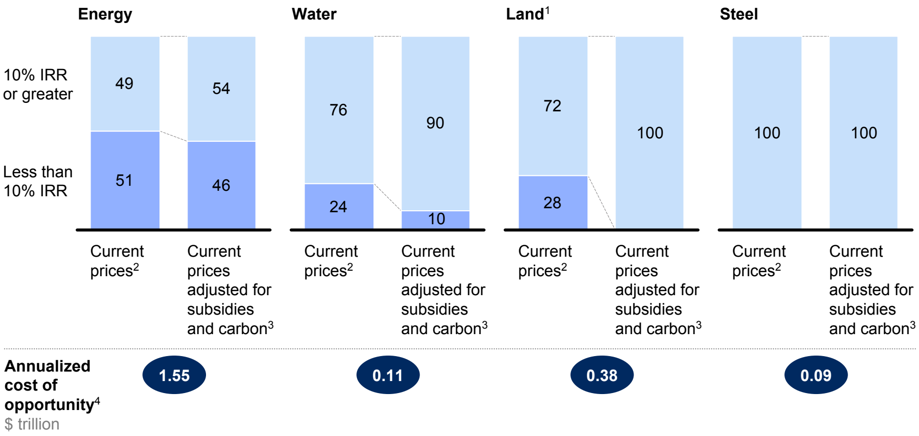
Despite the fact that capturing many productivity opportunities would have sizable benefits for society, a significant number of them are not attractive to private-sector investors. There are a number of reasons for this. One factor is that uncertainty about the future path of resource prices at a time when they are particularly volatile means that it is difficult for investors to judge what returns they might make on their investment, and this acts as a deterrent. Another is that fiscal regimes in many countries provide a disincentive to the productive use of resources because the world is subsidizing resources by more than $1 trillion a year and often failing to put a price on externalities of production such as carbon emissions. Removing agriculture, energy, and water subsidies and putting a price of $30 per tonne on carbon emissions would significantly improve the attractiveness of productivity opportunities to private-sector investors (Exhibit E5). Finally, uncertainty about whether financial support from governments for opportunities such as renewable energy will continue often means that investors demand higher returns to compensate for this risk. Governments could benefit from putting in place stable, effective policy regimes that strengthen market signals and ensure sufficiently attractive returns to engage the private sector.

Exhibit E5

Relatively low investor returns, especially for energy, make the resource productivity agenda even more challenging

Return distribution of productivity levers by resource

%



1 Agricultural levers such as yields and food waste that save both land and water have been shown only under land.
2 Internal rate of return (IRR) based on current prices including taxes and subsidies.
3 IRR based on current prices adjusted for subsidies in water, energy, and food plus a price of $30 per tonne of carbon dioxide equivalent emissions.
4 Assuming a 10 percent discount rate.

SOURCE: McKinsey analysis

B. ADDRESS (NON-PRICE) MARKET FAILURES

Governments can play a role in dismantling a range of barriers that do not relate to price. A lack of clear property rights, particularly in agriculture and fisheries, is one obstacle that engagement with local communities to strengthen governance of common resource pools and more effective planning can help. Many profitable energy-efficiency opportunities are not implemented because of agency issues where, for instance, a landlord bears the cost of installing energy-efficient insulation but the tenant enjoys lower energy bills. Government efficiency standards can be an effective, low-cost way of overcoming principal-agent barriers, but standards need to be designed to encourage rather than stifle market-based innovation.

Access to capital is a vital barrier to tackle given that much of the additional capital needed to finance the resource revolution will need to be in developing countries that may have under-developed capital markets. Between 70 and 85 percent of opportunities to boost resource productivity are in developing countries (Exhibit E6).[19] A number of mechanisms, including loan guarantees and other risk-sharing tools, can encourage financial institutions to lend. Multilateral development banks can play a useful role in offering concessional or blended lending. Some governments have also started to encourage collaboration among energy service companies, mortgage companies, and underwriters to pool

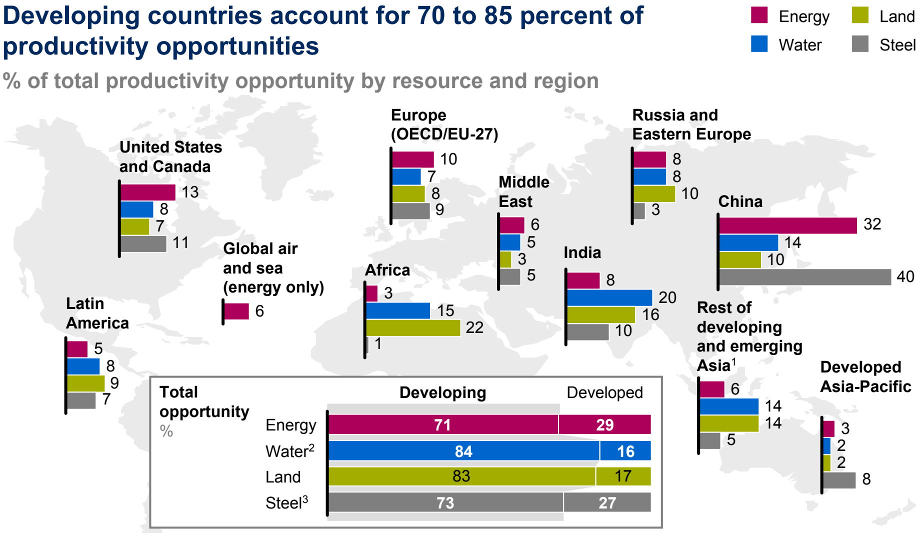
19 This is driven by the large share of future resource demand coming from developing countries and the generally larger opportunities to improve resource productivity in developing countries compared with developed countries (as resource productivity in developed countries is generally higher and many of the future expected productivity improvements in developed countries are captured in our base-case projections). It is important to stress that this analysis does not include behavioral changes that could lead to a welfare loss (e.g., living in smaller houses, reducing meat consumption), where opportunities are likely to be largest in developed countries.

technical expertise and long-term financing. New forms of regulatory and country risk insurance may also be necessary.

Exhibit E6

Developing countries account for 70 to 85 percent of productivity opportunities

% of total productivity opportunity by resource and region



1 Rest of developing Asia includes Central Asia (e.g., Uzbekistan), South Asia (e.g., Bangladesh), Southeast Asia (e.g., Laos), and North Korea.
2 Includes water savings from water-specific levers as well as water savings from improved agricultural productivity.
3 For steel, the chart represents all the demand-side levers and the scrap recycling lever but excludes supply- and conversion-side levers.
NOTE: Numbers may not sum due to rounding.
SOURCE: McKinsey analysis

Enabling innovation will also be crucial. We base our productivity analysis on technology that is already available. However, more innovation is necessary to meet the resource challenge beyond 2030. Many of the enablers for resource-related innovation are the same as for the broader economy: a stable macroeconomic environment, vigorous competition, more open international trading rules, and a sound financial system. Removing barriers to innovation would be important, but more investment in resource-related R&D would also be required. Government procurement rules can support the ramp-up of green technologies, and governments can make targeted investments in enabling infrastructure such as the use of smart grids to link the higher penetration of electric vehicles (EVs) to the increased deployment of renewable power.

C. BUILD LONG-TERM RESILIENCE

Societies need to bolster their long-term resilience in the face of the resource challenge, raising their awareness of resource-related risks and opportunities, creating appropriate safety nets to mitigate the impact of these risks on their poorest members, and educating consumers and businesses to adapt their behavior to the realities of today's resource-constrained world.

There is no effective early-warning system across resources that could give investors the necessary combination of national and integrated global intelligence on demand, supply, and potential risks. Putting such a system in place would require significant public investment in capturing primary data on the availability of resources, indicators of environmental health, the dynamics of the climate system, and more sophisticated modeling tools for analyzing the dynamic relationships between economic growth, resource systems, and the environment. Major advances in remote sensing tools and big data management can help in this effort. Strengthening the metrics that relate to the major productivity opportunities would deliver significant benefits. Governments could also help businesses and households to inform themselves about productivity opportunities through instituting the mandatory energy-efficiency labeling of appliances and by scaling up mechanisms (such as the C40 cities forum) that share best practice across regions and cities.

Increasing access to resources would be an important component of making society more resilient in the face of resource-related trends. Providing global universal energy access at an "entry level" of 250 to 500 kilowatt hours per person per year would cost less than $50 billion a year over the next 20 years. Alongside greater access, social protection schemes should be ramped up, as should investment in the resilience of key production systems, if people are to be able to deal more effectively with resource- and climate-related shocks.[20]

Change happens most decisively when individuals alter their way of thinking and therefore their behavior. In many developed countries, resource prices are only a small share of overall household budgets, except for the bottom 20 to 30 percent of households. This means that action beyond price signals will be necessary to alter the choices people make about the resources they use. The report identifies four critical elements to changing behavior. First, there is demonstration and role modeling of the behavior change. Morocco launched pilot programs to show how the country's new contract farming approach would work and to help make the argument for the transformation.[21] Second, governments can foster conviction and understanding about sustainability issues among not only up to three billion new middle-class consumers, but also the relatively more affluent consumers in OECD economies whose resource footprint is a multiple of that generated by these new middle classes. For example, in North America and Oceania, one-third of the fruit and vegetables that are purchased is thrown away.[22] Third, incentives and formal mechanisms can encourage change, particularly by mitigating the negative impact on some stakeholders during the transition process. A central element of the Danish energy tax reform was compensation (conditional on improving energy productivity at preset targets) for those industries most heavily affected. Fourth, there is a need to develop new talent and skills to support any change in behavior. During Australia's water reforms, for example, the government put significant funds into the retraining of farmers in more water-efficient techniques.

7. Firms should consider how to adjust strategy to take account of resource-related risks and opportunities

For much of the 20th century, private-sector companies have been able to plan their strategies and business models on the (often implicit) assumption that the implications for real costs of resource prices would be constant or fall. As a result, they have tended to focus on raising labor and capital productivity, given the increasing cost of labor and competition for capital. However, companies now

20 Alex Evans, *Globalization and scarcity: Multilateralism for a world with limits*, Center on International Cooperation, New York University, November 2010.

21 Contract farming is carried out according to an agreement between a buyer and farmers, which establishes conditions for the production and marketing of farm products.

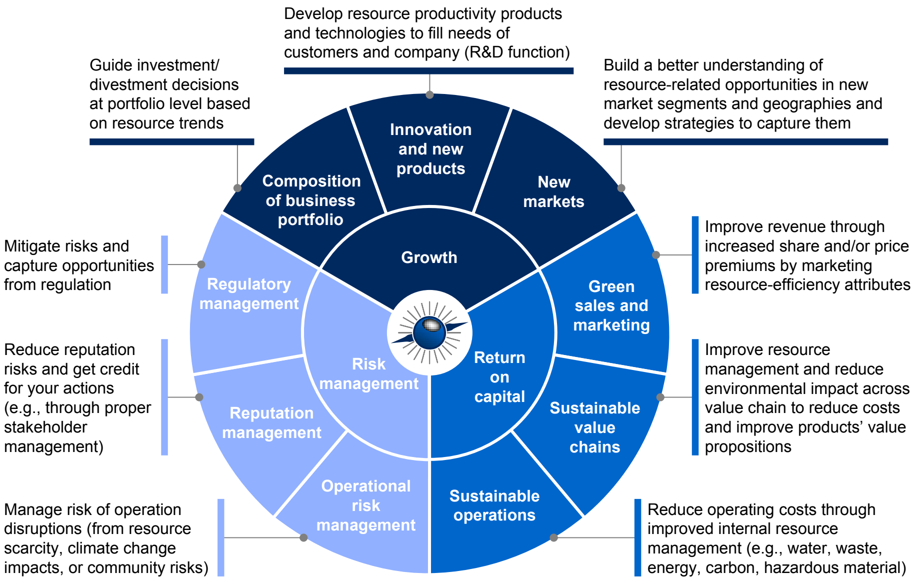
22 Food and Agriculture Organization, *Global food losses and food waste*, 2011.

need to increase their strategic and operational focus on resource productivity. Companies that succeed in improving their resource productivity are likely to develop a structural cost advantage; improve their ability to capture new growth opportunities, especially in resource-scarce, rapidly growing developing markets; and reduce their exposure both to resource- and environment-related interruptions to their business and to resource price risk. Increased resource productivity would clearly benefit customer-facing companies including those in the consumer goods, consumer electronics, and retail sectors. Higher resource prices may not translate automatically into higher profits for resource-supply companies through the cycle—but higher prices are almost certain to lead to increased regulatory action from governments and the upstream taxation of resources.

The strategic implications of resource-related trends are likely to vary from sector to sector, of course. Nevertheless, all companies are likely to benefit from adopting a more systematic approach toward understanding how resources might shape their profits, produce new growth opportunities and technological discontinuities, and generate new stresses on their management of risk and regulation (Exhibit E7). Industry leaders could usefully go one step further and strive to shape industry standards in a way that generates greater transparency throughout the supply chain about resource productivity and the end-to-end measurement of that industry's environmental footprint.

Exhibit E7

There are several resource-related value-creation levers for businesses



SOURCE: McKinsey analysis

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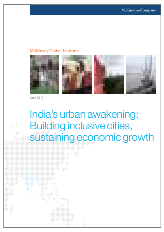

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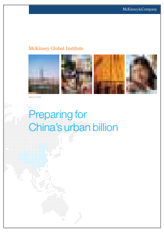

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By pursuing a more concentrated urbanization path guided by action to boost urban productivity, China's local and national policy leaders could minimize the pressures and maximize the economic benefits of urban expansion. A two-part report details the scale, pace, and global implications of urbanization at the sector and city levels.

Pathways to a low-carbon economy: Version 2 of the global greenhouse gas abatement cost curve (McKinsey & Company, January 2009)

This report includes an updated assessment of the development of low-carbon technologies and macroeconomic trends, and a more detailed understanding of abatement potential in different regions and industries. It also assesses investment and financing requirements and incorporates implementation scenarios for a more dynamic understanding of how abatement reductions could unfold.

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MGI research finds that the economics of investing in energy productivity—the level of output we achieve from the energy we consume—are very attractive. This detailed report assesses the additional investment and key actions needed to capture the productivity potential. Additional annual investments in energy productivity of $170 billion through 2020 could cut global energy demand growth by at least half while generating average internal rates of return of 17 percent. Such outlays would also achieve significant energy savings and cuts in greenhouse gas emissions.

Curbing global energy demand growth: The energy productivity opportunity (May 2007)

This report offers a detailed look at what's driving soaring global demand for energy in major regions and sectors. Drawing on a proprietary model of global energy demand, the report provides a glimpse into how global energy will grow and the fuel mix will evolve to 2020 with current policies. The research also sizes the substantial opportunity to curb this growth and, with it, CO_2 emissions, by boosting energy productivity—or the level of output we achieve from the energy we consume. It also looks at the reasons available opportunities to curb energy demand are not being captured and what policies could ensure that they are.

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