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Sustainable Steelmaking

Meeting Today’s Challenges, Forging Tomorrow’s Solutions

Introduction

The current financial crisis has hit economies hard. Steelmakers around the world, facing collapsing demand and falling prices, are shifting their business priorities to focus primarily on managing operating costs, securing capital, and sustaining client relationships. In this context, some in the industry may question the relevance of managing for environmental sustainability. In our view, however, environmental sustainability should be at the forefront of steelmakers’ agendas. Consumption of fossil fuels will remain a decisive factor in steel production, and prices for coal and other fuels will rise again. Managing for the sustainable use of these primary resources can both cut operating costs and enhance the company’s attractiveness to key stakeholders, including investors, customers, regulators, and the general public.

Indeed, for many steelmakers, managing for environmental sustainability is no longer merely an option but an imperative. Regulators are tightening controls—and raising fines—on carbon dioxide emissions and waste disposal. Meanwhile, investors strongly prefer companies that are managed for environmental sustainability, and the public at large is increasingly intolerant of anything less.

This pressure to manage for sustainability is based on the fundamental—if belated—realization that, around the globe, galloping development has led to a massive increase in the consumption of fossil fuels. This consumption, in turn, has driven the rapid growth of greenhouse gas emissions into the environment, with dramatic impacts on the earth’s climate. Polar ice and glaciers are already melting faster than climate scientists had predicted.

Unless companies—and countries—take strong action fast, there are far worse impacts to come. In 2007, the Intergovernmental Panel on Climate Change (IPCC) forecast dramatic increases in global temperature—by more than 4 degrees Celsius—unless global greenhouse-gas emissions are reduced significantly. Even if most of the policies on climate protection and energy efficiency currently under discussion are in fact implemented, we expect that primary energy demand will grow by about 50 percent from 2005 to 2030. The likely consequence will be severe impacts on climate. The IPCC has called for substantial reductions in annual global greenhouse-gas emissions to at least 50 percent of present levels by 2050, in order to stabilize the world’s climate.

In this paper we focus on steel producers, which currently face multiple challenges to their competitive positions and profitability. One such challenge is the fact that energy and ferrous raw materials account for most of the cost of making steel. Prices for such scarce resources are highly volatile in the short term, but over the long term they have risen significantly; and when the present crisis abates, they will certainly rise again as growing global demand encounters limited global supply.

But even in the unlikely case that the direct cost of energy resources does not rise for many years, the indirect cost of consuming fossil fuels, in the form of charges for CO₂ emissions, will increase. Moreover, the global trend toward tighter environmental legislation will continue, making the industrial use of many primary resources even more expensive. Despite the financial crisis, most governments in the world have pointed out that they will stick to their environmental targets.

This paper is based on The Boston Consulting Group’s extensive recent work with steel producers and their suppliers around the globe, as well as on conversations with many industry experts, who kindly shared their insights with us. In addition, we had access to data on the costs and performance of more than 30 steel-production sites worldwide. All this information helped us assess opportunities to improve
the energy footprint of global steel production and to estimate the global potential for optimizing steelmaking performance along several operational parameters. Our analysis of power generation capacities is based on the Utility Data Institute’s World Electric Power Plants Database and on BCG’s extensive experience in the energy sector.

In this paper, we first set forth the challenges facing the steelmaking industry as it moves toward sustainable business development and management. We then outline the potential impacts of those challenges and suggest how steel companies can cope with them—while at the same time increasing their profitability and positioning themselves for long-term success. Finally, we demonstrate the implications that this approach will have for business models and strategies. Along the way, we show the close links among energy efficiency, CO₂ reduction, and cost competitiveness in steel production. The bottom line is that sustainable steelmaking pays off.

**Challenges Facing the Steel Industry**

Clearly, the steel industry has been a prime beneficiary of the recent global boom. Until the more recent economic crisis, the industry appeared certain to enjoy a very bright future. Steel production surged, driven primarily by galloping demand for infrastructure, buildings, and transportation, much of it in rapidly developing economies (RDEs) such as Brazil, China, India, and Russia. As a result, steel prices soared as well. For example, the transaction price for hot-rolled coil in the United States grew from $250 per ton in early 2002 to more than $1,100 per ton in mid-2008. (See Exhibit 1.)

But even before the financial crisis started pushing steel prices down from their historic heights, steel producers were facing challenges to their profitability and to their production models.

**Profitability Pressures**

Rising steel prices in recent years were largely a consequence of strongly rising prices for the raw materials that go into steelmaking. For example, in Europe, prices for sinter feed and scrap tripled from 2002 to mid-2008. During the same period, the contract prices for Australian coking coal rose more than fivefold. As supplies of these materials failed to keep pace with demand, prices started to explode. Strong demand allowed steel producers to pass their increasing resource costs on to their customers, thereby ensuring stable operating profits at the cost of shrinking relative margins. (See Exhibit 2.)

![Exhibit 1. Steel Production and Prices Grew Strongly from 2002 to Mid-2008 Before Declining](image-url)
As this paper is prepared for release, however, the balance between supply and demand is still in flux. Clearly, the current economic crisis is slowing demand for both steel and primary resources. As a result, pressure to expand supply has eased. However, even if the economic crisis continues to curtail demand, causing capacity shortages in mining to evaporate in the near term, energy and raw materials will remain the principal cost factors in steel production, and their prices will increase down the road.

The key question is whether the anticipated resurgent demand for steel will be strong enough to allow steel producers to stabilize their profitability against rising resource costs. Margins will face additional pressure when higher charges for CO₂ emissions take effect.

Clearly, independent of CO₂ taxes, profitability will vary considerably among steel producers. Cost structures differ from country to country and also reflect the proximity of steelmaking facilities to resources and markets. Moreover, there are likely to be shifts in competitive advantage among regions and individual steel producers as price increases—and decreases—have different impacts, depending on energy efficiencies in production processes. This is where environmental sustainability meets economic interest: increased energy efficiency—that is, the minimization of energy usage and CO₂ emissions—is the prime lever for cost reduction in steel production.

**Energy Intensity and CO₂ Emissions**

Steel is an energy-intensive and emissions-intensive industry, relying strongly on fossil fuels. So it has a particularly critical role to play in environmental protection. According to the International Energy Agency, the iron- and steelmaking industry accounts for some 20 percent of industrial final energy consumption worldwide and for about 30 percent of the world’s direct industrial CO₂ emissions. (See Exhibit 3.) The most energy-intensive—and CO₂-emissions-intensive—process in steel production is the reduction of ferrous oxide into iron in the blast furnace. Overall, the production of iron and steel entails a high level of CO₂ emissions per unit of energy used, compared with other industries.

Energy, meanwhile, accounts for a large fraction of steel production cost—more than one-third for an integrated steel plant. So rising energy prices have had a direct impact on production cost. (See Exhibit 4.)
Exhibit 3. The Steel Industry Is Energy and CO₂ Intensive

Global final energy consumption by industry (in 10^9 gigajoules)  Direct CO₂ emissions by industry¹ (in gigatons)

<table>
<thead>
<tr>
<th>Industry</th>
<th>Energy Consumption</th>
<th>CO₂ Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other</td>
<td>116</td>
<td>6.7</td>
</tr>
<tr>
<td>Pulp, paper, and print</td>
<td>6%</td>
<td>3%</td>
</tr>
<tr>
<td>Cement</td>
<td>9%</td>
<td>25%</td>
</tr>
<tr>
<td>Iron and steel</td>
<td>21%</td>
<td>30%</td>
</tr>
<tr>
<td>Chemicals and petrochemicals</td>
<td>30%</td>
<td>16%</td>
</tr>
</tbody>
</table>

Sources: International Energy Agency; BCG analysis.

Note: These comparisons are based on 2005 data.

¹These data exclude indirect emissions from electricity production but include direct emissions from production processes and petrochemical feedstocks.

Exhibit 4. Coal Prices Have Caused Pressure on Costs

Example: a major Western European integrated steel works

Production costs for hot-rolled coil, 2006

<table>
<thead>
<tr>
<th>Percentage of cost</th>
<th>2004</th>
<th>2006</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total cost: $370 per ton</td>
<td>24</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td>Energy cost: $135 per ton</td>
<td>36</td>
<td>18</td>
<td>72</td>
</tr>
<tr>
<td>Electricity</td>
<td>10</td>
<td>72</td>
<td></td>
</tr>
<tr>
<td>Thermal energy</td>
<td>36</td>
<td>18</td>
<td>72</td>
</tr>
<tr>
<td>Reducing agents</td>
<td>36</td>
<td>18</td>
<td>72</td>
</tr>
</tbody>
</table>

Price evolution of main factors “at the plant”

Indexed: 100 = 2002 price level

Sources: Company data; BCG analysis.

¹Contains all credits for byproducts.
Environmental Protection

In addition to volatile prices for energy and ferrous raw materials, the steel industry has to cope with growing pressure from environmental-protection initiatives. Traditional steel production has caused significant air and water pollution. Coking, sintering, and blast furnace operations generate large amounts of sulfur- and nitrogen-based compounds and dusts. Toxins such as cyanine, heavy metals, acids, and phosphates create a dangerous concoction of byproducts that can harm the environment if exhaust gases and wastewater are not properly treated and handled. Insufficient filtering of exhaust gases and inadequate disposal of wastewater can cause serious environmental issues in regions close to steel plants. As a consequence, governments around the world are gradually tightening their regulations ensuring environmental protection, albeit mostly for new plants so far. These regulations increase companies’ capital expenditures but typically do not greatly affect operational cost, relative to the cost of energy and resources. In sum, while steel producers will invest to reduce their use of energy (and thus their production of CO₂) because there is a clear business case for such cost-cutting investments, they will confine their investments in technologies that reduce emissions other than CO₂ primarily to measures ensuring compliance with regulations for new capacity.

Some countries already assign trading prices to CO₂ emissions—in effect fining or taxing steelmakers for such emissions. In contrast to pollution minimization, such policies directly affect production cost. So the prospect of CO₂-emission trading provides an incentive for steel producers to reduce their energy consumption and thereby cut their CO₂ emissions. The good news is this: steelmakers’ investments in sustainability can strengthen both their cost positions and their environmental performance.

Fundamental Questions for Steel Producers

In the following sections of this paper, we address three fundamental questions for steel producers:

- How will volatile—and, in the long-term, rising—prices for energy and resources, together with tightening environmental regulations, affect steelmakers’ competitive positions?
- How can steel producers meet these challenges and maintain or even improve their operational performance with respect to energy intensity and environmental impacts?
- How can steel producers proceed toward sustainable steelmaking—to reap the benefits of sustainability-based strategies?

Impacts on Steelmakers’ Competitive Positions

The increasing scarcity and cost of resources, together with tightening environmental regulations, are pressuring steelmakers to improve their operations in two ways: by decreasing the energy intensity of their processes and by reducing environmental pollution. Enhancing the sense of urgency are the expectations of various industry stakeholders, including shareholders, governments, nongovernmental organizations, and the general public.

Measures that reduce a steelmaker’s consumption of energy and other inputs make the company less vulnerable to volatile resource prices. While companies have only limited potential to reduce their consumption of ferrous materials, they have far more potential to improve their energy efficiency. So energy efficiency is the prime lever they can use to reduce their vulnerability to volatile resource prices and to improve their cost positions relative to competitors.

The Influence of Resource Prices on Competitiveness

As prices for energy and other inputs resume their climb, steelmakers’ profit margins are likely to shrink further. Competitive advantage will move to the companies that are most energy efficient.

An analysis of the relative cost positions of three actual producers of hot-rolled coil in 2006 and mid-2008
Sustainable Steelmaking

shows that the U.S.-based steel manufacturer had higher production costs in 2006 than both the E.U.-based and the China-based producers, though all three had healthy margins. (See Exhibit 5.) By mid-2008, in contrast, faster-rising costs of production, energy, and transportation for the Chinese and European companies had shifted the competitive advantage toward the U.S. producer. While all three companies continued to enjoy stable profits, their relative profitability in terms of margins had shrunk considerably. The U.S.-based company’s estimated mid-2008 advantage resulted largely from the weak dollar and from the company’s control of proprietary resources. The Chinese producer had to cope with increasing logistical problems in ore supply, as well as problems in ensuring reliable access to energy. Additionally, on the eve of the 2008 financial crisis, both the European and the Chinese manufacturer were still affected by rising shipping costs caused by capacity bottlenecks and higher oil prices. All three companies could significantly improve their competitive positions by becoming more energy efficient.

The Rewards of Energy Efficiency

Steelmakers use, on average, some 20 gigajoules of energy to produce one ton of crude steel (excluding the energy used in mining as well as in the transport of input materials and steel products). Within the overall process of steel production, the main locus of energy usage—and CO₂ emissions—is in the ironmaking and steelmaking processes themselves. (See Exhibit 6.) Iron- and steelmaking in integrated steel plants and minimills account for some 80 percent of the total energy consumption along the steel production value chain (again, excluding mining and the transport of input materials). In integrated plants, some 75 percent of the energy used is consumed in the ironmaking process in the form of reducing agents, primarily coke. In minimills, electricity plays the dominant role.

A comparison of the prices paid by five representative steel producers in 2005 shows the importance of energy prices in the cost of steel production. (See Exhibit 7.) Discrepancies in steelmakers’ production costs reflect differences in proximity to resources, as well as varying local prices for input factors. These differences are further amplified by discrepancies in the energy intensity of the processes that companies employ.
The relative cost positions of these five producers have changed dramatically in recent years. (See Exhibit 8.) Producers in RDEs, in particular, have seen energy price increases hit their overall cost positions disproportionately, because their cost structures include relatively high energy usage. For example, although Russia has its own coal and gas resources, local producers have experienced strong price increases—up to 20 percent per year—for both gas and electricity, owing to adjustments to world market prices. Chinese producers, similarly, have had to deal with fast-rising energy prices, amplified by difficult logistics and increased energy demand in all parts of the economy. Western European producers, for their part, have
faced double-digit increases in coke prices because they import coking coal from abroad.

U.S. producers, meanwhile, recently experienced smaller increases in energy prices, thanks to the local availability of coking coal. In India, too, prices have remained relatively stable, because steelmakers use domestic coal, and natural-gas prices are controlled by the government. All the price trends described above affect minimills—which use mainly gas and electricity for their electric arc furnaces—as much as they affect integrated producers.

Increasing energy prices shift competitive advantage away from producers that are less energy efficient. Typically, those producers are located in RDEs, though a growing number of plants in RDEs are achieving state-of-the-art energy efficiency. At the same time, rising prices increase the need for energy-efficient processes and gas-recovery techniques—countermeasures that can offset rising prices and help control costs.

Regulatory Mandates for CO₂ Emissions

Also driving steelmakers’ urgent need to improve their energy efficiency are environmental regulations and (sometimes voluntary) industrial commitments to improved performance—for example, in areas such as reducing greenhouse gas emissions and energy consumption. In Europe, for example, these commitments include government-imposed and voluntary greenhouse-gas-reduction targets and associated allocation schemes; in the United States, voluntary industrial-efficiency targets; and in China, government-imposed industrial-efficiency targets.

Producing one ton of hot-rolled steel in an integrated plant generates some two tons of CO₂. Long-term prices for CO₂ allowances in Europe are expected to be some €25 to €50 per ton. So once steel producers need to pay for CO₂ allowances, their cost for producing a ton of crude steel could increase by an amount that may represent a decisive disadvantage when they compete with producers from low-cost countries.

Germany plans to reduce the number of free (that is, nonpaid) CO₂ allowances provided to the steel industry to a volume correlated to the current level of national steel production. This logic, if applied to the...
German steel industry alone and not to steel producers in other countries, would weaken the competitive position of German steel producers as well as their growth prospects.

Clearly, the cost of CO₂ emissions plays a significant role in determining the competitiveness of steel producers. Reducing energy consumption also reduces those emissions and thus has a doubly beneficial effect on steelmakers’ cost positions.

**Addressing Pollution Beyond CO₂ Reductions**

The need to reduce environmental pollution—unlike the need to boost energy intensity—is not driven by immediate cost considerations. So far, using environmentally beneficial technologies such as dedusting or wastewater treatment does not significantly affect steelmakers’ operating costs (although installing these technologies does increase capital expenditures).

Around the world, new limits on emissions of hazardous exhaust gases show a tendency to converge to similar magnitudes. In most cases, however, those new limits do not put specific improvement pressure on the installed base, because, unlike limits on energy consumption and CO₂ emissions, the limits are applied mainly to newly installed plants (greenfield and brownfield sites and major capacity extensions). This policy of applying new regulation only to new capacity as it becomes operational is normal practice in major industrial regions. Existing infrastructure in these regions generally operates under much older emissions limits, which were standard when the sites were built.

Nonetheless, steelmakers often have persuasive reasons to improve environmental emissions controls at existing plants. Chief among them is the pressing need to meet key stakeholders’ expectations. Often public opinion, local politics, or investors who have a strong preference for companies that pursue a green image force steel producers to invest in green technologies. Increasingly, steelmakers—among other industries—see environmental accountability as a business imperative and an essential aspect of positioning the company as a good citizen in the community. Moreover, the need to meet stakeholders’ expectations at home can also move companies to export high environmental standards to their offshore operations—and to their suppliers. An increasing number of stakeholders at home do not tolerate lower standards abroad.

**Six Levers for Enhancing Performance**

We have identified six main levers along the steel production value chain that steelmakers can use to reduce their energy consumption and environmental impacts. (See Exhibit 9.) These levers are:

- Improving the installed base and enhancing operations
- Upgrading industrial power plants
- Expanding other industries’ use of steelmaking byproducts
- Enhancing the quality of input materials and logistics
- Adopting new technologies and alternative production concepts
- Improving control of environmental pollution

Our analysis, firsthand experience in the industry, and discussions with industry experts indicate that over the next five years, companies can best achieve energy savings—and corresponding emissions reductions, based on the respective mode of energy generation—by taking action in the first three steps. Specifically, they should aim to

- Improve existing steel plants and their operations to bring them up to best-practice standards, thus achieving annual savings of some 2 to 3 exajoules of final energy consumption—or some 2 to 3 percent
of the industry’s global consumption

- Upgrade industrial power plants, thus saving an estimated 0.5 exajoule of annual primary energy consumption
- Increase the percentage of blast furnace slag used in cement production, thus saving an estimated 0.5 exajoule of annual final energy consumption

Other tactics within our six levers, such as increasing the use of scrap or introducing new technological concepts, either have limited potential because of preexisting conditions, including constrained availability, or will take a far longer time to have significant impact. Let’s have a look at the six levers one by one.

### Improving the Installed Base and Enhancing Operations

Steel production differs significantly from plant to plant in terms of efficiencies and operational practices. Integrated steel plants, for example, vary widely in energy consumption, depending on the basic technologies they employ. (See Exhibit 10.) Along the production value chain, the largest absolute differences in energy consumption generally occur in the ironmaking phase, because blast furnaces consume varying amounts of reducing agents, reflecting differing qualities of sinter, coke, and pellets, as well as different operating modes. There are also large variations in fuel consumption among hot stoves, based on their respective modes of operation.

The largest relative deviations are generally in the steelmaking phase, owing to missing or nonexistent gas recovery from basic oxygen furnaces, inefficient operation modes, or inadequate automation of electric arc furnaces. Outdated technologies, such as open-hearth furnaces and ingot casting, also consume considerable amounts of energy. In addition, inefficient reheating furnaces, limited hot charging, or inefficient drive systems can increase energy consumption in the solid phase.

The large differences in consumption of reducing agents in blast furnaces are particularly interesting. According to Stahlinstitut VDEh—an association of the German steel industry—best-practice blast furnaces in Germany today are operating close to the physical limits dictated by the process of reducing ferrous oxide employing carbon-based fuels. Nonetheless, there is still significant potential for improving blast-furnace-based steelmaking. Many producers around the world are still far from meeting best-practice standards in either blast furnace technology or operations. The plants that have the most room for im-

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1. One exajoule equals 10^{18} joule; the annual final energy consumption of the entire global industry is more than 110 exajoules.
Improvement are commonly located in RDEs, but not only there; and many producers in RDEs are far from laggards with respect to energy consumption. On the contrary, many of the most modern plants in the world have recently been built in RDEs. For example, the blast furnace of a first-class producer in China has the lowest energy consumption of all the representative plants shown in Exhibit 10.

Comparisons like those in Exhibit 10 do not necessarily reflect realistic potentials for improvement, because producers operate in conditions that are to some degree beyond their control. For example, larger plants are generally more efficient than smaller ones; this is particularly true of blast furnaces. Similarly, the cost, quality, and availability of input factors, such as local transportation and scrap, all influence the efficiency of the process. So in assessing a particular company’s potential for improvement, it is necessary to take into account the unique boundary conditions of the production sites involved.

How much improvement is possible in steelmaking worldwide? If the entire current installed base of integrated steel plants and minimills were to adopt existing best practices, we estimate that the theoretical improvement potential would be a reduction of more than 4 exajoules, or about 20 percent of global steelmakers’ annual energy consumption (based on 2006 consumption levels). This reduction in energy use would also mean producing some 600 million tons less CO₂ annually. (We projected these results to the global installed base from a benchmarking analysis of some 30 producers worldwide. The projection is based on 2006 capacity data—and on the assumption that capacity added since then has been state-of-the-art.)

Of course, theoretical estimates rarely coincide with realistic possibilities. Taking into account the physical, economic, and political conditions in which actual steel plants operate, we expect that it should be possible to realize some 50 to 70 percent of this potential. This means that more than 2 exajoules could be saved from annual energy consumption of the global steel industry and more than 300 million tons of annual CO₂ emissions could be avoided. (See Exhibit 11.)

From our recent work with steel producers and their suppliers around the globe, as well as from our discussions with industry and technology experts, we have learned that it is possible to achieve the perfor-

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**Exhibit 10. Steelmakers Vary Widely in Energy Intensity**

*Example: Energy intensities of selected integrated steel plants using blast furnaces*

<table>
<thead>
<tr>
<th>Ironmaking (without agglomeration)</th>
<th>Steelmaking</th>
<th>Casting</th>
<th>Hot rolling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Russian producer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Advanced Indian producer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U.S. producer¹</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Advanced Western European producer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Advanced Chinese producer²</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Improvement potential of comparable plants

-27%  -78%  -72%  -31%

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Sources: Company data; BCG analysis.

¹Different from the U.S. and Chinese producers analyzed in the preceding exhibits.
performance improvements cited above by employing existing technology. A major lever for reducing energy use is the direct improvement of the individual aggregates that go into the steelmaking process. For example, new state-of-the-art technologies to agglomerate the inputs for the blast furnace not only consume considerably less energy than older ones but also create higher-quality coke or sinter, contributing to lower energy consumption in the blast furnace.

In addition, modern automation systems can be used to minimize the superfluous use of energy—both by optimizing the operation modes of individual production units, such as blast furnaces and electric arc furnaces, and by improving production logistics along the whole process chain.

A significant lever for reducing net energy consumption is energy recovery. Especially in the liquid phase of the steelmaking process, large quantities of superfluous energy can be recovered in the form of heat, pressure, and caloric value (of exhaust gases). These forms of energy can be reused in other process steps as sources of heat or electrical power. In this context, the improved management and design of energy networks—for power, gases, or steam—allow steelmakers to save additional energy. They can realize further improvements by employing modern drive systems that combine highly efficient drives with state-of-the-art automation.

### Upgrading Industrial Power Plants

Integrated industrial power plants generate electricity and heat for steel production both from fuels (natural gas) and from gas recovered from the iron- and steelmaking processes. The global electricity-generation capacity installed at steel production sites amounts to about 24 gigawatts of electrical power. More than 8 gigawatts of this capacity is installed in power plants that are more than 30 years old. Another 4 gigawatts of the installed capacity is 20 to 30 years old. (See Exhibit 12.)

This age distribution suggests considerable potential for energy savings. Modern power plants are much more electrically efficient than older ones. The average electrical efficiency of the plants that are more

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**Exhibit 11. In Principle, Efficiency-Based Energy Savings Could Amount to 20 Percent of Annual Consumption**

Theoretically possible energy savings along the global steel-production value chain

<table>
<thead>
<tr>
<th>Exajoules per year</th>
<th>Coking</th>
<th>Sintering</th>
<th>Ironmaking</th>
<th>Steelmaking</th>
<th>Casting</th>
<th>Rolling and processing</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
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<tr>
<td>4</td>
<td></td>
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<tr>
<td>5</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Theoretical savings
- 20% of global annual consumption
- ~ 600 million tons of annual CO₂ emissions

*Sources: Data from approximately 30 steel producers; BCG steel-market model; BCG analysis.

*Based on 2006 global steel production with energy consumption of about 23 exajoules.*
than 30 years old is below 30 percent, whereas younger plants with modern steam cycles are more than 40 percent electrically efficient, and modern plants that employ combined cycles are about 55 percent electrically efficient (if gas treatment is required). Replacing old and outdated power plants would allow steel-makers to realize substantial savings in their primary energy consumption. Depending on how modern the technologies are that companies use for replacement, we estimate potential savings of some 0.1 to 0.5 exajoule of annual consumption of primary energy. (The higher number represents the potential savings if the entire power-generation capacity of steel production sites worldwide were switched to modern combined cycles.)

Historically, steam turbine power plants were the system of choice for steel production. Today they represent some 80 percent of the installed generation capacity worldwide. The main reason for their popularity has been that steam turbines are much easier to use than gas turbines. Gas recovered from the iron- and steelmaking processes often contains impurities and has a lower caloric value and lower pressure than natural gas. Before using such gases in a gas turbine, steelmakers must treat them with gas-cleaning and compression systems. This step not only increases investment cost but also decreases overall electrical efficiency, because gas pretreatment consumes a considerable amount of energy.

However, advances in turbine technology have made modern combined-cycle plants highly efficient electrically, despite the need to employ gas pretreatment systems. So combined cycles have become economically attractive for many steel producers. Nearly half of the approximately 7 gigawatts of power-generation capacity that is currently planned or under construction consists of new combined-cycle power plants, which are located primarily in RDEs. The trend toward these advanced technologies could be accelerated.
if energy prices resume their upward trend, making it even more advantageous to optimize the efficiency of power production or to produce even more electricity with combustible exhaust gases from iron and steel production.

**Expanding Other Industries’ Use of Steelmaking Byproducts**

The most significant byproducts of steel production, in terms of achieving energy savings in applications outside the steel industry, are metallurgical slags. They can be used as landfill, to reduce environmental impacts as building materials, or as a substitute for clinker in cement production. The cement industry, by adopting widespread use of such slags, could play a critically important role in reducing greenhouse gas emissions from both industries. The question is, which industry will be allowed to assign to its production footprint the CO₂ credits generated from the two industries’ joint optimization of slag use?

Within cement production, clinker production consumes by far the largest percentage of energy and is responsible for most of the industry’s CO₂ emissions. Blast furnace slag can be used to reduce the clinker content in typical Portland cement from more than 90 percent to about one-third—or even below that level. According to the International Energy Agency, substituting blast furnace slag for cement clinker would allow significant reductions in annual energy consumption and CO₂ emissions—up to 0.5 exajoule, or 200 million tons of CO₂, annually.

**Enhancing the Quality of Input Materials and Logistics**

At the beginning of the value chain, steelmakers have the opportunity to enhance the quality of input materials, such as fuels and ferrous ingredients, and to improve logistics—for example, by moving production sites closer to mines and by recovering higher scrap rates in steel production. Using higher-quality fuels and ferrous ingredients can theoretically save considerable amounts of reducing agents. For example, the ash content in coking coal—and hence in coke— influences the consumption of reducing agents in the blast furnace. Steelmakers need to weigh the tradeoffs between increased transportation and energy costs and the higher value of higher-quality coking coal from more distant mines. For some plants, for which purchasing higher-grade coal is too costly, a more feasible approach is to improve the quality of the input materials before agglomeration—if technically possible and cost competitive.

Another strategic option is to locate production sites close to ore or coal mines. The International Energy Agency estimates that producers could save up to 2 gigajoules of energy per ton of crude steel by reducing transportation and the associated consumption of energy and fuel. Again, these are long-term measures. Optimized resource access is an issue primarily for plants that will be built in the future, so it will not have a significant impact on global steelmakers’ consumption of transportation energy in the near term.

Far more promising as a way to reduce energy consumption is the higher usage of scrap. As mentioned above, minimills—which base their steel production largely on scrap—consume about half as much energy as integrated steel works (some 10 gigajoules versus more than 20 gigajoules of primary energy per ton of hot-rolled coil). But scrap usage is limited by scrap availability, and this factor is not likely to increase significantly for many years to come: Today global scrap availability averages about 0.4 ton of scrap per ton of crude steel produced. If today’s level of global crude-steel production were to double by 2050, we would expect scrap availability in 2050 to amount to about 0.6 ton per ton of crude steel. (In performing this analysis, we took into account typical lifetimes and expected relative shares of steel-based products.)

**Adopting New Technologies and Alternative Production Concepts**

Although ideas abound, breakthrough energy-saving technologies are not likely to become available for widespread use in steelmaking in the next few years. For example, new reduction methods, such as hydrogen-induced processes, even if proved feasible, will not be commercially available for many years. Moreover, these processes will reduce CO₂ emissions only if nuclear or renewable power sources are used to generate the necessary hydrogen.

Alternative concepts already in use, such as coal gasification and natural-gas-based fine-ore processes,
are very attractive because they would allow companies to eliminate coking and sintering. But these approaches will have limited impact because their installed bases are so small. However, if they were to be widely adopted, they could save a lot of net energy used and lower net CO₂ emissions if the combustible off-gases are fully recovered and used to generate power and heat. Corex and Finex are currently the most promising concepts for substituting for the emissions- and energy-intensive agglomeration and blast-furnace phases in the traditional ironmaking process; both have been well tested in large-scale applications. For example, to achieve its environmental targets, a large Chinese steel producer built a Corex plant, adding a low-emissions ironmaking process to its production network.

**Improving Control of Environmental Pollution**

The steelmaking process contains many sources of environmental pollution, all of which call for optimized pollution-control systems. Sintering and coking, for example, generate heavy air pollution, which requires effective dedusting systems and the removal of nitrogen and sulfur compounds. Similarly, wastewater appears along the entire steelmaking process. Such liquid wastes contain considerable amounts of heavy metals and phosphates, which need to be washed out by wastewater treatment systems.

Environmental-protection systems have played an important role in the steel industry for years. The main drivers of renewed capital investments are the tightening of governmental regulations, persuasive economic considerations, and the strongly held preferences of many investors and other stakeholders, as well as the general public.

The most important area of pollution control over the next several years will be the reduction of CO₂ emissions. In this context, economic calculations will come into play as various announced emission-trading plans take effect. The question of whether and how technologies for carbon capture and storage will be applicable to iron- and steelmaking is still under discussion. We believe that these technologies may be in widespread use by around 2030. The off-gases generated by ironmaking processes, such as blast furnaces or Corex technologies, contain major amounts of carbon dioxide, carbon monoxide, nitrogen, and hydrogen—comprising a gas mixture similar to the exhausts of oxyfuel-based power plants. So, in principle, steelmakers could apply the power plants’ technology for CO₂ separation, which uses water condensation. However, the issue of subsequent CO₂ storage raises further problems. As is the case with storage of nuclear waste, the environmental consequences—as well as the technical and logistical requirements—of CO₂ storage are not yet clear.

**Steps Toward Sustainable Steelmaking**

Best practices for optimizing energy consumption in steelmaking are both well established and economically attractive. So why have most steelmakers not moved to adopt those practices and reap the related benefits?

There are several reasons. For example, before the recent steep hikes in energy prices, there was just not enough financial pressure to concentrate on curtailing energy expenditures. For decades, prices of iron ore had been steelmaking’s dominant cost driver. So efforts to cut cost focused on improving processes to use ore more effectively and boost plant productivity. Another deterrent to investment was the fact that in the past (before the boom), investments in energy efficiency had relatively long payback times. Most investment decisions in the industry were traditionally based on relatively short-term profitability rather than on life cycle benefits. Finally, the recent boom years gave the industry comfortable profits, allowing steelmakers to focus more on growing their companies than on reducing energy use, environmental impacts, or cost.

However, the current financial crisis has made steel markets more volatile. Cost optimization and risk minimization have become imperatives for producers. Moreover, the industry’s inherent dependence on fossil energy creates a serious strategic threat: once steel prices become weaker than prices for fossil resources, base profitability and competitiveness are in danger. Further pressure may arise from diverse and intensifying environmental legislation.
These risks can be addressed and minimized by a sustainability-based business strategy. Such a strategy needs to be well suited to a steel producer’s individual needs. So it is useful for each producer to first evaluate its position relative to future threats and competition.

**Evaluate Your Relative Position**

To help steel producers understand their strategic positions with respect to the challenges arising from the cost of energy, resources, and CO₂ abatement, it is helpful to visualize their current positions in terms of a simple evaluation scheme that arrays two key dimensions:

- The urgency of the need to reduce energy intensity, caused by rising (or changing) prices for energy, increasingly stringent environmental regulations, and voluntary industry commitments to performance improvement
- The degree of potential improvement needed to match best-practice performance

This scheme can be used to evaluate the relative energy positions of whole national industries, individual companies, or—on a very detailed level—single steps in the steelmaking process. (See Exhibit 13.)

The two dimensions are measured relative to actual industry performance. A medium degree of urgency to improve is defined as the industry’s historic improvement rate—that is, about 1 percent per year. A medium degree of energy intensity, in turn, is calculated with respect to the relevant peer group. For global comparisons, it is useful to set it to the average global level of energy usage.

Where both the urgency of the need to improve and the degree of potential improvement needed are high,
“Invest ASAP” is reasonable advice. Smaller Chinese producers, for example, tend to be relatively weak on energy efficiency; as prices increase, they are forced to improve their energy efficiency.

Where urgency is high but potential for improvement low, companies can gain benefits only by investing in high-end technologies. Companies in this position include top-tier Chinese and most European producers, which already have highly efficient operations. But as government regulations become more stringent, along with voluntary industry commitments to improved performance, investments in high-end equipment can still be beneficiary. Another strategic option for companies in this position is to reassess the fundamental economics of the production site in question.

Opportunistic investment makes sense for companies experiencing high potential for improvement but low urgency to improve. In India, for example, energy prices are still comparatively low, while many producers are not very energy efficient and have considerable potential for improvement.

The matrix can be used to analyze current strategic positioning as well as future-based scenarios.

It is important to understand that the positions of both individual companies and national or regional industries depend very much on energy price scenarios and regulations. (See Exhibit 14 for a qualitative illustration.) Generally, companies in RDEs tend to be more vulnerable to fast-rising energy prices than those in developed economies because of differences in energy efficiencies. A scenario in which energy prices continue to rise sharply would enhance the urgency of the need to improve for companies in RDEs more than for those in more developed countries. Conversely, of course, increasing energy prices effectively improve the competitive position of producers in highly developed economies—at least in their home markets. According to our analyses, the high level of urgency to improve energy intensity in Western economies is based mainly on the need to meet regulatory requirements, as well as requirements posed by voluntary industry commitments.

However, the regional comparison shown in Exhibit 14 is far too general to determine individual positions and potentials of specific companies. It is possible to get a much more differentiated view when looking at individual plants and processes. For example, an analysis of the hot strip mills of several integrated steel

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### Exhibit 14. Producers in Many Parts of the World Urgently Need to Reduce Their Energy Intensity

<table>
<thead>
<tr>
<th>Potential for improving energy intensity</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urgency of need to improve energy intensity</td>
<td>Low</td>
<td>High</td>
</tr>
</tbody>
</table>

#### Energy positions of integrated steelmakers in selected industrial regions

- **India**
- **Eastern Europe**
- **Commonwealth of Independent States**
- **China (top tier)**
- **EU-15/Western Europe**
- **China (smaller producers)**
- **China (large producers)**

**Source:** BCG analysis.

1. Integrated steelmaking comprises agglomeration through hot rolling.
2. Large Chinese steelmakers that produce more than 10 million tons of crude steel per year: Baosteel, Tangshan, Anshan, Jiangsu, Shagang Group, Wuhan, Jinan, Magang Group, Laiwu, China Steel, and Shougang.
Exhibit 15. The Need of Individual Producers to Improve Energy Intensity Varies by Aggregates and Region

<table>
<thead>
<tr>
<th>Region</th>
<th>Potential for improving energy intensity (in percentage, relative to best practice)</th>
<th>Urgency of need to improve energy intensity (in percentage of required average annual improvement)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU-15/Western Europe</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>Eastern Europe</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>Commonwealth of Independent States</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>North America</td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>China</td>
<td>0</td>
<td>20</td>
</tr>
</tbody>
</table>

Sources: Company data; BCG analysis.
*We assume that midterm energy prices will recover from the current economic crisis.

producers reveals that their optimization potential depends more on the age of the individual mill than on the region in which it is located. (See Exhibit 15.) One Western European steel plant, for instance, is close to best-practice levels of energy performance, whereas another consumes more energy than any of the Chinese producers in the group we benchmarked.

The hot strip mills in the Commonwealth of Independent States show particularly high urgency and potential to improve. In contrast to the ironmaking and steelmaking phases in the overall production process, in which coal is the major driver of energy cost, the hot-strip-mill stage depends heavily on gas and electricity. Local price trends for gas and electricity have dramatic consequences for milling cost. Clearly, to make a detailed analysis of a plant’s overall energy efficiency, it is essential to analyze the individual steps in its value chain.

**Design a Sustainability-Based Business Strategy**

How can steel producers meet their need to improve their energy efficiency and capture the related financial benefits? We are convinced that it is critically important for every company to incorporate the sustainability perspective and principles into its business-development strategy, assessing the long-term implications of each of its decisions along all the major dimensions of its business: its business context and positioning, its stakeholders, its business model, and the positions of its competitors, suppliers, and customers.

Our experience shows that a sustainability-based business strategy can be built up in five steps.

**Step 1: Evaluate the status quo.** As discussed above, the development of a strategy based on sustainability starts with an assessment of the company’s status quo. It is important to evaluate the company’s performance on each step in the production value chain. A structured benchmarking of both the company’s own internal functions and those of its peers can shed light on areas that offer good potential for improvement. At the same time, relevant influence factors, such as rising energy prices or intensifying environmental legislation, need to be assessed and their likely impacts well understood. The matrix discussed above can help structure the issues and derive critical implications.
Step 2: Identify options to realize your potentials. Next, the company should identify possible technological measures or management actions that could help realize its improvement potentials. The first aspect should involve major suppliers in an economically oriented discussion on energy-efficiency and environmental-care opportunities. This assessment should be oriented to the six levers for enhancing performance listed in Exhibit 9.

Step 3: Prioritize and set up a blueprint for action. Once the status quo and options for improvements have been identified, the company should evaluate possible impacts on its future by means of a scenario-based analysis. The scenarios used should reflect varying ranges for economic factors such as energy prices, as well as possible developments in environmental legislation and in the interests of the company’s key stakeholders. Such scenario analyses will help companies give appropriate priority to those actions that have the highest likelihood of improving environmental sustainability and economic profitability.

The outcome of this step will be a blueprint for action: a set of prioritized measures and actions that—depending on local conditions—should be implemented among all production sites to meet companywide performance standards. In this context, the company should set clear and ambitious targets for reducing energy consumption and CO₂ emissions. Meeting these targets may not only boost the company’s profitability or improve its strategic position but also help improve its position toward its stakeholders.

Step 4: Implement. The company should communicate its new targets for environmental sustainability, and it should make the blueprint for action an imperative for its production sites. It is critical for the success of the sustainability-based business strategy that it not be considered less important than short-term economic interests: it has to be a long-term priority.

Step 5: Institutionalize. In the final step, the company should institutionalize the four previous steps: it should continuously seek to optimize both its energy efficiency and its environmental footprint—on the basis of growing experience and new developments.

Once the company has reached this point, it has become a successful “sustainable steelmaker.”
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