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Future Technologies for Energy-Efficient Iron and Steel Making Industry.

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Abstract: *Techniques for the reduction of the specific energy consumption for iron and steel making are identified and characterized to assess the potential for future energy-efficiency improvement and research and development priorities. Worldwide average specific energy consumption for steel making is estimated to be 24 GJ/tonne. The most energy-efficient process requires 19 GJ/tonne for primary steel and 7 GJ/tonne for secondary steel. Seven specific smelting reduction processesand four groups of near-net-shape casting techniques are described and evaluated. In the longer term, the specific energy consumption for making steel from iron ore can be reduced to 12.5 GJ of primary steel per tonne. A further reduction of up to 2.5 GJ of crude steel per tonne may be achieved when techniques are developed that can recover and apply heat from the hot steel at a high temperature. The specific energy consumption for secondary steel making can be reduced to 3.5 GJ/tonne by energy-efficient melting and shaping techniques.*
Keywords: Energy consumption, Energy efficiency, smelting process.

1. Introduction:

The iron and steel industry is the largest energy-consuming manufacturing industry in the world. In 1990, its global energy consumption was estimated to be 18–19 exajoule (EJ), or 10–15% of the annual industrial energy consumption (1). Figure 1 shows that annualworld steel production has increased from about 100 million tonnes in 1945 to about 770 million tonnes in 1990. Global steel production is expected to grow further, by about 1.7% a year, mainly because of an increase in steel consumption in developing countries.The apparent steel consumption per capita in these countries is only one seventh of that in Organization for Economic Cooperation and Development (OECD) countries, but this situation is likely to change. Whereas the crude steel production in OECD countries has remained fairly stable at 320–370 million tonnes per year since 1980, the production in developing countries is growing steadily at a rate of more than 6% annually and reached about 240 million tonnes in 1993 (1). This growth is expected to continue. As a result, global steel production might rise to 1280 million tonnes in 2020, assuming a businessas- usual scenario. In this scenario the global energy consumption of the iron and steel industry is projected to increase to more than 25 EJ in 2020. Improvement in the energy efficiency of steel production is one option to counteract the increasing demand for energy. There have been many studies of the potential for energy-efficiency improvement that can be realized in the short term, i.e. in less than 10–15 years from now (see e.g. 5–9). There have also been some estimates of the energy demand of the steel industry in the longer term. For instance, in a report of theWorld Energy Council itwas estimated that on the basis of an advanced technology scenario, primary energy demand would grow to about 20 EJ in 2020 (1). This amountwould be a 20% reduction in the energy demand projected by the aforementioned business-as-usual scenario. Although scenario studies may give us some insight into possible developments, they usually give little information about the techniques required to bring about the energy-efficiency improvements. More information is needed on each technique, and the information needs to be collected and presented in a systematic way. Only then will it be possible to assess the associated research and development (R&D) requirements and to determine how much a specific technique will contribute to an improvement in energy efficiency in the longer term. The objective of this paper is to identify and characterize, through a systematic approach, techniques that can contribute to an increase in the energy efficiency of steel making, to estimate the long-term potential for energy-efficiency improvement, and to assess R&D priorities. This approach has been described extensively in a previous energy-efficiency study that focuses on the paper and board industry. It consists of three steps: First, an energy analysis of the current process is performed. Second, an inventory is made of techniques that might contribute to an improvement in the energy efficiency in the long term. Third, each technique is characterized by determining the impact on the energy demand and costs of the production process, by evaluating the current state of development, and by assessing the technical change required to bring the technology to commercialization. In this paper, the historical perspective of iron and steel making processes is described. Next, an analysis is made of the theoretically lowest amount of energy required to produce iron and steel. In the following section, an exergy analysis is made of the currently prevailing steel production route, the blast furnace–basic oxygen furnace route. On the basis of the results of the energy and exergy analyses, a description is given of possible routes for energy-efficiency improvement. Next, different techniques are described that can improve the energy efficiency of steel making. The potential impact and costs of each technique are evaluated. Finally, the methodology applied and the results are discussed, and conclusions are drawn. In addition, recommendations for policy makers are given.

In this section a brief history of the major iron- and steel-making processes is presented. The aim is to place these processes in a historical perspective and to describe energy-efficiency improvement in the past. We first discuss the main processes involved in the making of pig iron, which is reduced iron ore that still contains impurities, mainly carbon. Then we deal with the main processes used to improve the quality by removing impurities, with an emphasis on steel-making processes. The first record of the use of iron goes back to 2500–2000 BC. It is believed that in that period iron was not produced deliberately but was obtained from natural resources, e.g. meteorites. Deliberate production of iron began in about 1300 BC with the use of charcoal as fuel and reducer, in small furnaces that made use of cold air. Evidence for the existence of such furnaces has been found in Africa, Asia, and central Europe. The temperature that could be achieved in these furnaceswas probably belowthe melting point of iron. The product had to be hammered for it to be freed from slag and to make wrought iron. When better blowing devices were introduced, the temperature could be raised, and liquid, high-carbon iron was formed. In 1300 AD the Stuckoven was introduced in Germany. Although the Stuckoven was only 3–5 m high and 1–1.2 m in diameter , its design was essentially the same as that of the modern blast furnace. Charcoal was used as fuel. Based on data on the use of charcoal to produce pig iron and bar steel in the United Kingdom in the period 1540–1760, we can make an estimate of the reduction in the energy demand in this period. The charcoal consumption to make pig iron decreased from 5.5 to 2 loads of charcoal per tonne of pig iron in this period. This is an improvement in energy efficiency of about 0.5% a year. [At that time, charcoalwas delivered in cartloads to the ironworks. A load did not seem to have a standard measure. Hammersley gives a range of 13.5–17.5 hundredweight (cwt) (1 cwt is about 50 kg) for a load of charcoal. Assuming an average lower heating value of 29.5 GJ/tonne (14a), 1 load of charcoal equals 20–26 GJ.] Pig iron was converted to bar steel in the finery process. Between 1540 and 1760, the energy demand for the finery process decreased from 16 to 4 loads per tonne of bar steel, or a decrease of 0.6% a year . Because both the demand for charcoal used for steel making and the amount of pig iron needed per tonne of steel decreased, the overall energy-efficiency improvement is greater than 0.6% a year. The aim of this section is to determine the theoretical specific energy consumption (SEC) for making iron. We start by describing the energy service and thereby set the boundaries for analysis. Thereafter, we determine the theoretically lowest SEC required to perform this energy service. Finally, we consider the theoretically lowest SEC for two importantways of producing steel, i.e. melting of scrap and reduction of iron ore in the blast furnace. An energy service is defined as the objective of energy use. Energy services can be defined at different levels. The level of definition affects the scope of energy-efficiency improvements. Consider the following energy services: (*a*) making a material with certain well-described properties, such as strength and resistance etc; (*b*) making steel, without any further specification; (*c*) making steel from iron ore. Each indicated energy service can be used for describing the production of steel. However, the scope of the energy-efficient alternatives differs considerably. In the first case, the production of materials that can compete with steel are taken into consideration, e.g. strong synthetic fibers competing with steel cables. In the second case, scrap recycling and melting are an important option. In the last case, only processes that start with the reduction of iron ore are taken into account. Although substitution by other materials is an important option for improving the energy efficiency of society, this option is not considered here because the focus of the paper is the energy-efficiency improvement of processes. [For studies of the improvement of material efficiency. In this study we use the second description of the energy service. Thus, recycling of scrap is taken into consideration. The production of steel according to the blast furnace–basic oxygen route is taken as the reference process, because this process is the main production route for steel.

2. Identification and selection of long-term energy-efficient techniques

2.1 Gathering of Information

The identification of new techniques started with a search for relevant literature, performed in two ways. First, the following literature databases were searched: Applied Science and Technology Index, Environline/Energy line, Metadex, and Compendex. These databases were searched in two steps. At the start of the research a general search was performed. Later, when more specific key words were known (e.g. names of techniques), the searches were repeated using these keywords. The second method of literature search was scanning volumes of journals specific to the iron and steel industry to identify emerging techniques. Of the following journals, the volumes from 1988 to 1995 were scanned: *Journal of the Iron and Steel Institute of Japan, Stahl und Eisen*, and *Steel Times*. We expanded our database of literature by checking the references of the collected literature. The next step in the gathering of information was contacting the developers of the techniques to obtain the most recent data. We checked all data for accuracy and reliability by consulting experts, and by making our own calculations and judgments, or by obtaining evidence from other sources.

2.2 Selection of Energy-Efficient Techniques

In the previous section we concluded that the main exergy losses are due to the application of high temperatures and the need for several cooling and heating steps. In current steel making, high temperatures are necessary to achieve several goals, e.g. to change the structure of the ore and coal so that they can be processed in the blast furnace, to overcome kinetic and thermodynamic limits to chemical reactions in the reduction of iron oxide, and to provide steel in a liquid form so that it can be shaped.Techniques that reduce exergy losses resulting from high-temperature applications can be divided into three groups, according to the degree to which the

need for high temperatures is avoided or reduced.

3. Techniques that avoid at least one heating and cooling step

The avoidance of one heating and cooling step can be achieved by techniques that combine two or more processes. The two major groups of techniques are smelting reduction processes and near-net-shape casting techniques. Smelting reduction processes make direct use of coal and usually also of iron ore, without having to convert coal to coke and ore to sinter or pellets. Near-net-shape casting techniques reduce or eliminate the reheating demand in the shaping of products. A completely different route involves avoiding the iron ore reduction by processing recycled scrap and subsequent melting, casting, and shaping.

4. Techniques that reduce the temperatures required in different process steps

Reduction of iron ore below the melting point is already commercially feasible in direct reduction processes. Coke making at lower temperatures is a topic of research. Casting and shaping without melting can be accomplished by powder metallurgy, a process that is already used commercially for the production of some speciality products.

3. Technologies that recover and apply heat at high temperatures

Technologies that recover and apply heat at high temperatures do not alter the need for high temperatures. In an integrated steel mill, waste heat recovery from clean gaseous flows like combustion gases is normal practice. Recovery of the heat from gaseous flows that are contaminated with, for example, organic compounds and small solid particles runs into technical problems, such as the fouling of heat exchangers. Recovery of the sensible heat from solid flows is not an important point of research interest; therefore information on this issue is not available.

5. Characterization of long-term energy-efficient techniques

In this section we characterize the selected techniques. The focus is first on techniques that avoid at least one heating and cooling step. Both sections start with a general description including the formulation of a general basis for comparison, i.e. the way the SEC and the costs are determined, and a description of the main production parameters. Then, separate techniques are described. Both sections conclude with a comparison of the techniques. we assess the degree of technical change that is required to implement the technique compared with the current technique. We distinguish three categories of required technical change. First, techniques that require an *evolutionary change* imply a continuation of the trend in technological development. No changes in the way the energy service is performed are expected, and the effects on the following aspects are small or negligible: performance, process parameters, quality and nature of the products, the purchasing and supply industry, and the plant layout. Second, a *major change* is required when at least part of the energy service is performed according to a new principle, the performance of the process increases more than one can expect by trend extrapolation, and there are considerable effects on the other aspects. Finally, a *radical change* is required when a new energy service arises or all the aspects change to a large extent. In Section 6.3 the state of the art and the developments in making steel from scrap are discussed. Section 6.4 deals with steel making at lower temperatures, and Section 6.5 with waste heat recovery techniques. Finally, in Section 6.6 future process routes for steel making are sketched and the potential for the reduction of the SEC is determined. In this concluding section we evaluate to what extent exergy losses can be reduced by the techniques described, and we suggest what needs to be done to achieve further reduction.

Smelting reduction (SR) processes involve reduction of iron ore without the need for coke and—in most cases—agglomerated ore. The driving forces behind the development of SR processes are the reduction of capital and operation costs and the smaller environmental impact, both of which can be achieved by eliminating coke ovens and ore agglomeration. The principle behind SR is that iron oxide is reduced in the liquid state by carbon or carbon monoxide. Liquid state reactions are much faster than solid state reactions. Because the reduction in a blast furnace is a solid state reaction, the reduction time can be reduced. In principle, an SR process can consist of a single reactor in which unprepared iron ore and coal react to form a product similar to steel; that is, decarburization of the iron takes place in the same reactor. In practice, SR processes consist of at least two reactors, and the product resembles pig iron, which has to be refined in a separate reactor for steel to be obtained. Figure 10 gives some schematic representations of SR processes.

6. Conclusions concerning smelting reduction

Now that several SR processes have been characterized, a founded estimate can be made for the potential of energy-efficiency improvement when these processes are implemented and a comparison can be made of the production costs. We also evaluate the chance of successful commercialization of the SR processes that are still under development and estimate how long it will be until the first commercial plant is in operation.

The conclusion that emerges is that SR processes are not necessarily more efficient than conventional iron making. The energy requirement for coke making and, in most cases, ore agglomeration is avoided. Energy consumption of the iron ore reduction itself increases, as a result of the higher coal consumption and the need for pure oxygen. The energy consumption can be minimized by selecting optimum values for the process parameters. Careful attention should be paid to the utilization of the export gas, both in the reactor and outside. The maximum energy-efficiency improvement appears to be about 20% compared to the current best-practice iron-making process. However, all data on energy requirement are still based on design values or on pilot-plant results. But SR technology is still in an early stage of development, and further work on these technologies might well lead to even more energy-efficient designs.

6.1 Steel Making at Lower Temperatures:

The ultimate technique for reducing the need for high temperatures would be steel making at room temperature, without any temperature rise. Since the reduction of iron ore at room temperature is thermodynamically and kinetically unfavorable, such a process is hard to conceive. The various unit operations, however, can be operated at lower temperatures than in present processes, although these temperatures are usually still far above room temperature. COKE Coke can be produced at a lower temperature (800±Cinstead of 1100±C) by completing the heating of the coke while it descends into the blast furnace . This process has been tested on a small scale by Kobe Steel in Japan. A saving of about 15% on the fuel consumption of coke making can be achieved. This process partially integrates coke making and iron making. However, cooling of the hot coke still occurs.

6.2 Conclusion concerning steel making at lower temperatures:

No technology avoids the melting of steel; melting remains necessary for shaping steel. Although direct reduction of iron ore is performed at a temperature that lies far below the melting temperature, the DRI still has to be heated further to be melted. When we compare the DRI-EAF route with the blast furnace BOF route, we see that both routes have comparable SECs. It can be concluded that as long as melting is required to shape the products, a decline in the temperature of iron ore reduction will not result in a significant decrease of the SEC.

6.3 Waste Heat Recovery at High Temperatures

The techniques discussed in the previous sections involved a reduction in the application of high temperatures. In this section, we explore techniques under development that can recover heat at high temperatures and make it available as a high-quality energy carrier. First, we discuss techniques that can be applied in the conventional integrated steel mill. Then we look at possible ways of recovering high-temperature heat from streams from future processes.

6.4 Conclusion concerning waste heat recovery at high temperatures

Many heat recovery techniques are available, for both gaseous and solid streams. Implementation of these techniques has not been achieved, mainly because of the high investment costs involved. One of the topics of R&D should therefore be to make heat recovery more profitable by recovering a larger part of the heat at higher temperatures. For future steel-making processes, the recovery of the heat of the cast steel over the whole temperature range from 1600±Cto environmental temperature is a big challenge. Recovery of heat in the low temperature range can probably be developed first, since this technique is already available for continuous casting. Recovery at higher temperatures still requires much R&D.

6.5 Conclusions Concerning the Potential of Long-Term Energy-Efficiency Improvement

This final section is an overview of the expected SECs of future steel-making processes. Furthermore, we discuss to what extent the exergy losses have been reduced and what needs to be done to achieve a further reduction. Finally, we estimate future potential energy consumption from steel making.Figure 18 gives an overview of four future steel-making routes and the expected SEC, expressed as GJ primary energy per tonne of hot rolled steel. The first process route is an improved version of the blast furnace route. The SECs are taken from Worrell et al . Most of the techniques that have to be applied to achieve this potential have already been demonstrated, and they can be added to the process without major adaptations. Although larger improvements are possible by usings newer techniques, it is likely that many integrated steel mills will be adapted in this way, because it involves only evolutionary changes. The second process route is an advanced primary steel-making route incorporating an efficient smelting reduction process and strip casting. The SEC is 34% lower than the SEC of the current best-practice integrated mill. All techniques have been proven on a pilot-plant scale and are expected to be commercially available within 15–20 years. The major driving forces are the lower environmental impact and the large reduction in production costs. The third process route depicted is based on an EAF combined with direct reduction of iron ore according to the AREX process and strip casting. The AREX process is the most efficient commercial DR process available. To account for energy-efficiency improvement of the AREX process, we assume that the SEC of the future AREX process is 0.5 GJ/tcs lower than that of the current process. This improvement is the same as that which can be achieved in the blast furnace.

The fourth process route is advanced scrap-based electric melting in combination with strip casting. The energy demand for melting scrap is lower than for melting DRI, because DRI contains slags that have to be heated and refined. All techniques required for these processes can probably be made commercially available within 20 years. Implementation will take considerably longer. In the next century all process routes may be used side by side. The choice of the process will depend on (*a*) geographical factors, such as the availability of natural gas or cheap electric power; (*b*) market factors, such as the availability of high-quality scrap and the demand for specific steel products; and (*c*) the development of the price of steel products. The development of the technologies described is taking place almost completely in the iron and steel sector and depends little on developments in other sectors. However, governmental support is not uncommon. The development of nearly all smelting reduction processes has been supported by the national government. Is a further reduction in SEC to be expected in the longer term? We discuss the major energy losses of the future processes.

7. Discussion

We opt for a definition of the energy service that allows us to include the recycling of steel scrap. Recycling and reprocessing of scrap has a much lower SEC than does primary steel making and is therefore an important energy-efficiency improvement option. However, it cannot be concluded that all steel should be made according to this process. First, the resources of scrap are not sufficient to meet demand if all steel were to be produced from scrap: World steel demand
will grow, it is impossible to collect all steel at the end of its lifetime, and the quality of scrap is not homogeneous. Second, the product mix of a scrap-based mill is different from that of an integrated mill. With the introduction of thin slab casting, this difference has been eliminated to some extent. To circumvent these problems we presented the potentials for energy-efficiency improvement in integrated mills and scrap-based mills separately. An even broader definition can also be considered, for instance one that includes the production of other materials that can replace steel. We realize that this might result in large energy-efficiency improvements in the long term. Studies that compare the energy requirement for the production of different materials have been published. An assessment of the energy-efficiency improvement potential as a result of material substitution requires additional information about and analysis of expected developments in energy efficiency and in the demand for different products, competition between products, and the emergence of new products. The selection of techniques was performed on the basis of the results of the exergy analysis. Three groups of techniques can be distinguished. The first group consists of techniques that avoid at least one heating and cooling step. The second group is made up of techniques that reduce the temperature level required in different processes. The third group contains techniques that recover and apply heat at high temperatures. Noteworthy is the lack of technologies that involve a completely different way of steel making. There do not seem to be any technologies to make steel at lower temperatures. The reduction of iron ore to iron hardly proceeds at low temperatres; the opposite reaction is favored thermodynamically. It can be concluded that the reason no technologies have been found for reducing iron oxide at low temperatures is that no practical ways of achieving this have been discovered.In theory, the reduction of hematite with carbon is very efficient. The Gibbs free energy of that reaction is 6.8 GJ/tonne of Fe, very close to the Gibbs free energy of decomposition of hematite into the elements, which is 6.6 GJ/tonne of Fe. From an energy point of view there is no reason to look for other reductants. Nevertheless, it has been proposed to use hydrogen . One advantage of using hydrogen is that no carbon dioxide is formed. Of course, this is true only when hydrogen is made without the use of fossil fuels. The uses of hydrogen does not entail energy saving in itself. To produce 1 tonne of pure iron, about 650 Nm3 of hydrogen is required theoretically. This equals about 6.5 GJ/tonne .This amount is of the same order of magnitude as the minimum energy demand when coke is used. Now we comment on the accuracy of the input data and on the way in which we had to convert data to make a comparison possible. We had to rely on figures presented by developers that were based on the results of pilot-plant experiments or were design values. Data on new techniques are rarely supported by other sources of information. Nevertheless, it is possible to make a rough check of the data for SR processes by calculating the expected demand for coal and oxygen.

The main energy input of SR processes is non coking coal. It can be expected that the coal demand is higher than the coke demand in blast furnaces, as coal still contains 20–30% weight (wt) volatile matter that has to be heated and evaporated. On the other hand, the ash content is a few percent lower. The coal demand of SR processes is up to 30% higher than the coal demand of the blast furnace, which is in line with what can be expected. On the basis of stoichiometric ratios, the oxygen demand (in tonnes) can be determined to be between 90% (for complete conversion to carbon monoxide) and 180% (for complete conversion to carbon dioxide) of the coal demand. SR processes with a high degree of postcombustion have a higher oxygen demand than processes with a low degree of postcombustion. Oxygen is not only provided externally, it is also generated within the process by the reduction of iron ore. Depending on the composition of the ore, the oxygen released per tone of Fe is about 300–500 kg. The oxygen released in the prereduction shaft is usually not available for coal combustion. It can be determined that the reported oxygen requirements for second-generation SR processes are well in line with the value that could be expected on the basis of coal requirement, degree of postcombustion, and degree of prereduction. Differences in the reported and the calculated oxygen demand equal 0.05–0.1 GJ/tonne of Fe (primary energy),or less than 1% of the SEC. On the basis of the foregoing analysis, we can state that the input data on oxygen and coal consumption of all SR processes are consistent with what can be expected from the stochiometric oxygen requirement and the differences in composition of coking and noncoking coal. We expect that variations in these input data are so small that they do not affect our conclusions with regard to energy-efficiency improvement potential of SR processes.For comparison of the SECs, we converted the energy carriers to primary energy carriers using a low and high case and a simple model for in-house electricity production. SECs of SR processes depend strongly on the way in which the export gas is utilized. SR processes with high export gas production are not always more efficient than the blast furnace process. Careful consideration should be given to the matter of what to do with the export gas. We assumed that all export gas is converted to electricity in a combined cycle plant. Other applications of the export gas may be considered as well. For instance, it can be used as fuel for a fuel cell, as reducing gas in DRI processes, or recycled at high temperatures to the melter. These options should be investigated to find the optimum use of energy for the production of iron (and electricity as a by-product).

8. Conclusions and recommendations

In this paper we have analyzed the potential for the improvement of energy efficiency in the iron and steel industry that can be realized in the long term. We used exergy analysis to show that the main exergy losses in an integrated steel mill are due to the use of high temperatures. On the basis of the results of this analysis, we concluded that long-term energy-efficiency improvement should be directed toward reducing these losses by (*a*) avoiding intermediate heating and cooling steps; (*b*) reducing the temperature required in various process steps; and (*c*) recovering and applying heat at high temperatures. The focus in this paper was on smelting reduction processes, which avoid coke making and ore agglomeration, and on near-net-shape casting techniques, which avoid or reduce the need for reheating before rolling. By a combination of these techniques, the SEC might be brought down from the current best-practice figure of 19 GJ/trs to 12.5 GJ/tcs, or a reduction of about 35%. The production costs of steel strip from a future integrated mill that uses smelt reduction and strip casting are far below those from a current integrated mill. Both smelting reduction and strip casting are likely to be available within two decades.Direct reduction has a lower energy requirement than reduction of ore in an SR process, mainly because melting is avoided. However, subsequent melting remains necessary to shape the steel. Because of the low carbon content, DRI has to be melted in an EAF. The SEC of production of steel in the DRI-EAF route is about 2 GJ/trs higher than that of the SR-BOF route. Electric arc furnaces can make steel from a 100% scrap charge, thus avoiding the need for iron ore reduction. The SEC of steel making of current best-practice EAF mills is about 7 GJ/tcs expressed in primary energy carriers, using a 40% efficiency of electricity generation. This may come down to 3.5 GJ/tcs bythe use of more efficient melting furnaces, more efficient casting and shapingtechniques, and assuming a 60% efficiency of electricity generation. Steel mills with an EAF have changed considerably over the past decade; they are now competitive with integrated steel mills in the production of flat products, a market that had previously been the monopoly of integrated steel mills. The use of scrap only for the production of steel is not possible, because not enough scrap is available and the quality of scrap is not sufficient to make all steel products. In the future, different routes to produce steel will continue to exist side by side. For all process routes, a further reduction of up to 2.5 GJ/trs can be achieved when techniques will become available for recovering and applying the hightemp erature heat of hot steel and slag. Several concepts of slag heat recovery have been developed. Because of the high investments, none of these concepts has been commercially applied. Heat recovery of the hot steel at temperatures below800±Cis a commercial technology. R&Dshould be directed at recovering heat at higher temperatures, including recovery of the heat of melting. No such technology is under development.The selected energy-efficient techniques described in this paper will probably become available before 2020. The diffusion of these techniques will take place in the decades following the market introduction. During this period the techniques will probably be improved, which may result in higher energy efficiency. It can be projected that when all the steel in the world is produced according to the most efficient processes, world energy demand for steel making will stabilize or even decline. In this projection it is assumed that the current ratio of primary to secondary steel making will still be applicable and that world steel production will grow by 1.7% a year on average. In addition, growth in developing countries is assumed to be 4% a year. Further reductions in energy demand can be achieved when advanced heat recovery techniques are developed and adopted and when the use of scrap is increased. New techniques are being developed within the iron and steel industry itself. However, governmental support is not uncommon. Nearly all smelting reduction processes are being developed with a form of financial support from the government. The main driver for the development of new techniques is a reduction in production costs. Improvement in energy efficiency can contribute to this. The role of the government in improving energy efficiency in the iron andsteel industry is still limited. Several areas may be the subject of governmental policy:

1. Financial support for the development of energy-efficient technologies;
2. Encouraging iron and steel companies to implement the most efficient techniques, e.g. through voluntary agreements;
3. Providing an efficient and effective scrap recycling system and stimulating the maximum use of scrap by iron and steel companies;
4. Encouraging research to further improve energy efficiency, e.g. by developing techniques to recover and apply high-temperature heat and processes to make steel directly from iron ore.

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