Future Technologies for Energy-Efficient Iron and Steel Making

Contents

1. Energy service and theoretical specific energy consumption

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 performing this energy service. Finally, we consider the theoretically lowest SEC for two important ways of producing steel, i.e. melting of scrap and reduction of iron ore in the blast furnace.

1.1 *Description of the energy service*

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 productions 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. 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.

1.2 *Calculation of the theoretically lowest energy demand*

The theoretically lowest energy demand is the amount of energy required to perform the selected energy service without taking into account practical processes. The theoretical steps required for the production of steel from ore are (*a*) separation of iron oxide from other compounds in the ore, (*b*) reduction of iron ore, (*c*) adjusting the composition to make the desired steel, and (*d*) shaping the steel in the form of the product. When steel is made from scrap, the theoretical steps are (*a*) upgrading the scrap and (*b*) shaping the steel in the form of the desired product. The energy required for mining and transporting the ore and for recycling the scrap are not taken into consideration. We give a brief explanation of each step.

PRODUCTION OF STEEL FROM IRON ORE: Many minerals in the earth crust contain iron. Besides iron, these minerals, or ores, can contain many other compounds, mainly other oxides, e.g. SiO_2, Al_2O_3, and MnO_2. The iron content of iron ore can be as low as 30%, but it is usually in the 60–70% range. Oxides are the most important iron ores. There are three types of iron oxides: hematite (Fe_2O_3), magnetite (Fe_3O_4), and wustite. Hematite is the most abundant oxide of iron.

a. *Separation of iron ore from other compounds in the ore:* In homogeneous oxides there is a three-dimensional network of covalent bonds. There is strong ionic and covalent bonding. Breaking this bonding requires high energy input, which is reflected by relatively high melting points. In multicomponent solids, such as ores, the entropy of mixing should also be taken into account. The entropy of two components that are mixed is smaller than the entropy of the separate components together. Mixing the compounds results in a decrease in the entropy and thus an increase in Gibbs free energy by an amount that is equal to the temperature times the entropy of mixing. For iron ore, consisting of 77% hematite, 15% SiO_2, 5% magnetite, and 3% other compounds, the difference in Gibbs free energy compared to the separate components is calculated to be -0.04 to -0.08 GJ/tonne Fe. It is assumed that all iron in the ore can be recovered.

To separate the mixture into the individual compounds, the same amount of energy has to be supplied to the mixture. There are two reasons for regarding this amount of energy as an upper limit for the minimum energy required to recover iron compounds from the ore. First, energy demand is based on the separation of the mixture into its pure compounds, whereas we are interested only in iron oxide. Second, ideal mixing is assumed, while in practice compounds will appear in clusters in the ore. In these clusters no mixing, or less mixing, occurs between different compounds; thus the entropy of mixing is smaller.

b. *Reduction of iron oxide:* Pure oxides can be decomposed into elements. We base the theoretically lowest SEC for the reduction of iron ore on the Gibbs free energy for reaction 1 because hematite is the most abundant iron oxide.

c. *Adjusting the composition of the iron to make the desired steel:* Steel consists mainly of iron. Besides the elements derived from the ore and coke, mainly C and some Si, Mn, P, and S, other elements are added to make alloy steels, including Zn, Cr, Cu, Ni, and Mo. Adding these elements does not require energy.

The production of these additives may require a significant amount of energy. Because this amount varies, depending on the type and amount of additive, we do not take it into account. New compounds can be formed by a reaction of the elements and compounds present during cooling or heat treatment, e.g. iron carbide and ferromanganese. As an indication for the energy required for these reactions, we consider the formation of iron carbide. The Gibbs free energy of formation of iron carbide (Fe_3C) is 0.11 GJ/tonne of Fe_3C. Because the average value for the carbon content in steel is less than 0.5% by weight, the maximum theoretical energy demand for iron carbide formation is 0.002 GJ/tcs.

d. *Shaping the steel into the form of the desired product:* Finally, the steel is shaped into the desired form, and the surface can be adjusted to give the steel certain properties. The difference in the energy content of shaped and nonshaped steel is small. Also, in theory, the changes in the surface properties require hardly any energy. We can conclude that the theoretical SEC for making steel from ore equals that of one step: the reduction of iron ore. The theoretical energy demand for the other steps is less than 1% of that for the reduction of iron ore. The energy for iron ore reduction is liberated when iron returns to the more stable iron oxide, a process known as rusting. Unfortunately, this energy is hard to recover. In practice, the energy demand for crushing and grinding, pelletizing, and/or sintering iron ore, along with shaping, may constitute a considerable part of the energy demand for making a steel product.

PRODUCTION OF STEEL FROM RECYCLED SCRAP: Steel scrap is recycled from many sources. The quality of the scrap depends on the source. One of the largest sources for recycled steel is from automobile bodies and frames. This scrap contains large amounts of zinc, which was used as a surface layer. If not removed, the zinc negatively affects the quality of the steel.

a. *Upgrading scrap* The quality of scrap is not uniform. It is possible to recycle homogeneous, relatively pure scrap. However, as steel is increasingly being used in combination with other materials, or is being coated, a major part of the scrap resource will be contaminated with other metals like zinc, nickel, copper, and tin and with polymers and other materials. If we assume that there are no covalent or ionic bonds, the minimum amount of energy that has to be supplied to the mixture to obtain the pure components equals the entropy of mixing times the temperature. We assume that this amount of energy is on the same order of magnitude as that required for the separation of ore into its components, thus less than a maximum of 0.1 GJ/tonne of iron.

b. *Shaping of the steel into the form of the desired product :* For shaping steel, the same conclusion can be drawn as for shaping of primary steel: The theoretically lowest energy demand for this process is negligible. We can conclude that, in theory, making steel out of scrap requires hardly any energy. However, practical processes require more energy than in the theoretical cases discussed above. Particularly, ore preparation and shaping of steel, of which we neglected the energy demand in this theoretical discussion, will contribute to a higher energy demand. In the next sections we discuss the theoretically lowest energy demand for melting iron and the chemical conversion that take place in a blast furnace.

1.3 *Heating and melting of iron*

When pure iron is heated, the lattice structure changes three times. Each change requires the input of transition energy. There are four forms of pure iron, known as α, β, χ and δ, with transition points at 760^0, 907^0, and 1400^0C. Each transition has its own transition enthalpy. Fe-δ melts at a temperature of 1535^0C. Heating iron from 25^0 to 1535^0C and subsequent melting requires 1.36 GJ/tonne of Fe.

Of this amount, the total enthalpy demand for all transitions is 0.35 GJ/tonne of Fe. The melting requires the largest part of this: 0.29 GJ/tonne. The melting point of iron is lowered when carbon is dissolved in the iron. When the carbon content is 4.3%, a typical value for pig iron, the melting point is lowered to 1150^0C. The enthalpy demand for heating iron from 25^0C to the melting point is reduced by about 0.3 GJ/tonne by this temperature decrease. Heating and melting of pig iron theoretically requires 1.05 GJ/tonne; melting of steel, which has a low carbon content, is close to 1.36 GJ/tonne. When the iron cools to environmental temperature, this energy is released again.

1.4 *Iron ore reduction in the blast furnace*

Iron in oxides has a positive oxidation state and therefore must gain electrons to become free iron. This result can be achieved in several ways, for instance, chemically—a chemical reductant provides electrons—or electrochemically—a direct current provides the electrons. In many metallurgical processes, high temperatures are used to promote reactions kinetics and to shift thermodynamic equilibria. A combination is also possible. Aluminum production using the Hall-Herault process, for instance, is a combination of both routes, performed at high temperature. Iron ore is reduced in the blast furnace with a chemical reductant, carbon (actually carbon monoxide) at high temperatures.

1.5 Comparison with practical processes

When the theoretically lowest SEC is compared with the SEC of practical processes, the following conclusions can be drawn.

a. The minimum SEC for making a steel product from iron ore equals the energy demand for iron ore reduction that is 6.6 GJ/tonne of steel. In modern blast furnaces, carbon is supplied in the form of coke, coal, and sometimes fuel oil. The total carbon demand is in the range of 350–400 kg of carbon/kg of pig iron. Additional energy is supplied by the hot blast. Furthermore, energy is recovered with the blast furnace gas. The net SEC of a modern blast furnace is in the range of 12.5–15 GJ/tonne of pig iron. In theory, the SEC for pig iron reduction can be reduced by about 50%. The SEC of modern integrated steel plants, including all other processes, is three times as high. Consequently, the theoretical potential for improvement of the SEC for steel making from iron ore is 65%.

b. The minimum SEC for making a steel product from scrap is negligible. Scrap is melted in modern EAFs with a final energy input of about 1.5 GJ/tonne (3.5 GJ/tonne on a primary energy basis). In theory, the potential for reduction of the SEC is 100%, when the minimum SEC for making steel from scrap is used as the reference. Note that the value of 1.5 GJ/tonne is about 10% above the energy required for heating and melting steel (the composition of scrap is almost similar to that of steel).

2. Energy analysis of an integrated steel plant

In this section we perform an energy analysis of an integrated primary steel plant to locate the main energy losses in the process and evaluate their cause. Energy is the amount of work obtainable when some matter is brought to a state of thermodynamic equilibrium with the common components of the natural surroundings by means of a reversible process. It is comparable to Gibbs free energy; the difference is that the common compounds in the environment are taken as reference rather than the elements. Energy analyses of selected processes in an integrated steel mill have been described in the literature.

2.1 The reference plant

The energy analysis is based on a hypothetical reference plant described by the International Iron and Steel Institute (IISI). The data for this plant were compiled by a group of international experts on energy use in the iron and steel industry and are based on actual operation data from plants in many countries. The plant is made up of components that were considered to be the most energy-efficient techniques at that time (early 1980s); they were technically proven and commercially viable. To assess whether use of this plant as the reference for our analysis is justified, we compare the reference plant with modern integrated steel mills.

2.2 Results of the energy analysis

The results of the energy analysis. Of the 22.6 GJ per tonne of hot rolled steel (trs) that goes into the process, mainly in the form of coal, 10.9 GJ/trs is inherited by useful products. External and internal energy losses are GJ/trs, gigajoule per tonne of hot rolled steel; LPG, liquid petroleum gas.

2.3 Conclusions

We can conclude that energy losses are due mainly to the application of high temperatures and the need for several cooling and reheating steps. Radiation and convection losses, physical energy lost with gaseous streams, losses resulting from the conversion of chemical energy to gases with a high temperature, irreversibilities in heat transfer, and even irreversibilities in some undesired chemical reactions that occur only at higher temperatures all contribute to these energy losses. Reducing the energy loss should therefore be directed at reducing the temperature or decreasing the number of temperature changes. In the next section we investigate whether techniques under development can achieve these objectives.

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

In this section we discuss the way information on long-term energy-efficient techniques was gathered and how we selected the techniques that may reduce the SEC of steel making in the long run.

3.1 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/Energyline, 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.

3.2 Selection of energy-efficient techniques

In the previous section we concluded that the main energy 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 energy 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.

(i) 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.

(ii) 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.

(iii) 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.

4. 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. Smelting reduction processes and near-net-shape casting techniques 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.

4.1 Smelting reduction processes

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.

In SR processes, iron ore is prereduced in the solid state in a prereduction shaft by a reducing gas generated in a smelting reduction vessel. Melting and final reduction generally take place in this smelting reduction vessel as well. In many SR processes, the reaction site is the slag floating on the bath of liquid iron. Coal reacts with oxygen or iron ore in the liquid state to form a gas that consists mainly of carbon monoxide. The gas causes the slag to foam. Foaming slag is important for improving reaction kinetics and heat transfer but should be kept under a critical value to ensure normal operation. The gas can be partially postcombusted above the slag to adjust the chemical composition. The degree of postcombustion should be controlled to ensure that the composition and the temperature of the reducing gas match the requirements of the prereduction.

The heat generated by postcombustion should be returned to the bath.

(i) Postcombustion degree: the degree to which the CO formed in the smelting reduction vessel by coal gasification is converted to CO_2. A too-low postcombustion degree means that the gas that leaves the reactor at the top and is used for prereduction is too rich, and a large amount of export gas is generated, resulting in high coal consumption. A too-high postcombustion degree means that the gas is too lean for prereduction and the off-gas temperature is too high.

(ii) Prereduction degree: the degree to which $Fe_2 O_3$ is reduced to Fe and FeO in the prereduction shaft.

(iii) Heat transfer efficiency: the ratio of the heat transferred from the hot gases to the bath of molten iron, ore, and slags and the heat generated by post-combustion. Too-low heat transfer efficiency results in a gas temperature too high for the constructing material of the prereduction shaft. Heat transfer efficiency is limited by the maximum attainable heat transfer from the gas to the liquid phase.

4.2 Near-net-shape casting

The second group of techniques that avoid at least one heating and cooling step is concerned with casting and shaping of steel. Traditionally, steel is cast into ingots of different shapes and weights ranging from several tonnes to about 300 tonnes. Nowadays, more than 60% of the crude steel is cast directly into blooms (square blocks with an outline of 0.15–1 m) and billets (small bars with an outline of less than 0.15 m) or slabs 0.15–0.2 m thick using a continuous caster. Blooms and billets are further processed in hot rolling mills to long products to change the shape into, for example, beams, profiles, and rails. Slabs are converted to flat products in a hot strip mill or hot plate mill to reduce the thickness to 1–10 mm for strips and 10–25 mm for plate.

The thickness of flat products may then be further reduced to about 0.1–3 mm in a cold rolling mill. The casting and shaping process is characterized by its discontinuity, requiring intermediate storage and putting high demands on logistics. Near-net-shape casting processes use techniques that can attain the final shape with fewer operations, or even in one step. The main advantages of near-net-shape casting are (a) reduction in investment and operation costs; (b) reduction in processing time between casting and final product; (c) reduction in intermediate heating and cooling and storage; and (d) improved (surface) properties resulting from a finer, more homogeneous microstructure. The state of the art in near-net-shape casting is thin slab casting: Slabs are cast with a thickness of 40–90 mm. Thin slab casting has been applied successfully since 1985 in connection with EAF steel plants. With a combination of an EAF and thin slab caster, flat products can be produced at costs that are competitive with the costs of flat products made in an integrated steel plant. This opened the market for flat products for EAF steel, a market that had been restricted to integrated steel producers. For a few years now, the technique has been applied in integrated steel plants as well. It is estimated that 10% of the world hot strip is produced using a thin slab caster. The direct casting of beams is also a commercial technique.

Four categories of near-net-shape casting techniques can be distinguished for flat products:

1. Thin slab casting: thickness range 40–80 mm
2. Thin slab casting with liquid core reduction: thickness range 10–25 mm
3. Strip casting: thickness range 1–10 mm
4. Spray casting: thickness range 5–20 mm

The first two techniques resemble the continuous caster and still require a reheating furnace, albeit with a smaller heating capacity. The third technique makes the hot strip mill redundant and is therefore interesting from the point of view of energy conservation. Spray casting produces semi-finished products of different geometry by spraying and rapid solidification of small metal particles onto a substrate surface.

4.3 Scrap-based process

In primary steel production, most energy is required to prepare the raw-materials and to reduce iron ore. In modern energy-efficient steel mills, the proportion of these processes (including heating and melting of the iron) can be as high as 90% of the total primary energy demand. It is obvious that large energy savings can be achieved if these processes are avoided. Recycling and reprocessing of steel scrap offers this possibility. To adjust shape and properties, however, melting is still required. Several options for melting scrap are available or under development:

a. in a basic oxygen furnace
b. in an electric arc furnace
c. in a scrap melter using both electricity and fossil fuel
d. in an all-fossil fuel melter

The quality of the steel depends largely on the quality of the scrap. Because high-quality scrap is expensive, virgin iron-containing materials can be added to upgrade the quality of the product. Direct reduced iron is frequently used for this purpose. Pig iron can also be used, and recently experiments have been performed in which an EAF is charged with iron carbide. Obviously, the use of these virgin materials increases the overall energy consumption, as their production consumes a considerable amount of energy. The quality of scrap can also be upgraded by chemical and mechanical separation processes. The additional energy demand for these processes can be estimated to be 0.5–2 GJ/tonne of scrap.

4.4 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.

4.5 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.

4.6 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 energy 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.

5. 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 energy analysis to show that the main energy 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 by the use of more efficient melting furnaces, more efficient casting and shaping techniques, 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 high-temperature 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 below 800±Cis a commercial technology. R&D should 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 and steel 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.

Reference:

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