Commission of the European Communities

energy

Energy audit No 1

The iron and steel industry in the European Economic Community

Report

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GENERAL INTRODUCTION

The international competitiveness of the Community industry depends to a large extent on energy factors. The availability of the requisite energy supplies in various forms and their average cost will in fact determine the future growth of those industries in which the energy cost accounts for a large proportion of the total cost of the product.

Particularly vulnerable in this regard are the basic industries (chemicals, iron and steel), electrometallurgy, cement and the like). These are the industries that transform raw materials, from the Community or imported from outside, into basic materials for the manufacturing industries and for major construction projects (dams, harbours, motorways, bridges, houses, offices, factories, etc.).

The chemical and physical processes which provide these basic industrial products generally consume large amounts of energy and the value they add is generally small. Moreover, there is fierce competition to supply these products from industries outside the Community which can count on abundant supplies of cheap energy and often raw materials too. This competition from many countries in Eastern Europe and outside Europe is bound to increase if the Community does not rationalize its energy structure, especially that of its basic industries.

The alternative is to import basic and semi-finished industrial products, but this would have an adverse effect on employment and would increase our strategic and therefore political dependance, points which should be given careful consideration.

At the present time the Community steel industry accounts for some 8% of primary energy consumption in the EEC. Moreover, in a modern integrated steel works in the Community the energy cost accounts for between 25 and 30% of operating costs.

In spite of the introduction of new technologies such as modern, high-performance blast furnaces, oxygen converters for the production of liquid steel, continuous casting plants for producing steel slabs, blooms and billets, etc., (see fig. 1), energy efficiency of a modern integrated steelworks is still low (50-60%).

The energy profile of the Community steel industry is also adversely affected by the large number of obsolete plants and even entire works. This puts the Community steel industry at a disadvantage compared with such countries as Japan, South Korea, South Africa, Australia and Canada with their ultra-modern plants, advanced technologies and, often, cheap raw material and energy supplies.

On the other hand, Community industry is the largest consumer of steel made in the EEC, and this is good from the Community steel industry's point of view, not least because of the lower transport costs.

If the Community steel industry is to survive, all available resources will have to be deployed to ensure that technologies and plants can always be brought up to date as required, thus fostering the process of renewal and rationalization of production, while providing every incentive to make best use of factors of production, especially energy.

The purpose of this study is to identify ways to bring about the required rationalization of production methods, manufacturing plant and energy use. In our opinion this can best be done by describing various model plants (integrated and electric), to serve as realistic objectives to be attained as a matter of urgency.

According to Eurofer, the Community steel industry accounts for 8% of the Community's total primary energy requirement and 20% of industry's requirement. Reduction of energy consumption is one of the ways of achieving the basic aim of improving the international competitiveness and profitability of the Community steel industry, so as to overcome the present crisis and enable it to face the future with more optimism.

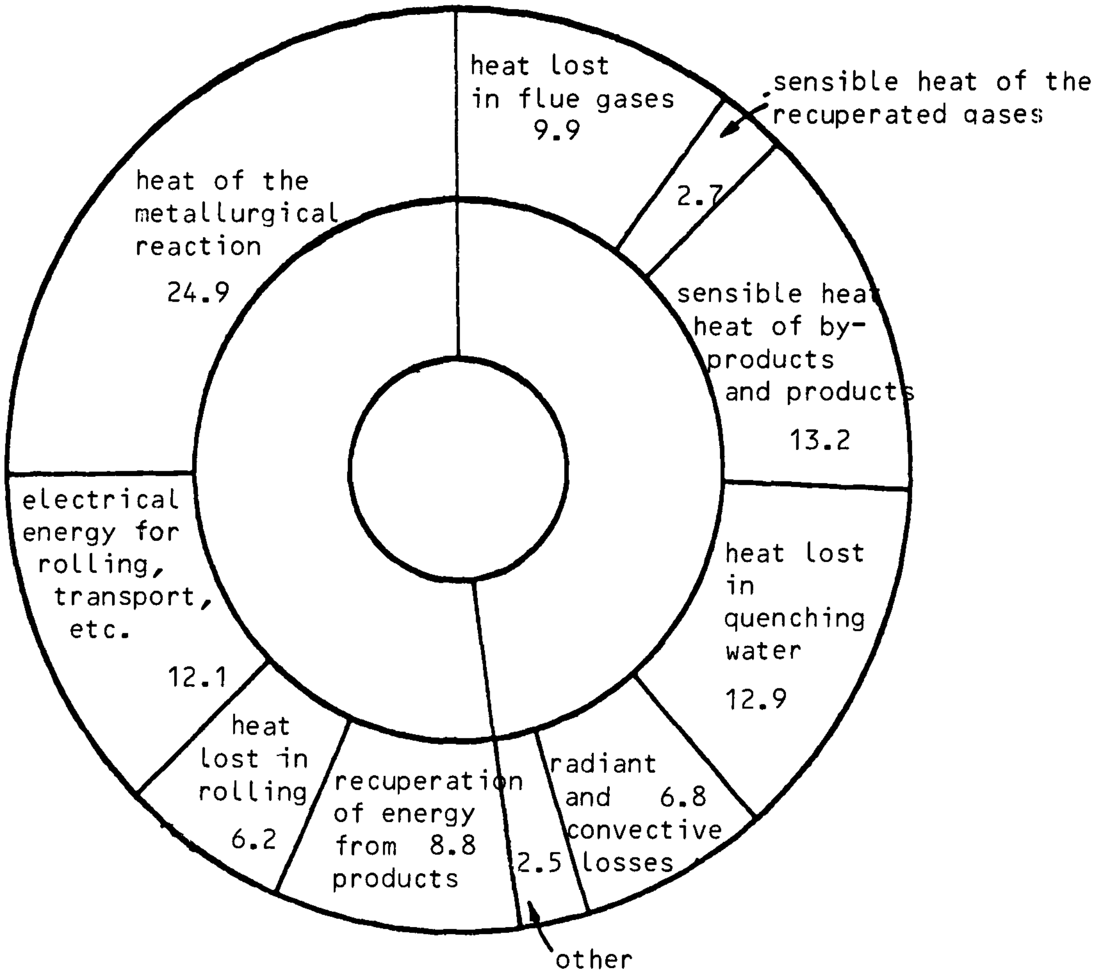

Fig. 1 - Energy utilization in a typical steel plant
(integrated cycle)

The pattern of energy consumption differs considerably according to whether a steel plant is :

(i) integrated

or

(ii) electric

Integrated steelmaking produces "new" steel from iron ore and coke, usually by producing pig iron in the blast furnace and then refining it in oxygen converters.

An interesting new process makes steel from iron ore by enriching the iron in the ore by direct reduction (sponge iron) or DRI - direct reduced iron - and converting this iron into steel in electric arc furnaces.

Scrap steelmaking produces remelted steel usually in electric arc furnaces.

Then there are various technological alternatives that permit the use of large quantities of scrap even in converters (as well as in the few open-hearth furnaces that still exist), or the charging of sponge iron and scrap together in electric arc furnaces.

Since integrated plants (blast-furnace + converter) and scrap remelting plants (electric arc furnace) require different quantities of energy and use different energy sources to produce each tonne of liquid steel, we have given careful consideration to the energy profiles of these two steelmaking processes (and the sponge-iron and electric arc furnace variant).

A modern integrated steelworks in Europe, using advanced but industrially proven steelmaking technologies and energy recovery systems (model plant), consumes

14.34 GJ per tonne of liquid steel

compared with

5.12 GJ per tonne of liquid steel

in an electric steelworks which melts scrap (assuming the scrap to have zero energy content).

When rationalizing the energy structure of the Community steelmaking industry, careful attention should be paid to this 3 to 1 ratio between the primary energy consumptions of the two different systems, and also to the prospects of scrap availability in the Community and the world at large.

Some 75% of the total primary energy requirement of an electric steelworks is for electricity. The remainder will probably be covered by coal derivates carbon electrodes, etc.) natural gas and oxygen.

The availability of low cost electricity (from nuclear or, at least, coal-fire power stations) is thus one of the essential preconditions for the future growth of electric steelmaking in the Community, the other being the availability of scrap at a reasonable price.

The kind of energy required in the two different processes also differs markedly. Integrated steelmaking is based on coal or, rather, metallurgical coke which acts both as raw material and basic energy source. In the modern integrated steelworks with its own coke ovens - which is considered in the study - the coal in the form of coke and recovered gas (coke-oven gas, blast furnace gas and converter gas) covers 90.9% of net overall energy consumption.

It would appear that the role of coal can be further boosted by using new recovery methods such as the dry quenching of the coke from ovens or the use of industrial coal gasification systems.

It could well be that the integrated steelworks of the nineties will use only coal as a primary source, although it might resort to outside suppliers for its oxygen and -occasionally - electricity requirements when its own waste-heat fuelled power plant is shut down for maintenance.

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(1) Summary published in "Europe" on 19 May 1982

UNITS OF MEASURE

The Système International, generally known as SI, has been adopted in this study. Energy is thus expressed in joules (J) or rather in multiples thereof (MJ, GJ, etc.).

For convenience, conversion factors for the most commonly used units of energy measurement are summarized in the following table.

CONVERSION TABLE FOR UNITS OF ENERGY MEASUREMENT

	Btu	kcal	MJ	kWh	tce	toe
Btu	1	0.2520	$1.0551.10^{-3}$	$293.1.10^{-6}$	36.10^{-9}	$25.20.10^{-9}$
kcal	3.968	1	$4.187.10^{-3}$	$1.1630.10^{-3}$	$0.14286.10^{-6}$	$0.1.10^{-6}$
MJ	947.8	238.8	1	0.2778	$34.12.10^{-6}$	$23.88.10^{-6}$
kWh	3412	859.8	3.6	1	$122.84.10^{-6}$	$85.98.10^{-6}$
tce	$27.78.10^{6}$	7.10^{6}	$29.31.10^{3}$	$8.141.10^{3}$	1	0.7
toe	$39.68.10^{6}$	10.10^{6}	$41.87.10^{3}$	$11.630.10^{3}$	1.4286	1

EXAMPLES 1 MJ = 947.8 Btu 1 MJ = $23.88.10^{-6}$ toe

Given below are the most commonly used prefixes together with their symbols and values :

Prefix	Symbol	Value	Prefix	Symbol	Value
kilo	k	10^3	milli	m	10^{-3}
mega	M	10^6	micro		10^{-6}
giga	G	10^9	nano	n	10^{-9}
tera	T	10^{12}	pico	p	10^{-12}

Gas is measured in cubic meters - m^3 - under standard conditions (0°C, 1 Atm = 101 kPa).

A. DESCRIPTION OF THE IRON AND STEEL INDUSTRY

A.1 COMMUNITY STEEL PRODUCTION-VOLUME, LOCATION, TYPE AND CAPACITY

Trends in Community crude steel production since 1971 are shown in Fig. 2, while Table 1 in annex gives a breakdown of crude steel production in the EEC Member States. Both show that steel production peaked in 1973 and 1974, after which there was a sharp decline, which has eased off slightly only in recent years, thus confirming that the sector is still in a state of crisis.

It has been estimated that only 62% of the Community's 204 million tonnes/year steelmaking capacity was used in 1980, compared with approximately 87% in 1974 when crude steel production capacity was estimated at 179 million tonnes a year. Table 2 in annex shows production capacities and crude steel production, with projections to 1986 and includes areas other than those given in Fig. 3.

There has been a gradual attempt to rationalize the Community iron and steel industry in recent years. Changes have been seen in the size of works. On one hand, advantage has been taken of economies of scale by concentrating integrated steel production in huge plants with large blast furnaces, the whole process being based in iron ore and coke. On the other hand, with the development of the process for making steel from scrap in electric furnaces, there has also been an increase in the number of "mini-mills", which have annual capacities of less than a million tonnes a year and require much smaller capital investment. These mini-mills are more flexible in meeting market demand and are better able to satisfy local needs. Fig. 4 shows electric steel production expressed as a percentage of total steel production.

Fig.-2 EEC Crude steel production
(source Eurostatistics IISI)

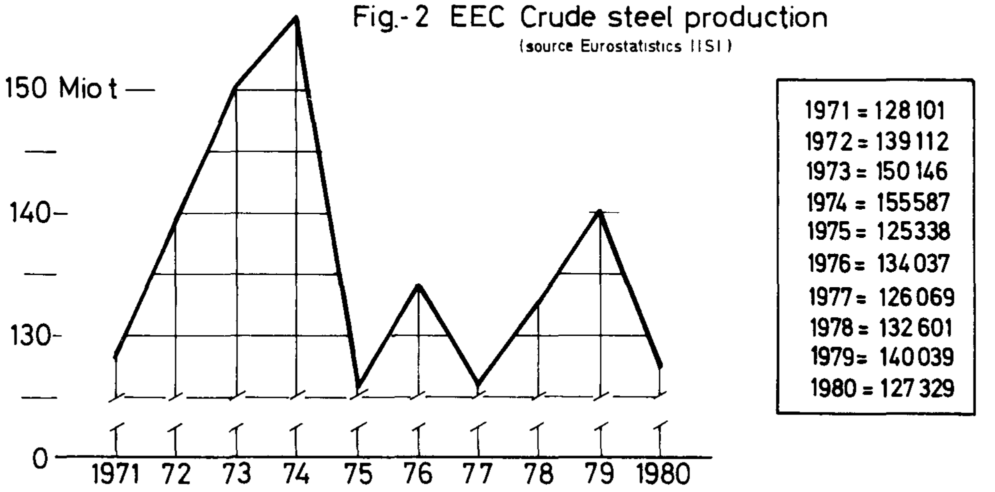


Fig.-4 Electric Furnace Steel Production as Percentage Steel Production
(source Eurostatistics IISI)

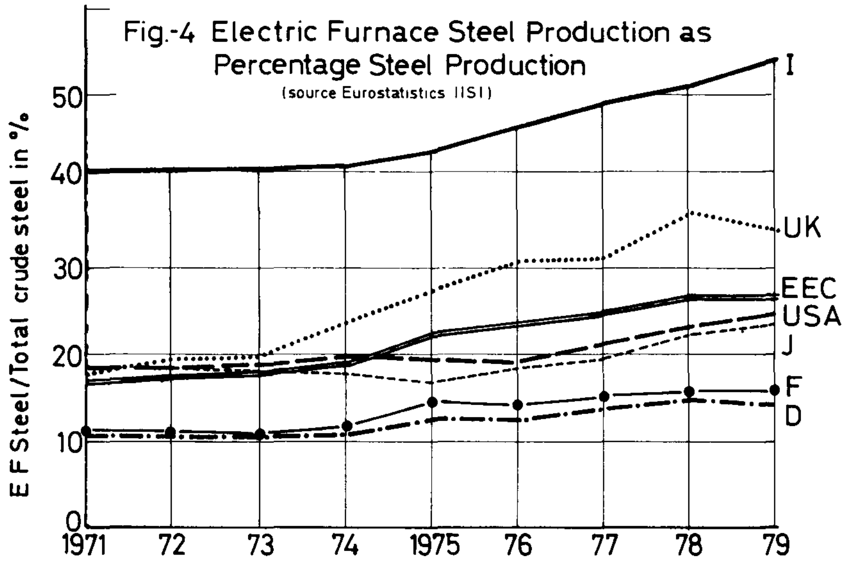
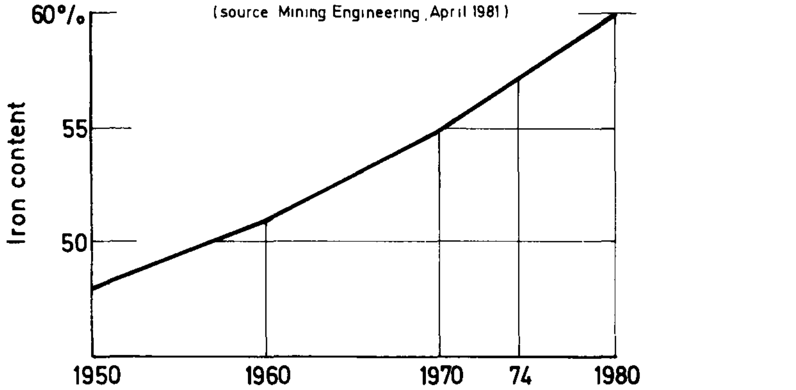


Fig.-5 Quality of iron ores in continuously improving
(source Mining Engineering, April 1981)



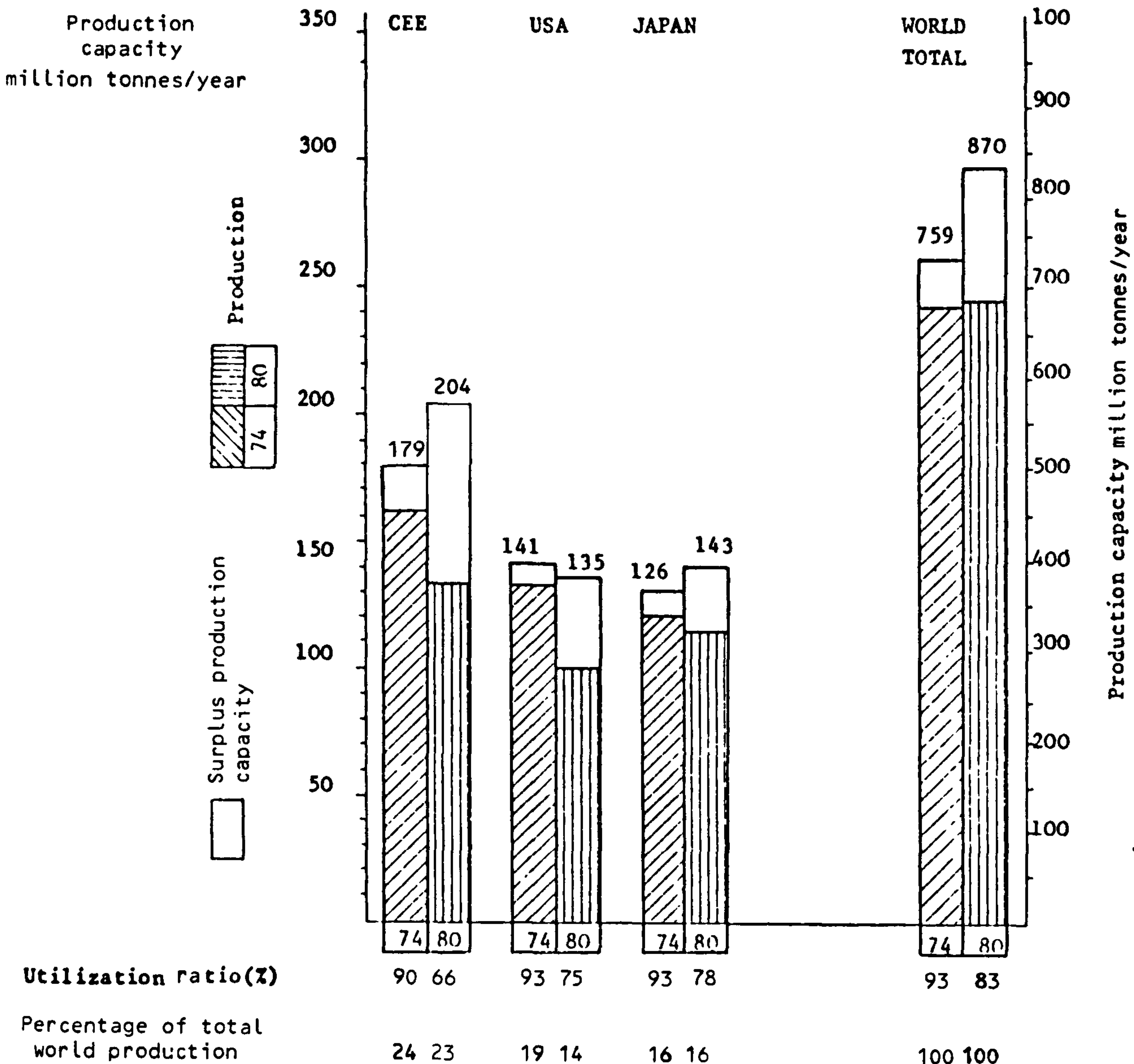


Fig.3 - **Production capacity and crude steel production (million tonnes)**

(data : OCSE, IISI, Chase Econ, Nippon Steel; elaborated by Italsider SpA (Italy)

The large new steelworks are located on the coast or are linked to the coast by canals or rivers, thus ensuring the lowest possible transport costs for good quality raw materials. In fact, huge quantities of iron ore, with higher and higher iron contents (see Fig. 5) are being imported from overseas (Australia, Africa, South America and Canada).

However, even the large integrated steelworks in the Community area are not as big as those in Japan. Their average annual crude steel production capacity ranges from 2 to 5 million tonnes and only a few are larger. In the whole of the Community, in fact, there are only five extra large blast furnaces (i.e. with a 14m hearth diameter, a useful volume of about 4000 m^3 and daily production capacity of some 10.000 tonnes of pig iron).

Table 3 in annex gives the breakdown of EEC steel production by country and process. As is evident from the table there are basically only two production processes nowadays: the electric furnace and the oxygen converter; the open-hearth process is definitely on the way out.

We shall now go on to give a general description of the iron and steel industry in the Member States of the Community .

Federal Republic of Germany

The German iron and steel industry which is mostly privately owned, is now the world's fourth largest producer, after the USSR, the USA and Japan. In 1974 it produced 40.2 million tonnes of pig iron and 53.3 million tonnes of crude steel compared with 33.9 and 43.8 million tonnes respectively in 1980. Most of Germany's steelmaking capacity is concentrated in the Ruhr, although the Saar and Lower Saxony also have large steel industries.
The German steel industry is highly concentrated, with more than 90% of production in the hands of only seven companies.

As in other Community countries, German steelworkers rely on imports for their ore supplies.

The annual coke consumption of the German steel industry is around 20 million tonnes; the coke is home produced. German coking coal is generally of good quality but mainly because of geological conditions mining costs are higher than in other countries.

Table 1 on page 18 gives the main iron and steel production figures for 1980.

Belgium

Most of the country's iron and steel works are in the Sambre and Meuse valleys and their natural extensions, where there used to be local mineral and coal deposits although these are no longer mined. The large waterways around which these Belgian steelworks grew up still facilitate the transportation of supplies of raw materials from Campine in the North of Belgium from other European countries (coal from Ruhr and Poland) and from overseas (rich minerals). Minerals from overseas are generally shipped through the ports of Antwerp and Ghent.

During the last fifteen years, a new steelworks has been built at the mouth of the Scheldt so as to have direct access to the sea. There are also several small companies which produce special steels. In 1974 and 1975 the production capacity of the Belgian steel industry stood at 19 mio tonnes a year (final production of crude steel in 1974 was 16 million tonnes), although various restructuring schemes, some already completed, others still in progress, should reduce this to 16 million tonnes a year.

At least 90% of the steel produced in Belgium is made in completely integrated steel works.
Table 1 on page 18 gives the main iron and steel production figures for 1980.

France

French steelmaking was initially centered chiefly in Lorraine, which is rich in coal and minerals.
Later on the coastal steelworks at Dunkirk in the North (8mio tonnes a year) and Fos in the South (3.5 million tonnes a year) also became very important. There are many steel firms in France, and many steelworks, but the industry is dominated by two companies and their associates, which together account for 90% of total crude steel production.

Nowadays, less and less iron ore is being mined in Lorraine - only 20.5 million tonnes in 1981 - because of its poor iron content.

The French steel industry can produce, from its own coking plants, about half of the coke it requires using coking coal from Lorraine and large quantities of coal imported from Germany and elsewhere. Approximately half the coal purchased by the steel industry is from coking plants operated by the national coal industry and the rest is imported.

Table 1 on page 18 gives the main iron and steel production figures for 1980.

Luxemburg

The steel industry in Luxemburg resembles that of the Lorraine except for its complete dependence on foreign coke. Practically all the country's steel is made by one firm.

Table 1 on page 18 gives the main figures for 1980 iron and steel production.

Italy

The Italian steel industry developed substantially after the Second World War. As the country has no large deposits of raw materials,the steelworks producing steel from iron ore are all coastal works (Genoa, Piombino, Naples, Taranto and Trieste). In 1976 Italy imported 17.6 million tonnes of iron ore (domestic production was a mere 650.000 tonnes and 10.7 million tonnes of coking coal. All the coke for integrated steelworks is produced in coking plants inside these steelworks. Alongside the integrated steelworks on the coast, Italy has also developed steelmaking from scrap, based primarily on the electric arc furnace. Electric steelworks are located in the more industrialized parts of the country and many of them are privately owned. In 1975 Italian steelworks used 13.5 million tonnes of scrap, 40 - 45% of which was imported. Almost half of Italy's crude steel is made in electric arc furnaces.

The largest integrated steelworks is at Taranto. It has an annual production capacity of 11.5 million tonnes of crude steel.

Table 1 on page 18 gives the main iron and steel production figures for 1980.

Netherlands

The Ijmuiden Works on the North Sea coast makes almost all the country's steel. The works was started before the war and completed afterwards and its annual production capacity subsequently increased to 8.2 mio. tonnes of crude steel. It is an integrated works with five blast furnaces for the production of pig iron.

All the iron ore and coking coal requirements are met by imports.

Table 1 on page 18 gives the main iron and steel production figures for 1980.

Denmark

The Danish steel industry really only developed after World War II. Denmark has virtually no large deposits of raw materials for the steel industry, but it does have considerable quantities of scrap.

Steelmaking is concentrated mainly at Fredericvaerk, which produces steel electrically. Finished products consist chiefly of boiler plate and shipbuilding materials.

Table 1 on page 18 gives the main figures for 1980 for iron and steel production.

United Kingdom

The distinguishing feature of the UK iron and steel industry is its large number of steel plants. Some of these are integrated steelworks, not all of them particularly modern, with capacities ranging from 1 to 5 million tonnes of crude steel a year. Some of its steelworks, on the other hand, are small and highly specialized.

The works can be grouped geographically according to whether they are based on :

a) coalfields (the Midlands and the West Riding of Yorkshire)
b) iron-ore deposits (Corby and Scunthorpe)
c) imported raw materials (Teesmouth, South Wales and Scotland)

Nowadays, the British iron and steel industry imports most of its iron ore from abroad. It uses its own coking coal but it also imports some.

Through the British Steel Corporation (BSC) the British Government controls more than 80% of crude steel production, the remainder being in the hands of the private sector.

The British iron and steel industry was badly affected by the crisis which hit the European steel industry, its production dropping from 28 million tonnes in 1970 and about 27 million tonnes in 1973 to 21.55 million tonnes in 1979.

The BSC is now totally reorganizing its production network, shutting down obsolete works and modernizing others.

Table 1 on page 18 gives the main iron and steel production figures for 1980.

Ireland

Ireland produces a small quantity of steel at a works in the South of the country on the island of Haulbowline not far from Cork. The steelworks is Government-owned and has an electric furnace. The highest annual production figure to date was 116.000 tonnes of crude steel in 1976, compared with a maximum capacity of 140.000 tonnes.

Although Ireland does have coking coal deposits, it has very little iron ore.

Table 1 on page 18 gives the main iron and steel production figures for 1980.

Greece

Greece has a fairly small steel industry capable of producing some 2.55 million tonnes of crude steel a year.

The country possesses very little iron ore and coal, but ferrous scrap mainly from ship-breaking, is in fairly plentiful supply. Virtually all steelmaking is concentrated around Athens and Thessaloniki. Most raw materials have to be imported because these areas are preferred for investment (some of it foreign) and because most consumers of steel products are in these areas. Greece has only one integrated steelworks which is at Elevsis and has an annual capacity of 2.5 million tonnes of crude steel. The others are small plants with electric furnaces and rolling mills, or just the latter. There are also quite often continuous casting plants.

In 1977 Greece produced 759.000 tonnes of steel, of which it exported 121.375 tonnes. It also imported 596.076 tonnes. In recent years production, expressed in tonnes of crude steel, has been as follows :

1973	1974	1975	1976	1977	1978
753 000	687 000	721 000	715 000	759 000	936 000

1979	1980
1 000 000	1 200 000

Table 1 - MAIN IRON STEEL PRODUCTIONS FOR THE EEC MEMBER COUNTRIES IN THE YEAR 1980 ('000 t/year)

Productions	Germany	Belgium	France	Luxembourg	Italy	Netherlands	Denmark	United Kingdom (1979)	Ireland
Sinter (consumed)	36,265	12,187	30,498	6,938	14,852	2,723	-	17,041	-
Crude iron	33,873	9,905	19,159	3,568	12,219	4,328	-	13,030	-
Crude steel	43,838	12,321	23,172	4,619	26,501	5,272	734	21,472	2
- Oxygen %	78	95	82	100	45	94	-	60	-
- Electric %	15	5	16	-	53	6	76	34	100
- Other %	7	-	2		2	-	24	6	-
- Continuously cast %	46.0	25.7	41.3	-	49.9	6.0	73.3	16.8	-
Rolled products									
- Raylway track materials and heavy sections	2,665	943	1,381	1,218	964	-	7	1,720	-
- Flat products	20,048	6,667	12,211	1,234	9,474	2,580	450	8,106	-
- Wire rod and concrete reinforcing bar (andother marchant bars)	8,058	1,724	5,375	1,118	9,968	595	192	5,246	23
- Coated products	2,916	1,331 *	2,321	1,331 *	1,060	505	-	2,115	13
- Tubes	4,747	226	2,101	113	3,405	265	non disp.	1,375	-

Source : Eurostat : Quarterly Iron and Steel Bulletin - 3/1981 * Belgium and Luxemburg

A.2 ENERGY CONSUMPTION IN THE COMMUNITY'S STEEL INDUSTRY

Fig. 6 shows total energy consumption and specific energy consumption for the production of crude steel in the EEC steel industry during the period from 1971 to 1980, while Fig. 7 gives the energy consumption of the iron and steel industry, of Community industry in general and of the EEC as a whole. Fig. 8 shows in percentage terms how energy consumption by the iron and steel industry compares with the figure for industry in general and with the total for the EEC.

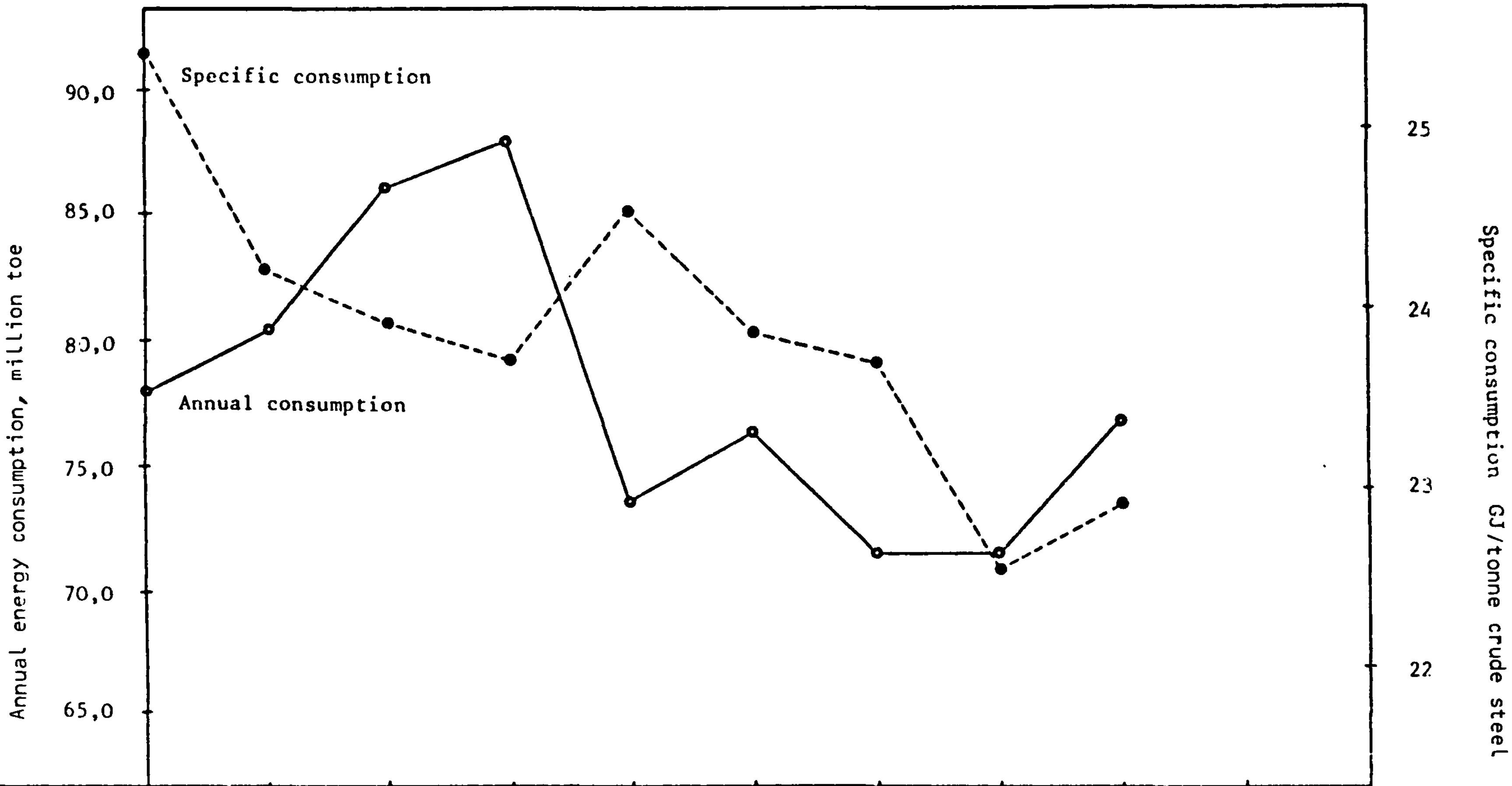
Tables 4 and 5 in annex give details of energy consumption by the iron and steel industry and industry in general and give the total consumption for each member state for 1974, together with the various percentages.

Fig. 9 shows trends in specific energy consumption by the iron and steel industry in the individual Member States and the average for the Community which is compared with the USA and Japan.

It can be clearly seen that the plants whose specific energy consumption is below the EEC average are the most recently developed iron and steel industries which rely mainly on imports of specially selected raw materials and which generally use more modern plants and technology. Of fundamental importance also, as regards the specific energy consumption figures of the iron and steel industry, is the number of plants which make steel electrically from scrap, since these plants use less energy than integrated steelworks.

Fig. 10 shows the consumption of various types of energy sources by the Community iron and steel industry over the period from 1971 to 1980.

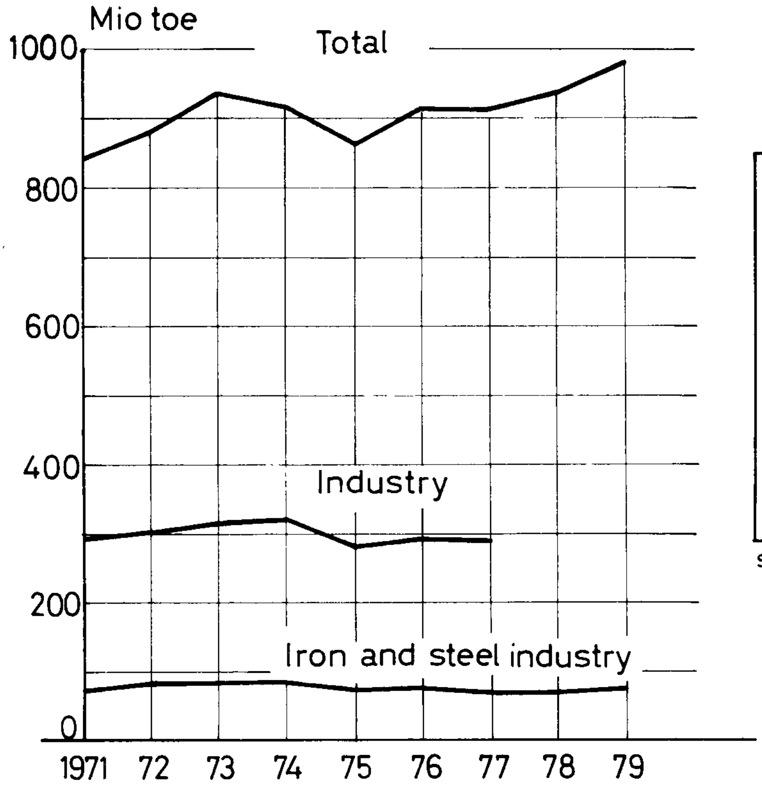
Coal is the main fuel and accounts for over 50% of total consumption. Then there are the other forms of energy such as liquid fuels, especially fuel oil, gaseous fuels (natural gas and coke-oven gas) and electricity.



Year	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Annual energy consumption/million toe	77,012	80,363	85,915	87,949	73,502	76,357	71,391	71,478	76,593	
Crude steel production/million tonnes	128,112	139,112	150,146	155,168	125,338	134,037	126,069	132,601	140,039	127,329
Specific consumption GJ/tonne crude steel	25,454	24,179	23,949	23,723	24,545	23,843	23,702	22,562	22,892	

Fig. 6 - Annual and specific energy consumption by the EEC iron and steel industry between 1971 and 1980 (Source : Eurostatistics)

Fig.-7 EEC Energy consumption

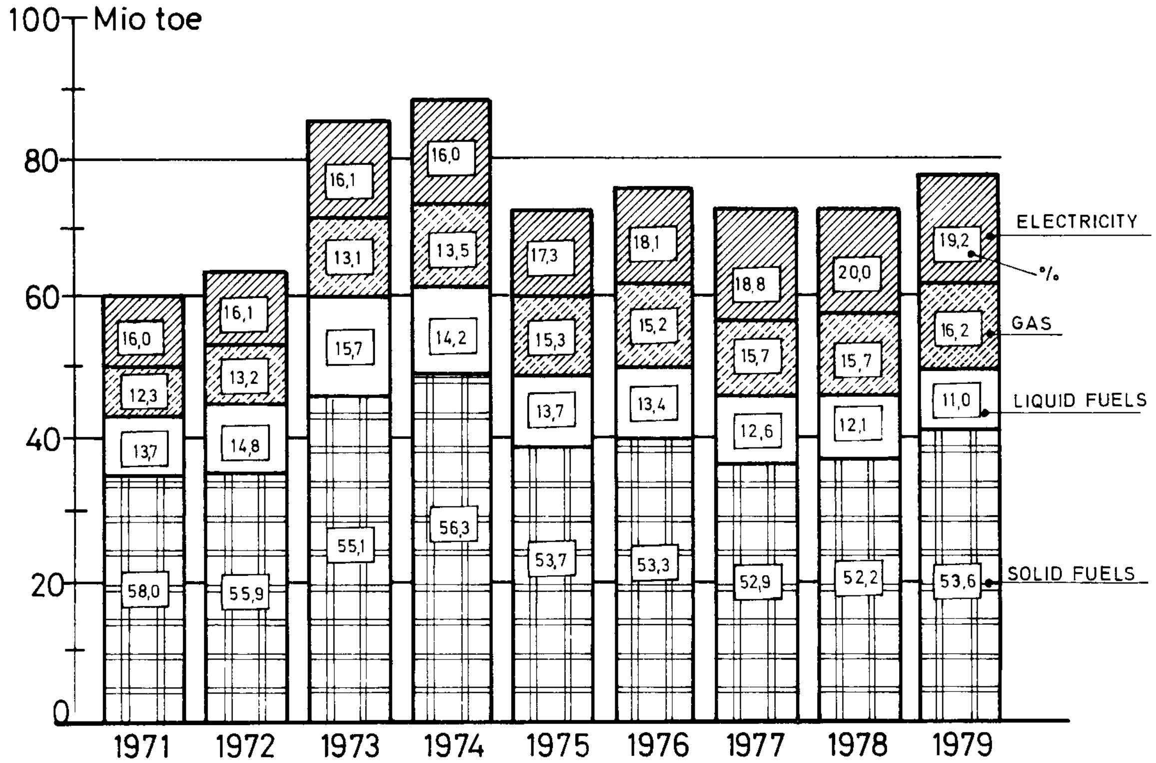


	Industry	Iron&Steel Industry	Total
1971	292.595	77.903	841.153
1972	301.923	80.354	882.840
1973	316.398	85.905	936.162
1974	320.308	87.939	918 238
1975	286.626	73.494	865.217
1976	294.388	76.348	914.256
1977	292.617	71.382	915.811
1978	–	71.469	938.000
1979	–	76.584	985.000

Source Eurostatistics

Fig-10 Breakdown of Energy Consumption in the EEC Iron and Steel Industry

Source Eurostatistics



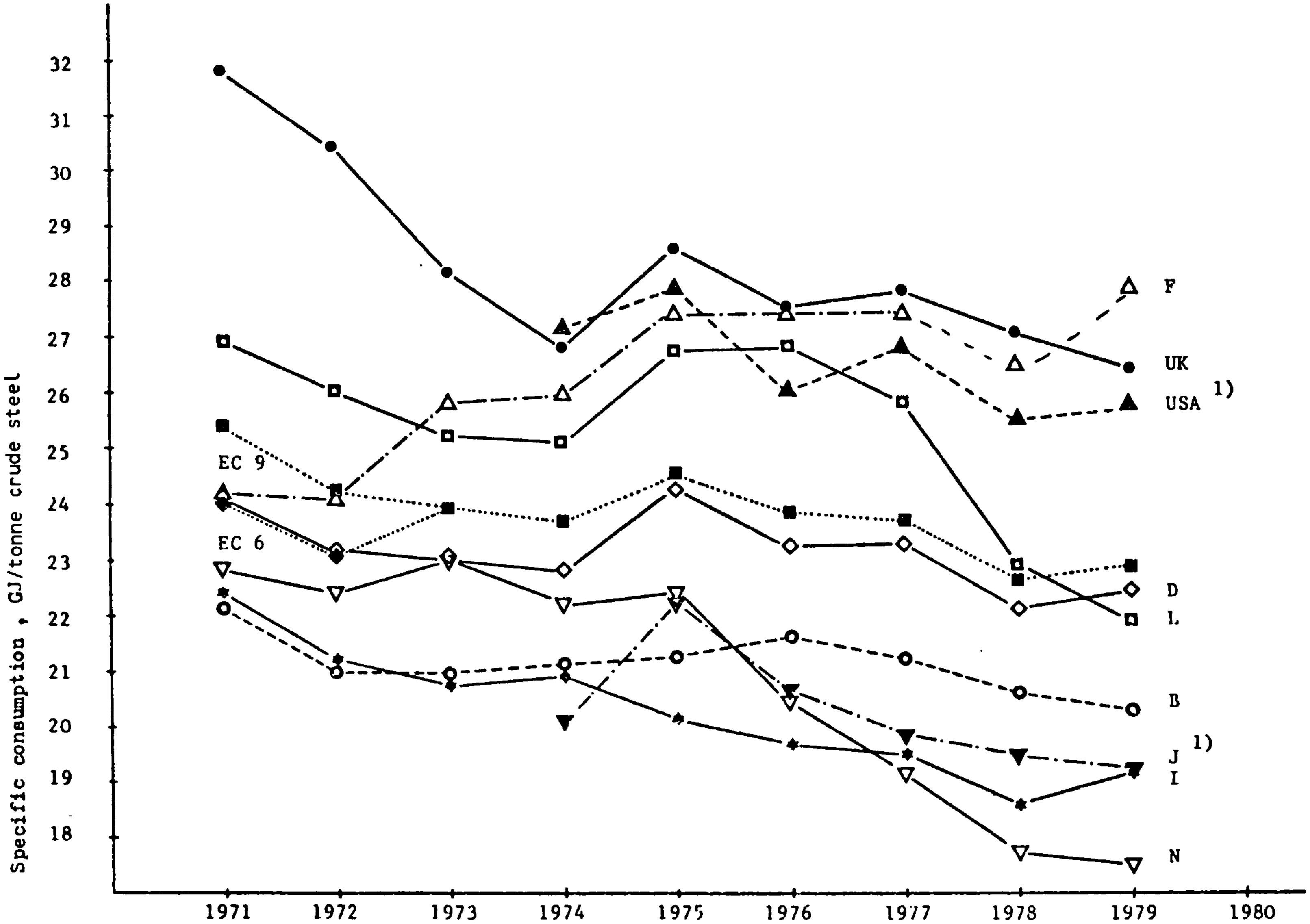


Fig. 9 - Energy consumption in the iron and steel industry in the EEC, the USA and Japan in the period from 1971 to 1980 (Source : IEA (OECD countries); Eurostatistics (EEC countries).

It is clear from table 6 in annex that the structure of energy consumption in the USA and Japan is similar in kind to that in Europe.

Table 7 in annex shows the proportion of total energy consumption in the individual Community countries accounted for by the iron and steel industry. In highly industrialized countries, where the development has been even, this proportion is in the 8 to 12% bracket. In Luxemburg, however, and to a lesser extent, in Belgium, both traditionally steel-exporting countries, energy consumption by the iron and steel industry accounts for a far larger proportion of national energy consumption (over 76% in the case of Luxemburg).

Ireland and Denmark have only small iron and steel industries, with the result that the proportion of energy consumption accounted for by the sector is less than 2%.

In the USA, where overall energy consumption is extremely high, consumption by the iron and steel industry accounted in 1974 for some 5% of the total, while in Japan, which is highly industrialized and has a strong iron and steel industry, the figure for 1974 was around 16%.

Table 8 in annex gives a breakdown of energy consumption by the iron and steel industry in the individual Member States in 1979.

A.3.1. THE PRODUCTION, SUPPLY AND CONSUMPTION OF THE MAIN ENERGY SOURCES

In 1980 demand for energy within the EEC amounted to 925.9 mio tonnes of oil equivalent to (million toe) (see table 2).

Oil

The EEC consumed 479.6 mio tonnes of oil, while it produced 90 mio tonnes as a result of the North Sea fields reaching full production in 1978. Community oil production thus covered 18.9% of its total requirement (see Table 3).

Coal and Lignite

In 1980, coal and lignite covered 23.8% of the EEC's gross inland energy requirement. Of this percentage, coal consumption accounted for 309 mio tonnes (191.7 mio toe) with lignite and peat accounting for the remainder (see Table 4).

Imports of coal from outside the EEC amounted to 73 million tonnes in 1980.

Natural gas

The EEC consumed 168.1 million toe of natural gas in 1980. Between 1979 and 1980 there was a further increase in the proportion of primary energy consumption accounted for by gas, from 17.8% to to 18%, despite a fall in Community production from 137.5 mio toe in 1979 to 128.3 mio toe in 1980.

Electricity

The EEC's consumption of electricity rose by 1.2% in 1980 to 1200 TWh (see Table 5).

The proportion of electricity generated in nuclear power stations increased by 15.4% in 1980. Table 6 shows the Community's production of the main primary energy sources in 1980 as compared with 1979.

It should be explained that the data given in the table were worked out on the basis of the final energy balance, whereby all the operations are based on the real energy content of each source. Thus, primary electricity (hydroelectric and geothermal) is converted at 3600 KJ/KWh (86 grammes oil equivalent). On the other hand, figures for nuclear energy, which is considered to be a national resource, are based on the quantity of primary heat produced by the reactor.

TABLE 2 - EEC energy balance (million toe) (Source : Eurostatistics)

	Europe (9)	Germany	France	Italy	Nether-lands	Belgium	Luxem-bourg	United Kingdom	Ire-land	Den-mark
Production	454.8	120.7	43.0	16.8	69.7	7.3	0.0	195.5	1.6	0.3
Imports	718.2(1)	179.8	166.7	132.3	77.2	60.5	3.7	69.9	6.8	21.1
Variations in stocks	-15.3	- 4.5	- 4.8	+ 0.2	- 0.9	+ 0.1	- 0.0	- 5.0	+ 0.0	- 0.0
Exports	208.3(1)	23.8	18.0	12.5	74.1	19.2	0.1	58.5	0.3	1.9
Gross consumption	949.4	271.7	186.9	136.9	71.9	48.8	3.6	202.0	8.0	19.5
Bunkers	23.6	2.9	4.0	4.4	6.9	2.4	-	2.4	0.1	0.4
Gross inland consumption	925.9	268.9	182.9	132.5	65.1	46.4	3.6	199.5	8.0	19.1

TABLE 3 - EEC crude oil production and consumption over the last six years (Source : Eurostatistics)

	1975	1976	1977	1978	1979	1980 (prov.)
Crude oil consumption (million toe)	478.3	508.4	469.2	512.7	525.2	479.6
Crude oil production (million toe)	12.1	22.2	48.7	63.7	89.0	90.7
$\frac{\text{Production}}{\text{Consumption}} \cdot 100$	2.5	4.4	9.8	12.4	16.9	18.9

TABLE 4 - EEC hard coal consumption and production (Source : Eurostatistics) (million tonnes/year)

	1978	1979	1980 (prov.)
Hard coal consumption	286.4	307.5	309.5
Hard coal production	238.1	238.7	243.0
$\frac{\text{Production}}{\text{Consumption}} \cdot 100$	83.1	77.6	78.5

TABLE 5 - EEC net electricity consumption (including losses)
(Source : Eurostatistics)

YEAR	EUR-9
1977	1081.5
1978	1128.6
1979	1186.3
1980	1200.6
1981	1242.8
Variations	
1978/77	+ 4.3 %
1979/78	+ 5.1 %
1980/79	+ 1.2 %
1981/80	+ 3.5 %

TABLE 6 - EEC production of primary energy sources (million toe)
(Source : Eurostatistics)

	1980		1979		1980/79
Hard Coal	151.7	33.4%	146.7	32.5%	- 3.4%
Lignite (and peat)	27.8	6.1%	27.9	6.2%	- 0.3%
Crude oil and petroleum products	90.7	19.9%	89.0	19.7%	+ 1.9%
Natural gas	128.3	28.2%	137.5	30.4%	- 6.7%
Nuclear energy	42.6	9.4%	37.2	8.2%	+ 14.5%
Primary electricity and others	13.7	3.0%	13.7	3.0%	- 0.0%
TOTAL	454.9	100 %	451.9	100 %	+ 0.7%

A.3.2. TRENDS IN PRICES OF MAIN ENERGY SOURCES, SCRAP AND SPONGE IRON

In 1974 there was a large jump in the prices of the main energy sources used by the iron and steel industry. After a period of substantial, regular increases, there was another sharp increase in 1979/80. Official prices of crude oil (Arabian light) rose from USD 12.7 a barrel in December 1978 to USD 24 a barrel in December 1979 to reach USD 32 a barrel by the end of 1980.

In particular, 3% sulphur fuel oil retailed at the following average prices in the EEC (before tax) :

December	1978	USD	97/tonnes
"	1979	USD	168/tonnes
"	1980	USD	215/tonnes

The price of natural gas now seems firmly linked to that of oil, especially fuel oil.

Coal, too, especially coking coal increased sharply in price in 1974, following the oil crisis provoked by the Yom Kippur War. Subsequent variations have to a large extent been caused by the fall in demand from the ailing steel industry. In recent times the price of coking coal has been affected by the growing demand for coal for heat applications and by circumstances in some of the coal-producing countries (e.g. Poland).

The price of scrap soared during the steel boom in 1973 and early 1974, but has fluctuated widely since then. This situation is typical of an unstable, highly-speculative market (see Fig. 11).

The price of sponge iron (DRI) has tended to be rather erratic as there is no international market.

The following graphs show price trends in respect of scrap (Fig. 11) and of some of the main energy sources (Figs. 12 to 15).

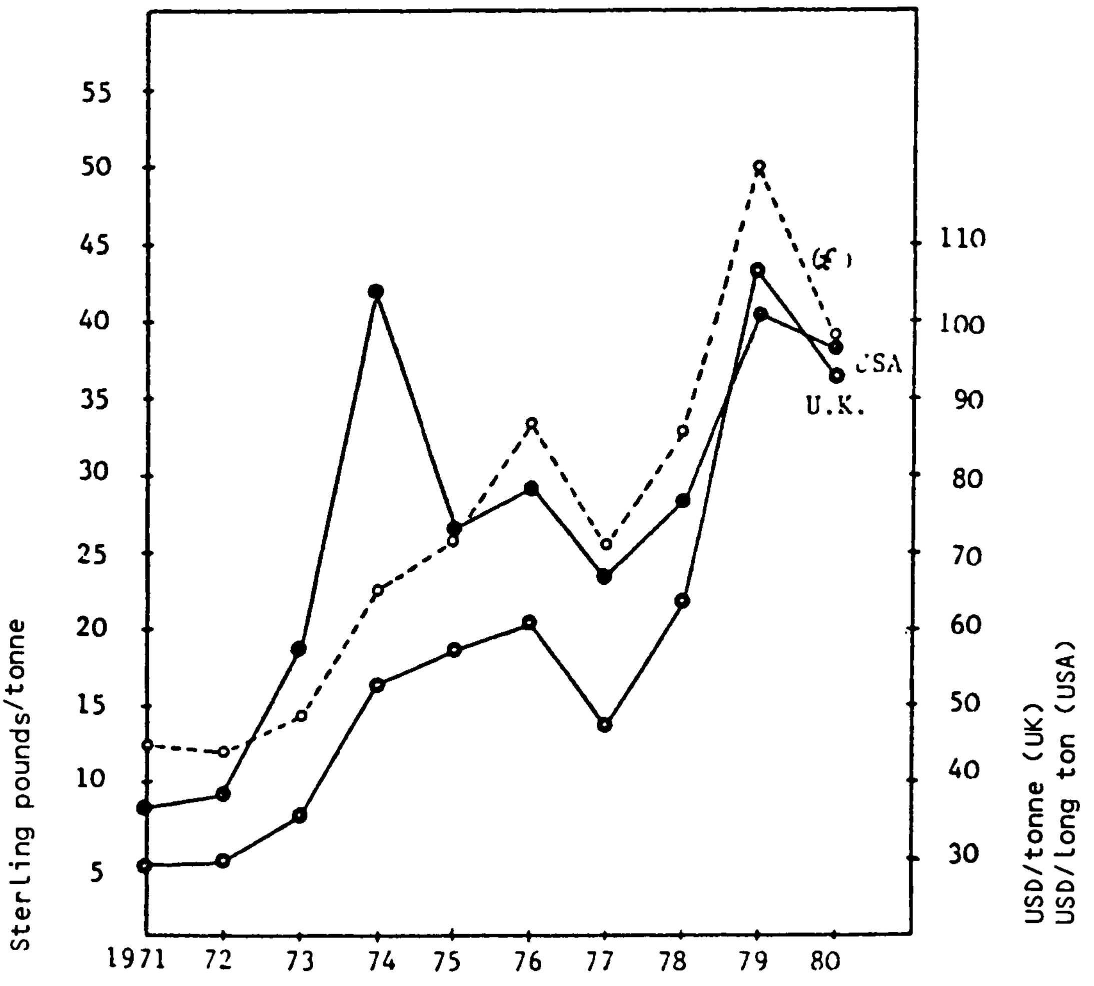


Fig. 11 - Trends in the price of scrap : 1) heavy steel-making scrap (delivered North East Coast UK 2) heavy steel-making scrap (delivered Pittsburgh USA) (Source : Monthly Bulletin of Statistics, UN)

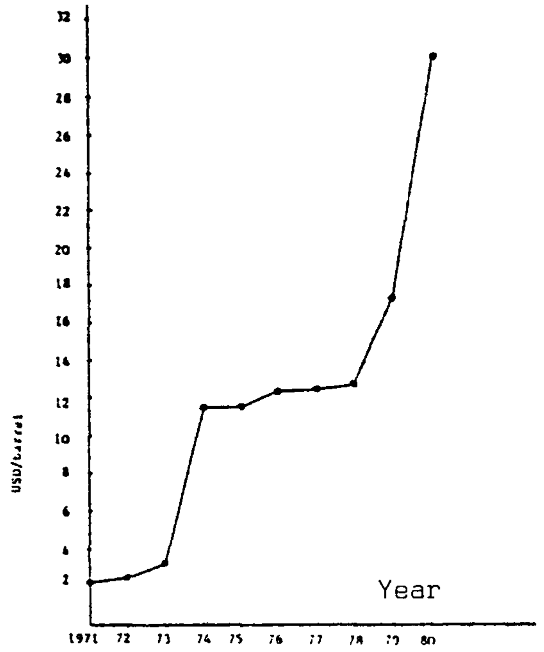


Fig. 12 - Trend of Saudi Arabia crude oil price (f.o.b Ras Tanura)
(Source : Monthly Bulletin of statistics, U.N.)

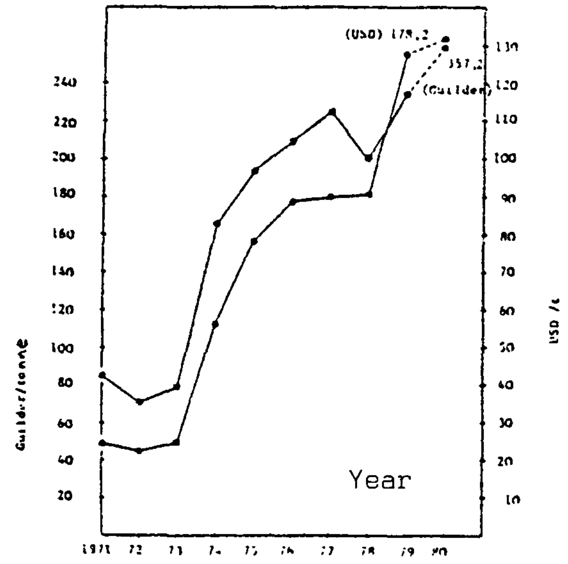


Fig. 13 - Heavy fuel oil price (ex Netherlands refinery)
(Source : Monthly Bulletin of statistics, U.N.)

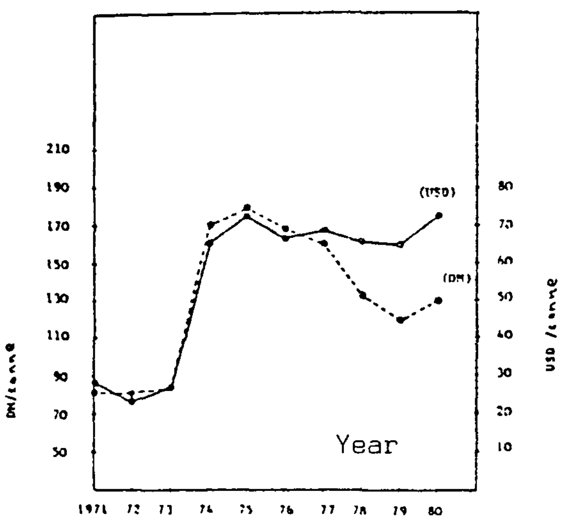


Fig. 14 - U S Coking coal import price (C.i.f. North Sea Ports)
(Source : Monthly Bulletin of statistics, U.N.)

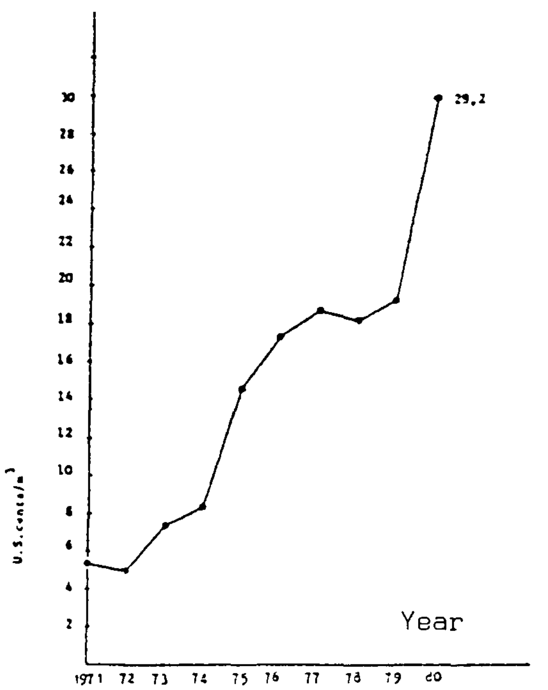


Fig. 15 - Natural gas price (producer price, Groningen, Netherlands)
(Source : Monthly Bulletin of statistics, U.N.)

A.4.1 THE US STEEL INDUSTRY

Until 1974 the US steel industry was the world's largest and even before World War II had the highest production figures (28.6 mio tonnes of crude steel in 1938). In 1974 however, the USA was overtaken in terms of production volume by the USSR (in 1979 the US produced 126.1 mio tonnes of crude steel and the USSR 149.5 mio tonnes). In 1980 Japan also made more steel than the US (111.4 mio tonnes compared with 100.6 mio tonnes, probably more as a result of the recession which hit the US steelmaking sector than because of any real reduction in capacity.

US steelmaking grew up mainly in the regions where iron ore and coal could be found or brought in easily (the iron-ore deposits of Lake Superior, the Marquette Range and the Mesabi Range and the coking coal deposits in Pennsylvania). Even today, steelmaking, especially in integrated steelworks, tends to be concentrated in the states closest to the sources of raw materials (Pennsylvania, New York, Ohio, Illinois, Indiana and Minnesota). There are also minor sources in the South and West.

Primary steelmaking in the US relies mainly on indigenous raw materials, though some iron ore is imported. There is enough coking coal, on the other hand, for some to be exported to other countries. Because of the nature of US iron ore (which requires beneficiation involving preliminary grinding) pelletization is very common. The ferrous burden of US blast furnaces consists mainly of pellets (65% on average, in 1974).

Electric steelmaking is fairly common - it accounts for almost one quarter of the country's production (24.1% in 1979) - because of the lower unit capital costs involved and the lower specific energy consumption and because the US has a lot of scrap available. The country does in fact export scrap (about 10 mio tonnes in 1980).

In 1979, some 14% of US steel was still being made in open-hearth furnaces, which have high specific energy consumptions but can be charged with very variable quantities of scrap.

Most integrated steelworks have a capacity of between 1 and 5 million tonnes of crude steel a year. There are only a few with higher capacity than this and all are below the 9 million tonnes a year mark. There are only two blast furnaces with 13-14m hearths.

The following table gives the main iron and steel production figures for 1979.

Steel production by main categories in 1979

(1000 tonnes/year)

Sinter (consumed)	114 833	(Sinter + pellets)
Crude iron	79 800	
Crude steel (°)	126 110	
- oxygen %	61.30	
- electric %	24.60	
- other %	14.10	
Rolled products		
- flat products	77 654	
- of which, coated	9 997	
- tubes	7 477	
- other products	5 827	

(°) 16.7% of which was continuously cast

The energy situation

Specific energy consumption for steelmaking is quite high in the US, largely because of the abundance of low-cost energy in the sixties and early seventies, and the decidedly obsolescent nature of many of the plants.

Technologically the US is behind both Japan and the best of the European steelmakers, despite the fact that some of the processes involved were developed in the States and then exported.

US steelmakers maintain that, with their profits eroded by high taxation and with increasing expenditure on environmental protection measures, they have not been able to invest heavily in modernization or more generally in replacing obsolete plants.

Energy-saving projects, too, have felt the repercussions of these financial difficulties. It is only in very recent years that there has been a greater commitment - with government aid - to reducing energy consumption. The investment plans drawn up in 1980 by the leading US steelmaking firm, for instance, provide for expenditure of USD 950 million on energy-saving. In addition to modernizing blast furnaces, constructing continuous casting facilities, fully utilizing production capacity in its steelworks and improving yields, the plan explicitly mentions the need to increase energy efficiency.

Virtually all US steel firms are making or plan to make a major financial and technical effort to reduce energy consumption. The reasons for this are basically the large amount of leeway to be made up in order to match the world's best steelmakers, the rising cost of energy and the incentives provided by the National Energy Plan.

According to the IEA specific energy consumption in the US steel industry in 1979 was 35% higher than that of its Japanese competitors. Even compared with European steelmakers the energy gap is substantial- specific consumption in 1978 for ex. was 16% higher than that of West Germany. (Source : IISI).

In 1978 the pattern of energy consumption by source was as follows (according to the IISI):

Coal	53.8%
Petroleum products	8.7%
Natural gas	18.2%
Electricity	19.3%

Of significance are the relatively small proportion accounted for by coal (according to the same source, coal accounted in 1978 for 60.2% of Japan's energy needs) and the highest proportion accounted for by natural gas.

In 1979, energy consumption by the steel industry accounted for 5% of inland energy consumption. This percentage is relatively small because of the high energy consumption of other manufacturing industries, transport and domestic users.

A.4.2. THE JAPANESE STEEL INDUSTRY

Japan is not well endowed with energy resources and its coking coal reserves are small (in 1979 the quantity of coking coal supplied from natural resources amounted to only about 12% of the quantity which had to be imported).

Japan's steelworks are located mainly in the regions of Kobe and Osaka on Honshu Island (in Tokyo Bay) and in northern Kyushu. There is also a steelmaking plant in northern Honshu and southern Hokkaido.

Japanese steelmaking developed considerably after World War II. Nevertheless, even after the initial stage of reconstruction and study of the techniques used in the US and Western Europe, by 1955 steel production was still very low (9.5 mio tonnes/year). Between then and 1964, however, the most modern steelmaking methods were introduced on a wide scale, especially oxygen converters and new rolling technology.

By 1964, crude steel production had risen to about 40 mio tonnes. The subsequent period from 1965 to 1974 was the golden age of Japanese steelmaking. After assimilating and improving on foreign techniques, Japan started to develop and export its own. The use of continuous casting spread rapidly, and integrated steelworks built during that period were designed with a capacity of not less than 10 mio tonnes a year. Production in 1974 was 117.1 mio tonnes, compared with 119.3 mio tonnes in 1973, and in spite of the world crisis in steelmaking, the Japanese still managed to produce 111.4 mio tonnes of steel in 1980.

Japan has several integrated steelworks capable of producing well over 10 mio tonnes a year (the largest has a capacity of 16 mio tonnes). The country also has a considerable number of high-capacity blast furnaces capable of producing over 10.000 tonnes of pig iron a day.

Japan also produces a large proportion of its crude steel electrically - generally over 20% of total output (23.6% in 1979).

The development of continuous casting has been more marked in Japan than anywhere else in the world; in fact, over 50% of the steel produced was cast in this manner in 1979.

The following table gives the main iron and steel production figures for 1979 :

Steel production by main categories in 1979

(1000 tonnes/year)

Sinter (consumed)	100 762
Crude iron	83 480
Crude steel (°)	111 748
- oxygen %	76.4
- electric %	23.6
- other %	-

(°) 52.0% of which was continuously cast.

Rolled products

- hot rolled	89 075
- cold reduced	26 117
- coated	9 925
- tubes	9 607

The Energy Situation

Japan's energy needs in 1978 amounted to 353 mio toe, about 16% of this for steelmaking to produce over 108 mio tonnes of steel... In 1978 Japan had to import nearly 90% of its energy and virtually all its oil. Natural gas, imported as LNG (liquefied natural gas) plays a marginal role only accounting for 4.5% of the total energy requirement. Only a small proportion of the country's coal consumption is met from indigenous sources.

This very heavy dependance on imported oil and on imports in general, the very important role of steelmaking and the need to keep the national industry competitive have all meant that maximum attention has been paid to the energy problem at both national and company level - even before the Yom Kippur war. The explosion in the price of oil and other imported fuels forced Japan's steelmakers to make even greater efforts to optimize the use of energy.

Specific energy consumption, which was already low in 1973 at 0.696 tce per tonne of crude steel was (according to the IISI) reduced even further in 1978 to 0.681 tce per tonne of crude steel despite the increased consumption of low-polluting plants.

The figures given by Nippon Kokan for energy consumption by source in 1980 are as follows: (figures in brackets are for integrated steelworks)

Coal	70.8% (81.8%)
Petroleum products	10.0% (8.3%)
Electricity	19.2% (9.9%)

Coal, which in 1973 covered 61.1% of total energy requirements in steelmaking, now accounts for 70% of the industry's total needs. By the end of the century Japanese steelmakers expect to be using only coal and electricity.

Considerable technical and economic efforts had to be made to improve the energy profile of Japanese steelmaking. All the country's steelmakers are committed to multiannual plans to save energy and to reduce dependence on oil.

The biggest Japanese firm, which produces some 35 to 40 mio tonnes of crude steel a year, invested over 43 000 mio yen between 1974 and 1978 in its energy-saving plan. This enabled the firm to reduce its already excellent specific energy consumption rate by 10%. A new energy-saving plan is designed to cut a further 10% off the 1978 figure by 1983. This plan will involve the firm in considerably higher investment than the previous plan. In fact, 29 000 million yen were invested in energy projects in 1980 alone.

This increased financial commitment is the result not so much of rising costs but rather of the increased emphasis on plant-infrastructure projects (changes to existing plant, new plant, and new energy-recovery systems, where investment costs are generally high) as opposed to improving operations and management (which usually involves little or no investment). There is a marked difference between the first and second energy-saving plans in this regard. Indeed, the improvements required to achieve a 10% saving in each case, can be broken down as follows:

	First Plan 1973 - 1978	Second Plan 1978 - 1983
Improvements to management and operations	55%	17%
Improvements to plant and equipment	45%	83%

For the current fiscal year (1980-1981), the Ministry of International Trade and Industry (MITI) expects Japanese steelmakers to be investing a total of 80 000 million yen in energy-saving projects.

B. ENERGY CONSUMPTION IN THE MAIN STEELMAKING PROCESSES

INTRODUCTION

This chapter examines in detail the energy consumption of two model steelworks, which can be considered to be truly representative of the iron and steel industry in the EEC and use today's most advanced technologies. The two types of steelworks are:

a) An integrated steelworks with a capacity of 5 000 000 tonnes of crude steel a year[(1)]. The steel is made into semi-finished products and widely-used products such as hot rolled and cold-rolled coils, plate and sheet, coated products and large diameter tubes.

b) A mini-mill making electric steel with a capacity of 500 000 tonnes of crude steel a year[(1)]. The steel is made into widely-standardized commercial products such as sections, wire rod and seamless tubes.

In the case of the electric steelworks, two alternative charges and three alternative production methods are considered.

Capacities of 5 000 000 and 500 000 tonnes a year were chosen because they seem to be the most representative of actual plants in the EEC, although they are smaller than the most recent steelworks built in the Community (Taranto, Dunkirk and Ijmuiden).

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(1) Crude steel includes all ingots and also continuously cast ingots (or billets and blooms).

It is assumed that these model steelworks have all the plant and use all the operational techniques for saving and recovering energy that have successfully passed the experimental stage and are now available to the iron and steel industry. This working hypothesis makes it possible to work out an energy plan which can constitute a realistic short-term objective for Community steelworks.

THE MODEL STEELWORKS

a) The Integrated Steelworks

The integrated steelworks produces steel in two 270 tonne oxygen converters charged with hot metal (about 76%) and scrap (mostly from internal recycling). The hot metal is produced in three medium-large blast furnaces (9.9 m in diameter) with a ferrous burden consisting of 80% sinter and 20% purchased pellets. The sinter plant has two 260 m^2 grates producing self-fluxing material.

The steel produced is divided between the continuous-casting plant (60%) and the conventional casting pit, soaking pit and slabbing line (40%).

The final products are hot-rolled and cold-rolled coils, tinplate, galvanized plate, welded tubes and plate and sheet.

Finally, the works has a thermal power station large enough to supply the required process steam and to convert into electricity all the gas not required for the production units.

The coke and coke-dust required for sinter production in the blast furnaces (which are supposed to operate without the injection of fuel into the tyres) are supplied by a coking plant which may be either inside or outside the works.

A complete picture of production is provided by the materials flow chart on the next page. It also indicates requirements in respect of fossil fuels, pellets, scrap and ferro-alloys brought in from outside. For the purpose of balancing recovered gas, steam and electricity, the coking plant is assumed to be connected to the steelworks.

b) <u>The Electric Steelworks</u>

The model is a works with a capacity of 500 000 tonnes of crude steel a year. Consumption of materials and energy is indicated. Two alternative charges are considered:

1) scrap only
2) sponge iron (65%) and scrap (35%), the sponge iron being brought in.

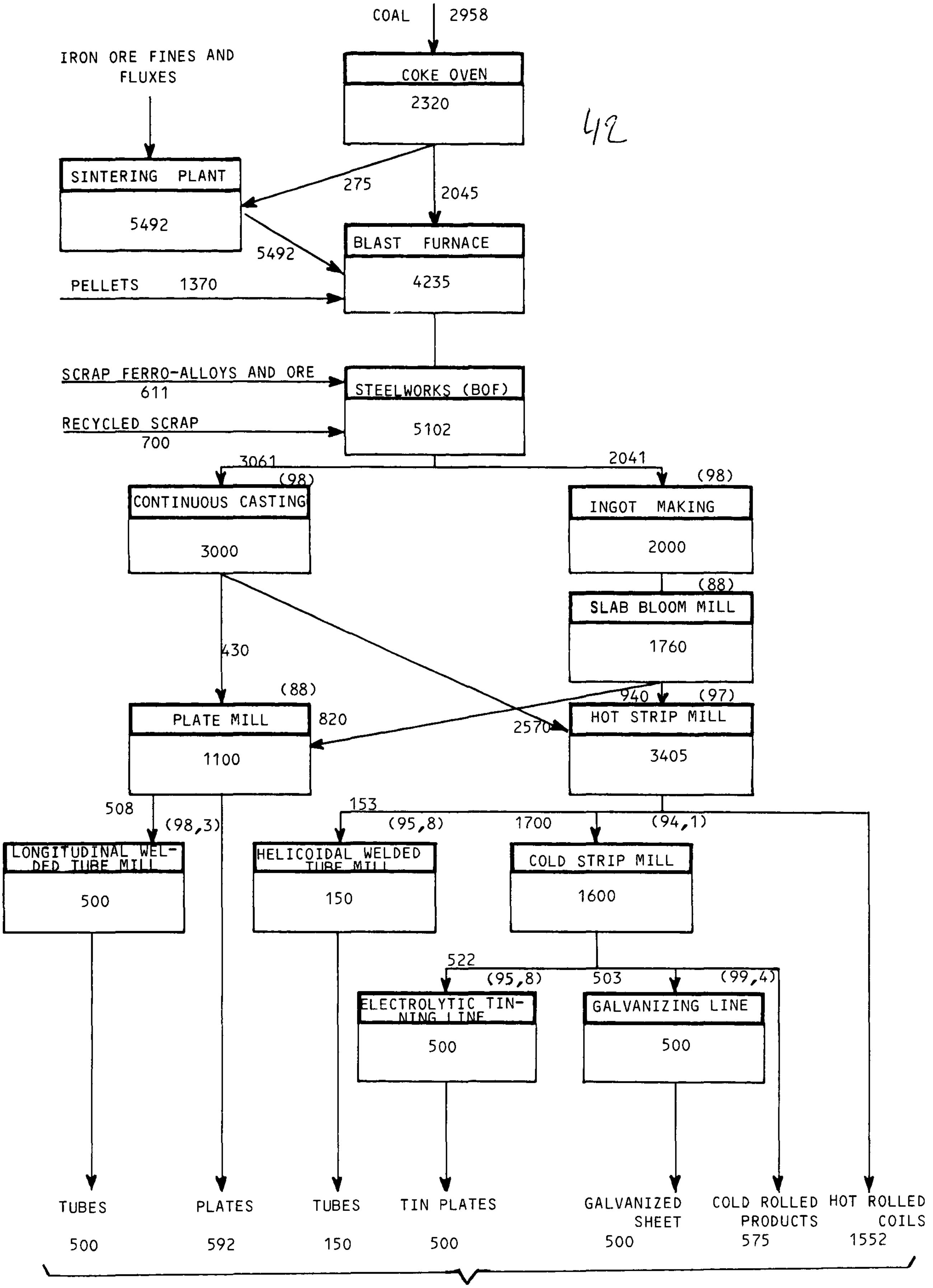
Three alternative types of products have been considered, to cover the most significant kinds of production of a works such as this:

1) medium-small sections 486 000 tonnes a year
2) 5.3-13 mm dia. wire rod 475 000 tonnes a year
3) 48-340 mm dia. seamless tubes 477 000 tonnes a year

The works has a 160 tonne 72 MVA UHP electric furnace with water-cooled walls and roof and three auxiliary oxy-fuel burners for melting operations.

All the liquid steel is continuously cast. The works has two continuous casting machines (plus one as a stand-by).

The semis (bars and billets) are fed hot (C. 700°C) into the appropriate primary reheating furnace, namely:



TOTAL FINISHED PRODUCTS DELIVERED/RAW MATERIAL FLOW ('000 t/y)-INTEGRATED STEELWORKS

- a pusher furnace for medium-small sections
- a walking beam furnace for wire rod
- a rotary hearth furnace for tubes.

All the furnaces are fired with natural gas and are equipped with heat exchangers and waste-heat boilers.

The flow of materials and products in the various charge and production alternatives is shown on the next page.

BASIC ASSUMPTIONS USED TO ESTABLISH HEAT BALANCES

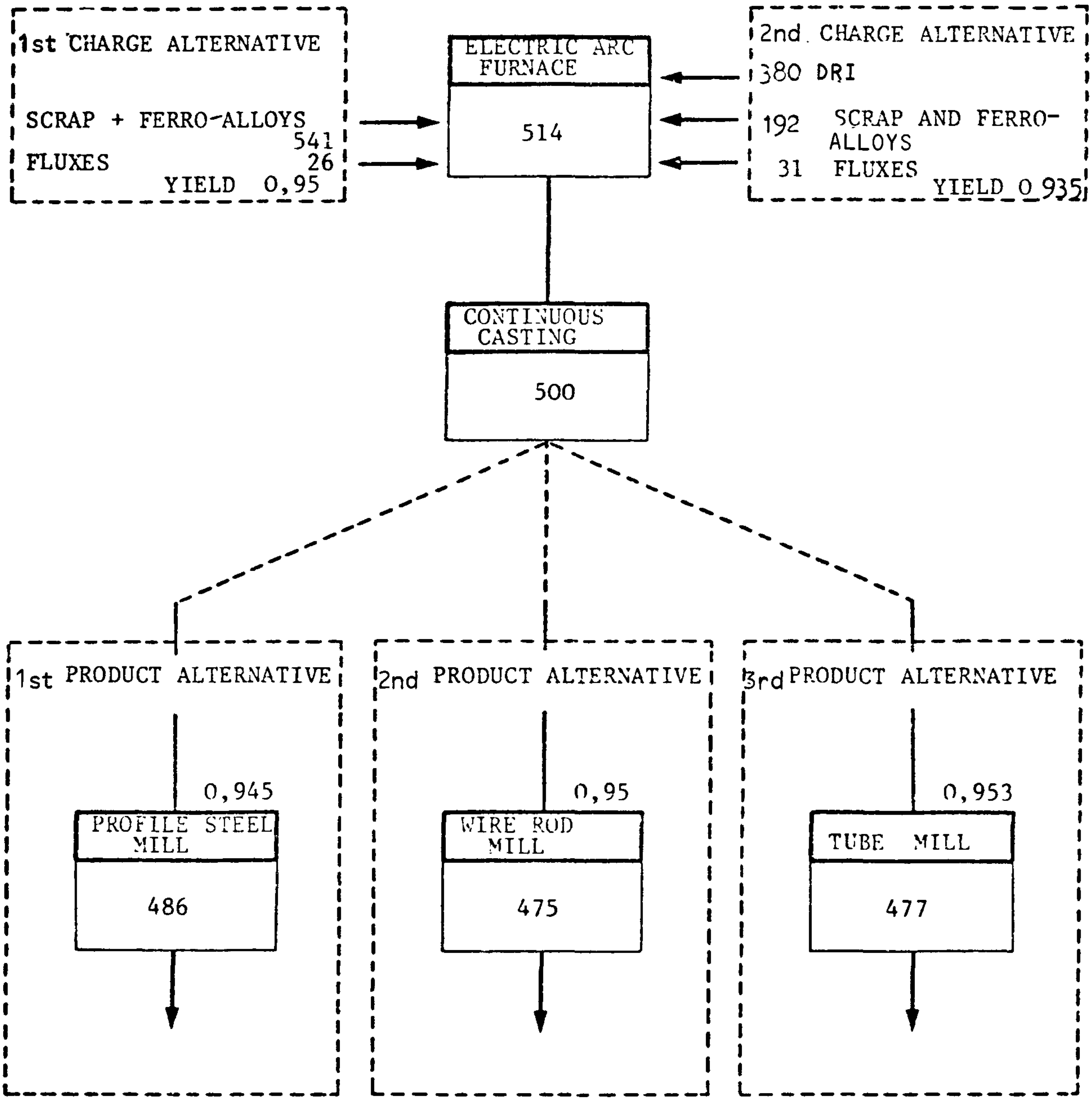
Heat values and energy equivalents

- Natural gas and fuel oil
  Lower calorific values of 35.5 MJ/m^3 and 41.90 MJ/kg are assumed for natural gas and fuel oil respectively.

- Electricity
  It is assumed that the primary energy content of the purchased electricity is 9.65 MJ/kWh.

- Oxygen
  It is assumed that the required oxygen is purchased and has a primary energy content of 7.5 MJ/m^3.

Scrap, pellets, pre-reduced materials, ferro-alloys and refractories
It is assumed that the energy content of these materials is zero. They are all purchased, apart from some scrap.



RAW MATERIAL AND PRODUCT FLOW FOR TWO CHARGE ALTERNATIVES AND THREE PRODUCTION ALTERNATIVES ('000 t/year) — ELECTRIC STEELWORKS

THE MAIN STEELMAKING PROCESSES

1. INTEGRATED STEELWORKS

Coking plant

The coking plant uses coal containing 26% volatile matter, and the product is coke with the following characteristics:

ash	10.0%
volatile matter	0.5%
carbon	89.5%

The lower calorific values of the coke and the coke-oven gas are 29.31 MJ/kg and 17.90 MJ/m^3, respectively.

Specific gaseous fuel consumption for the distillation process is 2 345 MJ/kg coal equivalent.
It requires 1 275 kg of dry coal to produce 1 tonne of unscreened coke.

Sintering

Self-fluxing sinter with a basicity (CaO/SiO_2) of 1.6 is produced.
Specific consumption of coke breeze is 50 kg/tonne of useful sinter.

Blast furnaces

The main operating data in respect of the blast furnaces are:

Burden:	Sinter	80% with 57% Fe
	Pellets	20% with 65% Fe

Specific consumption	483 kg/tonne of pig iron
Hydrocarbon injection	-
Slag volume	317 kg/tonne of pig iron
Slag basicity (CaO/SiO_2)	1.2
Dry blast volume	1 178 m^3/tonne of pig iron
Blast temperature	1 100°C
Blast moisture	18 g/m^3
Top gas pressure	3 bar
Dry gas volume	1 674 m^3/tonne of pig iron
Lower calorific value of gas	3 023 MJ/m^3

The blown air is supplied by electric fans which consume 0.08 kWh/m^3. Energy equivalent to 31 kWh/tonnes of pig iron is recovered from gas back-pressure. On each blast furnace four cowpers heat the blown air from 140 to 1 100°C, at an overall efficiency of 85%.

Steelworks

The steelworks has two 270 tonne oxygen converters continuously in operation, with a third available to allow the necessary rotation. The amount of gas recovered is equivalent to 80 m^3/tonne of steel and is used as fuel (lower calorific value : 8.37 MJ/m^3).
The amount of pig iron in the charge is 830 kg per tonne of steel accounting for 76% of the metal charge, whose yield is 0.91.

Specific consumption of oxygen is 53 m^3/tonne.

Continuous Casting

Yield : 0.98
Average sequence : 3 heats
Sixty percent of the steel produced is casted in two continuous casting machines.

Soaking pits and roughing mill

It is assumed that the whole of the soaking-pit charge consists of hot charge with standard track time.

The soaking pits have heat exchangers for preheating the combustion air (450°C) and the average specific fuel consumption is 750 MJ/ per tonne charged.

The fuel is appropriately blended recovered gas.
The yield of the roughing mill is 0.88.

Reheating furnaces and rolling mills

The furnaces which heat the slabs for the sheet rolling mill are pusher furnaces and, for the strip mill, walking beam furnaces. Both have heat exchangers for heating the combustion air (600°C) and waste-heat boilers.

Specific fuel consumption (recovered gas mixture) is 1 675 MJ/per tonne of feed.

Some 35% of the plate and sheet sent out is expected to be heat-treated in natural gas fired furnaces with a specific consumption of 2 000 MJ/per tonne treated.

Power Plant

The power plant is designed to use the excess gas recovered in the works to generate steam and electricity.

The power plant has three high-pressure (65 bar) 230 tonne/hour boilers and three 60 MW generators driven by condenser turbines which can pass out steam at 16 bar for works use and 7 bar for power plant services.

The electricity produced covers some 75% of the plant's total requirements.

The table on the overnext page, drawn up according to the IISI format, gives details of the energy balance (Table I).

Under the various fuel (or fluid energy vector) headings the table shows:

- the lower calorific value (or the primary energy content)
- the breakdown of consumption (or the quantities recovered) in the various parts of the works.

Against each production (or auxiliary) area which forms part of the works it shows:

- the production during the reference period
- the specific consumption (or recovery) of each fuel (or energy vector) expressed in physical units and MJ per tonne of product produced in that area and per tonne of crude steel
- the total net energy consumption (gross consumption minus amounts recovered) expressed in MJ per tonne of product produced in the area and per tonne of crude steel.

2. ELECTRIC STEELWORKS

Electric arc furnace charged with scrap (100%)

Average metal charge :

Scrap + ferro-alloys	1 053 kg/tonne liquid steel
Slag	70 kg/tonne liquid steel
Fluxes	50 kg/tonne liquid steel
Anthracite	5 kg/tonne liquid steel

MODEL PLANT	TABLE I - ENERGY CONSUMPTION DATA AS COMPILED AND CALCULATED	CRUDE STEEL PRODUCTION 5000 kt/year	PERIOD TYPICAL YEAR

PLANT PRODUCT ANNUAL PRODUCTION (kt/year)	UNIT OF MEASUREMENT	COAL 30.982 MJ/kg	COKE 29.310 MJ/kg	RECOVERED GAS 5.117 MJ/m3	NATURAL GAS 35.50 MJ/m3	SUB TOTAL	ELECTRICITY 10.22 MJ/kg	OXYGEN 7.50 MJ/m3	STEAM 3.257 MJ/kg	1st TOTAL	RECOVERED ENERGY: COKE 29.310 MJ/kg	RECOVERED GAS 5.117 MJ/m3	TAR 34.33 MJ/kg	BENZOL 40.19 MJ/kg	SUB TOTAL	ELECTRICITY 10.320 MJ/kwh	STEAM 3.257 MJ/kg	2nd TOTAL	PARTIAL SPECIFIC CONSUMPTION	% (OF TOTAL)
COKE PLANT	UNIT CONSUMP.	1275					20		160		1000		36.5	11.49						
COKE	MJ/t of Prod.	39502		2981		42483	204		521	43208	29310	8160	1253	462	39185			39185	4023	
2320 kt	MJ/t of C.S.	18329		1383		19712	95		242	20049	13600	3786	580	214	18180			18180	1869	9.6
SINTER PLANT	UNIT CONSUMP.		50				45													
SINTER	MJ/t P.		1466	201		1667	460			2127									2127	
5492 kt	MJ/t C.S.		1610	221		1831	505			2336									2336	12.0
BLAST-FURNACE	UNIT CONSUMP.		483				105		24							31				
HOT METAL	MJ/t P.		14157	1892		16049	1073		78	17200		5062			5062	320		5382	11818	
4235 kt	MJ/t C.S.		11990	1603		13593	909		66	14568		4287			4287	271		4558	10010	51.5
STEEL PLANT	UNIT CONSUMP.						23	53	14											
LIQUID STEEL	MJ/t P.						235	397	46	678		670			670			670	8	
5102 kt	MJ/t C.S.						240	405	47	692		684			684			684	8	-
CONT. CASTING	UNIT CONSUMP.						30	10	5											
SLABS	MJ/t P.			84		84	307	75	16	482									482	
3000 kt	MJ/t C.S.			50		50	184	45	10	289									289	1.5
SLABBING	UNIT CONSUMP.						34	5	1.5											
SLABS	MJ/t P.			856		856	347	37	5	1245									1245	
1760 kg	MJ/t C.S.			301		301	122	13	2	438									438	2.3
HEAVY P.M.	UNIT CONSUMP.						100		21								85			
HEAVY PLATES	MJ/t P.			1903	365	2268	1022		68	3358							277	277	3081	
1100 kt	MJ/t C.S.			419	80	499	225		15	739							61	61	678	3.5
HOT STRIP M.	UNIT CONSUMP.						100		21								77			
HOT COILS	MJ/t P.			1726		1726	1022		68	2816							251	251	2565	
3405 kt	MJ/t C.S.			1176		1176	696		46	1918							172	172	1746	9.0
TUBE MILL	UNIT CONSUMP.						60													
TUBES	MJ/t P.						613			613									613	
650 kt	MJ/t C.S.						80			80									80	0.4
COLD STRIP M.	UNIT CONSUMP.						150		120											
COLD COILS	MJ/t P.				1151	1151	1533		391	3075									3075	
1600 kt	MJ/t C.S.				369	369	490		125	984									984	5.1
TINNING LINE	UNIT CONSUMP.						160		250											
TIN PLATE	MJ/t P.						1635		814	2449									2449	
500 kt	MJ/t C.S.						164		82	246									246	1.3
GALVANIZ. L.	UNIT CONSUMP.				40		50		34											
GALVANIZ. SH.	MJ/t P.				1420	1420	511		111	2042									2042	
500 kt	MJ/t C.S.				142	142	51		11	204									204	1.0
POWER PLANT	UNIT CONSUMP.																			
ELECTRICITY	MJ/t P.			11319	707	12026				12026						10320	1706	12026	–	
1592 GWH	MJ/t C.S.			3604	225	3829				3829						3286	543	3829	–	
OTHERS	MJ/t C.S.						409		130	539									539	2.8
TOTAL	MJ/t C.S.	18329	13600	8757	816	41502	4170	463	776	46911	13600	8757	580	214	23151	3557	776	27484	19427	100.0

ELECTRICITY	PRODUCED	PURCHASED	DISTRIBUTED
MJ/kwh	10.32	9.65	10.22
%	85.9	14.1	100

RECOVERED GAS	COKE-OVEN GAS	BLAST FURNACE GAS	CONVERTER GAS	AVERAGE
%	12.36	82.87	4.77	100.00
MJ/m3	17.900	3.023	8.374	5.117

The furnace is charged with the metal in batches in the usual manner.

Energy consumption:

Electricity	460 kWh/tonne of liquid steel
fuel oil	6.2 kg/tonne of " "
oxygen	14.0 m^3/tonne of " "
electrodes	5.0 kg/tonne of " "

Electric furnace charged with scrap (35%) and DRI (65%)

The composition of the DRI is as follows:

Total Fe	93.92 %
Metallic Fe	87.81 %
Degree of metallization	0.935%
Gangue	3.6 %
C	1.25 %

The Fe yield of the DRI and scrap charge is assumed to be 0.935 in terms of liquid steel.

Metal charge:

DRI	739 kg/tonne of liquid steel
Scrap + ferro-alloys	374 kg/tonne of " "
Slag	110 kg/tonne of " "
Fluxes	60 kg/tonne of " "

It is assumed that the scrap is charged in the usual manner by baskets while the pre-reduced material is fed continuously.

Energy consumption:

Electricity	545 kWh/tonne of liquid steel

Fuel oil	3 kg/tonne of liquid steel
Oxygen	10 m^3/tonne of " "
Electrodes	5.0 kg/tonne of " "

Continuous Casting

A total of 1 027 kg of liquid steel is required to produce 1 000 kg of steel cast in various shapes and sizes (yield = 0.974).

Energy consumption:

Electricity	14 kWh/tonne
Natural gas	2.75 m^3/tonne
Oxygen	10.5 m^3/tonne

Medium-Small Section Mill

Billets between 115 and 140 mm square are charged at a temperature of 700°C into a pusher furnace. The pusher furnace heats the billets in a mixture of natural gas and air preheated to 450°C by the actual furnace gases in a forced-draft heat exchanger. After passing through the heat exchanger, the final temperature of the gases is about 300°C.

Specific consumption of natural gas is 27.5 m^3/tonne of finished product.

The electricity required for the subsequent rolling process is 60 kWh/tonne of finished product.

Wire-rod mill

Square billets 127 x 127 mm are charged into a walking beam furnace at 700°C. They leave the furnace at a temperature of 1 200°C.

Air for combustion is preheated to 500°C in the natural draft heat exchanger, which uses the heat from actual furnace gases.

Specific consumption of natural gas is 27 m^3/tonne of finished product, while specific consumption of electricity is 150 kWh/tonne. The material yield is 0.95 by weight.

Pipe mill

Billets between 222 to 320 mm square and rounds (190 mm dia) are charged into a rotary hearth furnace at a temperature of 700°C. They leave the furnace at 1 280°C.

The heat exchanger raises the temperature of the combustion air to 400°C using the heat from the actual furnace gases.

Specific consumption of natural gas is 34 m^3/tonne of finished product.

The products are rolled in a Multistand Pipe Mill (MPM) where the material is heated to 900°C in a walking beam furnace.

Specific consumption of natural gas is 13 m^3/tonne of finished product.
Specific consumption of electricity is 148 kWh/t.
The billet to final product yield is 0.953.

The following three tables, drawn up according to the IISI format give details of the energy balance of the model works, considering the various charging and production alternatives. The tables do not show the recovery of steam from the reheating furnaces: it is assumed that the amount recovered (some 50kg/tonne of finished product) is sufficient to cover fuel needs for general services which have been allocated an electricity consumption of only 50 MJ/tonne of crude steel (Tables II, III and IV).

TABLE II - Energy consumption by electric arc furnace steelworks for the production of light and medium sections

	MODEL PLANT		ENERGY CONSUMPTION DATA AS COMPILED AND CALCULATED				CRUDE STEEL PRODUCTION 500,000 t		PERIOD TYPICAL YEAR	
	PLANT/PRODUCT/ ANNUAL PRODUCTION (kt/year)	UNIT OF MEASUREMENT	ANTHRACITE	FUEL OIL	NATURAL GAS	ELECTRICITY	OXYGEN	ELECTRODE	TOTAL	CUMULATIVE TOTAL
			31.80 MJ/kg	41.90 MJ/kg	35.50 MJ/M^3	9.65 MJ/kwh	7.50 MJ/M^3	33.50 MJ/kg		
EAF CHARGE 100% SCRAP	EL. FURNACE LIQUID STEEL 514 kt	UNIT CONSUMPTION	5	6		460	14	5		
		MJ/t of prod.	159	251		4439	105	168	5122	
		MJ/t of crude steel	163	258		4563	108	172	5264	5264
	CONTINUOUS CASTING/CRUDE STEEL 500 kt	UNIT CONSUMPTION			2.75	14	10.5			
		MJ/t of prod.			98	135	79		312	
		MJ/t of crude steel			98	135	79		312	5576
	SECTIONS MILL SECTIONS 486 kt	UNIT CONSUMPTION			27.5	60				
		MJ/t of prod.			976	579			1555	
		MJ/t of crude steel			949	563			1512	7088
	OTHERS	MJ/t of crude st.				50			50	7138
	TOTAL	MJ/t of crude st.	163	258	1077	5311	187	172	7138	7138
EAF CHARGE SPONGE IRON AND SCRAP	EL. FURNACE LIQUID STEEL 514 kt	UNIT CONSUMPTION		3		545	10	5		
		MJ/t of prod.		126		5259	75	168	5628	
		MJ/t of crude steel		129		5407	77	172	5785	5785
	CONTINUOUS CASTING/CRUDE STEEL 500 kt	UNIT CONSUMPTION			2.75	14	10.5			
		MJ/t of prod.			98	135	79		312	
		MJ/t of crude steel			98	135	79		312	6097
	SECTIONS MILL SECTIONS 486 kt	UNIT CONSUMPTION			27.5	60				
		MJ/t of prod.			976	579			1555	
		MJ/t of crude steel			949	563			1512	7609
	OTHERS	MJ/t of crude st.				50			50	7659
	TOTAL	MJ/t of crude st.		129	1047	6155	156	172	7659	7659

TABLE III – Energy consumption by electric arc furnace steelworks for the production of wire rod

	MODEL PLANT		ENERGY CONSUMPTION DATA AS COMPILED AND CALCULATED				CRUDE STEEL PRODUCTION 500,000 t		PERIOD TYPICAL YEAR	
	PLANT/PRODUCT/ ANNUAL PRODUCTION (kt/year)	UNIT OF MEASUREMENT	ANTHRACITE	FUEL OIL	NATURAL GAS	ELECTRICITY	OXYGEN	ELECTRODE	TOTAL	CUMULATIVE TOTAL
			31.80 MJ/kg	41.90 MJ/kg	35.50 MJ/M^3	9.65 MJ/kwh	7.50 MJ/M^3	33.50 MJ/kg		
EAF CHARGE 100% SCRAP	EL. FURNACE LIQUID STEEL 514 kt	UNIT CONSUMPTION	5	6		460	14	5		
		MJ/t of prod.	159	251		4439	105	168	5122	
		MJ/t of crude steel	163	258		4563	108	172	5264	5264
	CONTINUOUS CASTING/CRUDE STEEL 500 kt	UNIT CONSUMPTION			2.75	14	10.5			
		MJ/t of prod.			98	135	79		312	
		MJ/t of crude steel			98	135	79		312	5576
	WIRE ROD MILL 475 kt	UNIT CONSUMPTION			27	150				
		MJ/t of prod.			959	1448			2407	
		MJ/t of crude steel			911	1375			2286	7862
	OTHERS	MJ/t of crude st.				50			50	7912
	TOTAL	MJ/t of crude st.	163	258	1009	6123	187	172	7912	7912
EAF CHARGE SPONGE IRON AND SCRAP	EL. FURNACE LIQUID STEEL 514 kt	UNIT CONSUMPTION		3		545	10	5		
		MJ/t of prod.		126		5259	75	168	5628	
		MJ/t of crude steel		129		5407	77	172	5785	5785
	CONTINUOUS CASTING/CRUDE STEEL 500 kt	UNIT CONSUMPTION			2.75	14	10.5			
		MJ/t of prod.			98	135	79		312	
		MJ/t of crude steel			98	135	79		312	6097
	WIRE ROD MILL 475 kt	UNIT CONSUMPTION			27	150				
		MJ/t of prod.			959	1448			2407	
		MJ/t of crude steel			911	1375			2286	8383
	OTHERS	MJ/t of crude st.				50			50	8433
	TOTAL	MJ/t of crude st.		129	1009	6967	156	172	8433	8433

TABLE IV - Energy consumption by electric arc furnace steelworks for the production of seamless tubes

	MODEL PLANT		ENERGY CONSUMPTION DATA AS COMPILED AND CALCULATED				CRUDE STEEL PRODUCTION 500,000 t		PERIOD TYPICAL YEAR	
	PLANT/PRODUCT/ ANNUAL PRODUCTION (kt/year)	UNIT OF MEASUREMENT	ANTHRACITE	FUEL OIL	NATURAL GAS	ELECTRICITY	OXYGEN	ELECTRODE	TOTAL	CUMULATIVE TOTAL
			31.80 MJ/kg	41.90 MJ/kg	35.50 MJ/M³	9.65 MJ/kwh	7.50 MJ/M³	33.50 MJ/kg		
EAF CHARGE 100% SCRAP	EL. FURNACE LIQUID STEEL 514 kt	UNIT CONSUMPTION	5	6		460	14	5		
		MJ/t of prod.	159	251		4439	105	168	5122	
		MJ/t of crude steel	163	258		4563	108	172	5264	5264
	CONTINUOUS CASTING/CRUDE STEEL 500 kt	UNIT CONSUMPTION			2.75	14	10.5			
		MJ/t of prod.			98	135	79		312	
		MJ/t of crude steel			98	135	79		312	5576
	TUBE MILL 477 kt	UNIT CONSUMPTION			47	148				
		MJ/t of prod.			1669	1428			3097	
		MJ/t of crude steel			1592	1363			2955	8531
	OTHERS	MJ/t of crude st.				50			50	8581
	TOTAL	MJ/t of crude st.	163	258	1690	6111	187	172	8581	8581
EAF CHARGE SPONGE IRON AND SCRAP	EL. FURNACE LIQUID STEEL 514 kt	UNIT CONSUMPTION		3		545	10	5		
		MJ/t of prod.		126		5259	75	168	5628	
		MJ/t of crude steel		129		5407	77	172	5785	5785
	CONTINUOUS CASTING/CRUDE STEEL 500 kt	UNIT CONSUMPTION			2.75	14	10.5			
		MJ/t of prod.			98	135	79		312	
		MJ/t of crude steel			98	135	79		312	6097
	TUBE MILL 477 kt	UNIT CONSUMPTION			47	148				
		MJ/t of prod.			1669	1428			3097	
		MJ/t of crude steel			1592	1363			2955	9052
	OTHERS	MJ/t of crude st.				50			50	9102
	TOTAL	MJ/t of crude st.		129	1690	6955	156	172	9102	9102

ENERGY REQUIREMENTS FOR THE PRODUCTION OF LIQUID STEEL AND FINISHED PRODUCTS

Examination of the energy balances for the three steelmaking alternatives shows that the coke-oven blast furnace oxygen converter cycle requires far more energy than the electric furnace cycles (see Fig. 16).

Alternative A -	Coke oven blast furnace oxygen converter cycle	14 337 GJ/tonne of liquid steel
Alternative B -	Electric furnace cycle (100% scrap)	5 122 GJ/ " " "
Alternative C -	Electric furnace cycle (DRI + scrap)	5 628 GJ/ " " "

It should be remembered, of course, that in the case of Alternative A, new steel is being made from iron ore and coke, while in Alternatives B and C all that is being done is to remelt scrap or DRI brought in from outside. As has been mentioned, the energy content of these two materials is assumed to be zero.

The energy requirement for making finished products via the blast furnace oxygen converter process (Alternative A) depends to a large extent on the process used:
- the soaking-pit + slabbing process
- the continuous-casting process

Fig. 17 illustrates the energy requirement on the basis of the energy balance (given on Page 49) for making one tonne of:
- hot-rolled coil
- plate
- cold-rolled coil
- galvanized plate
- tinplate

as well as the main semi-finished products (pig iron, liquid steel and slabs).

Though the figures given in the graphs correspond with the energy balance worked out for the integrated model plant they must be taken only as a guide, since they have been arrived at by adopting average yields and energy consumptions for the various stages and not specific values for each product.

Fig.-16 Energy required to produce one tonne of liquid steel in each of the three processes

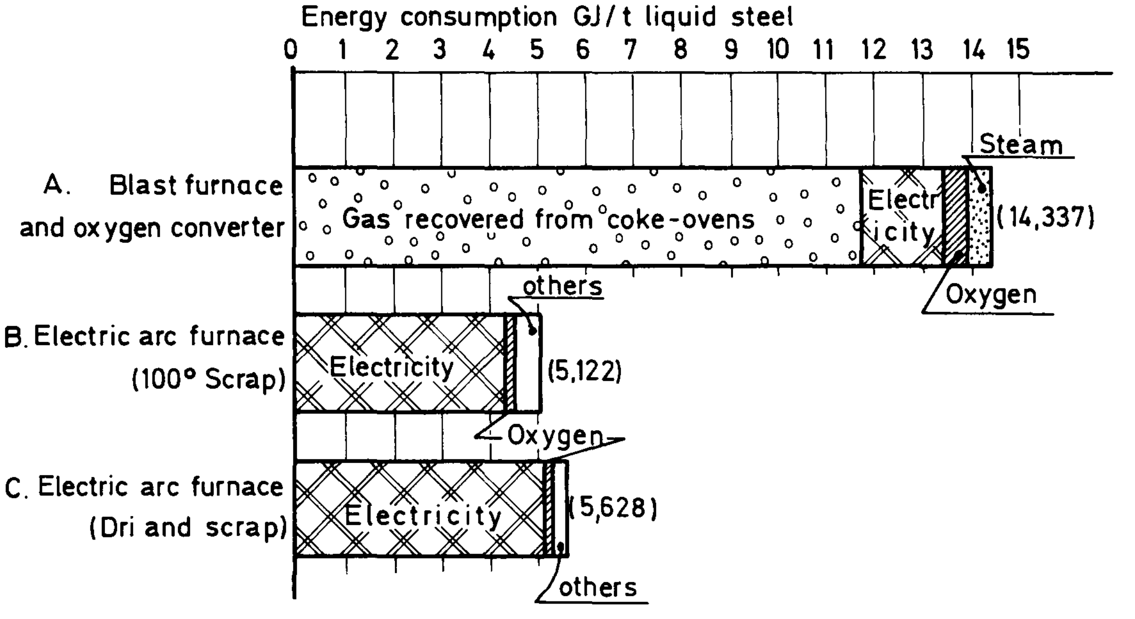
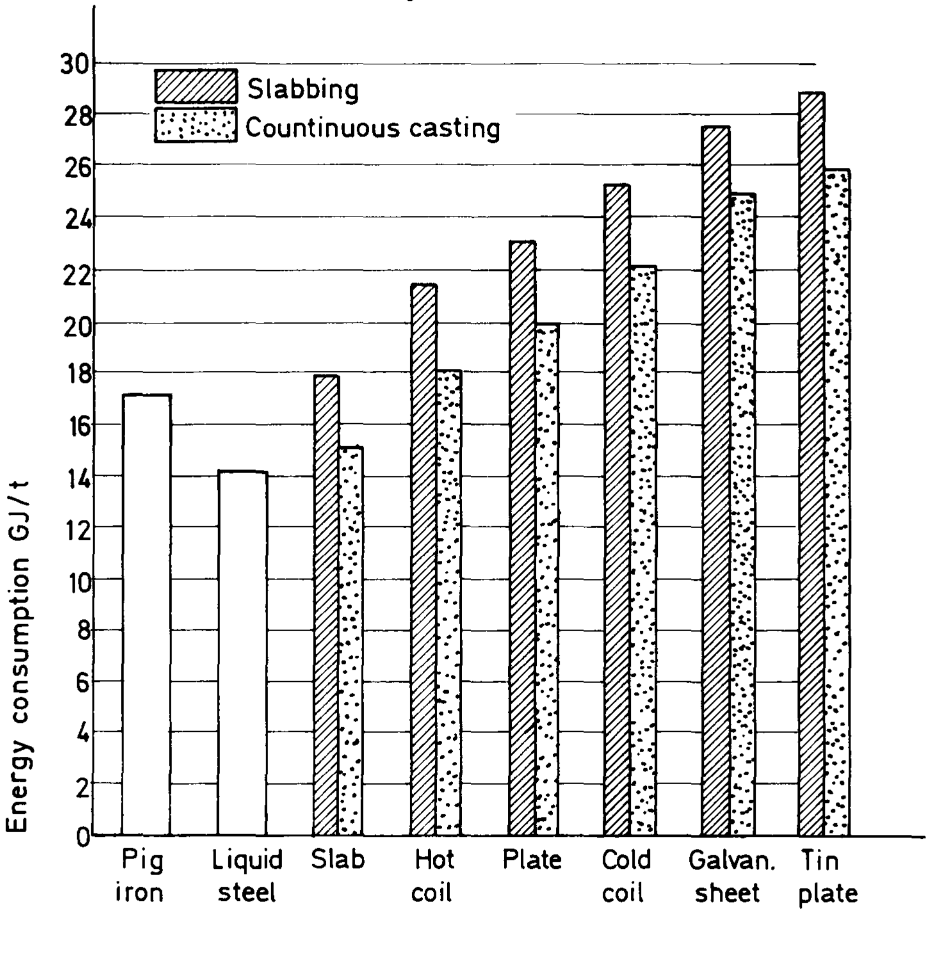


Fig.-17 Energy required to produce one tonne of finished product using the blast furnace and oxygen converter process (A)



QUALITY AND QUANTITY ASPECTS IN THE MODEL STEELWORKS

ENERGY BALANCES

1. The Integrated Steelworks

The following points emerge from examination of the energy balance for the integrated steelworks:

a) A large proportion (75%) of the total net energy consumption of the works is required to produce pig iron (including the production of coke and ascribing a zero heat value to the pellets in the blast furnace burden).

Making the iron into steel and producing slabs account for another 4% or so.

The remaining 21% is for processing the slabs into the finished product and for galvanizing or tinplating. Consumption by ancillary services is allocated to the various areas of production.

b) The energy requirement of the works, including the tar and benzene sold outside, amounts to 20.2 GJ/tonne of crude steel. About 90% of this requirement is met by coke and the remainder by natural gas, electricity and oxygen. Some of the energy input to the works, equivalent to 0.8 GJ/tonne of crude steel, is returned in the form of raw materials for the chemical industry (tar and benzene).

c) The works is not dependent on petroleum products, except perhaps indirectly through the oxygen and electricity that are purchased from outside and which account for some 5% of the total energy requirement. As is evident from the following table, 21.5% of Community electricity production in 1980 was based on oil products (Table 7).

TABLE 7 - EEC electricity production (source: EEC news 1981)

YEAR		HYDRO	GEO-THERMAL	NUCLEAR	COAL	BROWN COAL	OIL PRODUCTS	NATURAL GAS	OTHERS	TOTAL
1979	TWh	140.7	2.4	127.6	383.6	92.4	276.7	127.0	28.6	1179.0
1980	"	143.1	2.5	147.3	404.2	95.2	257.9	117.2	28.8	1196.3
1981 (provisional)	"	136.4	2.7	179.3	412.3	98.5	265.8	118.1	29.4	1242.4
1979	%	12.0	0.2	10.8	32.5	7.8	23.5	10.8	2.4	100
1980	%	12.0	0.2	12.3	33.8	8.0	21.5	9.8	2.4	100
1981 (provisional)	%	11.0	0.2	14.4	33.2	7.9	21.4	9.5	2.4	100

d) The integrated works meets some 4% of its requirements with natural gas. The reason for this is basically that it needs to use particularly clean (sulphur-free) gas for some applications, though it would be easy to find alternatives.

It is important to stress the role played by the gases recovered from coke-ovens blast furnaces and converters which meet 45% of the plant's energy requirements. These gases are to be used in the power plant and, possibly after passing through mixing plants to ensure the most suitable calorific values, in the various furnaces (coke ovens, soaking pits, reheating furnaces, cowpers and the sinter plant ignition furnace). Of course the gas distribution networks will have storage facilities (gasometers) to provide the required flexibility;

it will also be necessary to ensure that the main user (the power plant) is able to cope with variations in gas availability.

e) Electricity is extremely important in a modern integrated steelworks and is likely to become even more so with the increasing development of working and finishing plants and the increasing proportion of total consumption accounted for by pollution control plant (flue-gas treatment, dust removal, water treatment etc, etc.), mainly in the form of electricity.

In the model works, electricity consumption amounts to 408 kWh/tonne of crude steel.

The figure on page 64 shows how the energy balance is made up.

2. The Electric Steelworks

Examination of the energy balance of the various electric steel-making processes considered shows that energy consumption per tonne of crude steel varies considerably according to the charge and the product namely :

(GJ/tonne of crude steel)

CHARGE \ PRODUCT	MEDIUM-SMALL SECTIONS	WIRE ROD	SEAMLESS TUBES
Scrap only	7.14	7.91	8.58
DRI (65%) + Scrap(35%)	7.66	8.43	9.10

With both charge alternatives, scrap only and 65% DRI + 35% scrap, the production of billets and blooms accounts for over two thirds of the total energy requirement (assuming the energy content of the scrap and DRI to be zero). The detailed breakdown is as follows :

(as %)

PRODUCT	PRODUCTION OF BILLETS AND BLOOMS	ROLLING INTO A FINISHED PRODUCT
SCRAP ONLY CHARGE		
Medium-Small Section	78.5	21.5
Wire Rod	70.9	29.1
Seamless Tube	65.3	34.7
DRI + SCRAP CHARGE		
Medium-Small Sections	80.0	20.0
Wire Rod	72.7	27.3
Seamless Tube	67.3	32.7

Some 80% of the energy requirement is met by electricity.

Electricity consumption in terms of crude steel production for the various charge and production alternatives is as follows:

a) Scrap only charge and production of:

medium-small sections	550 kWh/tonne	of	crude	steel
wire rod	635 "	"		"
seamless tubes	633 "	"		"

b) Sponge-iron + scrap charge and production of:

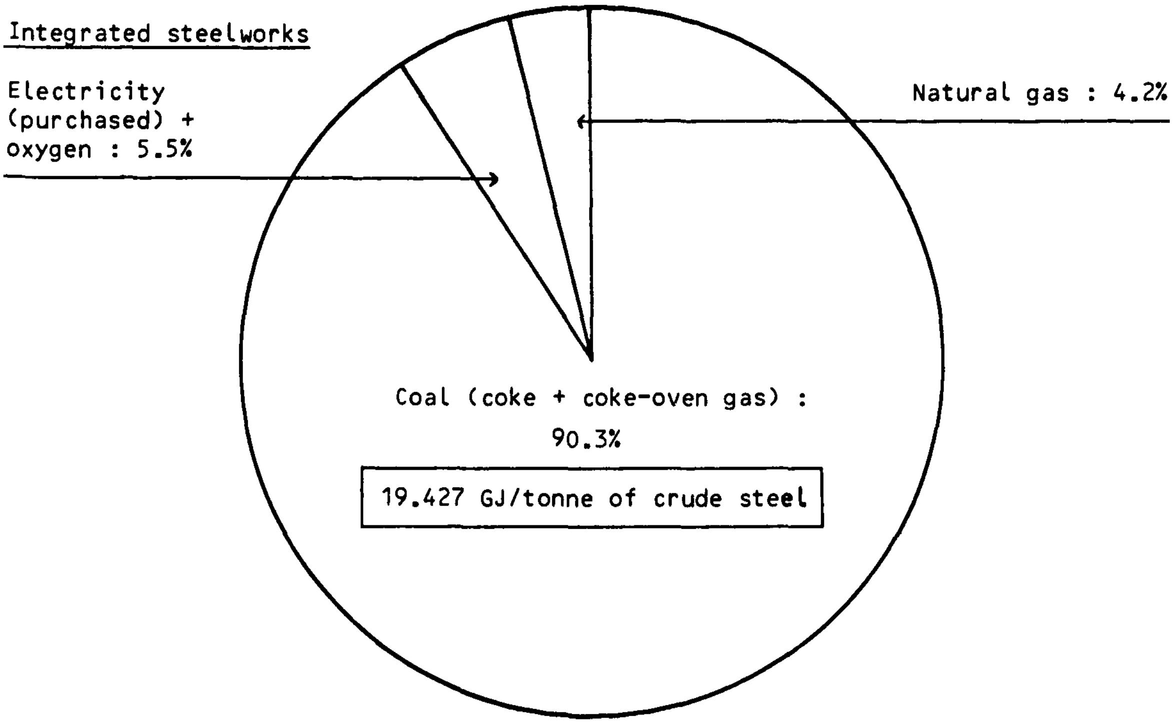
medium small sections	638 kWh/tonne	of	crude	steel
wire rod	722 "	"		"
seamless tubes	721 "	"		"

Natural gas meets between 15 and 20% of requirements.

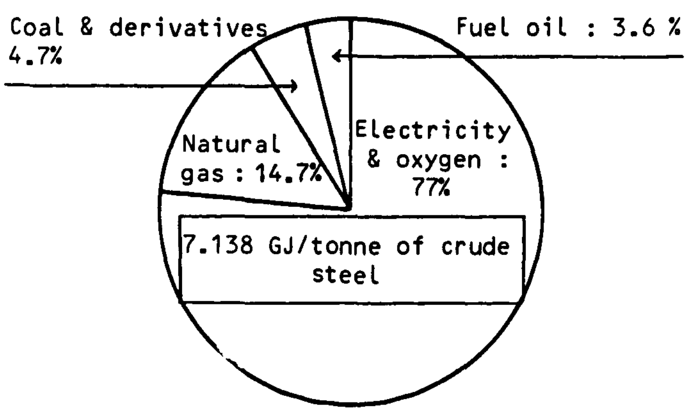
Very little use is made of oil products.

The figure on page 64 shows how the energy balance is made up.

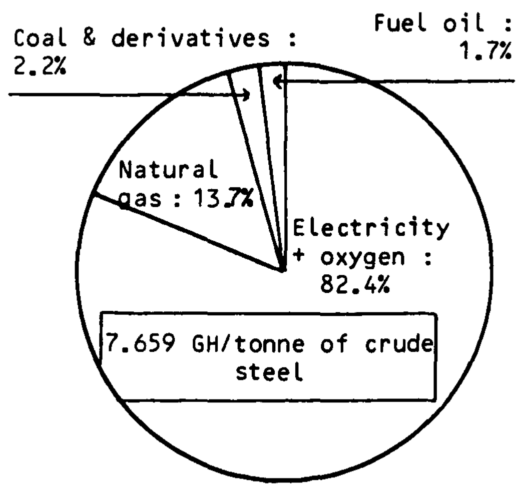
Integrated steelworks



Electric steelworks making medium-small sections



Charge : 100% scrap



Charge : 35% scrap + 65% DRI

Percentage breakdown of the primary energy requirements of the model plant

HOW THE MODEL STEELWORKS COULD BE FURTHER IMPROVED

1. The Integrated Steelworks

By adopting various possible measures described in the following chapters, which are not universally applied at present but which will certainly find increasing application in the coming years, it should be realistically possible to achieve an improvement of about 130 MJ/tonne of crude steel (6.5%) in the performance of the model integrated plant. This improvement can be broken down as follows, (Table 8):

SUGGESTED MEASURES	MJ/tonne of product	MJ/tonne of crude steel	REMARKS
Dry quenching of coke	1200	560	Steam production
Recovery of sensible heat from sinter	200	220	Ditto
Recovery of sensible heat from slag	300	260	Ditto
Hot feeding of pusher furnaces for rolling mills	170	40	30% of hot feed on which there is 30% fuel saving
Hot feeding of walking beam furnaces for strip mills	150	100	Ditto
Direct rolling in strip mill	250	170	20% of direct rolling on which there is a saving of 1250 MJ/tonne
TOTAL		1350	

Table 8 - Reduction of Energy consumption for integrated steel plant

With all these improvements, and at a cautious estimate, the integrated plant virtually no longer requires natural gas or electricity. Apart from coking coal, it remains dependent on external sources only for its oxygen needs, which account for less than 2.5% of its total energy requirement.

2. The Electric Steelworks

It is possible to envisage further reductions in specific consumption, compared with the figures given for the models, by using proven technologies which are already available or which soon will be available, especially in the liquid steel processing stage.

A saving of 50-60 kWh/tonne of crude steel can be achieved by using the hot gases leaving the furnace to preheat scrap to 350°C.

By closing the so-called "fourth hole", through which gases and dusts are sucked plus a large volume of air, it is possible to save 40-60 kWh/tonne of crude steel. Closing the "fourth hole" means modifying plants that are undergoing industrial trials.

In the processes producing the finished product, the possibilities of achieving further savings are very limited compared with the models presented, apart from improving plants and perhaps rolling immediately after continuous casting - although this causes problems regarding the organization of production and quality control.

In order to cut consumption of hydrocarbons in the electric steelmaking process, it is possible to inject not only more oxygen but also coal at the end of the melting stage.

With reheating furnaces, it should be possible under certain operating and power-cost conditions, to use induction heating.

To sum up, the most obvious improvements which could be made on the model plants are the following (Table 9) :

IMPROVEMENTS	MJ/TONNE OF PRODUCT	MJ/TONNE OF CRUDE STEEL	REMARKS
Preheating of scrap or DRI (100%) to 350°C	485	500	Uses waste heat (sensible heat from gases,semis,etc.)
Closing the "fourth hole" in electric furnaces	485	500	Reduces losses, less pollution
Induction heating (instead of by burners)			Replaces one form of energy with another Smaller losses through oxidation Greater flexibility
T O T A L		1000	

Table 9 - Cutting energy consumption in an electric steelworks

C. ENERGY SAVING POTENTIAL

C.1 EFFECT OF VOLUME AND PATTERN OF PRODUCTION ON SPECIFIC ENERGY CONSUMPTION IN A STEELWORKS

The three main factors which affect specific energy consumption - in terms of crude steel production are :

(i) The process used to produce liquid steel (blast furnace + oxygen converter, direct reduction + electric furnace, scrap melting in electric furnace, etc.).

(ii) The extent to which the production process is vertically integrated.

(iii) The level of utilization of plant capacity.

As regards the second factor, the integrated steelworks described as a model plant in this study does in fact have its own coking plant and thermal power station.

It also processes the coils and plate into cold-rolled products, welded tubes and coated products. This increases the value of the finished products, but at the expense of a considerable increase in energy consumption.

Specific energy consumption in terms of crude steel production is some 20% higher than in a works which purchases its coke and electricity and produces only coils and plate.

The level of utilization of the productive capacity of numerous steelmaking plants (especially those which operate hot batteries of coke ovens, sinter lines, blast furnaces, converters, reheating furnaces, hot rolling mills and the like) has a very noticeable effect on energy consumption per unit of product. A high volume of production and regular operation of the plant ensure an appreciable reduction in fixed and semi-fixed energy consumption.

This applies to a greater or lesser extent to all the individual plants mentioned above. Level of utilization also affects the overall specific energy consumption of the works as a whole. The following graph (Fig. 18) plots specific energy consumption against monthly crude steel production in an integrated steelworks with a capacity of 8 - 10 million tonnes of crude steel a year.

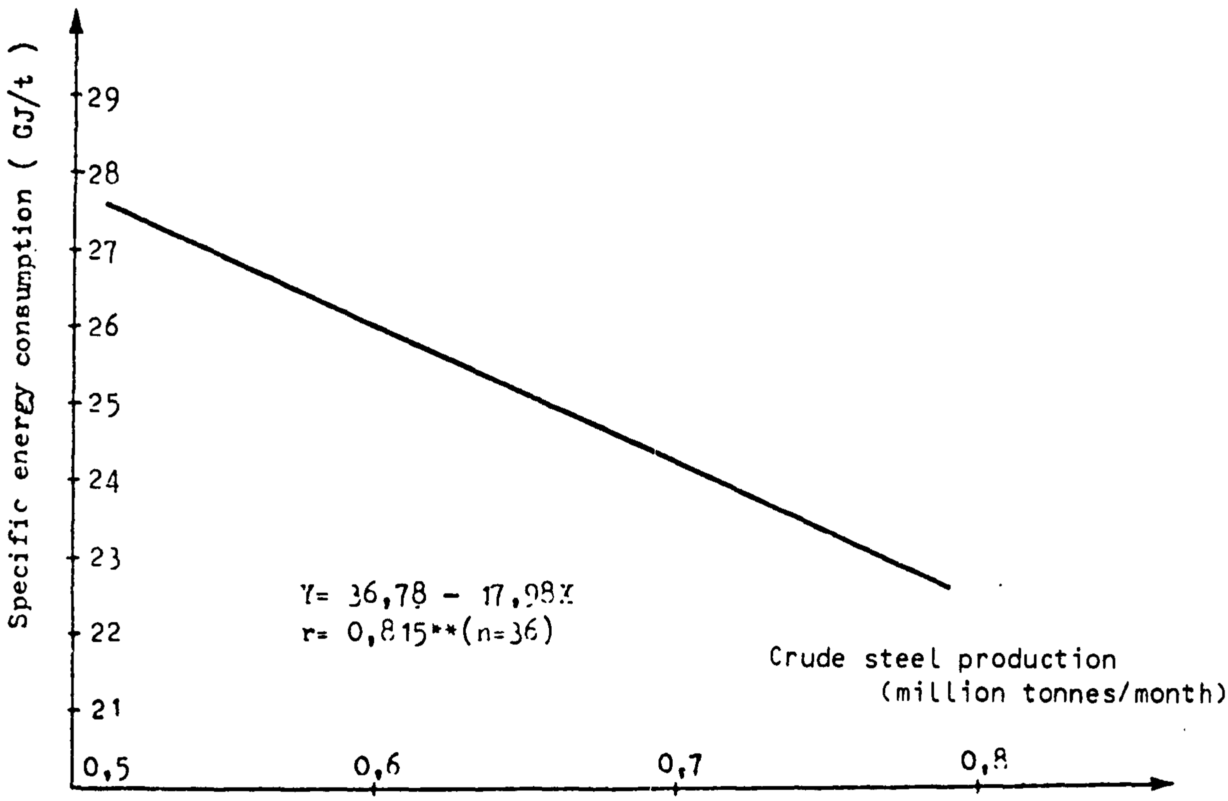


Fig. 18 Correlation between specific energy consumption and monthly crude steel production in an integrated steelworks.

The following graph, Fig. 19 shows a 10% drop in steel production - e.g. from 800 000 to 720 000 tonnes a month results in an increase in specific energy consumption of about 6%.

This marked "volume effect" can be attributed not only to the fixed and semi-fixed energy consumption of the works (general services), heating, transport, pollution control, etc.) but chiefly, as we have seen above, to the fact that most works are affected to a greater or lesser extent not only by the level of utilization of production capacity but also by the volume of production (scale effect).

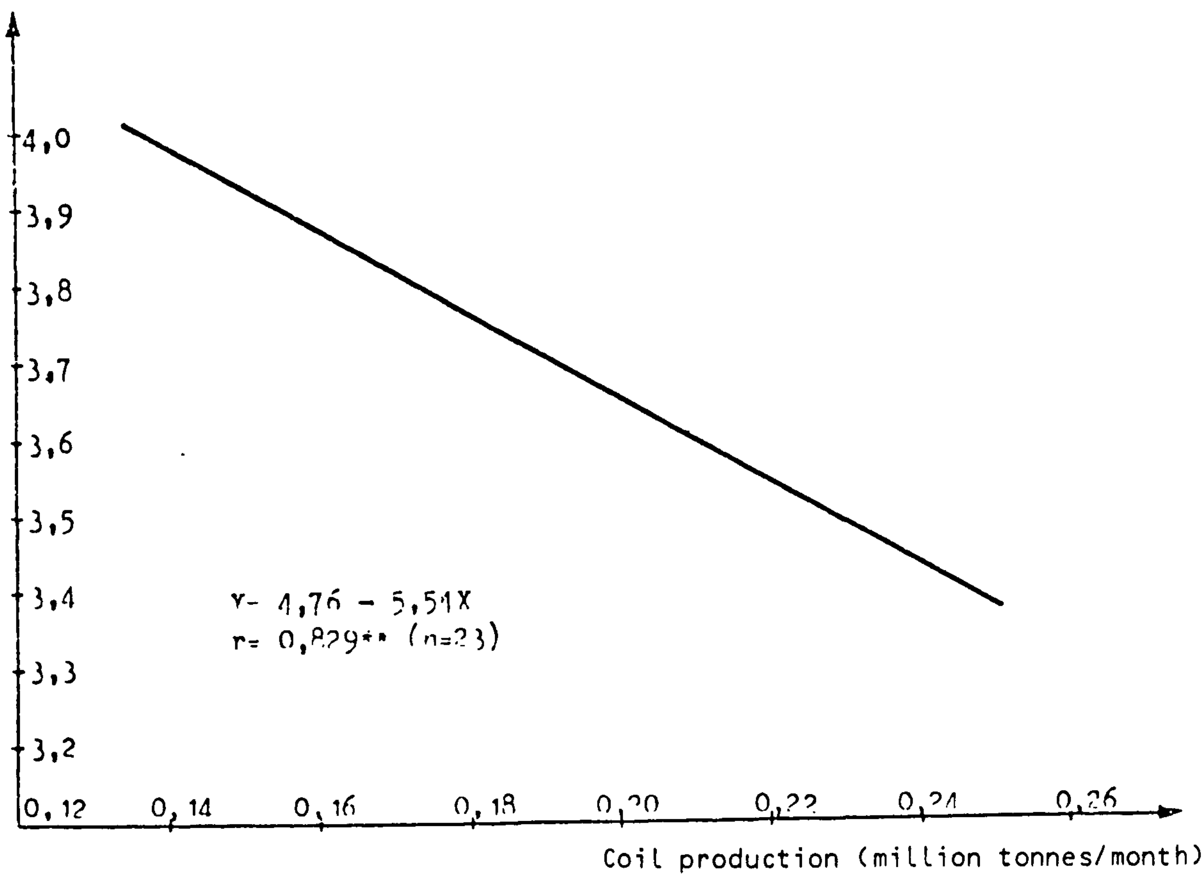


Fig. 19 Correlation between energy consumption of a hot strip mill and monthly coil production

Here again, other things being equal, a 10% decrease in utilization results in an increase in specific energy consumption (per tonne of coils) of about 4%.

In times of crisis, as at present, the close correlation between specific energy consumption in steelmaking (especially in an integrated steelworks) and the volume of production or rather the level of utilization of the plants, is a particularly serious problem. There are three ways of helping to overcome this problem:

(i) minimizing stoppages as a result of waiting for materials, accidents, breakdowns and strikes while plants are in operation.

(ii) As far as technologically possible, planning to run plants to ensure a high level of utilization, interspersed with longer stoppages when furnaces can be shut down and motors switched off.

(iii) Pursuing a systematic policy of reducing fixed and semi-fixed energy consumption.

C.2 WAYS OF SAVING ENERGY IN STEELMAKING

Some of the measures whereby energy can be saved in individual steelmaking plants and processes are particularly important because of the amount of energy they save, although they generally involve considerable investment.

We have drawn up a profile for each of these measures, giving a brief description of the measure and evaluating its energy saving potential.

The following section considers a number of other ways of saving energy, and Table 10, pages 107, 108, 109 and 109a summarizes and attempts to classify the various measures outlined, indicating the advantages and feasibility of each.

PROFILES

1. RECOVERING ENERGY FROM COKE QUENCHING

Brief description

Once distillation is complete, coke is discharged from the ovens at a temperature in excess of 1 000°C. To prevent the coke from burning in the air, it is rapidly cooled by sprays of water. Most of the sensible heat is thus lost into the atmosphere, in the form of large quantities of steam.

Recently, in order to save energy, to reduce pollution and to overcome the problems of operating in particularly cold climates, plants have been designed and built in which the coke is cooled by an inert gas which extract heat from the coke and uses it to produce steam in special boilers or to preheat the coal used to the ovens.

The steam thus produced may have a high heat content and can be used either to generate electricity using turbogenerators or as process steam for industrial purposes.

Apart from recovering large quantities of energy which would otherwise be wasted,this process improves the quality of the coke and eliminates a source of atmospheric pollution.

Evaluation

The sensible heat of incandescent coke, which accounts for about half the heat supplied to the coal for distillation, amounts to about 1 500 MJ/tonne of coke. The most modern dry quenching plants are capable of recovering slightly more than 80% of this heat, so the heat that can be used to generate steam should amount to around 1 200 MJ per tonne of unscreened coke.

The amount of steam that can be obtained this way accounts for a large proportion (over 70%) of the total required by an integrated steelworks and will thus govern the size of the power plant.

This project requires substantial investment but results in the recovery of considerable quantities of energy.

2. RECOVERING SENSIBLE HEAT FROM BLAST FURNACE STOVE (COWPER) GASES

Brief description

Blast furnace stoves heat the air blast to temperatures of around 1000 - 2000°C by burning enriched blast-furnace gas (rated at about 4.2 - 4.6 MJ/m^3), the products of combustion being discharged at a temperature of around 300 - 350°C. Thus the flue gases discharge into the atmosphere some 18-20% of the heat developed during combustion. A large proportion of this lost heat can be readily and cheaply recovered and used to pre-heat the fuel gas and the air blast.

The most modern recovery plants consist of heat exchangers in which the hot gases yield up their heat to an intermediate fluid (water at 30 bar pressure or diathermic oil) which in turn yields it to the fuel gas and the air blast. The temperature at which the flue gases are discharged can be lowered to 160°.

Evaluation

The amount of sensible heat in flue gases at 300°C is around 380-400 MJ/tonne of pig iron. By lowering the temperature at which the products of combustion are discharged to 160°C, there is a 50% reduction in heat loss, thus the recovery is in the region of 190 - 200 MJ/tonne of pig iron. Making a 10% allowance for heat losses in the plant and for the energy used to circulate the intermediate fluid (1 - 1.2 kWh/tonne of pig iron), net recovery is in the order of 170 - 180 MJ/tonne of pig iron.

Plants for the recovery of sensible heat from blast furnace stove gases have already been constructed or designed for various blast furnaces, especially in Japan.

This project requires substantial investment, but results in the recovery of considerable quantities of energy.

3. RECOVERING BACK-PRESSURE ENERGY AT THE TOP OF THE BLAST FURNACE

Brief description

One method of increasing blast-furnace production introduced in the last ten years has been to increase air pressure inside the furnace. This requires a considerable energy input to compress the air, to overcome friction inside the furnace and partly because some of the energy is dispersed in the downstream plants before entering the gas network for use as fuel.

Recently, with the soaring cost of energy, various reliable turbo-generators have been developed to recover a fair proportion of the energy used by the blowers.

Evaluation

The amount of energy that can be recovered depends on a variety of factors, the most important being top-gas pressure and the quantity of gas produced per tonne of pig iron; Fig. 20 shows recovery potential. This system of top gas energy recovery is very widespread in Japan where the quantity recovered amounts on average to one third of that spent on blowing.

This project requires substantial investment but results in the recovery of considerable quantities of energy.

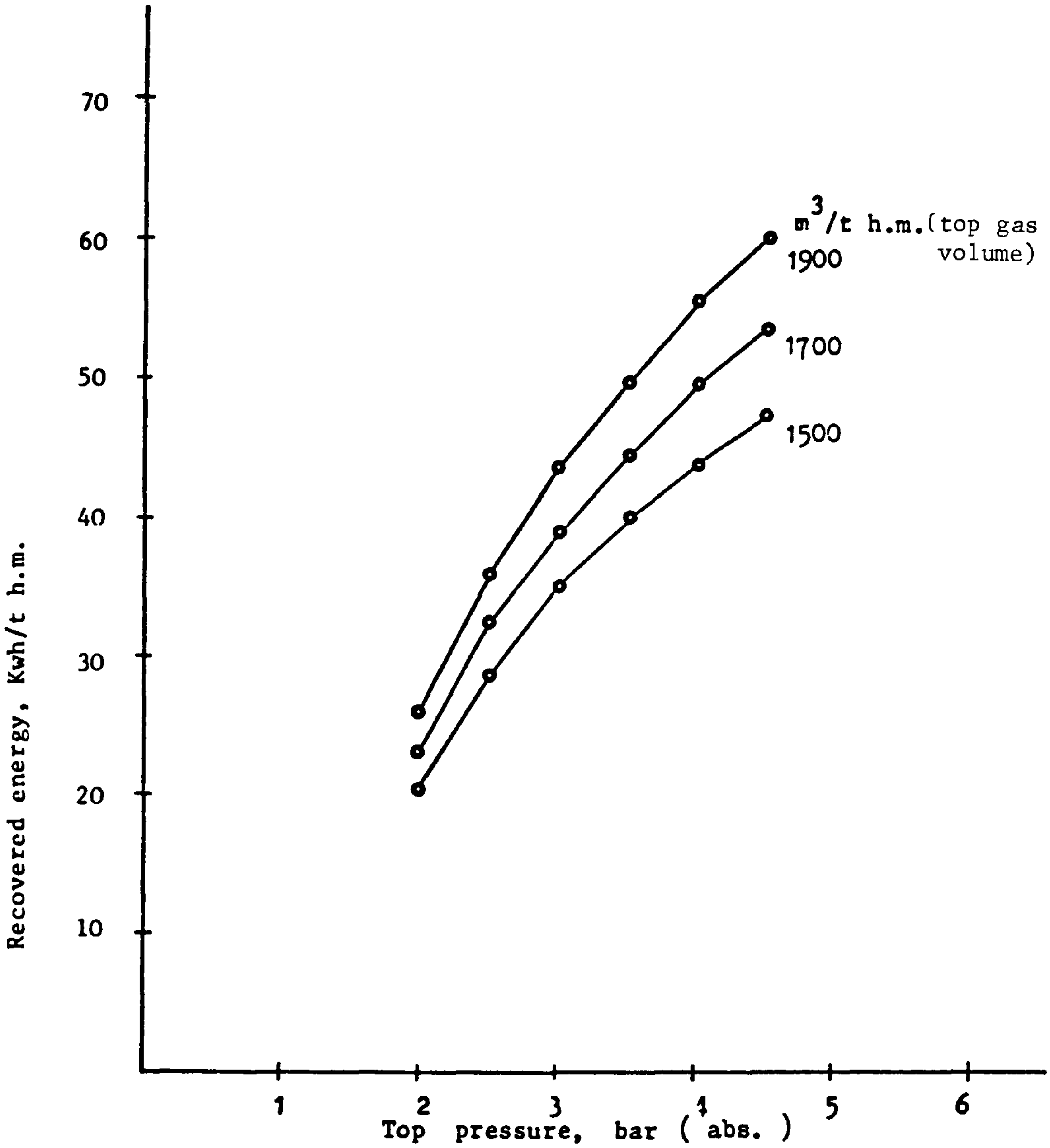


Fig.20 Energy recovery as a function of blast furnace top pressure

4. RECOVERING ENERGY FROM OXYGEN CONVERTER GASES

Brief description

Gas generated in the converter while oxygen is being injected consists mainly of carbon monoxide, and a small amount of carbon dioxide. During the first three minutes of injection, the carbon monoxide content rises to about 65%. It then reaches some 75%, after which, during the last minute, it falls below these levels. Apart from the gas generated at the beginning and end of the injection process which consists of oxygen and only a small amount of carbon monoxide, the quantity of gas generated varies between 90 and 95 m^3/tonne of steel, depending on the percentage of pig iron in the charge (between 75% and 85%). Its temperature is around 1500°C.

The gas from the converter contains a large quantity of energy in the form of sensible and latent heat, recovery of which is possible and worthwhile. At the present time, there are two recovery processes in industrial use:

1) Processes which recover all the heat from the gas by total combustion and the production of steam. The gases pass through the boiler installed above the converter before being sent for cooling and dust-removal. Production amounts to 220-160kg of steam per tonne of steel, depending on the type of unit (full-boiler which discharges spent gases at about 500°C; half-boiler which discharges them at about 1000°C).

2) Processes which recover only the latent heat. This involves cooling the gases, removing the dust and passing them into the distribution network for use as fuel (8.35 MJ/m^3). In view of their high CO content, these gases may also be used for chemical purposes.

Since these are batch processes, there have to be adequate storage facilities (steam accumulators in the first case and a gasometer in the second).

Evaluation

The total energy of the gas at the top of the converter can be estimated at around 1000 MJ/tonnes of steel (230 as sensible heat and 770 as latent heat). The quantities of energy which can be recovered with available technology are :

Process (1) 520-710 MJ/tonne of steel depending on type of recovery unit used.

Process (2) 670 MJ/tonne of steel.

Both versions of the project require a substantial investment but result in the recovery of considerable quantities of energy.

5. DIRECT ROLLING

Brief description

Direct rolling consist in making the output of the roughing mill directly into the finished product, thus avoiding any intermediate cooling and subsequent reheating.

Direct rolling the finished product can be done by utilizing the sensible heat still in the slab at the end of the roughing stage.

From the organizational point of view, direct rolling involves a number of problems, since it imposes planning constraints in respect of the roughing mill and the finishing mill.

Direct rolling also results in awkward metallurgical problems. Elimination of the cooling stage makes inspection of the slab difficult and makes it impossible to eliminate surface defects (scarfing). It is thus necessary to evolve practices that minimize the danger of defects, all of which imposes limits on the use of direct rolling.

Manufacturing processes have to be changed to ensure that the temperature in the final stages of rolling does not fall below an acceptable level (withdrawal from soaking pit at higher temperature, a different rolling sequence, a different size of primary-mill product, etc.).

Because of these difficulties, direct rolling cannot be used for all types of work. Indeed, as a rule, it cannot be used for more than 30-40% of the total production of a line.

Evaluation

In theory, direct-rolling should save all the fuel required by the reheating furnaces (1750 MJ/tonne of product). In practice, however, it is not possible to achieve a 100% saving because of increased consumption at the previous heating stage (soaking pits) and discontinuity in the process described. It can be taken that the actual saving is around 1250 MJ/tonne of direct rolled product.

The capital investment needed to convert a plant for direct rolling is generally low, since the roughing and finishing mills are already directly connected by conveyors.

This project requires low investment, but results in the recovery of considerable quantities of energy.

6. RECOVERING HEAT BY HOT CHARGING

Brief description

Before products from the primary mills and continuous casting (slabs, blooms and billets) are sent to the reheating furnaces to be brought up to rolling temperature, they undergo several operations (inspection, scarfing) which involve cooling them, so they lose the sensible heat they had at the end of the manufacturing process.

Studies have been carried out recently to find ways of recovering this heat by feeding the primary mill products into the reheating furnaces while still hot or by rolling them directly. The studies concentrated on two different aspects :

a) developing operational methods which reduce the surface defects of the slabs in order to avoid the need for inspection and scarfing.

b) examining organizational and plant changes which would allow inspection and elimination of defects while products are still hot.

When the primary mill pproducts are fed into the reheating furnaces while still hot, it is also necessary to modify the system of production planning in order to coordinate the production schedules of converters, continuous-casting lines and rolling mills.

With hot-charging, slabs are not in the reheating furnace as long and so produce smaller quantities of scale (iron oxide).

Evaluation

For each tonne of hot-charged slab the fuel saving ranges from 500 to 1200 MJ depending on the charging temperature, the dimensions of the slab and the type of furnace.

The project requires little investment but results in the recovery of considerable quantities of energy.

7. HEATING AIR AND POSSIBLY GASEOUS FUEL USING HEAT EXCHANGERS IN INDUSTRIAL FURNACES

Brief description

The preheating of air and possibly of gaseous fuel prior to combustion offers a number of advantages, all of which result in improved thermal efficiency of the furnace (or of the boiler). It also permits the use of fuel with a low calorific value (e.g. blast-furnace gas) for applications that require high combustion temperatures.

The preheating temperature can be varied according to requirements and the type of preheater. Combustion air for reheating furnaces is preheated using the sensible heat of the gases leaving those same furnaces. The heat exchangers can be either metal or ceramic. With the former, the preheating temperature that can be achieved is lower (500-600°C), while with the latter it is higher (700-800°C). Of particular interest is the effect that preheating the air and the fuel has on the combustion temperature.

Fig. 21 shows the effect of preheating natural gas, and the effect of preheating air and gaseous fuels such as blast-furnace gas mixtures to 400 and 600°C.
It can be seen, for instance, that if blast-furnace gas with a calorific value of less than 3.56 MJ/m^3 is preheated to 600°C and the combustion air is also heated to the same level, this gives a combustion temperature of 1760°C, which is not far off that achieved when natural gas (with a calorific value of less than 31.4 MJ/m^3) is burned in cold air.

Evaluation

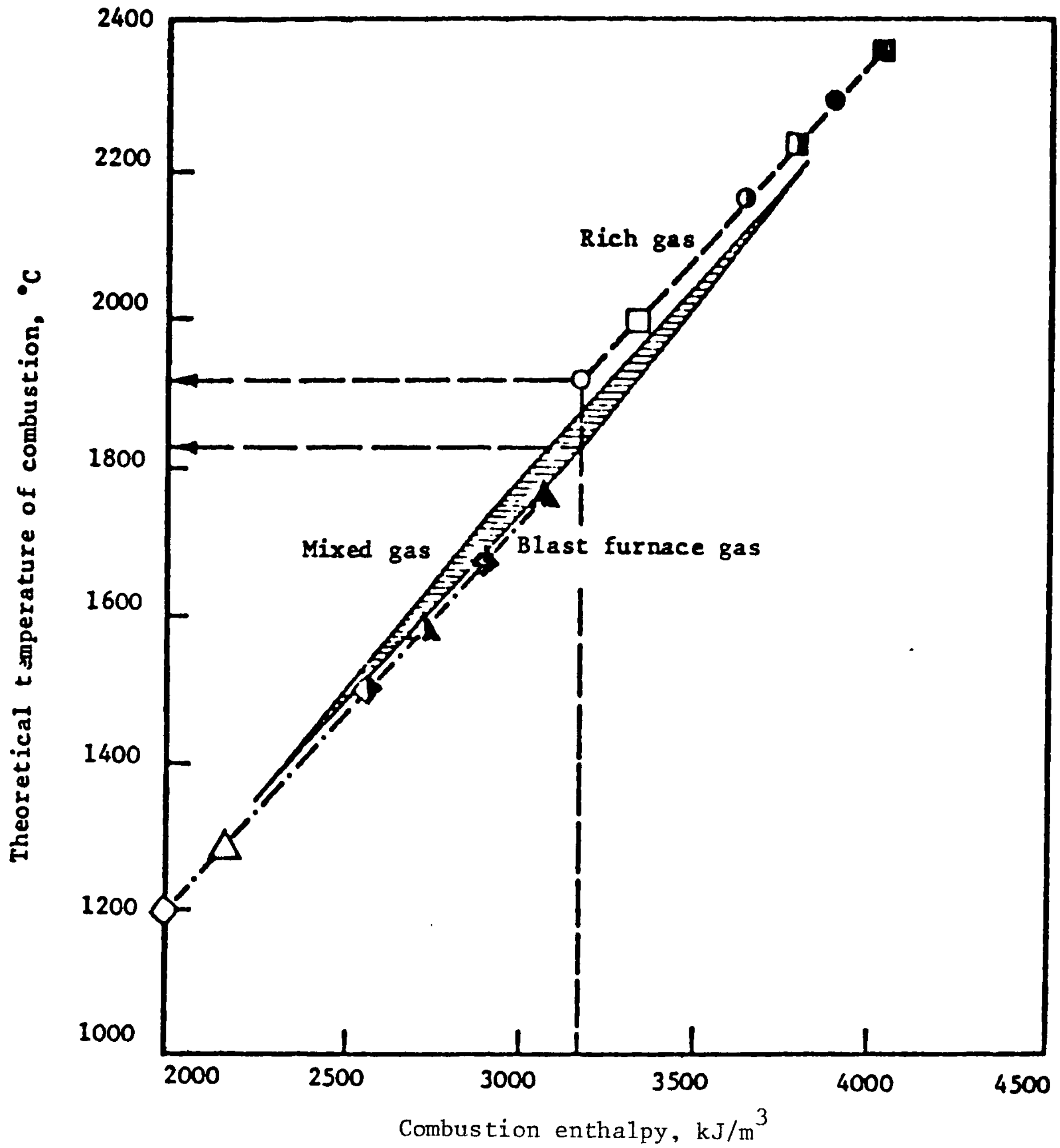
Most modern industrial furnaces have preheating systems, often of the combined type (radiation + convection) which recover most of the sensible heat from the flue gases (over 50%, with a net saving of between 20 and 25%).

In the case of such plants the project requires low investment, but saves a lot of energy.

Installing a new recovery unit in existing heating plant is more costly and not always feasible. In such cases, the project generally requires substantial investment, while the level of energy saving can be high or low, depending on the previous situation.

A high investment, high energy saving variant would be a case involving the installation of a waste-heat boiler for the production of steam or hot water in series with the preheating system. The energy saving can be estimated at between 10 and 15%.

Fig. 21 - Enthalpy and temperature of the combustion gases as a funtion of gas type and preheating (combustion with air)
(Source : Stahl und Eisen Nr. 4 1978)



	Heating Value kJ/m3	Preheating of	Temperature °C 20	400	600
Natural gas Coke-oven gas	31217 17689	Air	○ □	◑ ◨	● ■
Mixed gas	4187 to 8374	Gas + Air	(hatched)		
Blast-furnace gas I Blast-furnace gas II	3140 3560		◇ △	◈ ◭	◆ ▲

8. PREHEATING ELECTRIC ARC FURNACE SCRAP OR DRI CHARGE

Brief description

The scrap or DRI charged into the electric arc furnace can be preheated, in a number of ways, in order to save some of the electricity needed at the electrodes and to improve productivity. The preheating can be done by burning fuel - which may be recovered fuel - or by harnessing the heat in the gas leaving the furnace. A third possibility is to recover the sensible heat from the semi-finished products.

a) Burning fuel

The scrap is preheated to 300-400°C using blast-furnace gas, coke-oven gas or natural gas. This operation is performed in batches in special containers (refractory clad if the preheating temperature makes this necessary). The advantages are : saving of electricity, shorter smelting times and reduced electrode consumption. Preheating is limited only by the risk that the scrap may become stuck together.

b) Recovery of sensible heat from furnace gas

Preheating can be done in batches or on a continuous basis. The latter appears to be the more attractive alternative, although it is possible only if there is a continuous furnace charging system and if the scrap is the right size for treatment. The preheating takes place in a rotary drum where the hot gases, with perhaps some additional fuel, flow in the opposite direction to the scrap. Several Japanese steelworks preheat scrap in batches to 300°C using exit gases (from the furnace).

c) Recovery of sensible heat from semi-finished products

If the layout of the works permits and if no provision is made for recovering heat from semi-finished products in other ways (hot charging, waste-heat boiler, etc.), it may be practical to use this sensible heat to preheat the scrap.

The operation is carried out in batches by using supports to hold baskets of scrap above or next to the hot semi-finished products. It is possible to preheat the scrap to a temperature of 200 - 300°C without using any fuel.

Evaluation

a) Burning fuel

Preheating scrap to 300°C in batches using coke-oven gas can yield an overall energy saving of around 1kg/tonne of steel and shorter smelting times have also to be taken into account.

b) Recovery of sensible heat from furnace gas

By continuous preheating to 1000°C using electric furnace gas and additional fuel (natural gas) total net energy savings of around 13% can be achieved. There are obviously also advantages in respect of electrode consumption and smelting times. Preheating to 300°C in batches can save 30 - 50 kWh per tonne of steel.

c) Recovery of sensible heat from semi-finished products

The amount of energy saved depends, of course, on the temperature to which the scrap can be raised and the continuity of the heating operation (heating all or only some of the baskets). Estimated energy saving ranges from 10 to 15%.

Version a) of the project requires little investment but provides only limited energy recovery. Versions b) and c), on the other hand, involve major plant modifications and thus require substantial investment but result in the saving of considerable quantities of energy.

OTHER WAYS OF SAVING ENERGY

Sintering

a) Heating the sinter blend using low calorific value gaseous fuels to save coke breeze

In modern plants the sinter blend is heated partly by gaseous fuels which burn in hoods set over the grate. Thus, less valuable fuels, generally mixtures of blast-furnace gas and coke-oven gas, are used to save solid fuel, usually coke breeze. There is also a saving in absolute terms, because of the greater efficiency of outside heating (more uniform temperature and lower losses to the outside).

The heat introduced through outside heating can amount to some 25% of the total heat obtained through burning gas. The absolute saving of heat in the sinter process is around 6 to 8% or around 120 MJ/tonne of useful sinter. The saving in coke breeze amounts to around 10%.

This technique is now being incorporated in new works. Some recent Japanese plants have 20 to 25 m of heating hood, for a total grate length of around 120 m (600 m^2).

b) Increasing the use of basic sinter

In the model integrated steelworks it is assumed that the ferrous burden of the blast-furnace consists of 80 parts sinter and 20 parts pellets, i.e. the whole burden consists of sintered ores.

Basicity (CaO/SiO_2) is around 1.6, which means a good combination of properties (cold mechanical strength, reducibility, permeability to high-temperature gas flow and softening range).

The advantage of using larger quantities of sinter in the burden is shown by the following example : starting with a reference burden consisting of about 80% sintered material, a 10% increase in the sinter content results in a saving of 5 to 10 kg of coke/tonne pig iron, which is equivalent to 150 to 300 MJ/tonne. Although of course, energy is needed to produce this larger amount of sinter and less blast-furnace gas will be recovered, due consideration must also be given to the difference in the quality of the fuels involved (blast-furnace coke as against coke breeze or other fuels such as coal or blast-furnace gas); and there is the added advantage of higher productivity from the blast furnace (1.7 to 3%).

c) Recovering sensible heat from sinter

Sinter is normally discharged from the strand at a temperature of around 750°C and is then sent to a cooler, where the sensible heat - estimated at around 750 MJ/tonne - is lost to the atmosphere.

Some of this sensible heat could, however, be recovered.

1. by using some of the recycled cooling air at 300- 350°C as combustion air for the sinter ignition and heating furnace. This would enable about 140 MJ/tonne of energy to be saved in the form of lower fuel consumption (coke breeze and gas mixture).

2. by generating steam or electricity using organic fluid turbo-generators, the heat content of the cooling air being used in boilers or heat exchangers. The amount of recovered steam (at 14 bar, 270°C) can range between 200 and 400 MJ/tonne of sinter.

Heat recovery systems of this kind are already being used by Japanese steelmakers, and some EEC steelmakers have them at the design stage.

Blast Furnace

a) Improving burden charging and distribution techniques. Modifying tops of blast furnaces

Consumption of coke or hydrocarbons can be reduced by improving the distribution of gas flow through the blast-furnace burden to give more uniform radial distribution of gas flow and of ferrous materials, care being taken to ensure a higher gas flow at the centre in order not to overstress the refractory lining and to make maximum use of the reducing gases.

This result is achieved by installing at the top of the blast furnace movable plates or rotating channels which allow the distribution of the solid burden to be regulated. The installation of probes at the top of the blast furnace, in the shaft and in other parts to measure distribution of temperature, pressure, etc., is also highly beneficial, and the use of mathematical models is very useful too.

Application of these techniques reduces coke consumption by 10-20 kg/tonne of pig iron, equivalent to 300-600 MJ/tonne.

b) Recovering sensible heat from blast furnace slag

When slag is separated from the pig iron on leaving the blast furnace, its temperature is about 1500°C, which means that it possesses a large quantity of sensible heat. At present this heat is not being recovered, whether the slag is crushed or dumped.

It is reported that the Japanese steel industry has recently studied and designed plants for using the sensible heat from slag to produce steam, which can readily be used in the works, either in other processes or for the generation of electricity. Steam is produced either by using panels through which water is circulating to absorb the heat radiating from the surface of the liquid slag at 1400-1000°C, or by transferring the heat to an intermediate fluid (air) which then passes through the boiler.

Some such plants are now in the construction or testing stage, but there are as yet no reliable data on the operating results. According to the design forecasts, energy recovery should be around 300 MJ/per tonne of pig iron, which is over half the sensible heat of the slag.

It should also be added that the sensible heat of steelworks slag can be recovered via the dry crushing plant.

Oxygen Steelworks - Continuous Casting

a) Optimizing the silicon content of pig iron

Increasing the silicon content of the pig iron results in a higher energy input at the converter stage from the oxidation reactions. Every additional 31.8 MJ of heat, which enables a larger quantity of scrap to be heated and melted (1.35 MJ/kg of scrap). It is thus possible to increase the scrap fraction of the charge and reduce the amount of pig iron. This results in an energy saving as a result of the smaller quantity of iron needed to produce the same quantity of steel.

For example, because of the sensible heat of the iron and the latent heat of the silicon, an 820 kg charge of iron with 0.7% Si as opposed to an 830 kg charge of iron with 0.6% Si provides the converter with additional quantities of energy virtually equivalent to that required to heat and melt the 10kg of scrap necessary to compensate for the 10 kg less of iron.

However, optimizing the Si content of pig iron is not as simple as may appear from the example given. Each case has to be considered separately, taking account not only of the marginal effects in the steelworks (on fluxes or oxygen) and in the blast furnace (on fuel, recovered gas, slag, etc.) but also of the availibility of scrap and the effects on the saturation and productivity of the plants concerned.

b) Charging the converter with pig iron at higher temperatures

It is obviously advantageous from the energy point of view to conserve as much as possible of the sensible heat of the pig iron which is to be refined. The greater the amount of heat that can be retained, the greater the quantity of scrap that can be charged. The advantages can be evaluated along the lines of the previous example : if 830 kg of pig iron is charged at 1510°C instead of 1500°C, an additional 7.43 MJ is available to the converter; this is sufficient to heat and melt about 5 kg of scrap.

c) Increasing the proportion of continuously-cast steel

The advantages of increasing the fraction of continuously cast steel in an integrated works are as follows :

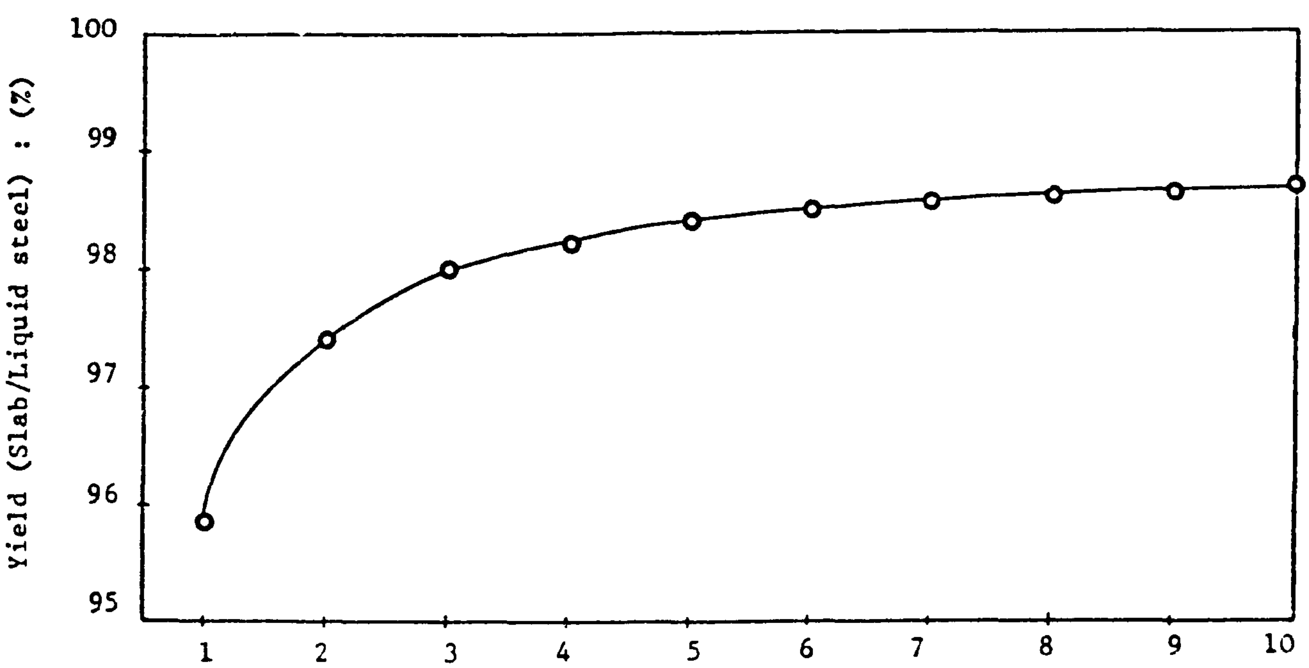
1. it increases the yield of liquid steel as an end product, so that a smaller quantity of liquid steel will suffice for a given end product. The production of one tonne of continuously cast slab requires 1020 kg liquid steel, while the production of one tonne of slab from ingot through the soaking pit and roughing mill requires 1160 kg liquid steel (see materials and product flowsheet of model plant).

2. it saves energy by eliminating the ingot heating, rolling and scarfing operations. Transformation from liquid steel slabs requires 482 MJ/tonne of slab, while transformation of ingot to slab requires 1245 MJ/tonne of slab (see model plant energy balance).

Because of the improved yield, as described in (1), it is possible to utilize som 13.7 % less liquid steel, pig iron, sinter and coke while achieving a substantial energy saving) for the same quantity of end - products - or if the plant so permits - to increase the output of end products while continuing to produce the same quantity of liquid steel. In both cases there remains the fact that - still with reference to the model plant data - one tonne of slab produced by the convertional cycle requires a total of 19.320 MJ, while the same tonne of slab produced by continuous casting requires 16.368 MJ. The difference of about 2.950 MJ is made up as follows : 2180 MJ because of the different yields of the two cycles and 770 because of the different energy needs.

d) Improving the yield from continuous casting

A factor which very much affects the yield from continuous casting is the number of continuous casting heats, as can be seen from the following graph taken from "A technological study on energy in the steel industry" by the IISI (see Fig. 21b).



Number of continuous continuous casting heats

Fig. 21b - Relationship between number of continuous continuous casting heats and metal yield

The figure shows that on passing from 3 to 6 heats per sequence the yield rises from 0.98 to 0.985 which means that the liquid steel needed per tonne of slab falls from 1020 to 1015 kg, thus saving 5 kg per tonne of slab. In energy terms this saving is equivalent to 77 MJ per tonne of slab, which is the energy needed to produce 5 kg of liquid steel.

e) Post-combustion of carbon monoxide in the oxygen converter

Because of the need to try to recover energy and to make converter charging more flexible, trials have been run to ascertain the possibility of increasing the amount of scrap in the charge, irrespective of the pig iron composition by post-combustion of carbon monoxide inside the converter itself.

This practice, which involves the injection of oxygen through the tuyeres, which have been correctly orientated in the upper part of the converter, ensures that energy recovery occurs under the best conditions, namely :

- at the point of formation (inside the converter);
- when the gas is at a high temperature, hence saving most heat.

The advantages are as follows :

- energy recovered without the need for complex and costly plant;
- the steelworks is not so dependent on the blast furnace being in operation and can adapt more easily to changing conditions on the steel and scrap markets.

Rolling

a) Minimizing track time

Track time is the time which elapses after the casting of the ingot in the mould until it is put in the soaking pit. Obviously, the shorter this time, the greater the sensible heat of the ingot when it enters the soaking pit, and the lower the fuel consumption needed to raise it to rolling temperature.

However, there are metallurgical and operational considerations which limit the extent to which track-time can be reduced. In fact, the ingot has to attain a certain degree of solidification before it can be stripped, and this means that there must be a minimum cooling time, depending on the quality of the steel, the size of the ingot and handling requirements.

The fuel saving that can be achieved by reducing track time depends on the quality of the steel and the size of the ingot : for 15-20 tonne ingots this saving ranges from 100 to 200 MJ tonne of ingot per hour of track time.

There are basically two ways of reducing track time, namely:

1. by carrying out a critical review of operating practices to determine whether a lower degree of ingot solidification would be acceptable for stripping. In some cases solidification at stripping has been reduced from 80 to 50%, with a reduction in track time of up to 30 minutes.

2. studying the transport and feed cycle in order to minimize the time required and especially to identify the organizational changes which could be made to eliminate the causes of delay in feeding, compared with a standard minimum track time.

b) Improving combustion in the soaking pits

Improving combustion entails achieving the optimum air fuel ratio so as to obtain maximum flame temperature. This can be done either by first establishing ratios for the various stages of reheating or by monitoring the oxygen content of the gases after combustion. In this connection it is useful to recall that the zirconium-cell continuous analysers which have been marketed recently, work extremely well and can be connected to microcomputers to create control systems.

The best air fuel ratio can be defined as follows :

1. during the temperature-rise stage, the air fuel ratio which gives the maximum furnace temperature gradient when operating at constant fuel flow, or the air fuel ratio which gives the minimum fuel flow gradient when operating at a constant temperature gradient.

2. during the soaking period, the air fuel ratio which gives the maximum downward fuel flow gradient.

The fuel saving that can be achieved by maintaining proper control over combustion is estimated at around 80 MJ/per tonne slab fed to the soaking pits.

Advantages as regards combustion can also be obtained by using a short-flame internal mixing burner that gives a better distribution of temperature in the soaking pit.

c) "Inverted L" reheating in soaking pits

The ordinary practice of reheating ingots in soaking pits initially involves burning a large quantity of fuel for a short period of time and then less and less as the pit temperature first rises and then stabilizes at higher levels (about 1300°C). The temperature of the surface and outer layers of the ingot steadily increases while at the same time the core temperature is decreasing. The surface temperature decreases somewhat in the time between removal of the slab from the pit and rolling.

The "inverted L" reheating method takes advantage of the heat contained in the core of the ingot, which may not yet be completely solidified (e.g. the degree of solidification may be between 70 and 80%). Thus to begin with the ingot is heated using a smaller quantity of fuel, after which the fuel flow rate is increased for a short final period to raise the surface temperature of the ingot to compensate for the drop during the rolling stage.

This method has already been adopted by various Japanese and European works. It has the following advantages :

- track-time can be shortened slightly (e.g. by ten minutes)

- it takes a slightly shorter time in the soaking pit for the ingot to solidify completely (about ten minutes)

- less scale is formed (some 0.1% less).

On the other hand the disadvantages are :

- a larger portion of the surface has to be conditioned to eliminate surface defects;
- higher electricity consumption in the subsequent roughing stage (some 1 kWh/tonne).

The fuel saving obtained with this method varies according to the quality of the steel and the size of the ingot. For instance, with rimmed steel, the saving is around 100 MJ/per tonne fed to the soaking pit.

d) Optimizing temperature distribution in reheating furnaces

The materials to be rolled (blooms, slabs and billets) can be heated according to the specific furnace temperatures and fuel flows considered to be most advantageous or according to temperature models specified for the material in the different parts of the furnace (which can be varied during the course of operations, in the event of slowdowns, hold-ups, etc.). This is done by continuously measuring the temperatures and using a computer to adjust the rate of advance of the materials. This practice yields fuel savings in the order of 5% of total consumption or 60 MJ/per tonne fed to the reheating furnaces.

e) Improving the insulation of soaking pits and reheating furnaces

Lining reheating furnaces and soaking pits with ceramic fibre refractory material saves energy because of the improved thermal insulation and because, in the case of batch processes, the low heat capacity of the ceramic fibres enables heating and cooling cycles to be shortened. For instance, if ceramic fibre insulating material is installed behind the refractories in a 240 tonne/hour reheating furnace, this increases the thickness of insulation by 50%. This yields a fuel saving of 1.5%, which is equivalent to 25 MJ/per tonne fed to the pits or furnaces.

f) Recovering heat from reheating furnace guides with steam production

Some parts of reheating furnaces can be cooled and useful heat recovered. Instead of cooling the slide guides by circulating water, which means no heat is recovered,(at best, heat dispersal can be reduced by cladding with insulating material) it is better to cool them by water evaporation, which is also less costly as regards capital investment.

In a 100 tonne/hour pusher furnace, for instance, where the evaporation cooling system is used for the guides, the support girders, the bearings, the turn-over device and the beams of the suspended roof, the feed water is preheated using the exhaust gases from the heat exchanger and the steam produced is superheated by the same exhaust gases to 350°C (34 bar). Heat recovery amounts to around 300 MJ/per tonne fed to the furnace.

g) Recovering sensible heat from slabs using a waste heat boiler

The sensible heat from new slabs straight from the continuous casting line or the roughing mill is usually dispersed into the atmosphere by air cooling or by water sprays so they can be inspected cold and scarfed if necessary.

Whenever it is impossible to use this sensible heat by "hot charging" (see chart), it may be worth recovering it for the production of steam or hot water. In this case, heat is recovered by passing the hot slab (at about 1000°C) close to tubes or panels through which water is being circulated so as to collect the thermal energy dispersed. There are reports of a plant built in a Japanese steelworks where the quantity of heat recovered in the form of saturated steam at 16 bar amounts to 300 MJ/per tonne of slab. The steam is fed into the works network.

h) Preheating or reheating furnace charges using the "jet process"

Much of the heat loss from a reheating furnace (about half) is carried away by the products of combustion. To reduce heat consumption it is thus necessary to reduce the amount of energy lost in the flue gases. This can be done in two ways :

1) by recovering as much of the heat content of gases as possible at the outlet (with heat exchangers for preheating combustion air and gaseous fuel and waste heat boilers);

2) by reducing the energy content of the gases before they reach the outlet (controlling combustion, optimizing reheating processes, improving tranfer of heat from gases to slab).

To improve the transmission of heat from gases to the slab without the furnace having to be excessively large, two leading Japanese steelmakers have designed and installed "gas jet preheating equipment". This entails the addition of a preheating zone upstream of the furnace where the cold slab passes through jets of hot gases which can be regulated and directed so as to ensure a high rate of heat exchange with the slab.

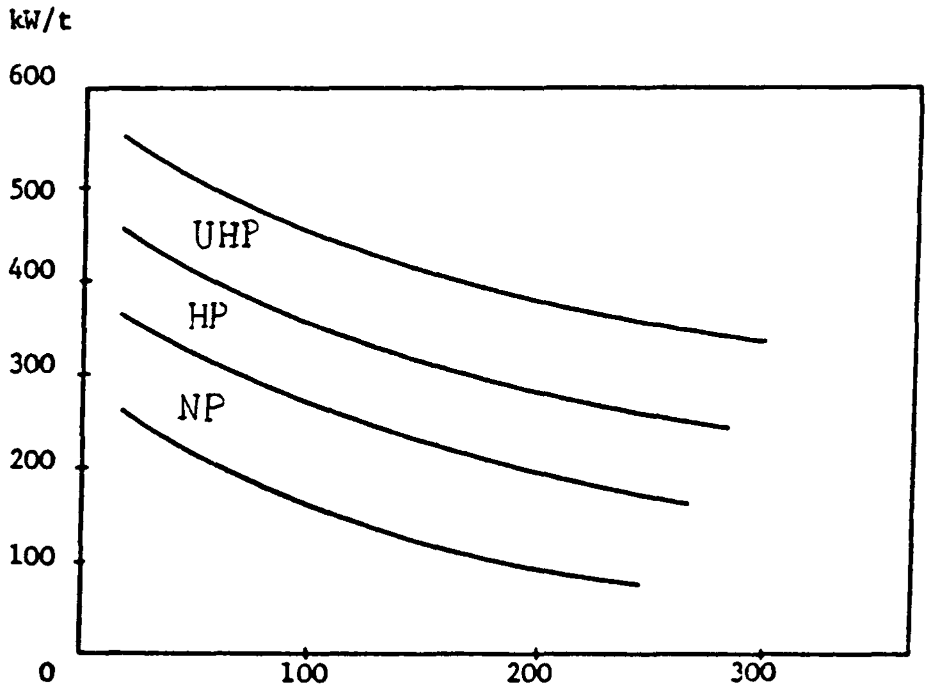
By using the preheating system described, a reheating furnace in a Japanese plant has obtained specific consumption levels, of around 1200 MJ/per tonne of slab - a saving of some 15% compared with a conventional furnace.

Electric steelworks

a) Extending the use of the UHP technique

The UHP (Ultra High Power) technique speeds up the melting of the arc furnace charge by using much more electric power than with other techniques (HP and NP) and less power than was widely used previously. The UHP technique enables heat to be transferred more rapidly and more efficiently to the charge with smaller heat losses and at the same time saving energy (even though electrical efficiency decreases somewhat because of the lower power factor). Cast-to-cast time (i.e. time between heats) is reduced and so productivity is increased. There is an additional advantage when these furnaces are operated mainly as melting furnaces, as the operations required for completing the refining, alloying and degassing processes are performed later outside the furnace.

Fig. 22 shows (specific) maximum power per tonne of charge during melting (expressed in kW/t).



Pig iron capacity of furnace in tonnes

UHP = Ultra High Power HP = High Power NP = Normal Power

Fig. 22 - Range of specific power levels for electric arc furnace

The specific power selected for the 160 tonne furnace envisaged in the model electric steelworks is 450 kW/per tonne. With this order of magnitude, a decrease of 100 kW/tonne results in an increase in specific consumption of 35 kWh per tonne of liquid steel. Of course, this applies only if other factors remain unchanged.

b) Using oxy-fuel burners

During the melting stage, oxy-fuel burners can be used as an auxiliary source of heat to save large quantities of electricity. In the case of fuel burnt with oxygen, there are limits to the quantity of auxiliary energy that can be used,because of the risk that iron will be lost through oxidation of the charge, and also because of the high cost of oxygen. In general, between 6 and 11 kg fuel oil is used for each tonne of steel. After taking into account the energy needed to produce the oxygen, 1 kWh can be replaced by 7.5 MJ.

Heating efficiency using oxy-fuel burners varies depending on the temperature reached by the charge and decreases as the temperature increases (a thermal efficiency of 60% is obtained at around 700°C).

An additional advantage of oxy-fuel burners is the reduction in time between heats, which results in improved productivity.

A recent trend is to reduce the use of hydrocarbons by injecting more oxygen and fine coal at the end of the melting stage. Modern plants have three burners per furnace, each finely regulated.

c) Recovering heat from the water used to cool the electric furnace walls and roof

In the latest high-powered electric arc furnaces, the walls and roof are cooled by water panels. Though this technique is justified because of the refractory saving, it results in slightly higher electricity consumption (about 10 kWh/tonne), although it also makes it possible to recover a large proportion of the energy required by the process. Considering also the water used to cool the exhaust gas flues, it is possible to recover the equivalent of 170 kWh/per tonne in the form of hot water or low-temperature steam that can be used for space heating, district heating or any other purpose where a moderate temperature will suffice.

d) Monitoring and controlling the electric steelmaking process: potential for automation

Process control here means the whole range of measurements and adjustments aimed chiefly at regulating electric power at the various stages of the process, both to ensure lower consumption and to reduce thermal and mechanical stress on the refractory lining. The control programmes are based on predetermined specific consumption figures and measurements made during furnace operation.

There is potential for automating :

1) process management (optimizing the charge, optimizing alloying costs, optimizing management of the power supply contract, optimizing production schedules, etc.)

2) furnace operation control (electrical measurements, measurement of radiation received by furnace walls, measurement of characteristics of phases present in the furnace, etc.)

3) metallurgical operations control(oxidation of the metal, dephosphorization and desulphurization in oxidising phase, desulphurization in reducing phase, etc.).

All these monitoring, control and automation techniques produce direct and indirect energy benefits (lower consumption, increased productivity) as well as economic benefits which differ according to the quality and extent of their application.

e) Post-refining in separate furnaces

The advantages of dividing the process into two stages - smelting and refining - are a reduction in furnace size, an increase in utilization time, a reduction in the proportion of electricity as a component of the cost of steel, greater potential for using auxiliary fuels in the smelting stage and a reduction in smelting time (a particular advantage with special steels which require longer treatment).

The direct saving in electricity depends on the type of steel being produced, but on average, it is unlikely to be high (in the order of 15 kWh/per tonne of steel).

f) Closing the fourth hole

Collecting fumes via the fourth hole in the roof of the furnace has to some extent at least eliminated the pollution caused by the outflow of gas and dust resulting from the increased power input when HP and UHP techniques are used.

The fourth hole, however, means an increase in the specific consumption of electricity (from 40 to 60 kWh/per tonne of steel) because less pressure develops in the furnace so cold air is drawn in from outside and has to be heated using up valuable process energy.

A system has been developed which prevents pollution without any air being drawn in through the fourth hole. This is now undergoing industrial trials. The system uses a kind of bell to enclose the furnace, insulating it from the external environment. Although final results are not yet available, the trials are encouraging. It should be possible to recover between 40 and 60 kWh/per tonne by eliminating suction through the fourth hole. It will also provide other benefits, such as improved working conditions, less noise, less fumes to be absorbed, etc.

TABLE 10 - Classification of possible energy saving measures on the basis of energy benefits and feasibility

MEASURE	BENEFITS			FEASIBILITY		REMARKS
	Energy saving (fuel)	Energy recovery	Substitute energy source	Technology already available	Technology to be developed	
COKE OVENS						
Energy recovery by dry quenching of coke		1200 MJ/t coke		x		Improves coke quality less pollution
SINTER PLANT						
Heating the sinter blend using low calorific value gaseous fuel to save coke breeze	x 120 MJ/t sinter		x	x		
Increasing the use of basic sinter			x	x		Higher productivity
Recovering sensible heat from sinter	x 140 MJ/t sinter	x 200 - 400 MJ/t sinter		x		
BLAST FURNACE						
Improving burden charging and distribution techniques. Modifying top of blast furnaces	x 300 - 600 MJ/t pig iron		x	x		
Recovering sensible heat from blast furnace		x 300 MJ/t pig iron			x	
Recovering sensible heat from cowper gases		170 - 180 MJ/t pig iron		x		
Recovering back-pressure energy at top of blast furnace		20-40 kWh/t pig iron		x		

MEASURE	BENEFITS: Energy saving (fuel)	BENEFITS: Energy recovery	BENEFITS: Substitute energy source	FEASIBILITY: Technology already available	FEASIBILITY: Technology to be developed	REMARKS
OXYGEN-CONTINUOUS CASTING STEELWORKS						
Optimizing the silicon content of pig iron	x			x		Also makes blast furnace cheap to operate
Charging the converter with pig iron at higher temperatures	x			x		
Increasing the proportion of continuously-cast steel	30 MJ/t of slab per 1 % increase			x		Higher productivity and better yield
Improving the yield from continuous casting (continuous-continuous)	150 MJ/t of slab per 1 % of yield			x		Higher productivity
Post-combustion of CO in oxygen converter	x			x		
Recovering energy from oxygen converter gases	520-710 MJ/t crude steel or 670 MJ/t crude steel			x		Depends on whether all heat content is recovered by combustion, or only latent heat
ROLLING MILL						
Minimizing track time	x 100-200 MJ/t of ingot			x		
Improving combustion in soaking pits	x 80 MJ/t of ingot			x		
Optimizing temperature distribution in reheating furnaces	x 60 MJ/t of semis			x		

MEASURE	BENEFITS			FEASIBILITY		REMARKS
	Energy saving (fuel)	Energy recovery	Substitute energy source	Technology already available	Technology to be developed	
Improving the insulation of soaking pits and reheating furnaces	x reheating furnaces 25 MJ/t of semis			x		
Recovering heat from reheating furnace guides with steam production		x 300 MJ/t of semis		x		
Recovering sensible heat from slabs using a waste-heat boiler		x 300 MJ/t of semis		x		
Preheating reheating furnace charges using the "jet process"	x 210-290 MJ/t of semis			x		
Direct rolling	1250 MJ/t rolled product			x		Saving varies according to charging temperature
Recovering heat by hot charging	500-1200MJ/t charged			x		Higher productivity
Preheating combustion air and gaseous fuel to high temperatures using heat exchangers in industrial furnaces	x	x		x		Advantages vary according to nature of plant (new installations or existing plant). Recovery with preheating gives savings of 20-25 % on furnace consumption. Recovery of gases with steam production should yield a further 10-15 %.

MEASURE	BENEFITS			FEASIBILITY		REMARKS
	Energy saving (fuel)	Energy recovery	Substitute energy source	Technology already available	Technology to be developed	
<u>ELECTRIC STEELWORKS</u>						
Extending the use of the UHP technique	x			x		For an electric furnace of the power considered in the mode (450kW/t) a 100 kW decrease in power would lead to higher consumption of around 35 kWh/t. Higher productivity
Using oxy-fuel burners			x	x		1 kWh of electricity is replaced by consumption of 7.53 MJ (taking into account the energy cost of oxygen). Higher productivity.
Recovering heat from the water used to cool the electric furnace walls and roof		x				Possibility of recovering the equivalent of 170 kWh/t of steel
Monitoring and controlling the electric steelmaking process : potential for automation	x			x		Higher productivity
Post-refining in separate furnace	x			x		Higher productivity
Preheating electric arc furnace scrap charge	4-15% of specific electr. energy cons. of furnace	x		x		Saving varies according to preheating used and the temperature
Closing the fourth hole	10% of spec. electr.energy consumption of furnace				x	Higher productivity

C.3 POSSIBILITY OF USING WASTE ENERGY FOR HOUSEHOLD AND INDUSTRIAL PURPOSES OUTSIDE THE STEELWORKS

As a rule, over 40% of the net primary energy input in an integrated steelworks is lost, without being recovered. Losses can be broken down as follows :

cooling water	34%
semis and byproducts	31%
flue gases, etc.	27%
radiation + convection	8%

Some of these heat and temperature losses are of a sufficiently high level to warrant re-use in the works (for preheating air and fuel, for generating steam, etc.) provided that adequate technology, capital and space are available. In some cases however, the amount of heat and the temperatures involved are rather low, making in-works use not particularly worthwhile e.g. when temperatures are below 250-300°C. This applies to some 55% of the heat loss, as follows:

heat lost through furnace wals	8%
cooling water	34%
flue gases	13%

Included here are the cowper gases (whose temperature is around 300°C), which can be conveniently used at the present time for preheating the combustion air and the low-grade fuel used in the cowpers themselves.

Then there are the gases and cooling air from sinter plants and flue gases from coke ovens and power stations, whose temperature is in the 180-300°C range. The temperature of the cooling waters is below 50°C.

Waste heat from a steelworks can effectively be harnessed for a variety of household and industrial uses outside the works (central heating and air-conditioning, miscellaneous industrial applications requiring the relatively low temperatures which can be transmitted by a vector such as water : agriculture, food-processing, the textile industry, etc.). Pressurized water is generally used to carry the heat once the heat has been given up to the user the water is recirculated via a system of heat exchangers and pumps.

In some cases, the recovered heat is distributed in the form of saturated or slightly superheated steam. It is also possible in some cases to connect up directly to the heat source.

A Japanese study on the use of waste heat outside plants reaches conclusions which deserve some consideration : in a 25 km^2 area around a steelworks, the study concludes that household use can absorb only 4.3% of the available heat (based on peak values), while the seasonal nature of many applications (e.g. household heating) is also an important consideration. In addition, the area served must not be too extensive, otherwise distribution losses will be unacceptable. The Japanese study concludes that the wholesale transformation of waste heat into electricity by hot-water and organic-fluid generators may be a more convenient solution. The power produced could then be used in the works or outside.

A German study on the same subject foresees the use of energy not only from steelworks but also from thermal power stations. A heat distribution network, using hot water would supply the whole of Federal Germany. The study concludes that this would be economic if it were possible to guarantee a high number of hours of heat use each year.

It is difficult to use cooling water for heating unless the temperature is raised by means of heat pumps, but this technique is not yet feasible because of the very large amounts of power involved. Careful examination of the technical and economic aspects is required.

In electric steelworks there is promising potential for using the furnace cooling waters which, if kept at a pressure of 10 bar in the circuit, can reach a temperature of 120 to 140°C and contain an amount of heat equal to 10-15% of the total energy input to the furnace. Between 30 and 80% of this heat can be recovered in a form that can be used both in the works and outside.

There are already some limited examples of the use of waste heat from steelworks for household purposes in Europe, while numerous schemes are under study in the Community steelmaking sector.

The integrated steelworks normally reuse recovered gases (blast-furnace gas, coke-oven gas and converter gas) as fuel in furnaces and boilers, as well as for the protection of energy in the works. In some cases it might be worth selling these gases for chemical uses, for producing electricity in large power stations and for various other purposes.

C.4 NEW TECHNOLOGIES NOT YET IN INDUSTRIAL USE

There are unlikely to be any substantial changes in steelmaking up to the end of the century, at least as far as the more rational use of the various energy sources is concerned.

The blast furnace and oxygen converter combination will continue to be the main process, with oxygen also being injected from the bottom (Q-BOP process) or simultaneously from the top and the bottom. The electric furnace will continue to develop and it will be increasingly necessary to improve the quality of the charge by using some direct reduced iron and scrap iron.

Energy savings are expected to be in the order of 15-20%, achieved by the replacement of obsolete plants, by plant improvements (insulation, control, etc.) and more widespread use of continuous casting. Particular care will be given to the recovery of energy that at the moment is being wasted.

It is unlikely that, before the year 2000, we shall see the industrial applications of substantially innovatory processes, such as the reduction and direct melting of powdered iron ore (unsintered) in gas plasma or direct reduction and melting by means of various fluid and solid fuels (hydrogen, natural gas, coal) and oxygen, or continuous steel-making processes from ore to end product.

However, some of these experiments have yielded interesting results, not least from the energy viewpoint and they appear attractive because of the possibility of using diverse sources of energy that are not being depleted or becoming scarce (coal and coal-derived gases, hydrogen, etc.).

An alternative to using the traditional energy vectors in steelmaking, which may be considered in the near future, i.e. before the year 2000, is the gas obtained from the gasification of coal. This can be used both in conventional steelmaking processes and in direct reduction, and, particularly if the coal is gasified in a fluidised bed plant, there are few quality disadvantages.

Of particular interest is the prospect of using hydrogen as a reducing gas and fuel; the hydrogen could be obtained from heat or from nuclear-generated electricity.

Of great interest in the medium to long term is the prospect of the direct use in steelmaking of heat obtained from cooling nuclear reactors (especially gas-cooled HTGRs).

The possibility of using nuclear-generated electricity is of fundamental importance for the future of Community steelmaking. The continuity of the steelmaking process (especially the integrated type) fits in well with the basic operating characteristics of large nuclear power stations. This could enable steelmaking to benefit from low-cost electricity, particularly at night and at weekends, thus in the medium term becoming virtually independent of oil and natural gas.

CONCLUSIONS

Steelmaking accounts for substantial proportions of the energy consumed in the industrialized countries : for example, 5% in the USA, 8% in the Community and 16% in Japan. The amounts of energy it consumes are considerable and most countries have to import the bulk of it.

However, this study has highlighted the fact that there are numerous ways - in the short, medium and long term - of appreciably reducing energy consumption per tonne of product and of boosting the role of coal. Potential for saving in the short to medium term - by 1990 - can be estimated at between 10 and 15% (from 7.5 to 11.5 million toe) of 1979 energy consumption.

These figures do not of course take into account the saving which would be possible if plant capacities were more fully used. A 10% increase in the use of present overall production capacity alone would reduce specific energy consumption by between 4 and 6%.

It should be emphasized that most of this energy-saving potential can be achieved by improving operation and management, or by plant improvements and modifications which do not require much investment. Although it is obviously impossible to make detailed calculations, it has been estimated that the investment required to achieve the overall objective of a 15% reduction in the current level of specific energy consumption of the Community steelmaking industry, which produces 140 million tonnes of steel a year (1979), amounts to around 3100 ECU (at current prices).

This figure does not include capital expenditure on modifying blast furnaces, converting steelworks and other improvement schemes not yet decided upon, which are designed chiefly to conserve or recover energy that for the moment is being wasted. Nor does the figure include capital expenditure on district heating schemes to utilize waste heat from steelworks.

Fig. 23 on the next page lists in decreasing order of "energy profitability" (toe/year per million USD invested), some of the main investment projects which could save 2.5 mio toe/year in the Community's integrated steelworks, representing a total investment of over USD 1600 million.

If the Community steelmaking industry takes decisive action on energy, there is every likelihood that it will become competitive again and that it will gain considerable ground on its major rivals. At the moment, the energy costs account for some 30% of the industrial cost (including depreciation) of making steel in an integrated steelworks and 20% in an all-scrap electric steelworks (not counting the cost of scrap or DRI). A 15% reduction in the consumption of the highest-grade forms of energy (fuel-oil, natural gas and electricity would produce benefits equivalent to an estimated 3 to 6% of the present cost of the main steel products (coils, plate, sections and wire rod).

These figures clearly illustrate the need for studies such as this, which technically analyse the potential for rationalizing the use of energy in the various sectors of industry and especially in steelmaking, thus identifying how much energy can be saved, the financial outlay required and the benefits that will ensue for the individual sectors of production and for the Community as a whole.

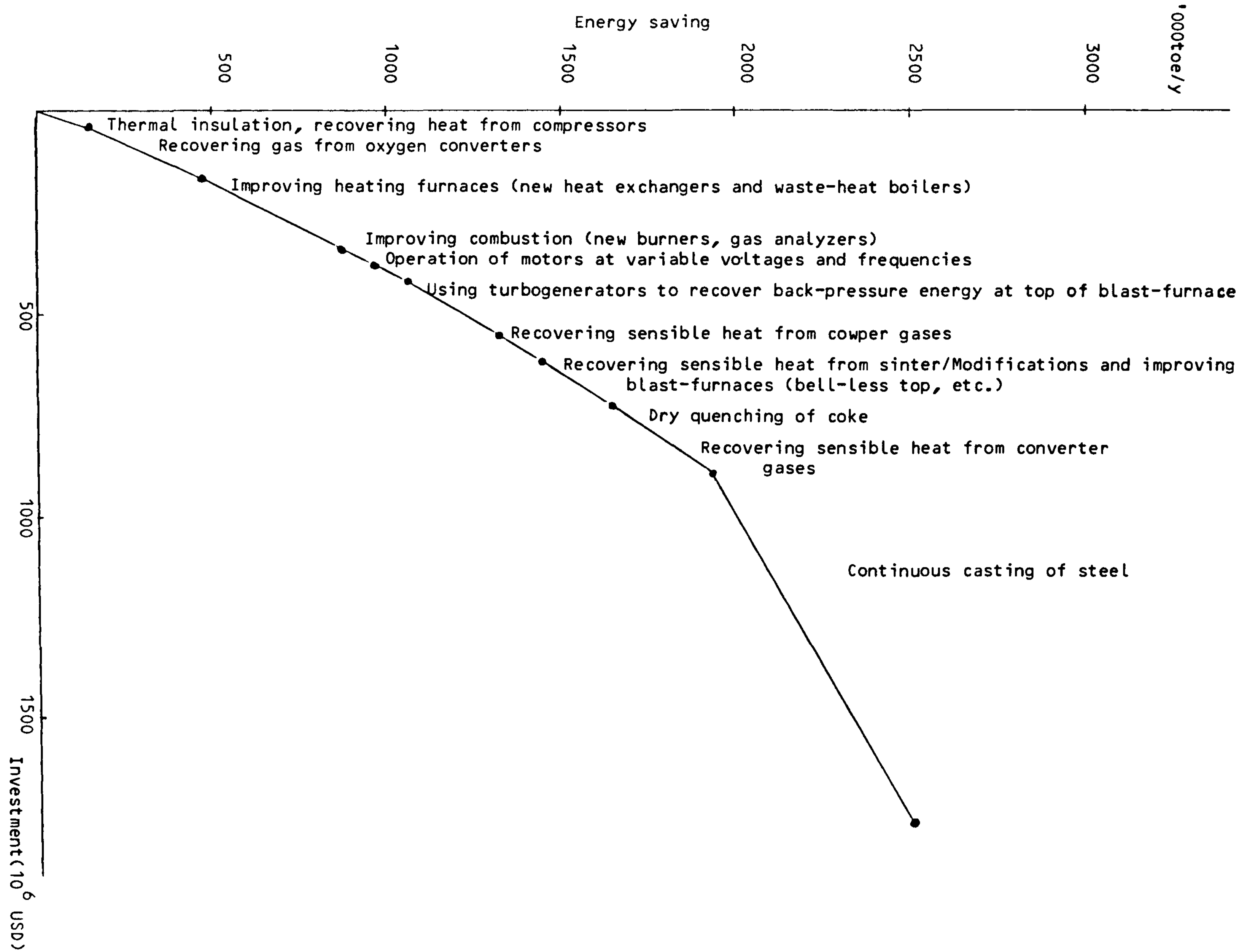
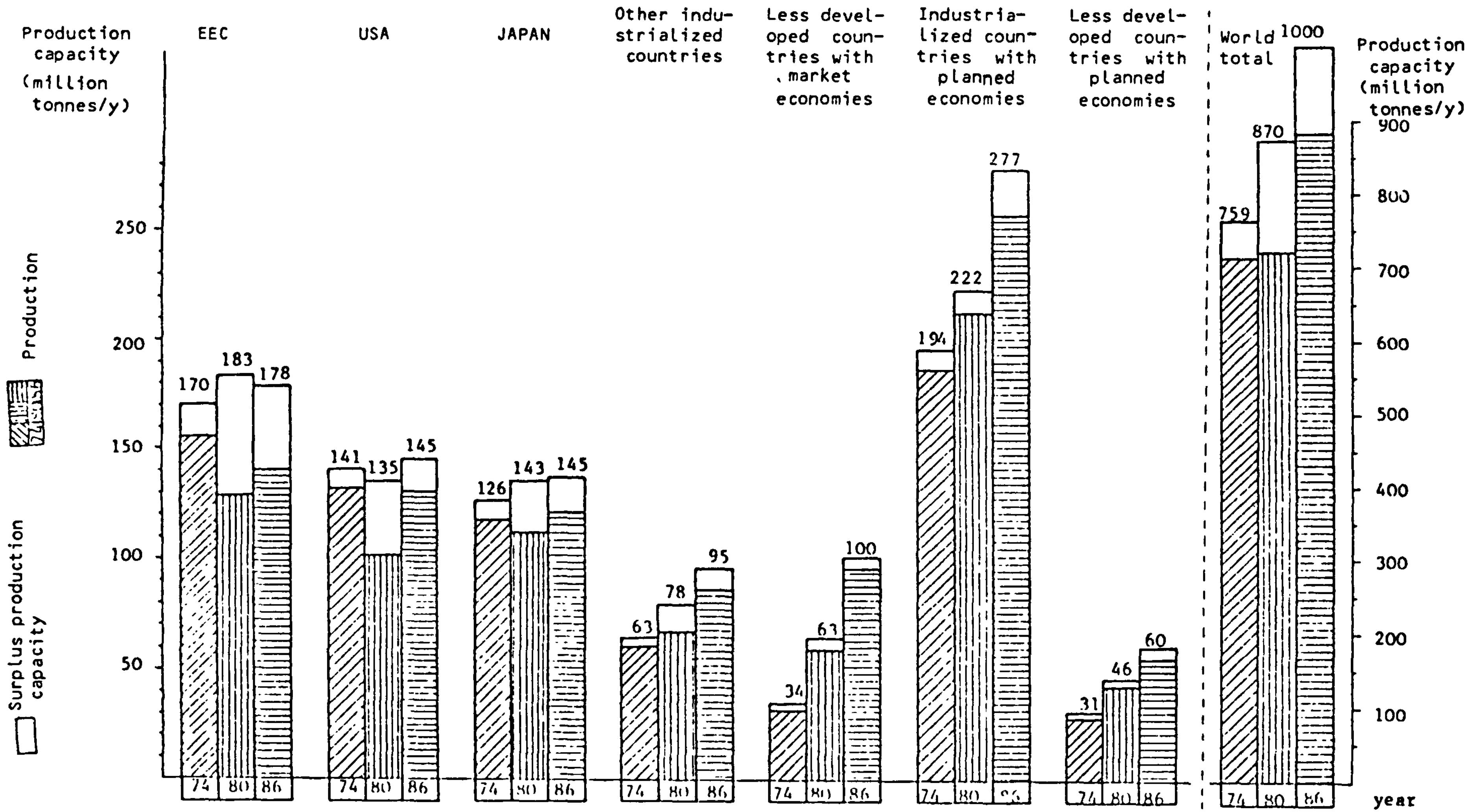


Fig. 23 Energy saving compared with amount of investment

ANNEX

TABLE 1 - Crude steel production of EEC Member States ('000 t) (Source : Eurostatistics, IISI - Statistische Bundesamt - Germany)

	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Germany	40,313	43,705	49,521	53,232	40,415	42,415	38,985	41,253	46,040	43,840
France	22,843	24,054	25,270	27,020	21,530	23,221	22,089	22,837	23,360	23,162
Italy	17,452	19,813	20,995	23,798	21,837	23,447	23,333	24,283	24,022	26,522
Netherlands	5,083	5,585	5,623	5,840	4,826	5,186	4,923	5,590	5,801	5,264
Belgium	12,445	14,532	15,522	16,225	11,580	12,145	11,256	12,601	13,442	12,329
Luxembourg	5,251	5,457	5,924	6,448	4,624	4,566	4,329	4,790	4,950	4,618
United Kingdom	24,174	25,391	26,649	22,379	19,780	22,396	20,474	20,302	21,551	11,341
Ireland	80	77	116	110	81	58	47	68	72	28
Denmark	471	498	453	535	558	722	685	863	801	734



	EEC			USA			JAPAN			Other industrialized countries			Less developed countries with market economies			Industrialized countries with planned economies			Less developed countries with planned economies			World total		
Utilization ratio (%)	:92	70	79	93	75	90	93	78	83	92	85	89	92	92	95	95	95	92	95	93	92	93	83	88
Percentage of total world prod.	:22	18	16	19	14	15	16	16	13	8	9	10	5	8	11	26	29	29	4	6	6	100	100	100
Balance (Production-consumption)	:+31	+22	+20	-12	-13	-15	+41	+36	+40	-9	+5	+10	-42	-38	-45	-2	-2	+5	-4	-9	-15	-	-	-

TABLE 2 - Production capacity and crude steel production (million tonnes) (data OCSE, IISI, Chase Econ, Nippon Steel; elaborated by Italsider SpA, Italy)

TABLE 3 - Crude steel production by different processes for the EEC Member States - 1973-1980 (in percentage) (Source : Eurostatistics)

	1973			1974			1975			1976		
	Oxygen conv.	El. furn.	Others	Oxygen conv.	El. furn.	Others	Oxygen conv.	El. furn.	Others	Oxygen conv.	El. furn.	Others
Germany	67.84	10.40	21.76	68.78	10.80	20.42	69.34	12.56	18.10	71.87	12.40	15.72
France	51.41	10.66	37.39	58.38	11.53	30.08	63.36	14.23	22.41	68.26	14.26	17.48
Italy	41.57	41.12	17.31	43.80	41.42	14.78	45.75	42.96	11.28	45.48	46.15	8.36
Netherlands	91.68	6.70	1.61	92.03	6.54	1.42	92.36	6.84	0.79	92.98	6.73	0.29
Belgium	77.68	3.48	18.84	79.70	4.28	16.01	86.11	5.35	8.54	92.70	4.36	2.94
Luxemburg	48.92	1.52	49.56	65.14	1.66	33.20	70.05	1.40	28.55	86.20	1.86	11.94
United Kingdom	47.24	19.86	32.89	47.97	23.54	28.49	50.06	27.69	22.25	51.50	30.33	18.17
Ireland	-	43.48	56.52	-	50.91	49.09	-	64.63	35.36	-	100.00	-
Denmark	-	3.98	96.02	-	3.92	96.07	-	17.35	82.65	-	46.40	53.60

	1977			1978			1979			1980		
Germany	74.40	12.98	12.62	74.57	14.47	10.96	76.09	13.96	9.94	78.40	14.90	6.70
France	73.44	14.54	12.02	78.16	15.12	6.72	79.71	15.30	4.99	81.90	15.90	2.20
Italy	44.79	48.39	6.81	43.10	50.65	6.25	42.02	53.25	4.72	45.20	53.10	1.70
Netherlands	93.72	6.28	-	94.42	5.58	-	94.50	5.50	-	94.50	5.50	-
Belgium	95.53	4.14	0.33	95.60	4.37	0.02	95.68	4.30	0.02	94.70	5.30	-
Luxemburg	99.05	0.62	0.32	99.85	0.16	-	100.00	-	-	100.00	-	-
United Kingdom	53.10	30.73	16.16	55.84	35.42	8.74	60.05	34.43	5.52	59.4	40.60	-
Ireland	-	100.00	-	-	100.00	-	-	100.00	-	-	100.00	-
Denmark	-	53.58	46.42	-	58.40	41.60	-	61.32	38.68	-	76.20	23.80

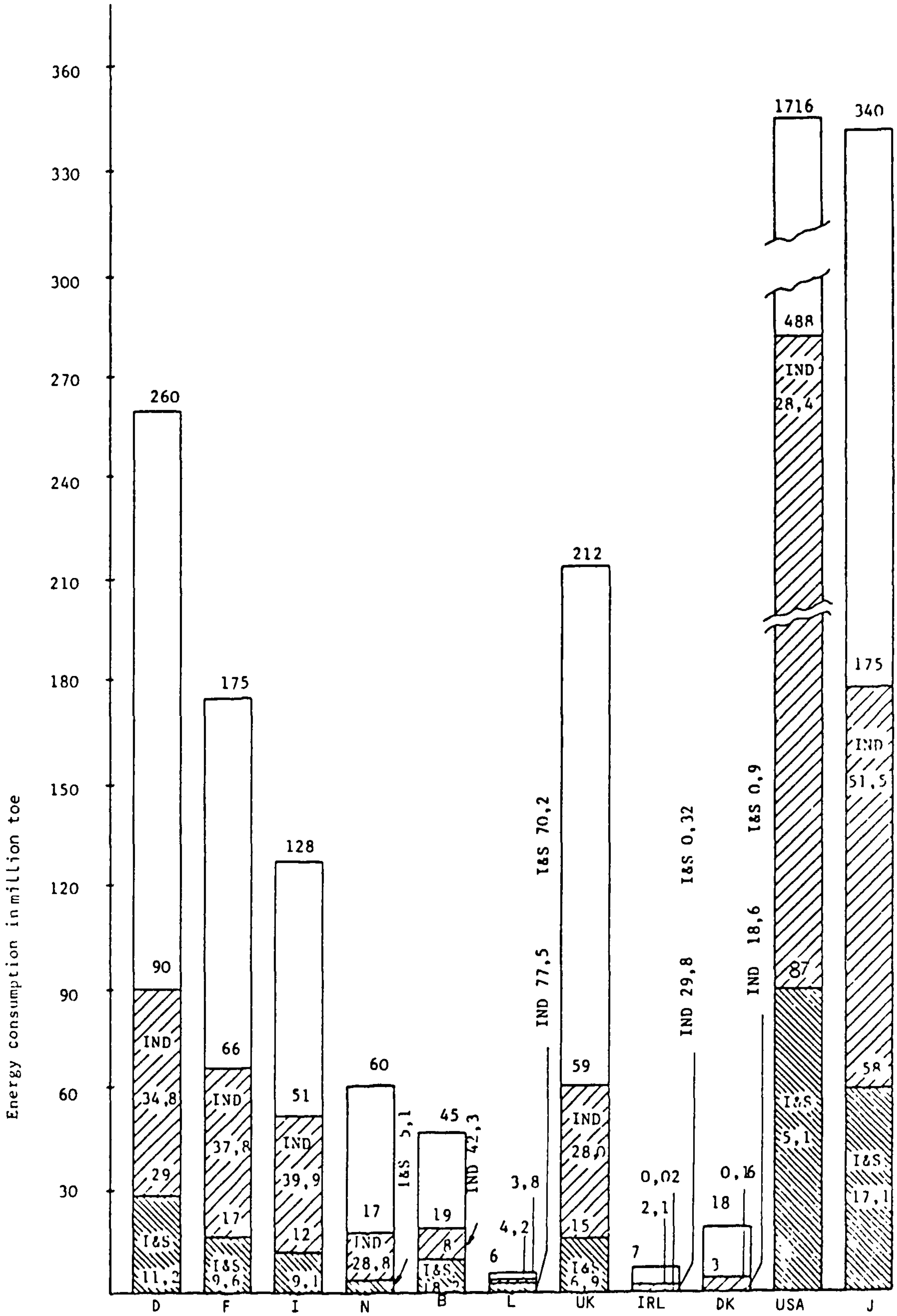


Table 4 - Primary energy consumption - total, industry and iron and steel industry - in the EEC Member States, USA and Japan (1974) (absolute value in million toe and percentage) (Source : Eurostatistics; IEA)

TABLE 5 - Energy consumption by the industrial sector in the EEC Member States - 1974 (in million toe)
(Source : Eurostatistics)

	Germany	France	Italy	Netherlands	Luxembourg	Belgium	United Kingdom	Ireland	Denmark
Hard coal	2,259	2,863	0.128	0,020	0,405	0.648	5.856	0,028	0.315
Coke	12,287	6,747	4,126	1,270	1,333	4.159	5.276	0.011	0.055
Lignite	0,267	0,090	0,007	-	-	-	-	-	-
Brown coal briquettes	0,435	-	-	-	-	-	-	-	-
Non-gaseous petroleum products	23.139	23,992	18,596	1,995	0.678	3.776	21,344	1.420	1,887
Natural gas	12,562	4,610	8,124	7,290	0,218	3.240	1,105	-	-
Coke-oven gas, blast-furnace gas	6,418	3,090	1,373	0,527	0,708	1.722	2,977	0.027	0.017
LPG	0,649	5,265	0,962	0,719	0.006	0,093	0,749	0,029	0.169
Electricity	32,367	19,515	17,706	5,503	0,914	5.422	22,110	0.615	0,892
TOTAL	90,383	66,172	51.022	17,324	4,256	19,060	59.417	2.130	3.335

TABLE 6 - USA and Japan iron and steel industry energy consumption, total and specific for the years 1974-1980
(total in million toe and TJ; specific in GJ/tonne of crude steel) (Source : I E A)

U S A	1 9 7 4	1 9 7 5	1 9 7 6	1 9 7 7	1 9 7 8	1 9 7 9	1 9 8 0
Solid fuels	45.070	38.110	32.450	36,870	39,020	38,930	
Crude oil							
Petroleum products	6.360	5.240	6.440	5.120	5,070	4,750	
Gas	17.100	13.700	12.830	11,500	11,580	22,260	
Electricity	18,950	15,670	17.110	20.860	21,360	22,260	
Total in million toe	87,480	72.720	73,830	74.350	77,030	77.630	
Total in TJ	3,661,871	3,042,892	3,090,482	3,112,165	3,224,476	3,249,592	
Crude steel ('000 t)	135,290	109,120	118,960	115,997	127,170	126,110	
Specific consumption GJ/tonne of crude steel	27,07	27.90	25.98	26.83	25.36	25.77	
J							
Solid fuels	30.790	28.720	28.480	26.790	25.270	26.930	
Crude oil							
Petroleum products	10.900	9.080	9.180	7.330	6.770	7.280	
Gas	--	--	--	0,660	0,690	0,700	
Electricity	16,520	16,450	15.270	14,760	14,700	16,210	
Total in million toe	52.210	54.250	52.930	49,540	47,430	51,120	
Total in TJ	2,436,461	2,270,905	2,215,524	2,031,801	1,985,420	2,139,883	
Crude steel ('000 t)	117,131	102,314	107,399	102,405	102,105	111,750	
Specific consumption in GJ/tonne of crude steel	20.80	22.195	20.63	19.84	19.45	19,15	

TABLE 7 - Impact of energy consumption in the iron and steel industry on the total (national) energy consumption of energy (in million toe) (Source : Eurostatistics)

	1971			1972			1973			1974			1975		
	I & S	TOTAL	%	I & S	TOTAL	%	I & S	TOTAL	%	I & S	TOTAL	%	I & S	TOTAL	%
Germany	23.33	238.3	9.79	24.28	248.5	9.80	27.24	265.3	10.27	29.03	259.8	11.77	23.48	241.9	9.24
France	13.98	156.1	8.96	14.62	164.5	8.89	15.58	179.7	8.67	16.76	175.2	9.56	14.28	164.3	8.69
Italy	9.34	113.5	8.23	-	120.8	-	-	127.9	-	11.94	131.5	9.08	10.60	127.2	8.30
Netherlands	2.77	50.6	5.46	2.98	57.9	5.14	3.09	61.5	5.02	3.10	60.2	5.14	2.58	59.0	4.38
Belgium	6.57	40.4	16.30	7.28	44.2	16.47	7.79	46.0	16.93	8.20	45.0	18.22	6.19	41.4	14.95
Luxemburg	3.37	4.6	73.27	3.38	4.8	70.43	3.57	5.7	70.00	3.86	5.5	70.25	2.95	4.5	65.50
United Kingdom	18.38	208.6	8.81	17.58	213.1	8.25	17.28	221.0	8.10	14.71	212.4	6.93	13.54	200.8	6.74
Ireland	0.030	6.6	0.46	0.030	6.7	0.45	-	7.1	-	0.022	6.8	0.32	0.022	6.5	0.34
Denmark	-	188.0	-	-	19.6	-	-	19.6	-	-	17.9	-	-	17.7	-

	1976			1977			1978			1979		
	I & S	TOTAL	%	I & S	TOTAL	%	I & S	TOTAL	%	I & S	TOTAL	%
Germany	23.53	261.0	9.01	21.68	258.0	8.40	21.82	267.9	8.14	24.72	281.5	8.78
France	15.21	174.2	8.73	14.48	175.4	8.26	14.46	184.3	7.84	15.51	192.6	8.05
Italy	11.01	135.1	8.15	10.88	134.4	8.10	10.78	135.7	7.94	11.07	140.4	7.88
Netherlands	2.53	65.7	3.85	2.25	63.8	3.53	2.36	64.1	3.68	2.43	70.0	3.47
Belgium	6.27	44.1	14.20	5.70	43.9	13.00	6.19	46.3	13.37	6.52	47.8	13.64
Luxemburg	2.92	4.6	63.50	2.67	4.4	60.70	2.62	4.5	58.22	2.58	4.5	57.33
United Kingdom	14.73	204.0	7.22	13.60	209.1	6.50	13.09	208.1	6.29	13.60	218.5	6.22
Ireland	0.024	6.7	0.36	0.020	7.1	0.28	-	7.5	-	0.028	8.5	0.32
Denmark	-	19.2	-	-	19.7	-	-	19.6	-	-	21.1	-

TABLE 8 - Energy consumption in the iron and steel industry in the EEC Member States (total in '000 tce and TJ, specific in tce per tonne of crude steel and GJ/tonne of crude steel) - 1979 (Source : Eurostatistics)

	Germany	France	Italy	Netherlands	Belgium	Luxembourg	United Kingdom	Ireland	Denmark
Hard coal	117	1.281	56	3	118	280	183	-	-
Coke	12,616	6,965	(4,237) (1)	1,300	4,470	1,484	6,081	-	-
Lignite	-	18	5	-	-	-	-	-	-
Brown coal briquettes	6	-	-	-	-	-	-	-	-
Non-gaseous petroleum products	3,950	(3,748) (1)	(1,293) (1)	616	456	283	3,601	21	X
Natural gas	5,184	1,838	2,577	590	1,330	362	1,543	-	-
Coke-oven gas, blast-furnace gas	6,095	3.499	1,629	355	1,270	578	2,792	-	X
LPG	-	-	-	-	-	-	-	-	-
Electricity	7,340	4.811	6,016	604	1,673	707	5,222	19	183
Total ('000 tce)	35,308	22,160	15,814	3,468	9,317	3,694	19,422	40	183
Total TJ	1,034,595	649,332	463,382	101,619	273,007	108,242	569,103	1,172	5,362
Crude steel production ('000 t)	46,040	23,360	24,022	5,801	13,442	4,950	21,551	72	801
Specific consumption tce/ton of crude steel	0.766	0.949	0.658	0.598	0.693	0.746	0.901	0.555	X
Specific consumption GJ/ton of crude steel	22.472	27.797	19.289	17.518	20.310	21.867	26.407	16.278	

(1) Source : IISI

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