特集記事●4
鉄の環境との共生

Evolution of Coke and Iron Making in Europe and the Challenges to Reduce CO_2 Emission

Hans Bodo Lüngen *

Abstract

The integrated steel works in EU 27 operate most modern plants for the production of a wide variety of high grade steel products. The blast furnace/converter route will remain dominant within the EU 27 on a long term with a share of 58%. The basic pre-product for this route is hot metal from blast furnaces. Blast furnaces cannot be operated without coke and they are dependent on high grade coke supply. Many young and high tech coke plants are operated in Europe, but some are old and need lifetime enlargement measurements or revamping. The new batteries of the coke plant Schwelgern in Germany represent the most advanced state of development of the multi chamber system. This plant has by far the biggest coking chambers in the world. The European integrated steel works operate successfully blast furnaces at low reductant rates, high productivities and long campaign lives. This can only be achieved with the use of cokes having excellent properties, especially for the operation of large volume blast furnaces. The coke demand and supply balance of the EU was characterized by a steady decrease in available coke plant capacities since 1990 and a coke shortage since 2000 for the former EU 15. Poland is the main internal coke supplier for other EU 27 countries. R&D in the EU 27 is amongst others focused on the reduction of CO_2 emissions by the development of the oxygen blast furnace process. The use of excess coke oven gas for the production of DRI is an alternative option instead of power generation.

要旨

EUの一貫型製鉄所では、あらゆる種類の高品質鉄鋼製品を製造している。EUでは、58%を占める高炉・転炉法が主流であるが、高炉には高品質コークスが不可欠であり、多くの新しいコークス炉が稼動している。現在、ドイツのSchwelgernには、世界最大の炭化室を有する最新型のコークスプラントが稼動している。ヨーロッパの一貫型製鉄所では、高品質のコークスを用い、低還元比、高生産性、長寿命化を達成しつつ、高炉操業を行っている。EU内のコークスの需給バランスをみると、コークスの供給量は1990年から一貫して減少しており、2000年には需要が供給を上回っている。EUでのCO_2排出量削減に関する研究開発事例として、高炉への純酸素吹き込みやコークスガスを利用した還元鉄製造があげられる。

1 Introduction

Worldwide the steel industry has produced of 1327 million t of crude steel in 2008. The share of oxygen steel making amounted to 67.2%, that of the electric steel making route to 30.7%, Fig.1. It can be seen that the coke plant/blast furnace/oxygen converter route is worldwide the dominating crude steel production route.

The ratio of hot metal to crude steel remained nearly unchanged during the last years at a level of 0.70, Fig.2. The hot metal production increased since 1995 from 500 to 927 million t/a. The ratio of coke to hot metal production in the world decreased from 0.72 in 1995 to 0.59 in 2008 as a result of worldwide decreases in coke consumption in the blast furnaces.

* Dr.-Ing.H.B.Lüngen, Senior Manager Operation Unit Technology, Steel Institute VDEh, Düsseldorf, Germany

The worldwide hot metal production of 927 million t in 2007 was by nearly 100% produced in blast furnaces, Fig.3, 5 million t liquid hot metal came from Corex and Finex plants. The corresponding coke consumption of the steel industry was 435 million t of blast furnace coke and coke breeze for the sinter plants.

In 2008 worldwide coke production reached with 545 million t, Fig.4. China holds a share of 60%. The demand of coke from other consumers than the sinter plants and blast furnaces of the steel industry has increased from 67 million t in 2000 to 94 million t in 2008. Some coke was also stored. It is anticipated that nearly 90 million t coke will remain necessary in the future for consumers outside the steel industry, like Foundries, Ferrochrome, Soda Ash, Manganese Alloys, Calcium Carbide and other industries as well as for household firing in some regions of the world.

2 The European steel industry at a glance

The EU 27 is after China the second biggest steel producer of the world, Fig.5. Total crude steel production in 2008 amounted to 197.4 million t corresponding to a share of 14.9% of total world crude steel production. The ratio of oxygen to electric steel differs in a wide range in the shown countries or regions. Very high shares of oxygen steel making of 90.9% are applied in China and of 75.1% in Japan. A high amount of electric steel is produced in the USA with s share of 58.1%. In the EU 27 the ratio of electric steel making has today reached 41.2%.

Looking to the EU 27 scenario the share of oxygen steelmaking has remained nearly at the same level

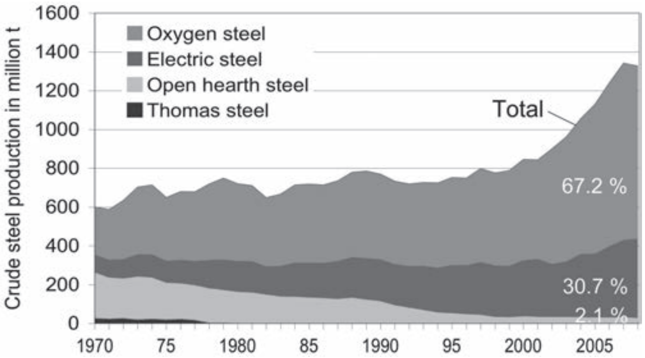

Fig.1 World Crude Steel Production by Process

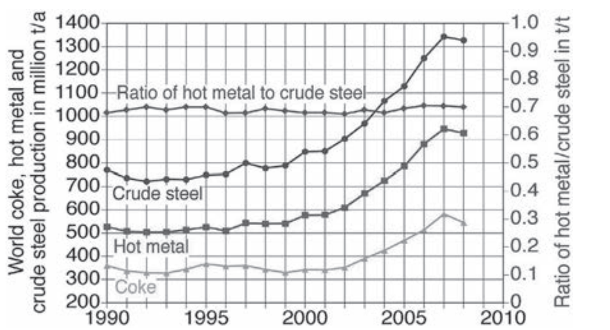

Fig.2 World Crude Steel, Hot Metal, Coke Production and Ratio Hot Metal/Crude Steel

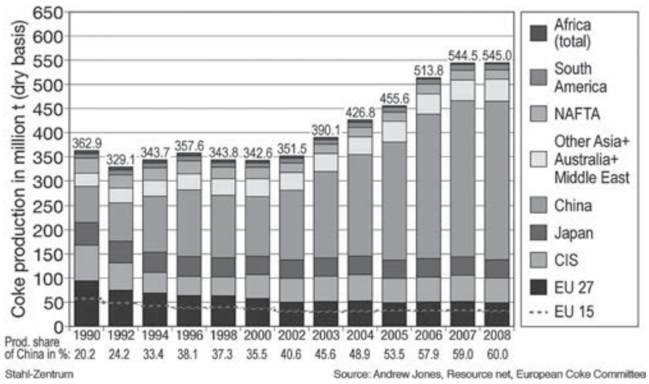

Fig.4 World Coke Production by Region

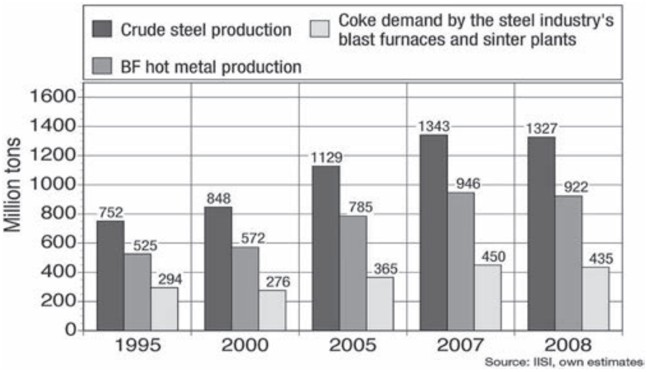

Fig.3 World Hot Metal, Crude Steel and Steel Industry's Coke Consumption

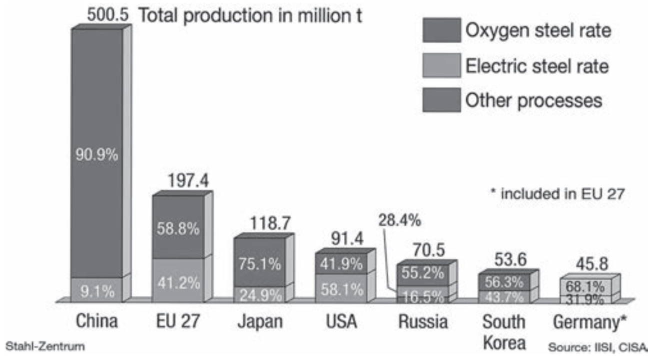

Fig.5 Crude Steel Production in 2008 World Crude Steel 1327 million t

of approximately 59% or 116 million t, Fig.6. Electric arc furnaces have completely replaced the obsolete open hearth furnaces.

There are approximately 200 steel producing locations in the EU 27, the 20 biggest having a crude steel capacity of over 3 million t are identified and listed in Fig.7. The biggest side is the town of Duisburg in Germany which can look back to a long tradition and history in steel making of more than 150 years. The production capacity amounts to 19.5 million t crude steel. The next biggest locations are the coastal sides of Taranto in Italy with 11.5 million t, IJmuiden in The Netherlands having a capacity of 7.2 million t and Dunkerque in France with 7.1 million t annually. The biggest steel town of the new EU member countries in 2008 is Galati in Romania.

Shanghai is today the biggest steel producing location in the world followed by Duisburg, Fig.8. Shanghai is a new industrial location with remarkable growth rate over the last years and the end is not yet seen. The location Duisburg was chosen for steel making in the middle of the 19th century because of the close by located coal mines and because of its location directly at the river Rhine. Most of all the other integrated steel works shown in this map were built in the past 25 to 50 years at the coast with deep sea harbours. This enables the direct transport and handling of the imported raw materials and steel products for export without any turnover to other transportation units. It is remarkable that the local capacities of over 10 million t of crude steel are only located in Asia, CIS and Europe.

The main steel producing countries in the EU 27 are Germany, Italy, Spain, France and Great Britain, Fig.9. The average share of oxygen steel making is 58.3%. High shares for electric steel making exist in Italy (64.4%), Spain (78.1%) and Luxemburg (100%).

3 Coke plant situation

45 coke plants are operated in the EU 27, Fig.10. Most of them are directly linked to the interconnecting energy network of an integrated steel plant. A few of them are so-called island coke plants. The total capacity is 56 million t coke dry, Table 1. The average weighted age of the plants is 26.1 years when taking the year of the commissioning and 15.9 years when using the year of the last modernization as the basis. The German coke plants are very young. To-

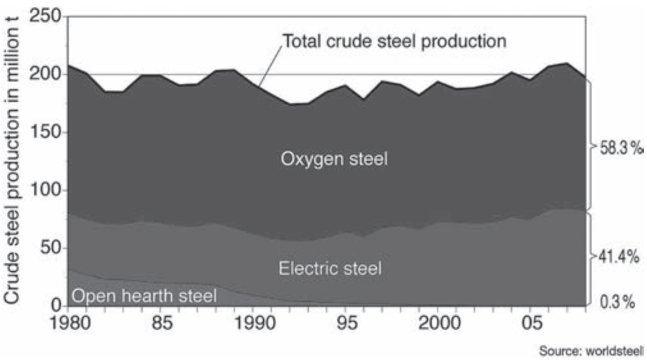

Fig.6 Crude Steel Production in EU 27 Countries by Process

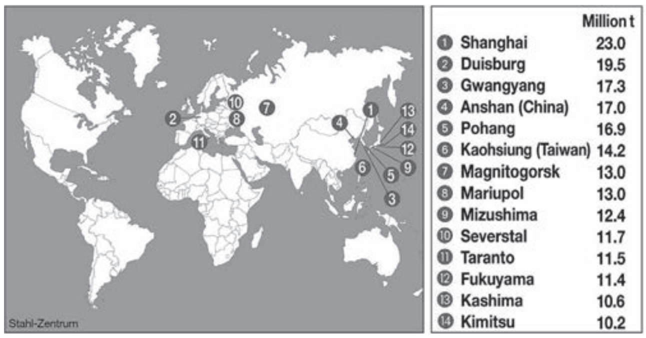

Fig.8 Crude Steel Production Sites in the World with a Capacity > 10 Million t/a, 2008

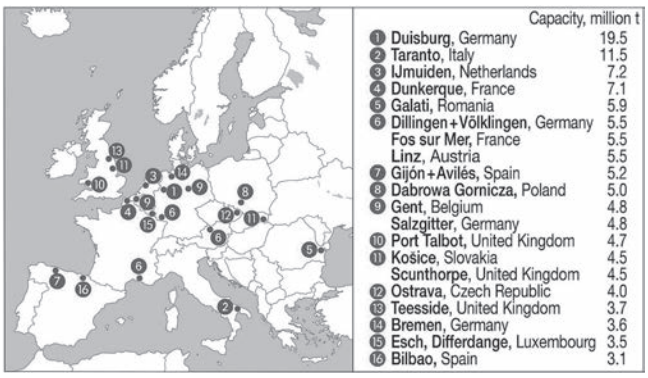

Fig.7 Crude Steel Production Sites of EU 27 with a Capacity > 3 Million t/a, 2008

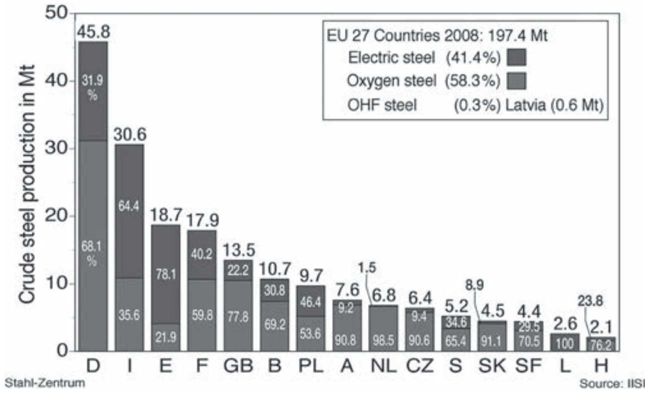

Fig.9 Crude Steel Production of EU 27 Countries 2008 by Process

day it cannot be said how the economical crisis effects the overall coke capacity in the EU 27.

Germany's youngest and world's most modern coke plant went on stream in Duisburg Schwelgern on the production site of ThyssenKrupp Steel (TKS) in 2003, Fig.11. The plant, which has a capacity of 2.6 million t coke/a, possesses of two batteries with 70 ovens each. The coke ovens are the biggest in the world. They have a useful chamber volume of 93 m^3 each.

4 Blast furnace situation

The evolution of blast furnace operation data is focused on the former EU 15 countries[1], because no blast furnace operation data are available by now for the new EU member states.

Fig.12 demonstrates the dramatic reduction in the number of operated blast furnaces in the EU (15) since 1990. In 1990 94 million t of basic hot metal were produced in 92 blast furnaces and in 2008 89.6 million t was produced by only 58 blast furnaces. The average production per blast furnace and year increased by 48% from 1.04 to 1.54 million t hot metal. The average working volume of the furnaces increased by 27% from 1630 m^3 to 2063 m^3 and the average productivity of the blast furnace increased by 6.3% from 2.2 to 2.34 t/m^3 (w.v.) 24 h. This demonstrates that apart the enlargement of the furnaces also the measures taken to increase furnace productivity enabled the required hot metal production with fewer furnaces. This slide also shows the effects of the economical crisis in the steel industry which started in the 4th quarter of 2008.

The majority of the furnaces are medium sized with hearth diameters between 8.0 and 11.9 m, Fig.13. The average hearth diameter for all blast furnaces is 10.0 m. The large units over 12.0 m are listed in this Table 2.

Whilst the total reductant consumption of the EU 15 blast furnaces remained nearly unchanged on the same level the coke rate was decreased from 408 kg/t HM in 1990 to 351.8 kg/t HM in 2008 through increased coal injection rates from 50 to 123.9 kg/t HM, Fig.14. Oil plus others remained nearly un-

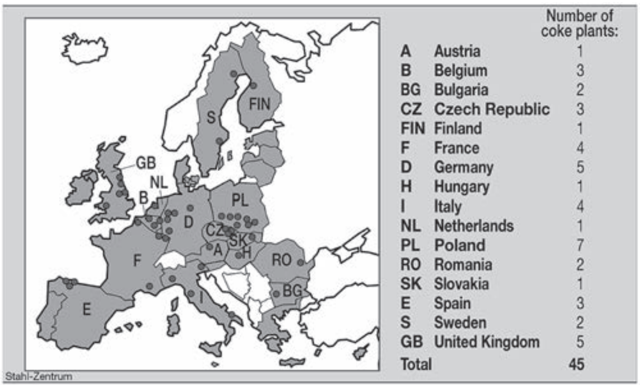

Fig.10 Coke Plants in the EU 27

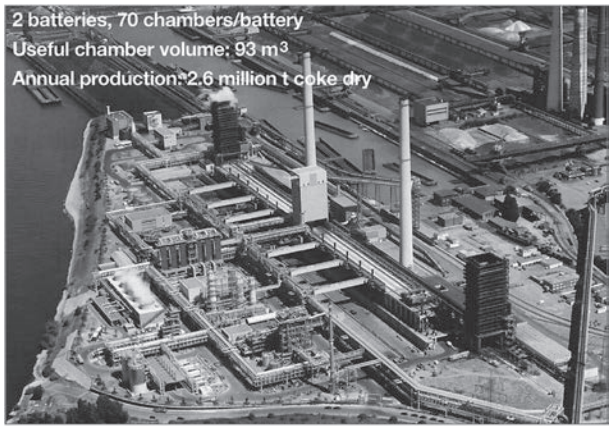

Fig.11 Coke Plant Schwelgern, commissioned 2003

Table 1 Coke Plant Capacities and Age Structures in EU 27 (2007)

	Designed capacity million t coke/a	Age[1]	Age[2]
Austria	1.38	24.0	11.0
Belgium	2.89	37.7	26.5
Bulgaria	1.26	21.2	21.2
Czech Republic	3.97	19.2	19.0
Finland	0.94	20.0	10.0
France	4.69	27.5	13.6
Germany	8.50	17.0	16.0
Hungary	1.11	30.0	8.2
Italy	5.29	32.5	8.9
Netherlands	2.32	29.2	23.0
Poland	12.08	27.6	12.4
Romania	2.54	22.6	13.1
Slovakia	1.89	32.6	20.6
Spain	2.44	33.7	28.7
Sweden	1.15	40.6	31.8
United Kingdom	4.18	26.7	22.2
Total	56.63	26.1	15.9

1) Average age since year of first commissioning 2) Average age since last modernization

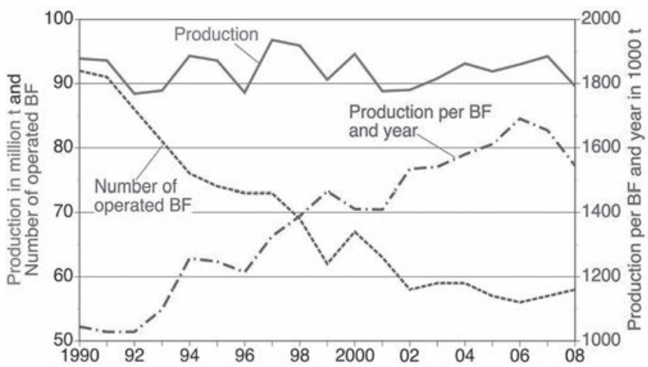

Fig.12 Evolution of Hot Metal Production in the EU 15 Number of Operated Blast Furnaces (BF) and Production per BF and Year

changed for the same period at a level of approximately 20 kg/t HM.

On a worldwide level the European blast furnaces are playing in the top league, Fig.15. The world average reductant rate in 2007 was 559 kg of coke plus injection coal plus oil and gas. The comparison of the reached reductant rates in blast furnaces in different countries or regions shows that there is still potential to reduce the coke rate as a worlds average. The European blast furnaces also achieved very low total reductant consumptions.

When considering the evolution of average reductant consumption of the blast furnaces in Germany over the last 55 years the success of blast furnace operators in minimising reductant inputs becomes abundantly clear, Fig.16[2]. The measures taken to achieve this evolution are listed in this figure. However, it is also evident with regard to potential future reduction capabilities that the downtrend achieved over the last few years shows an asymptotical pattern. In other words, the blast furnace operator's day-to-day work to optimise process costs has actually resulted in a minimisation of reductant consumption already. Further substantial cuts, particularly of the "quantum leap" variety, are not to be anticipated. The blast furnace process as implemented under German and West European boundary conditions has evolved into a best available technique. Nevertheless, the question needs to be discussed which possibilities this best available technique has to offer with regard to further lowering the level of reductant consumption and hence the resulting CO_2 emissions.

It must of course be taken into consideration that these results have to be adapted to the continual de-

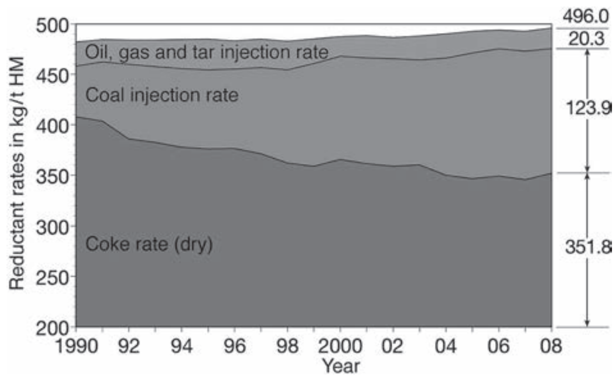

Fig.14 Evolution of BF Reductant Rates in the EU 15

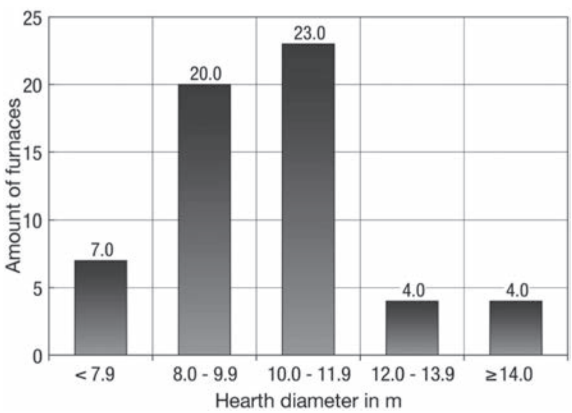

Fig.13 Actual Blast Furnace Sizes in EU 15 as of July 2009

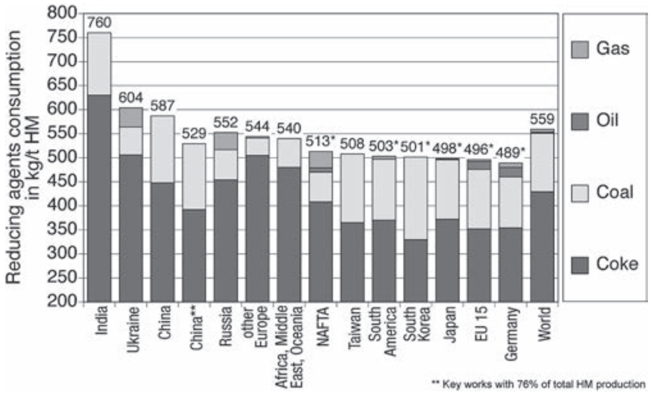

Fig.15 Reducing Agents Consumption of Blast Furnaces in the World, 2007/2008*

Table 2 Largest West European Blast Furnace (EU 15)

Country	Company	BF No.	Hearth Diameter, m	Working Volume m³	HM Production 2008, million t
Germany	TKS	Schwelgern 2	14.90	4796	4.1
UK	Corus	Redcar	14.00	4017	3.0
France	ArcelorMittal	Dunkerque 4	14.00	3940	3.1
Italy	Ilva	Taranto 5	14.00	3650	3.5
Netherlands	Corus	IJmuiden 7	13.83	3790	3.6
Germany	TKS	Schwelgern 1	13.60	3775	2.6
Germany	ArcelorMittal	Bremen 2	12.00	3143	2.1
Germany	Rogesa	5	12.00	2857	2.3

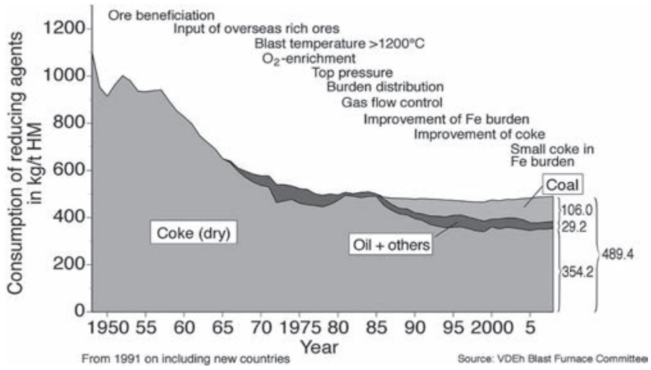

Fig.16 Average Consumption of Reducing Agents of the Blast Furnaces in Germany

velopment of blast furnace operating modes. Table 3 illustrates this for the evolution of hot metal production in Germany during the past 38 years[2). Productivity-conditioned high material and gas throughputs, low coke consumption and increasing injection rates of especially for coal during this period were a steady challenge for plant units and their operators. 33.6 million t hot metal were produced by 80 blast furnaces in 1970 whilst only 15 blast furnaces produced 28 million t in 2008. This is an output increase per blast furnace and year of 319%. This was not only achieved by increasing the blast furnace size but also by increasing the productivity of the furnaces by 52%.

At individual European furnaces extraordinary operation modes regarding coke rate and injections were achieved in 2008, Table 4. Highest coal rate was realized at the blast furnace 6 of Tata Corus in IJmuiden with 235 kg/t HM as yearly average. The lowest coke rate of 281 kg/t HM was achieved at this furnace.

Today certain amounts of nut coke are charged with the ferrous burden. In 2008 at TKS Hamborn No. 9 furnace the coke rate of 333.5 kg/t HM includes 70.9 kg/t HM nut coke charged with a grain size of 10 to 35 mm, the remaining bell coke rate being only 262.6 kg/t HM. However, not all blast furnace operators switched to coal injection. Oil injection was maintained at some furnaces in EU 15. Blast furnace 2 of Ruukki was operated with an oil injection rate of 100 kg/t HM. This furnace reached the highest productivity level which was 3.44 t HM/m³ (W.V.) 24 h. At blast furnace B HKM in addition to heavy oil (23.5 kg/t HM) natural gas (84.9 kg/t HM) was injected. At HKM injection will be switched from oil and gas to pulverized coal in 2009.

Further special injectants to be mentioned here are the injection of plastics and tar at voestalpine Stahl Linz No. A blast furnace.

Injection technology and oxygen enrichment are inseparably linked together, giving the chance to match operational conditions for lower gas volume, favorable coke replacement ratio, higher hydrogen input and optimal flame temperatures. The oxygen content of the blast reached 36% at blast furnace Corus IJmuiden No. 6.

The ferrous burden composition of the West European blast furnaces differs in a wide range, Fig.17. High sinter rates of over 50% are charged to the blast furnaces in Belgium, Finland, France, Germany, Italy, Spain and United Kingdom whilst high pellet rates of 52% are used in The Netherlands and of 95% in Sweden. The average burden composition of the blast furnace in the EU 15 was 62.4% sinter, 27.3% pellets and 10.3% lump ores plus others.

Table 3 Evolution of Hot Metal Production in Germany

Year		1970	2008	Relative Change, %
Number of operated blast furnaces		80	16	−80
Production per BF and year,	million t HM	0.42	1.76	+319
Average productivity,	t HM/m³ (W.V.) 24 h	1.54	2.34	+52
Coke consumption,	kg/tHM	537	354	-34
Total reductant consumption,	kg/tHM	577	489	-15
Share of agglomerated Fe burden,	%	62	86	+38
Slag volume,	kg/tHM	379	278	-27

Table 4 Examples for extraordinary BF results Average for 2008

Country		B	F	FIN	D	D	D	NL	NL
Works		Arcelor Sidmar	AM Dunkerque	Ruukki Raahe	HKM	TKS	TKS	Corus	Corus
BF No.		A	4	1	B	Ha 9	S 1	6	7
Hearth diam.	m	10.0	14.0	8.0	11.0	10.2	14.9	11.0	13.8
Bell coke	kg/t HM	261.9	266.1	319.0	289.0	262.6	289.5	245.6	271.1
Nut coke	kg/t HM	66.5	47.8	39.0	66.8	70.9	53.5	35.3	32.1
Total coke	kg/t HM	328.4	313.9	358.0	355.8	333.5	343.0	280.9	303.2
Injectants									
Coal	kg/t HM	169.7	171.5			147.9	159.8	235.1	214.9
Oil	kg/t HM			100.5	23.5			0.9	
Plastics	kg/t HM								
Natural gas	kg/t HM				84.9				
Total injectants	kg/t HM	**169.7**	**171.5**	**100.5**	**108.4**	**147.9**	**159.8**	**236.0**	**214.9**
Total reductants	kg/t HM	**498.1**	**485.4**	**458.5**	**464.2**	**481.4**	**502.8**	**516.9**	**518.1**
Productivity	t/m³(WV)x24h	2.18	2.24	3.44	2.57	2.80	2.49	3.18	2.64
HM production	Million t	2.0	3.1	1.2	2.5	1.7	4.1	2.5	3.6

5 Coke property requirements

The excellent blast furnace results with high productivities, low coke and reductant rates and long campaign lives are only achievable with charged cokes being excellent in properties. Coke plays a triple role in the blast furnace, namely a physical, thermal and chemical role, of which the physical and chemical are the most important ones.

Coke quality test standards and requirements for chemical and physical properties can be related to the tasks coke performs in the blast furnace and to

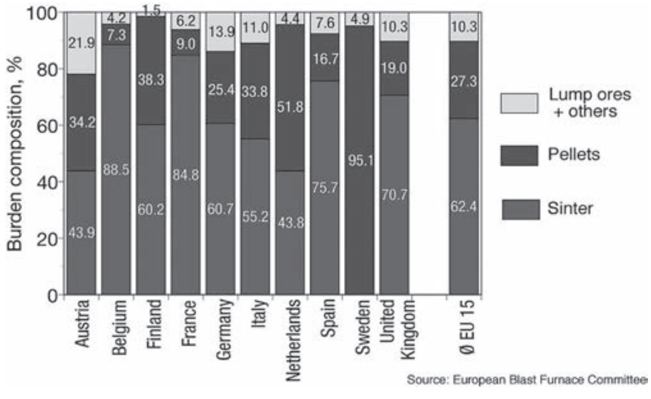

Fig.17 Ferrous Burden Composition of Blast Furnace Works in Europe, 2008

the mode of blast furnace operation. The requirements on blast furnace coke properties are listed in Table 5.

The physical and mechanical properties are today described by the level of coke stabilisation, grain size distribution, its cold strength for the dry part of the furnace (for example I_{40}, I_{10}) and for the high temperature zone by the coke CRI (Coke Reactivity Index) and the CSR index (Coke Strength after Reaction with CO_2).

High cold strength I40 values of over 57% guarantee the permeability in the dry region of the furnace. The CSR index should be high, that means over 65%, to produce a permeable dead man coke bed in the hearth. CRI indices which correlate with CSR indices should be kept as low as possible to shift the solution loss reaction to higher temperatures but the index should also be in a range, which guarantees satisfactory carburisation of the hot metal.

As to the ash, it is generally considered that its content should be below 9.0%. The main problems with coke ash are related to tramp elements. The sulphur content should be below 0.7%. In order to minimise the effect of alkalis on the blast furnace operation their content in the coke should be below 0.2%. The phosphorus content should be limited to 0.025%. According to the experience of blast furnace operators the coke moisture has no negative effect, if it is kept below 5.0%.

The amount of coke minus 40 mm is limited to 18%. The coke size fraction greater than 80 mm is limited to a maximum of 10% and the coke size fraction over 100 mm must be 0%.

6 Coke balance in the EU 15

16 years ago there still was more coke produced in the EU 15 than required by the steel industry. Compared to 1990 the coke production fell by 48% from nearly 60 million t to 31.2 million t coke in 2008, Fig.18. In this period many coke plants of the mining industry and also of the steel industry due to closures of integrated iron and steel works were shut down. The coke demand of the steel industry decreased by 20% only from 43 million t to 34.5 million in the past 18 years. Since 2000 the coke demand of the EU 15 steel industry is higher than the coke production. The shortage needs to be balanced by coke imports from the world market.

Germany was one driving force for this evolution in coke production within the EU 15. From Fig.19 it can be seen that coke production distinctly decreased caused by the disappearance of other coke consuming markets and by the lower coke consumption of the blast furnaces. This decrease has mainly effected the mining company. From the beginning of the 1990ies the demand of the steel industry for the first time could not be covered by Germany's coke production. Since then additional coke is imported from the world market. The situation meanwhile has improved by the commissioning of coke plant Schwelgern which supplies coke for ThyssenKrupp Steel.

Table 5 Requirements on Blast Furnace Coke Properties

		Requirement
Physical properties:		
CSR,	% > 10 mm	> 65
CRI,	%	< 23
I_{40},	% > 40 mm	> 57
I_{10},	% < 10 mm	< 18
Chemical properties:		
Ash,	% wf	< 9.0
S,	% wf	< 0.7
P,	% wf	≤ 0.025
Alkalis,	% wf	< 0.2
Moisture,	% wf	< 5.0
Size fraction:		
< 10 mm,	%	< 3
< 40 mm,	%	< 18
> 80 mm,	%	< 10
> 100 mm,	%	0

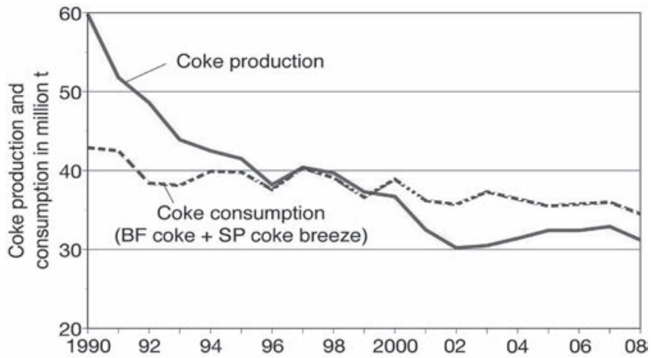

Fig.18 EU 15 Coke Production and Consumption by the Steel Industry

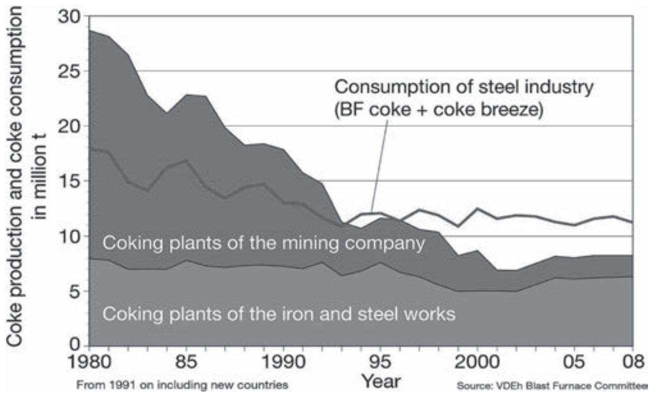

Fig.19 Coke Production and Consumption by the Steel Industry in Germany

7 Future need for R&D in the EU network

An intensive network of collaborative research work within coal and steel already exists in the EU, built up more than 50 years ago with the foundation of the ECSC (European Commission for Coal and Steel) which continues today within the successor organization RFCS (Research Fund for Coal and Steel). The main emphasis for the future need for R&D to be performed in the EU network are topics focusing on production technologies, new steel grades, new surface coatings, innovative processing of steel, improvement of energy and environmental efficiency and on the reduction of CO_2 emissions during steel making. As the blast furnace is indirectly the main CO_2 emitter it is clear that the main target is the reduction of carbon carriers, especially the coke, in the blast furnace process. A large project in Europe is the so-called ULCOS project (Ultra Low CO_2 Steel making), which evaluates biomass, electrolysis, hydrogen and natural gas use for steel making, but also the massive carbon reduction in the blast furnace[3].

Within a big multinational RFCS research project it is the aim to develop the nitrogen-free or oxygen blast furnace process, Fig.20, to industrial application[4]. In this process cold oxygen is injected into the tuyeres instead of hot blast; most of the top gas is passed to a CO_2 scrubber and a portion of the recovered CO-rich gas is re-circulated into the tuyeres heated up to 1200℃ while the remainder is heated to 900℃ and injected into the lower part of the blast furnace shaft via a second row of tuyeres[5].

From model calculations for this process variant it is evident that at a PCI rate of approximately 175 kg/t hot metal the coke rate could be decreased to only 200 kg/t hot metal[5]. The very much lower amount of coke required in comparison with today's operating practice may certainly come as a shock to blast furnace operators but need not necessarily result in operating problems. Given a requisite 95% pre-reduction degree of the ferrous burden in the lower furnace shaft, the amount of coke needed for the Boudouard reaction is reduced to only 15 kg/t hot metal compared to 107 kg/t hot metal during conventional blast furnace operation. The consumption of reductants (coke plus injection coal) was decreased by 24% as demonstrated in the experimental blast furnace of LKAB in Lulea, Sweden[6]. At this time plans to build a small industrial blast furnace with top gas recycling for a production of 0.5 million t hot metal annually are discussed. The time for development and implementation of such a technology at big blast furnaces, if ever possible, will take another 15 to 20 years. Additionally it has to be taken into account, that in the top gas recycling blast furnace process the amount of top gas available for the works gas network is decreased by 80%[5].

With the Hisarna smelting reduction process, Fig.21, liquid hot metal is produced on the basis of fine ores and coal[7]. The two step plant uses a cyclone, in which the fine ores are pre-reduced and melted, and an iron bath reactor where the ores are finally reduced. The pyrolysis of the coal is done outside the process in a reactor, which uses the heat generated by degassing the coal. The process is also operated with pure oxygen. The energy needed to produce oxygen is supplied by recovering the waste heat of the smelting plant. It is anticipated, that the plant has a waste gas with extreme high CO_2 concentration which may be directly stored. The construction of a pilot plant in Europe is planned.

One proposal to improve efficiency refers to the alternative utilization of coke oven gas[8,9]. The economy of the coke production in an integrated iron and steel works is directly connected to the credits achieved for the produced coke oven gas. Generally, a coking plant is linked with the interconnecting network of an integrated iron and steel works. Excess

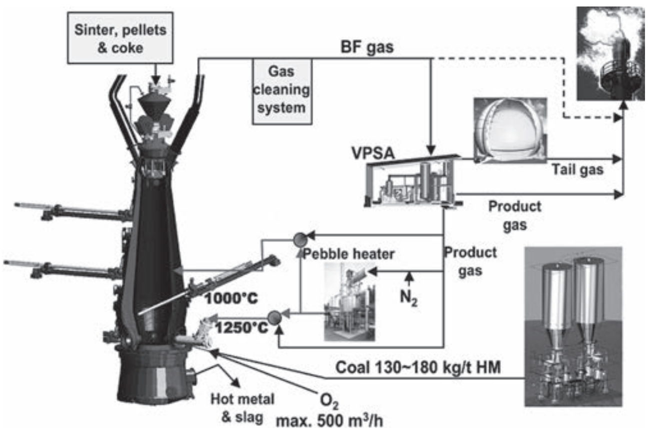

Fig.20 Top gas recycled blast furnace

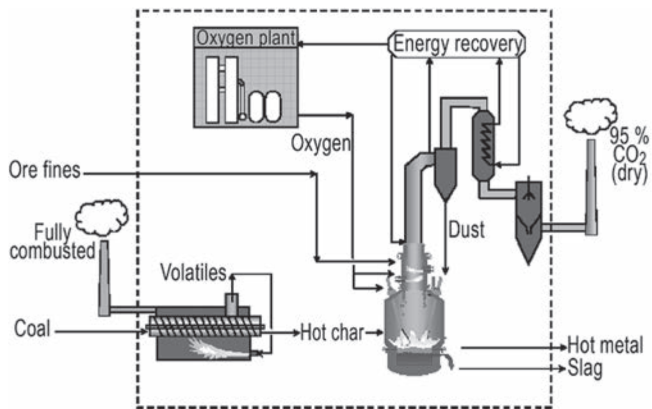

Fig.21 Hisarna concept

coke oven gas is internally used by other steel works consumers for heating of sinter plant ignition furnaces, pusher type heating furnaces in rolling mills and for electric power generation in power plants[9]. The specific amount of coke oven gas generated differs from 410 to 560 m^3 (S.T.P.) per t of coke depending on the content of volatile matters in the coal charge. Coke oven gas needs to be cleaned from tar, benzol and sulfur. The low calorific value is in the range of 16.4 to 18 MJ/m^3 (S.T.P.). Coke oven gas is rich in H_2 content in the range of 55 to 65% and has a lower CO_2 load than natural gas. The CO_2 emission factor for natural gas is 56 t CO_2/TJ and for coke oven gas 40 t CO_2/TJ[10]. As a result of measures aimed at optimizing the energy consumption of integrated iron and steel works production systems, there partially is coke oven gas in excess which must be internally and externally used for power generation in a power station. The profit depends on the regional electric power prices. Besides the energy production, the following potentials are offered for coke oven gas utilization within the works economy, Fig.22:

- Injection of coke oven gas and tar as auxiliary reducing agents into the blast furnace. This technique has already been put into practice.
- Minimizing of equipment- and process-related resources in conventional coke oven gas treatment of a coking plant by heat, hydrogen and methanol generation or the utilization of coke oven gas as reducing gas in the production of DRI (Direct Reduced Iron) or HBI (Hot Briquetted Iron).

The gas generated from additional tar gasification may also be used in the DRI production or as a CO source in the methanol synthesis. The coke oven gas is partially cleaned and/or partially oxidized, densified and used in a direct reduction process for DRI/HBI production, Fig.23. A mixture of recycled gas from the direct reduction plant and coke oven gas is heated up in a reducing gas heater and introduced to the reduction zone of the stack after oxygen is added.

The produced DRI can be offered on the world market or processed in-plant in an electric arc furnace or in the basic oxygen furnace (BOF), Fig.24. For the DRI production an additional production plant is needed within the integrated iron and steel works. Recent cost calculations based on investment cost for a DR plant providing the required capacity and for hot charging the DRI to the BOF have shown a return of investment after approximately 3 years.

8 Conclusions

The integrated steel works in EU 25 operate most modern plants for the production of a wide variety of high grade steel products. The blast furnace/converter route will remain dominant within the EU 25 on a long term with a share of approximately 60%. The basic pre-product for this route is hot metal

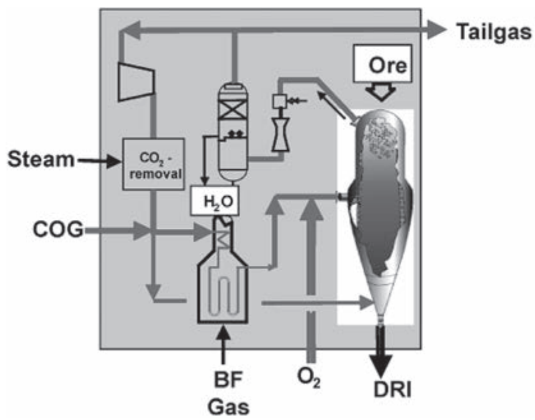

Fig.23 DRI - Process

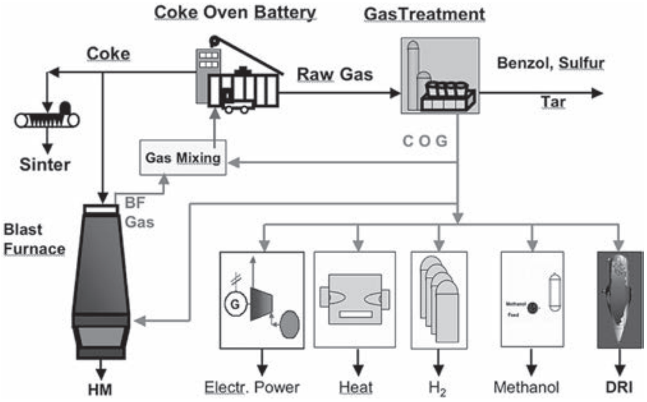

Fig.22 Different optional Products from Coke Oven Gas (COG)

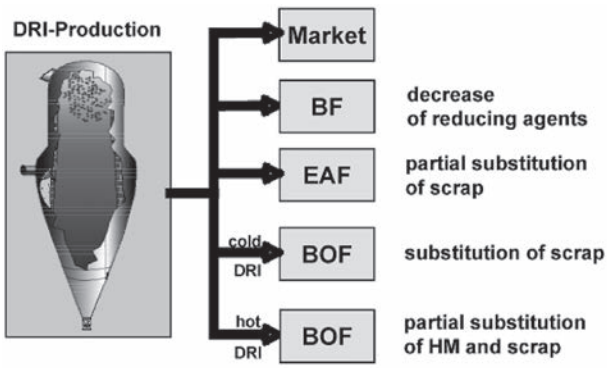

Fig.24 Different Options for Utilisation of DRI in Integrated Iron and Steel Works

from blast furnaces. Blast furnaces cannot be operated without coke and they are dependent on high grade coke supply. Many young and high tech coke plants are operated in Europe, but some are old and need lifetime enlargement measurements or revamping. The new batteries of the coke plant Schwelgern in Germany represent the most advanced state of development of the multi chamber system. This plant has by far the biggest coking chambers in the world. The European integrated steel works operate successfully blast furnaces at low reductant rates, high productivities and long campaign lives. This can only be achieved with the use of cokes having excellent properties, especially for the operation of large volume blast furnaces. The coke demand and supply balance of the EU was characterized by a steady decrease in available coke plant capacities since 1990 and a coke shortage since 2000 for the former EU 15. Poland is the main internal coke supplier for other EU 27 countries. R&D in the EU 27 is amongst others focused on the reduction of CO_2 emissions by the development of the oxygen blast furnace process. The use of excess coke oven gas for the production of DRI is an alternative option instead of power generation.

References

1）Source：European Blast Furnace Committee
2）Source：VDEh Blast Furnace Committee
3）J.-P.Birat, F and Hanrot：ULCOS – European steelmakers efforts to reduce greenhouse gas emissions; Proceedings 2nd volume of the 5th European Coke and Ironmaking Congress, paper We 7：3, Stockholm, Sweden, 12-15 June（2005）
4）B.Korthas, M.Peters and P.Schmöle：Back to the future – ideas for new blast furnace concepts; Proceedings 1st volume of the 5th European Coke and Ironmaking Congress, paper Mo 1：4, Stockholm, Sweden, 12-15 June（2005）
5）P.Schmöle and H.B.Lüngen：Hot metal production from the economical point of view; Proceedings 2nd International meeting on ironmaking, Vitória, Brazil, 13-15 September（2004）, 238-253.
6）G.Zuo, et. al.：Trials for the new blast furnace concept ULCOS; presented at STAHL 2008, Düsseldorf, 13 November（2008）
7）http://www.ulcos.org
8）P.Diemer, H.-J.Killich, K.Knop, H.B.Lüngen, M.Reinke and P.Schmöle：Potentials for utilisation of coke oven gas in integrated iron and steel works; Proceedings 2nd International Meeting on Ironmaking, Vitória, Brazil, 13 to 15 September（2004）, 433-446.
9）H.B.Lüngen, R.Poss, M.Reinke and C.-D.Wuppermann：Utilisation of coke oven gas for the production of DRI. Paper presented at IISI – TECHCO 38 Meeting, Buenos Aires, 6./7. April（2006）

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