ACTUAL STATUS AND FUTURE ASPECTS OF COKE AND IRONMAKING IN EUROPE[1]

Hans Bodo Lüngen [2]
Helmut Schulte [3]

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 60%. 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. The projects for new coke batteries or revamping of batteries will result in an enlargement of available coke capacity within the EU 27 from 2008 on. R&D in the EU 27 is amongst others focused on the reduction of CO2 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.

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2 *Dr.-Ing. Senior Manager Metallurgy and Team Production, Steel Institute VDEh, Düsseldorf, Germany*
3 Dipl.-Ing. *General Manager Process Technology Coke Plant Technologies, Uhde, Dortmund, Germany*

INTRODUCTION

Worldwide the steel industry has set a new record with a production of 1343 million t of crude steel in 2007. To estimate the future demand for hot metal and coke the evolution of the share of steel making processes has to be considered, Figure 1. Worldwide the share of oxygen steel making amounted to 66.4 %, that of the electric steel making route to 31.4 %. The growing steel production of 93 million t in 2007 compared to 2006 was achieved by an increase of 65 million t of hot metal production as pre-product for oxygen steel making. It can be seen that the coke plant/blast furnace/oxygen converter route is worldwide the dominating crude steel production route.

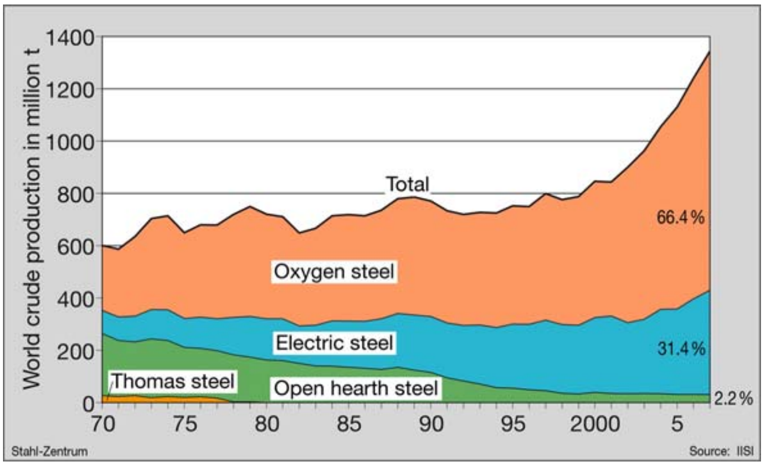

Figure 1: World Crude Steel Production by Process

The ratio of hot metal to crude steel remained nearly unchanged during the last 15 years at a level of 0.70. The hot metal production increased in the same period from 500 to 946 million t/a, Figure 2. The ratio of coke to hot metal production in the world decreased from 0.72 in 1995 to 0.58 in 2007 as a result of worldwide decreases in coke consumption in the blast furnaces.

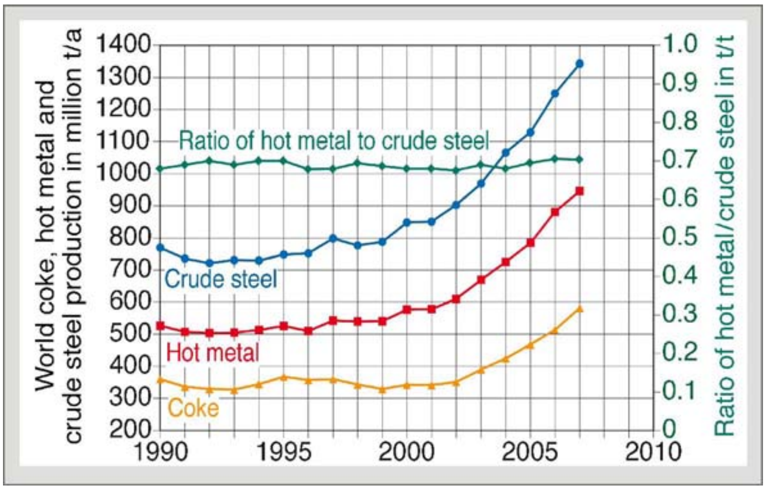

Figure 2: World Crude Steel, Hot Metal, Coke Production and Ratio Hot Metal/Crude Steel

It is expected that the growth in steel making will continue, Figure 3. The worldwide hot metal production of 946 million t in 2007 was by nearly 100% produced in blast furnaces, 4 million t liquid hot metal came from Corex and Finex plants. The corresponding coke consumption of the steel industry was 430 million t of blast furnace coke and coke breeze for the sinter plants. For 2010 a crude steel production of 1580 t is estimated /1/. From the metallic charge for crude steel production it is anticipated that the hot metal supply plays the major role. The metallic charge demand will be 1843 million t and met by 1140 million t hot metal, 623 million t steel scrap and 80 million t DRI. The steel industry's coke demand for blast furnaces and sinter plants could reach 520 million t.

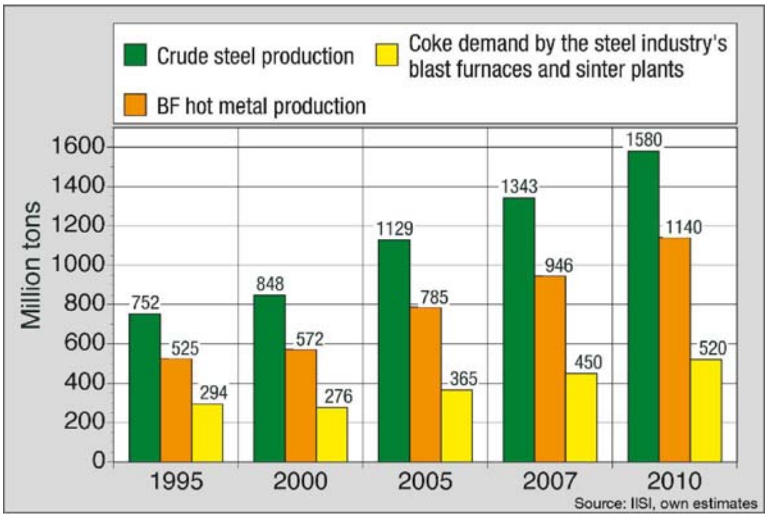

Figure 3: World Hot Metal, Crude Steel and Steel Industry's Coke Consumption

In 2007 worldwide coke production reached a new peak with 544.5 million t, Figure 4. China holds a share of 59 %. 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 94.5 million t in 2007. 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. This would require a total coke demand in 2010 of approximately 610 million t. To counteract this increasing demand new coke plant projects are on the way, not only in China, but also in regions not being self sufficient in coke supply today, like Europe, South East Asia, South America and North America.

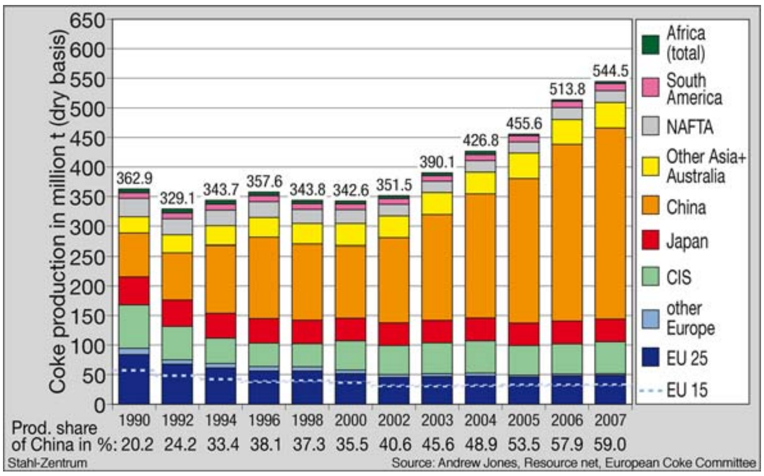

Figure 4: World Coke Production by Region

THE EUROPEAN STEEL INDUSTRY AT A GLANCE

The EU 27 is after China the second biggest steel producer of the world, Figure 5. Total crude steel production in 2007 amounted to 209.5 million t corresponding to a share of 15.6% 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 88.9 % are applied in China and of 74.2 % in Japan. A high amount of electric steel is produced in the USA with s share of 58.9 %. In the EU 27 the ratio of electric steel making has today reached 40.2 %.

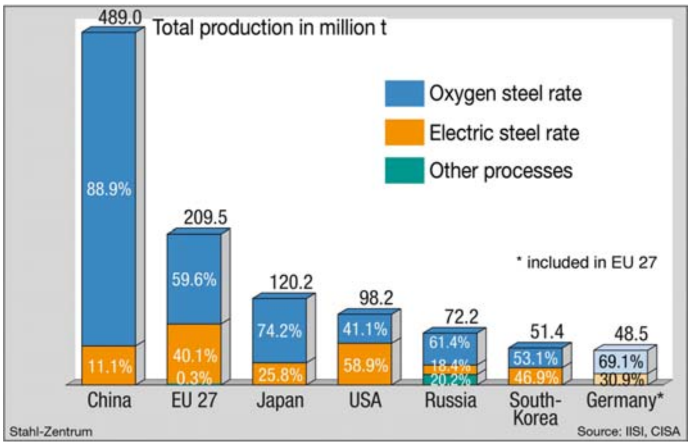

Figure 5: Crude Steel Production in 2007 World Crude Steel 1343 million t

Looking to the EU 27 scenario the share of oxygen steelmaking has remained nearly at the same share of 60 % or 125 million t, Figure 6. Electric arc furnaces have completely replaced the obsolete open hearth furnace.

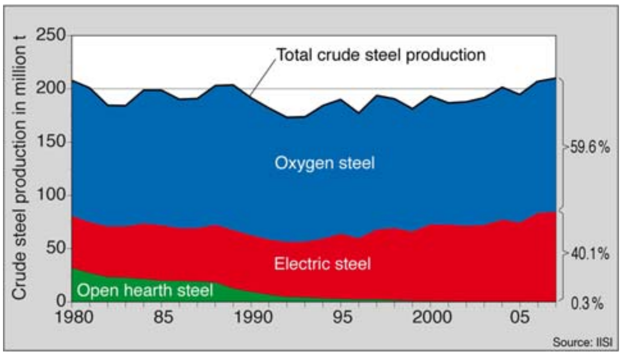

Figure 6: Crude Steel Production in EU 27 Countries by Process

There are existing approximately 200 steel producing locations in the EU 27, the 19 biggest having a crude steel capacity of over 3 million t are identified and listed in Figure 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, Dunkerque in France and IJmuiden in The Netherlands having a capacity of 6.5 million t each. The biggest steel town of the new EU member countries is Dabrowa Gornicza in the south of Poland.

Figure 7: Crude Steel Production Sites of EU 27 with a Capacity > 3 Million t/a, 2007

Shanghai and Duisburg are today the biggest steel producing locations in the world, Figure 8. Shanghai is a new industrial location with remarcable growth rate over the last years and the end is not yet seen. Steel and Duisburg are bound to each other for generations. This location was choosen for steel making in the middle of the 19^{th} 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 10 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 and Europe.

Figure 8: Crude Steel Production Sites in the World with a Capacity > 10 Million t/a, 2007

The main steel producing countries in the EU 27 are Germany, Italy, France, Spain and Great Britain, Figure 9. The average share of oxygen steel making lies at around 59.6 %. High shares of electric steel making exist in Italy (63.3 %), Spain (78 %) and Luxemburg (100 %).

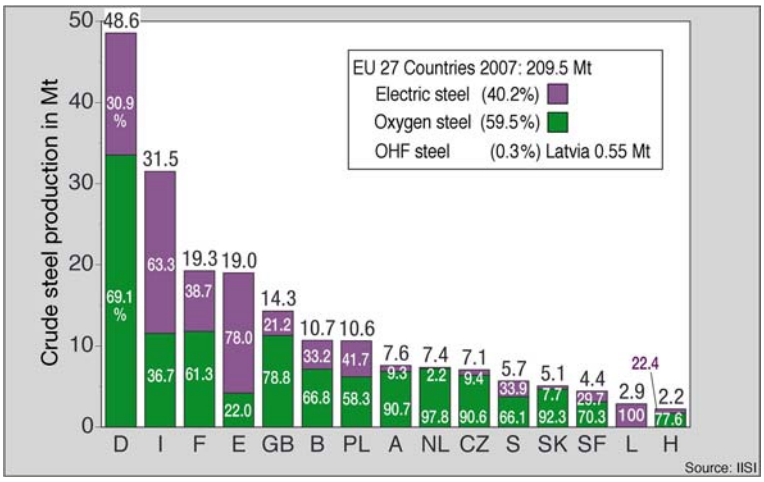

Figure 9: Crude Steel Production of EU 27 Countries 2007 by Process

COKE PLANT SITUATION

45 coke plants are operated in the EU 27, Figure 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, Figure 11. 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.

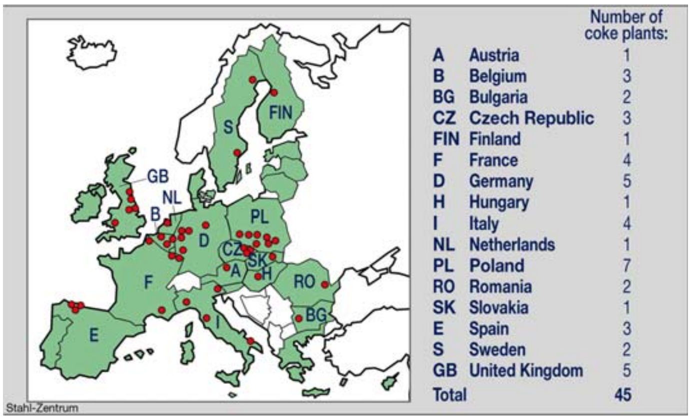

Figure 10: Coke Plants in the EU 27

	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

Figure 11: Coke Plant Capacities and Age Structures in EU 27 (2007)

Germany's youngest and world’s most modern coke plant went on stream in Duisburg Schwelgern on the production site of ThyssenKrupp Stahl (TKS) in 2003, Figure 12. 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.

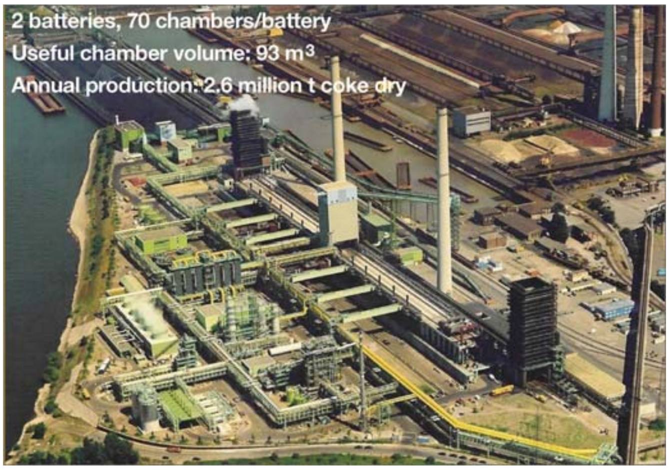

Figure 12: Coke Plant Schwelgern, commissioned 2003

BLAST FURNACE SITUATION

The evolution of hot metal production is focused on the former EU 15 countries /2/, because no blast furnace operation data are available by now for the new EU member states.

Figure 13 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 2007 the same amount was produced by only 57 blast furnaces. The average production per blast furnace and year increased by 59% from 1.04 to 1.65 million t hot metal. The average working volume of the furnaces increased by 25% from 1630 m^3 to 2035 m^3 and the average productivity of the blast furnace increased by 10.5 % from 2.2 to 2.43 t/m³ (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.

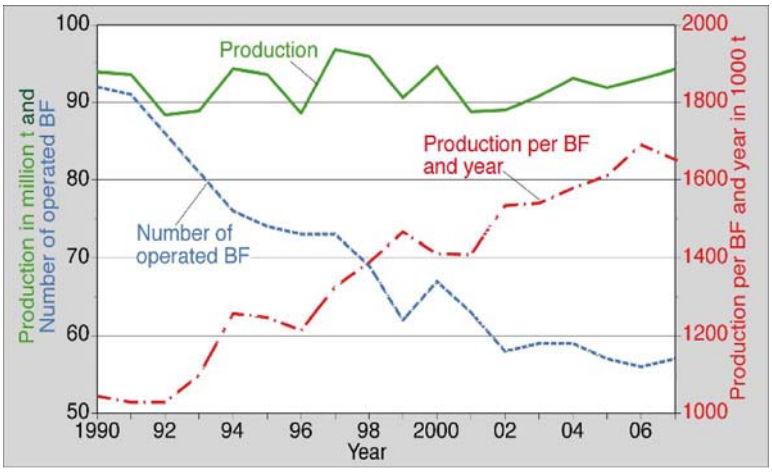

Figure 13: Evolution of Hot Metal Production in the EU 15 Number of Operated Blast Furnaces (BF) and Production per BF and Year

The majority of the furnaces are medium sized with hearth diameters between 8.0 and 11.9 m, Figure 14. The average hearth diameter for all blast furnaces is 10.0 m. The large units over 12.0 m are listed in this Figure 15.

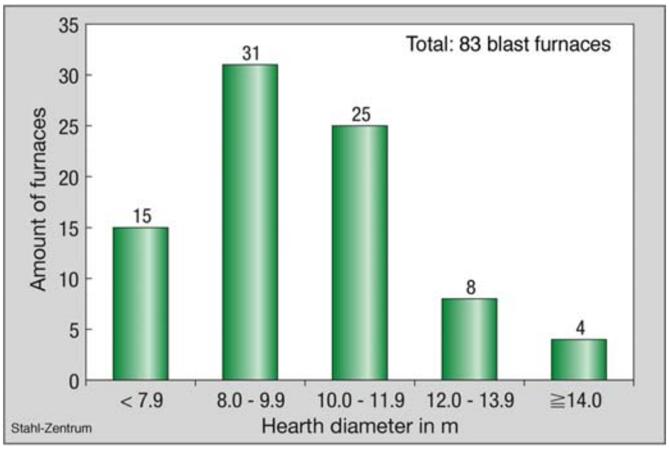

Figure 14: Actual Blast Furnace Sizes in EU 27 as of June 2008

Country	Company	BF No.	Hearth diam., m	Working vol., m^3	HM capacity, million t/a
Germany	TKS	Schwelgern 2	14.90	4796	4.20
Italy	Ilva	Taranto 5	14.00	3650	3.54
France	Arcelor	Dunkerque 4	14.00	3940	3.45
UK	Corus	Redcar	14.00	4017	3.20
Netherlands	Corus	IJmuiden 7	13.83	3790	3.47
Germany	TKS	Schwelgern 1	13.60	3844	3.50
Austria	voestalpine	Linz A	12.00	3125	2.80
Germany	Stahlw. Bremen	Bremen 2	12.00	3148	2.45
Germany	Rogesa	Dillingen 5	12.00	2581	2.43
Poland	Mittal Steel	Dabrowa 1	12.00	3200	2.46
Poland	Mittal Steel	Dabrowa 2	12.00	3200	2.05
Poland	Mittal Steel	Dabrowa 3	12.00	3200	2.20

Figure 15: Largest West European Blast Furnace (EU 27)

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 345.4 kg/t HM in 2007 through increased coal injection rates from 50 to 127.6 kg/t HM, Figure 16. Oil plus others remained nearly unchanged for the same period at a level of approximately 20 kg/t HM.

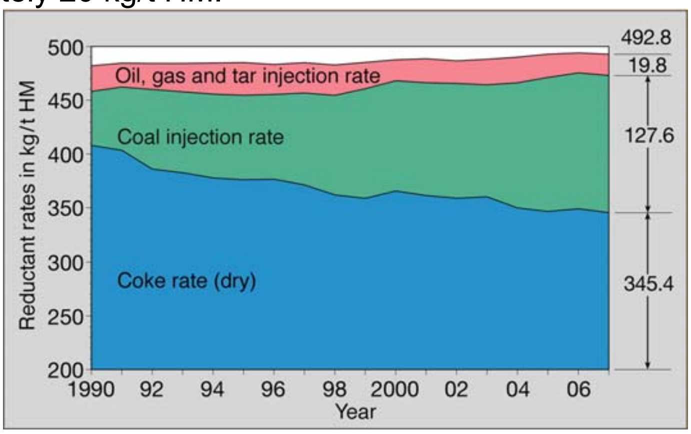

Figure 16: Evolution of BF Reductant Rates in the EU 15

On a worldwide level the European blast furnaces are playing in the top league, Figure 17. The world average reductant rate in 2006 was 543 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 world`s average. The European blast furnaces also achieved very low total reductant consumptions.

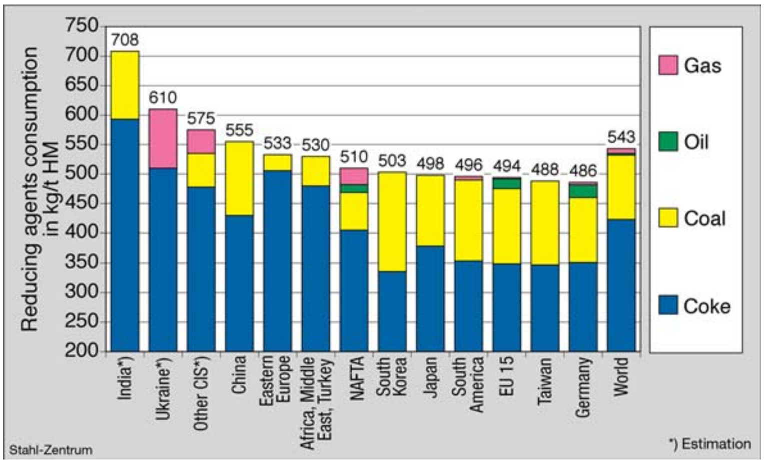

Figure 17: Reducing Agents Consumption of Blast Furnaces in the World, 2006

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, Figure 18. The measures taken to achive this evolution are mentioned 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.

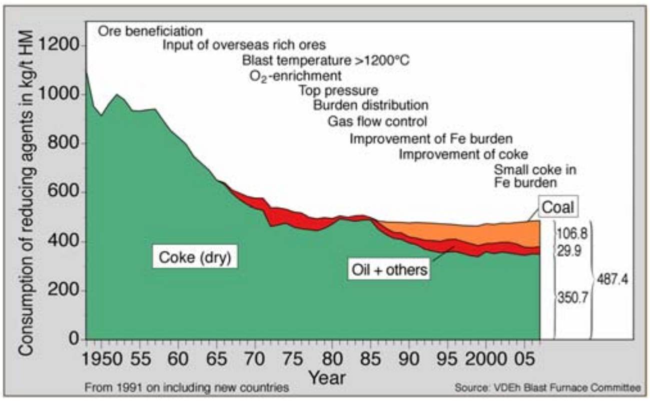

Figure 18: Average Consumption of Reducing Agents of the Blast Furnaces in Germany

It must of course be taken into consideration that these results have to be adapted to the continual development of blast furnace operating modes. Figure 19 illustrates this for the evolution of hot metal production in Germany during the past 37 years /3/.

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 30 million t in 2007. This is an output increase per blast furnace and year of 376%. This was not only achieved by increasing the blast furnace size but also by increasing the productivity of the furnaces by 56%.

Year		1970	2007	Relative change %
Number of operated blast furnaces		80	15	- 81
Production per BF and year,	million t HM	0.42	2.00	+ 376
Average productivity,	t HM/m^3 W.V. 24h	1.54	2.40	+ 56
Coke consumption,	kg/t HM	537	351	- 35
Total reductant consumption,	kg/t HM	577	487	- 16
Share of agglomerated Fe burden,	%	62	85	37
Slag volume,	kg/t HM	379	270	- 29

Figure 19: Evolution of Hot Metal Production in Germany

At individual European furnaces extraordinary operation modes regarding coke rate and injectants were achieved in 2007, Figure 20. Highest coal rate was realized at the blast furnace 6 of Tata Corus in IJmuiden with 238 kg/t HM as yearly average. The lowest coke rate of 262 kg/t HM was achieved at this furnace.

Country		NL	D	D	FIN	D	D	D	A
Works		Corus IJmuiden	TKS Schwelg.	TKS Hamborn	Ruukki Raahe	ArcelorMittal Bremen	HKM Huckingen	Arcelor Mittal EH	voestalpine Linz
BF-no.		6	2	9	2	2	B	5A	A
Hearth-Ø	m	11.0	14.9	10.2	8.0	12.0	11.0	9.75	12.0
Coke rate	kg/t HM	261.7	345.9	317.8	358.5	326.9	361.4	330.1	349.3
Coal rate	kg/t HM	238.2	152.0	176.3		165.8		168.3	
Oil rate	kg/t HM	0.5			107.2	3.0	25.9		78.1
Plastics+tar rate	kg/t HM								17.6 + 11.2
Natural gas rate	kg/t HM						85.6		
Total inj. rate	kg/t HM	238.7	152.0	176.3	107.2	168.8	111.5	168.3	106.9
Reducing agents	kg/t HM	500.4	497.9	494.1	466.1	495.7	472.9	498.4	456.2
Productivity	t/m$^3_{WV}$d	3.44	2.60	3.00	2.95	1.98	2.64	2.47	2.80
Slag volume	kg/t HM	191	278	290	225	269	284	272	225
O_2-contentin blast + lances	%	36.0	28.5	30.7	26.6	23.2	28.1	23.7	26.6
HM production	Mill.t/a	2.85	4.39	1.89	1.20	2.15	2.58	1.51	3.05

Figure 20: Examples for extraordinary BF results Average for 2007

Today certain amounts of nut coke are charged with the ferrous burden. In 2007 at TKS Hamborn No. 9 furnace the coke rate of 317.8 kg/t HM includes 86.2 kg/t HM nut coke charged with a grain size of 10 to 35 mm, the remaining bell coke rate being only 231.6 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 107 kg/t HM. At blast furnace B HKM in addition to heavy oil (25.9 kg/t HM) natural gas (85.6 kg/t HM) was injected.
Further special injectants to be mentioned here is 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.

This furnace also reached the highest productivity level which was 3.44 t HM/m³ (W.V.) 24 h.
The highest yearly production of 4.39 million t HM in 2007 was achieved at blast furnace Schwelgern 2 of ThyssenKrupp Steel.
The ferrous burden composition of the West European blast furnaces differ in a wide range, Figure 21. High sinter rates of over 50 % are charged to the blast furnaces in Belgium, France, Spain, Germany and Italy whilst high pellet rates of 53 % are used in The Netherlands and of 95 % in Sweden. The average burden composition of the blast furnace in the EU 15 was 62 % sinter, 26.9 % pellets and 11.1 % lump ores plus others.

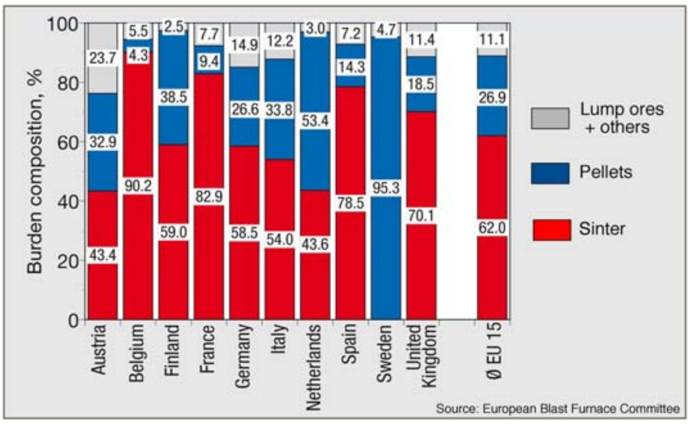

Figure 21: Ferrous Burden Composition of Blast Furnace Works in Europe, 2007

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 the mode of blast furnace operation. The requirements on blast furnace coke properties are listed in Figure 22.

		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

Figure 22: Requirements on Blast Furnace Coke Properties

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 I_{40} 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 – especially in Germany – 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 %.

COKE BALANCE IN THE EU 15

15 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 45% from nearly 60 million t to 32.9 million t coke in 2007, Figure 23. 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 only decreased by 16% from 43 million t to 36.0 million in the past 17 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.

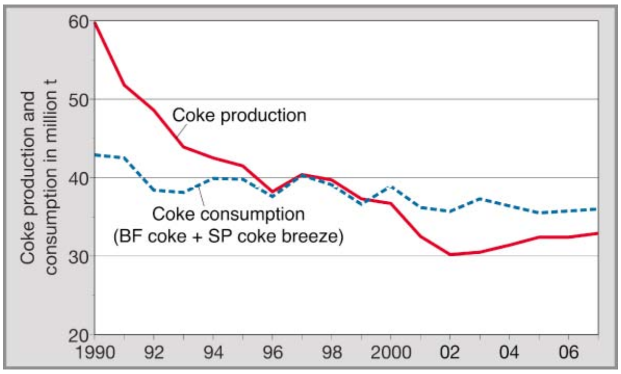

Figure 23: EU 15 Coke Production and Consumption by the Steel Industry

Germany was one driving force for this evolution in coke production within the EU 15. From Figure 24 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 and by the taking over of the French coke plant Carling by the German Rogesa (AG der Dillinger Hüttenwerke).

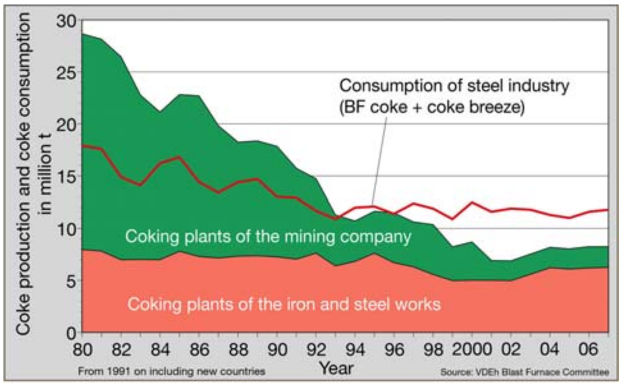

Figure 24: Coke Production and Consumption by the Steel Industry in Germany

A second coke battery is planned at Hüttenwerke Krupp Mannesmann which will more than double the coke production from currently 1.1 to 2.3 million t. Commissioning is planned for end of 2011.
Within the EU 27 Poland is the main coke supplier for external coke demands of other EU countries.

FUTURE NEED R&D IN THE EU NETWORK

An intensive network of collaborative research work within coal and steel already exists in the EU, built up 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 environmental efficiency and on the reduction of CO_2 emissions during steel making. As the blast furnace is 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 use natural gas use for steel making but also the massive carbon reduction in the blast furnace, Figure 25 /4/.

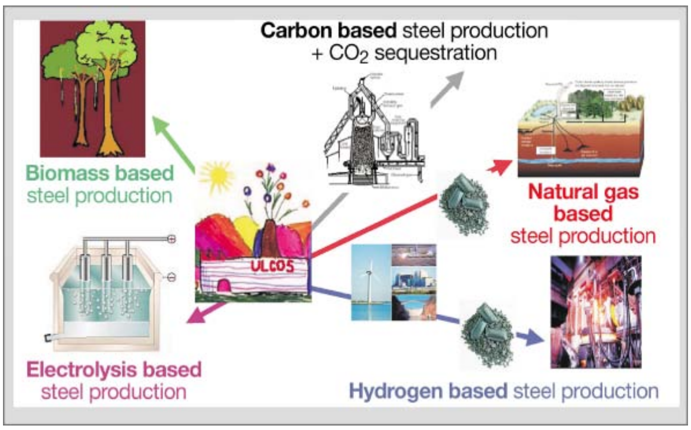

Figure 25: World Steel Initiative in R&D: ULCOS - Part of the IISI CO_2 Breakthrough Programs

Within a big multinational RFCS research project it is the aim to develop the nitrogen-free or oxygen blast furnace process, Figure 26, to industrial application /5/. 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 CO gas formed is fed into the tuyeres in its cold state while the remainder is heated to 900° C and injected into the lower part of the blast furnace shaft via a second row of tuyeres. 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 /6/. 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) can be decreased by 20% if this research project will supply successful results. But this also means, that carbon-free and coke-free blast furnace operation is generally not possible.

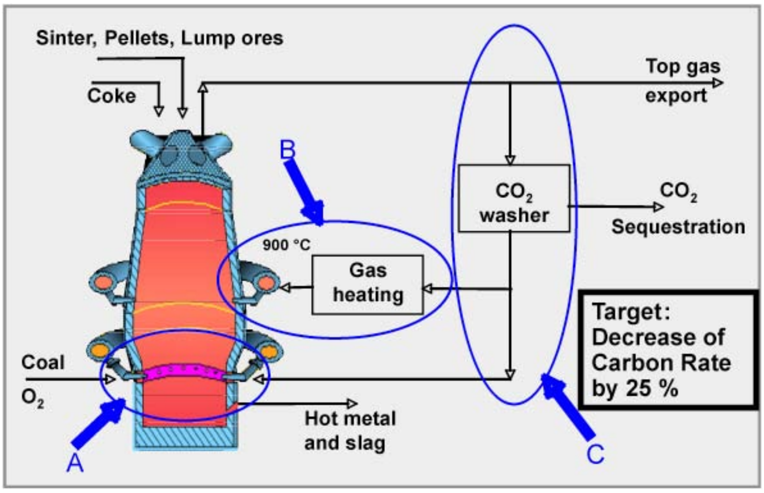

Figure 26: Design, Engineering and Modification of the Oxygen BF

One proposal to improve efficiency refers to the alternative utilization of coke oven gas. This is not yet included in a RFCS project. 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 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 /7/. 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 /8/.
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, Figure 27:

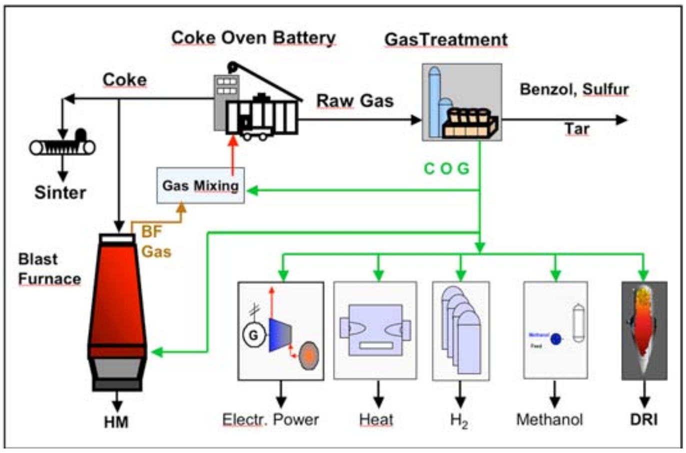

Figure 27: Different optional Products from Coke Oven Gas (COG)

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, Figure 28. 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.

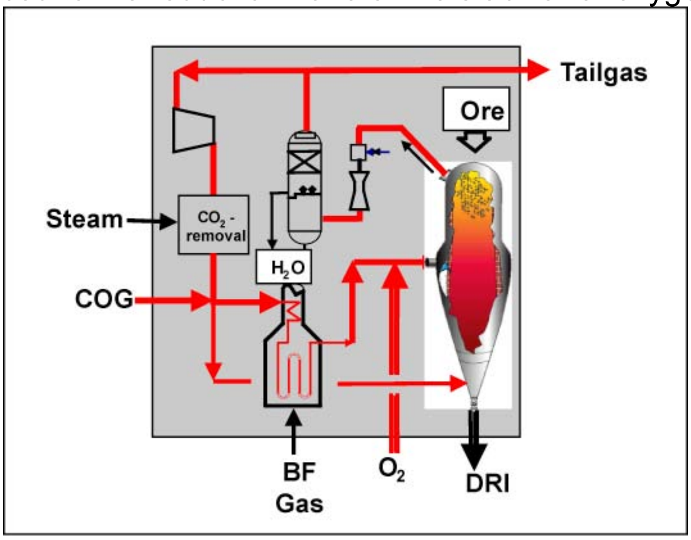

Figure 28: DRI - Process

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), Figure 29. 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/.

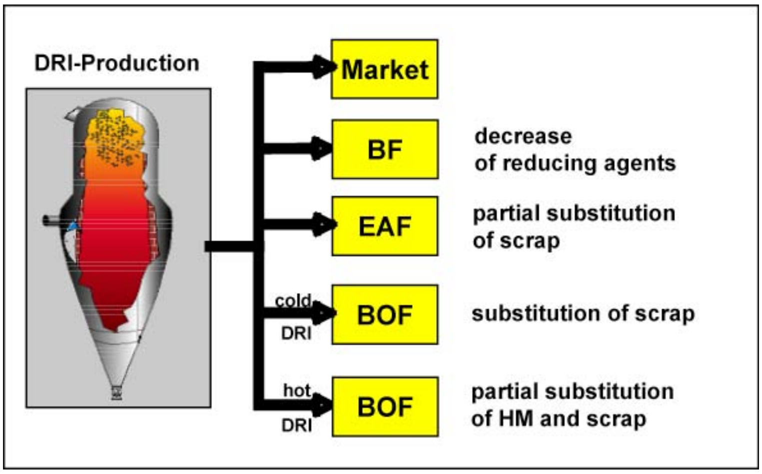

Figure 29: Different Options for Utilisation of DRI in Integrated Iron and Steel Works

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 60%. 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.

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