7th ECiC 2016

7th European Coke and Ironmaking Congress

EVALUATION OF THE CAPABILITIES OF DIRECT AND SMELTING REDUCTION PROCESSES TO ENHANCE THE ENERGY EFFICIENCY AND TO REDUCE THE CO_2 EMISSION OF THE STEEL PRODUCTION IN EUROPE

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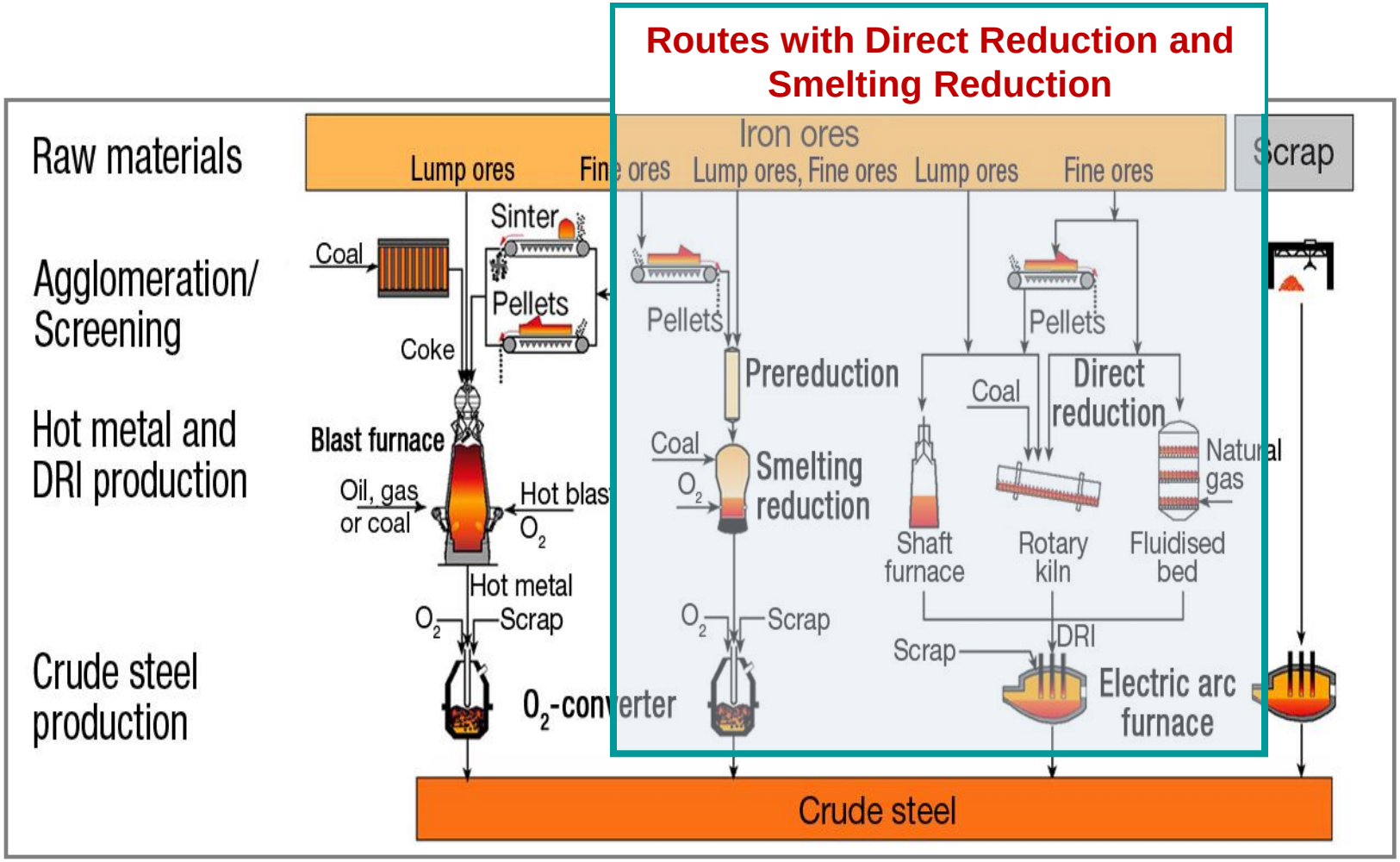
Outline of presentation

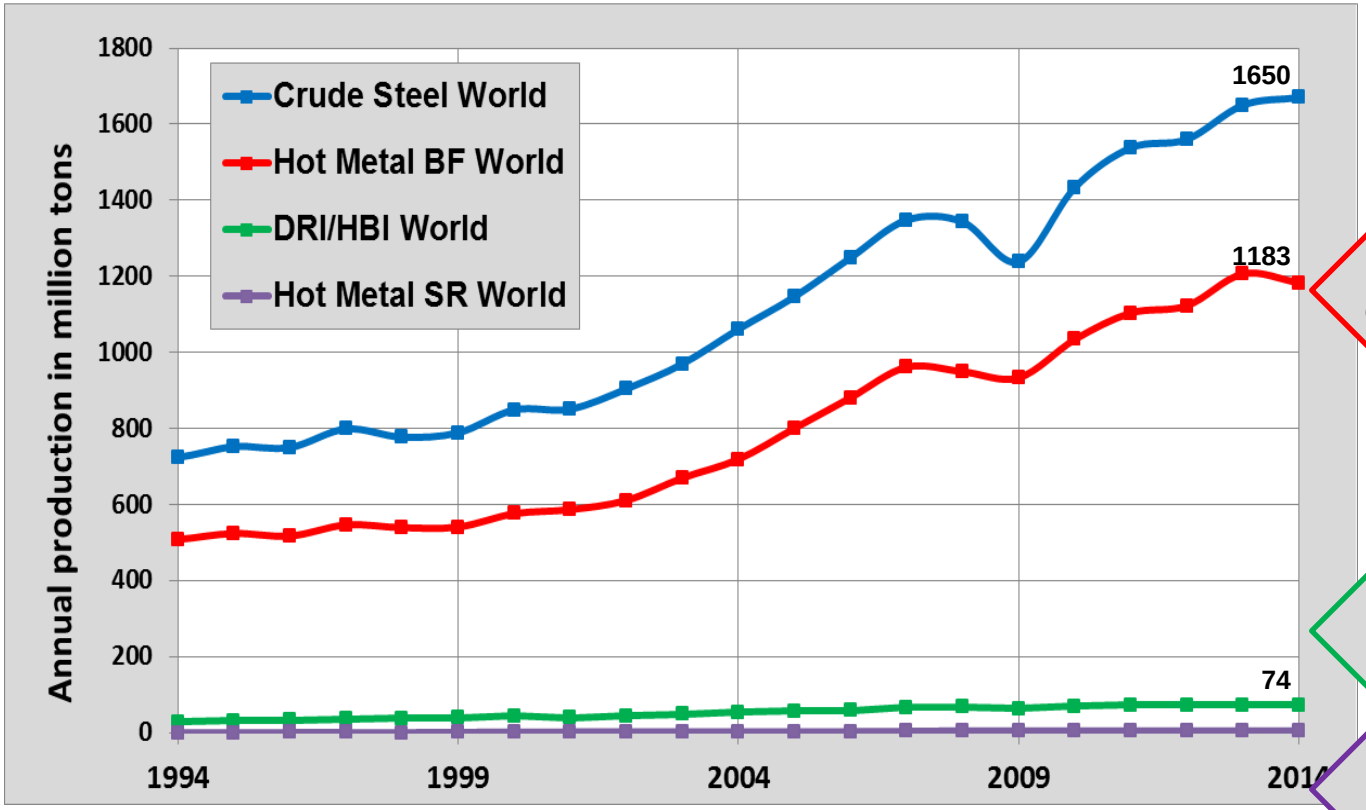
- State of the art technology and penetration of iron production with DR and SR processes
- Boundary conditions and requirements for the DR and SR processes to produce iron in Europe
- Possible concepts for integration of DR and SR processes into existing integrated iron and steelworks
- Comparison of energy consumption of the process routes
- Comparison of emissions of the process routes
- Hydrogen production and hydrogen reduction

Process Routes for Production of Crude Steel



Source: Stahlfibel (Herausgegeben vom Verein Deutscher Eisenhüttenleute, 1999)

Production of Crude Steel, Hot Metal and DRI/HBI (1994 – 2014)



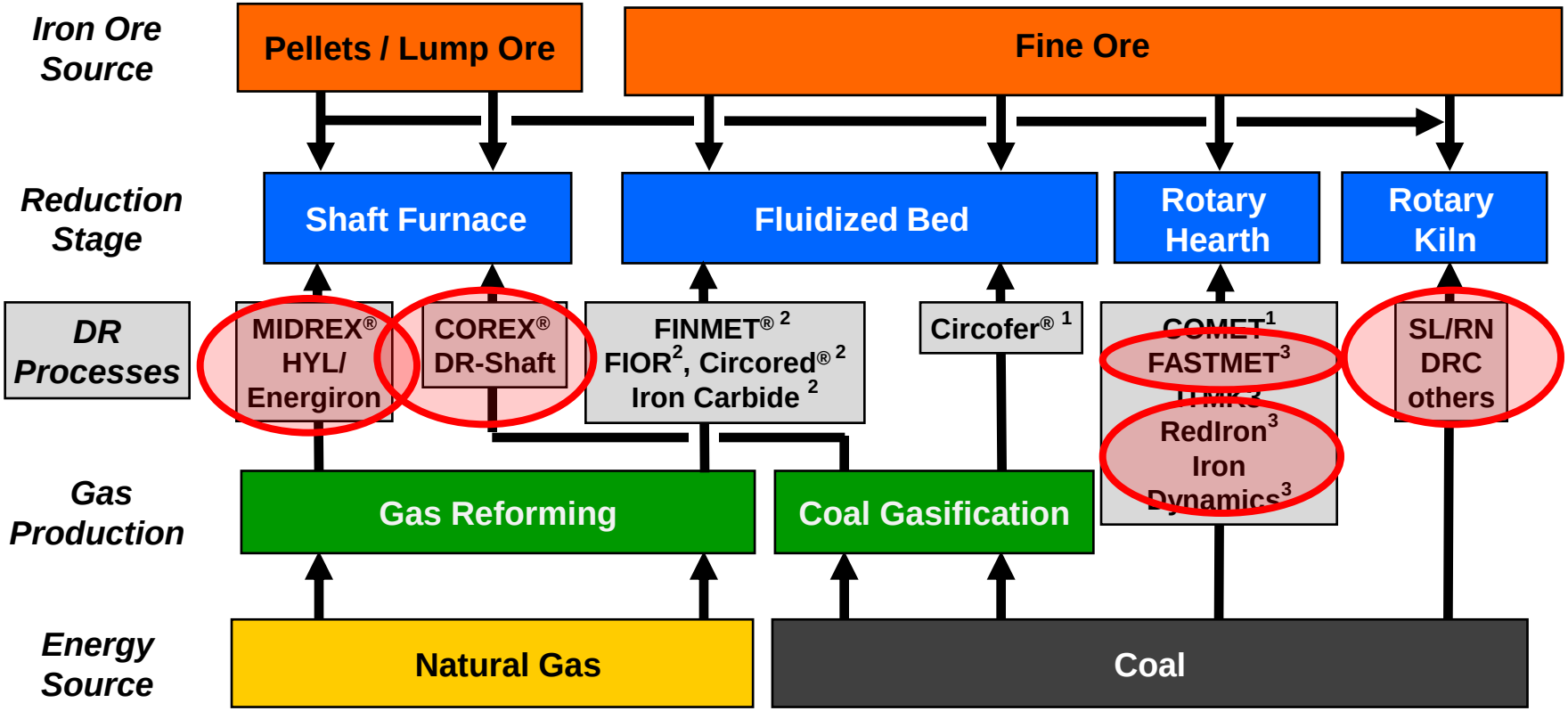
Hot Metal from BF is ~ 71 % of Crude Steel Production

DRI/HBI is ~ 5 % of Crude Steel Production

Hot Metal from SR ~ 0.3 % of Crude Steel Production

Quelle: World Steel Association, Steel Statistcal Yearbook 2014, own data

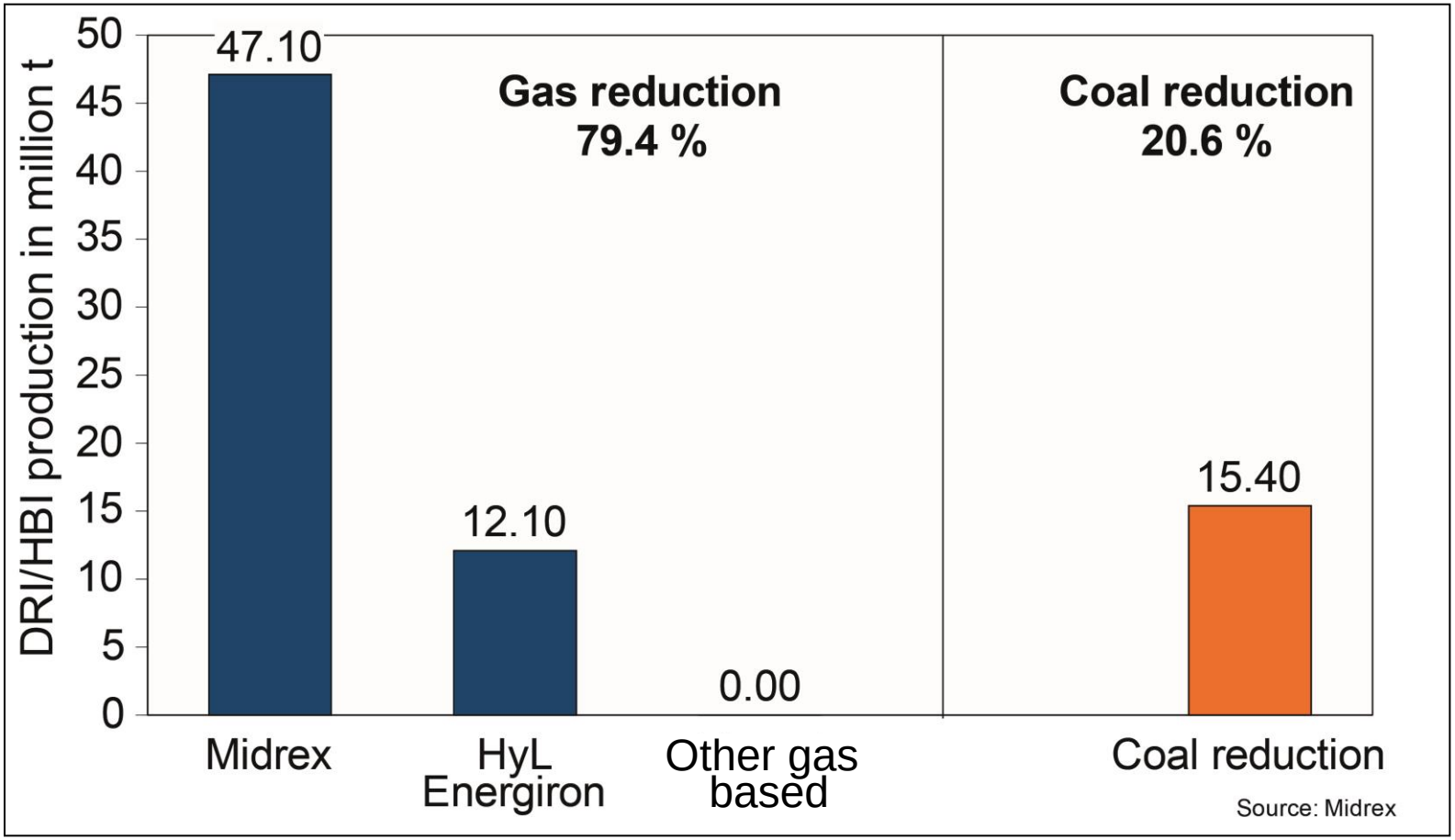
Classification of Direct Reduction Processes



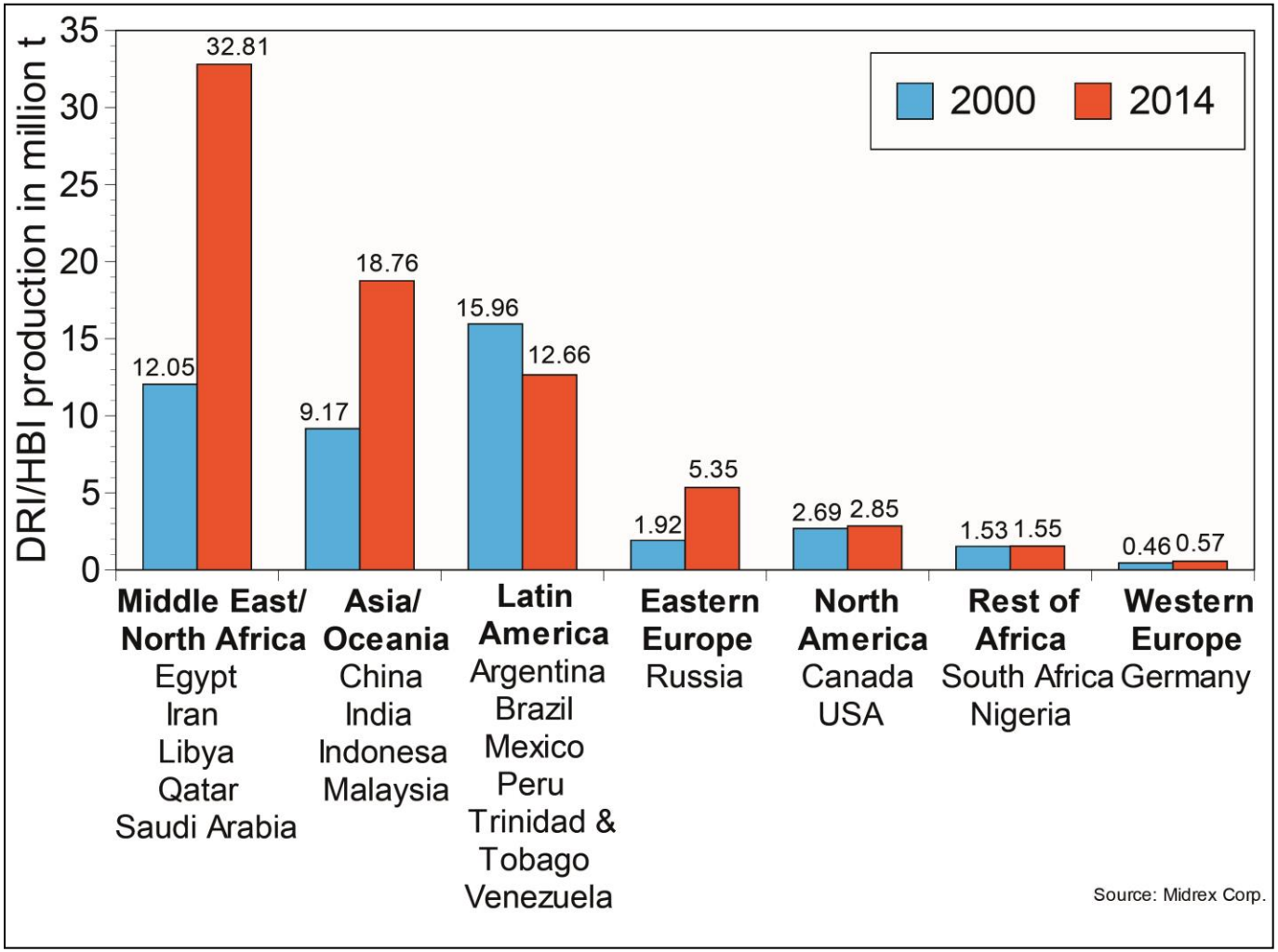
[1] Process tested in pilot scale, [2] Operation stopped, [3] Recycling of residues

Plants in industrial scale are in operation

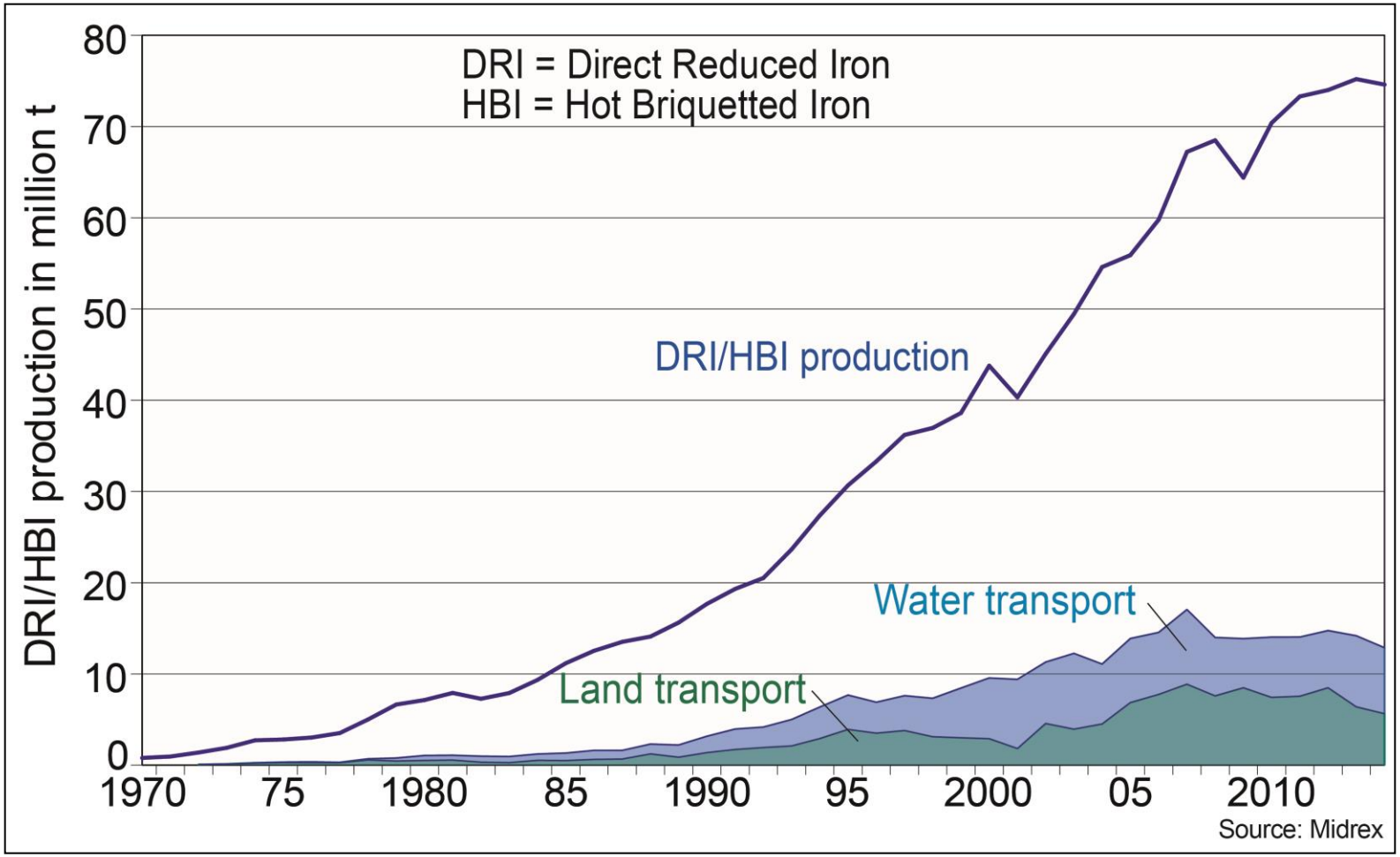
DRI/HBI Production by Process
(production 2014: 74.6 million t)



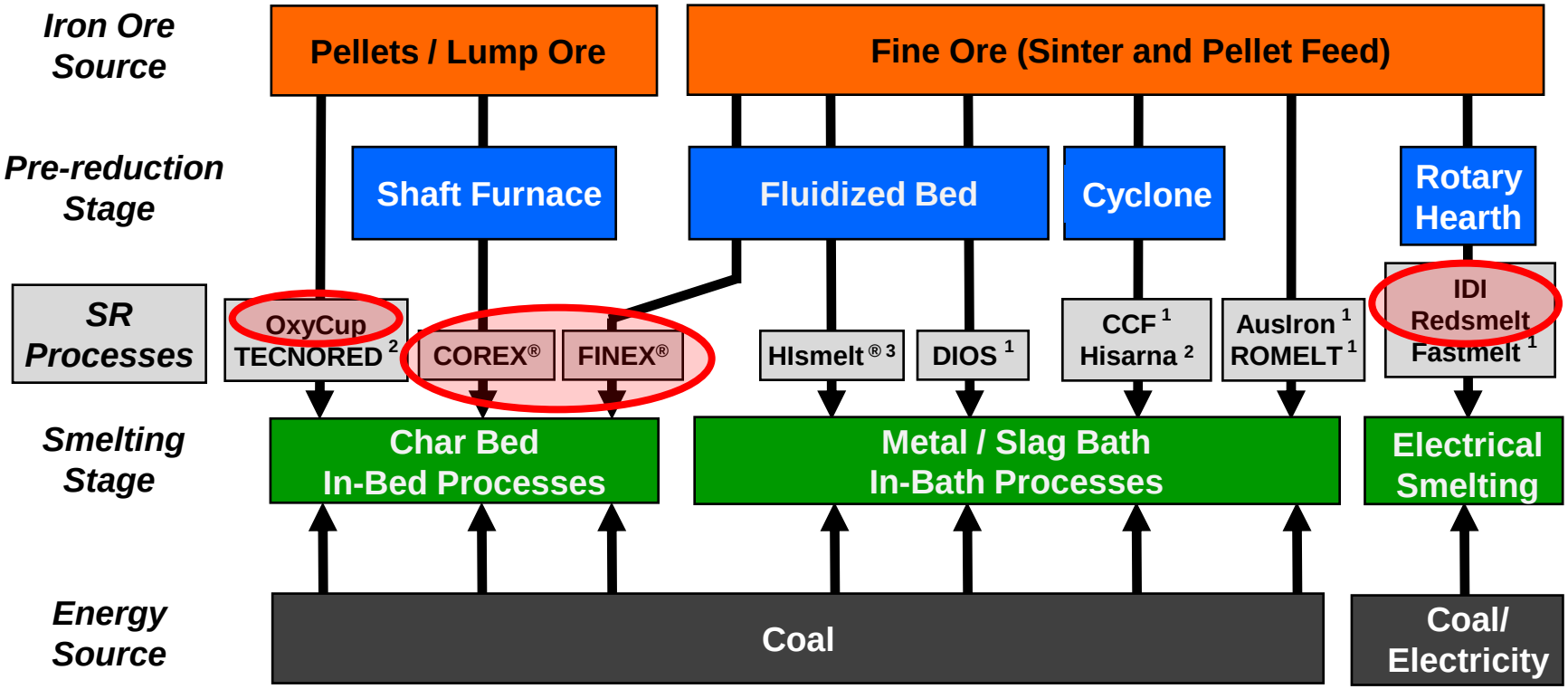
DRI/HBI Production by Region 2000/2014



World DRI/HBI Production and Transports



Classification of Smelting Reduction Processes



[1] Process tested in pilot or semi-industrial scale, [2] Pilot tests under execution, [3] Operation stopped

Plants in industrial scale are in operation

Overview of Corex and Finex Plants (as of August 2015)

Customer	Type of plant	Number of module	Year of start-up	Fe burden	Capacity in million t/a HM	Use of the export gas
POSCO, Pohang Works, Korea	Corex/Finex plant	01	1995/2003*)**)	Iron ore fines	0.8	Power plant, steel shop
POSCO, Pohang Works, Korea	Finex plant	02	2007	Iron ore fines	1.5	Power plant, steel shop
POSCO, Pohang Works, Korea	Finex plant	03	2014	Iron ore fines	2	Power plant, steel shop
Jindal South West Steel, Toranagallu, India	Corex plant	01	1999	Lump ore, pellets	0.8	DR plant, power plant, steel shop
Jindal South West Steel, Toranagallu, India	Corex plant	02	2001	Lump ore, pellets	0.8	DR plant, power plant, steel shop
ArcelorMittal Steel South Africa; Saldanha Works, South Africa	Corex plant		1998	Lump ore, pellets	0.8	DR plant, steel shop
Baosteel, Luojing/ Shanghai, China	Corex plant	01	2007***)	Lump ore, pellets	1.5	Power plant, steel shop
Bayi Steel, Xinjiang	Corex plant	01	2015****)	Pellets, Sinter	1.5	Power plant, steel shop
Baosteel, Luojing/ Shanghai, China	Corex plant	02	2011***)	Lump ore, pellets	1.5	Power plant, steel shop
Bayi Steel, Xinjiang	Corex plant	02	2017****)	Pellets, Sinter	1.5	DR plant (?), steel shop
Essar Steel, Hazira, India	Corex plant	01	2011	Lump ore, pellets	0.8	Power plant, DR plant and steel shop
Essar Steel, Hazira, India	Corex plant	02	2011	Lump ore, pellets	0.8	Power plant, DR plant and steel shop

*) Conversion of a Corex plant to a Finex plant

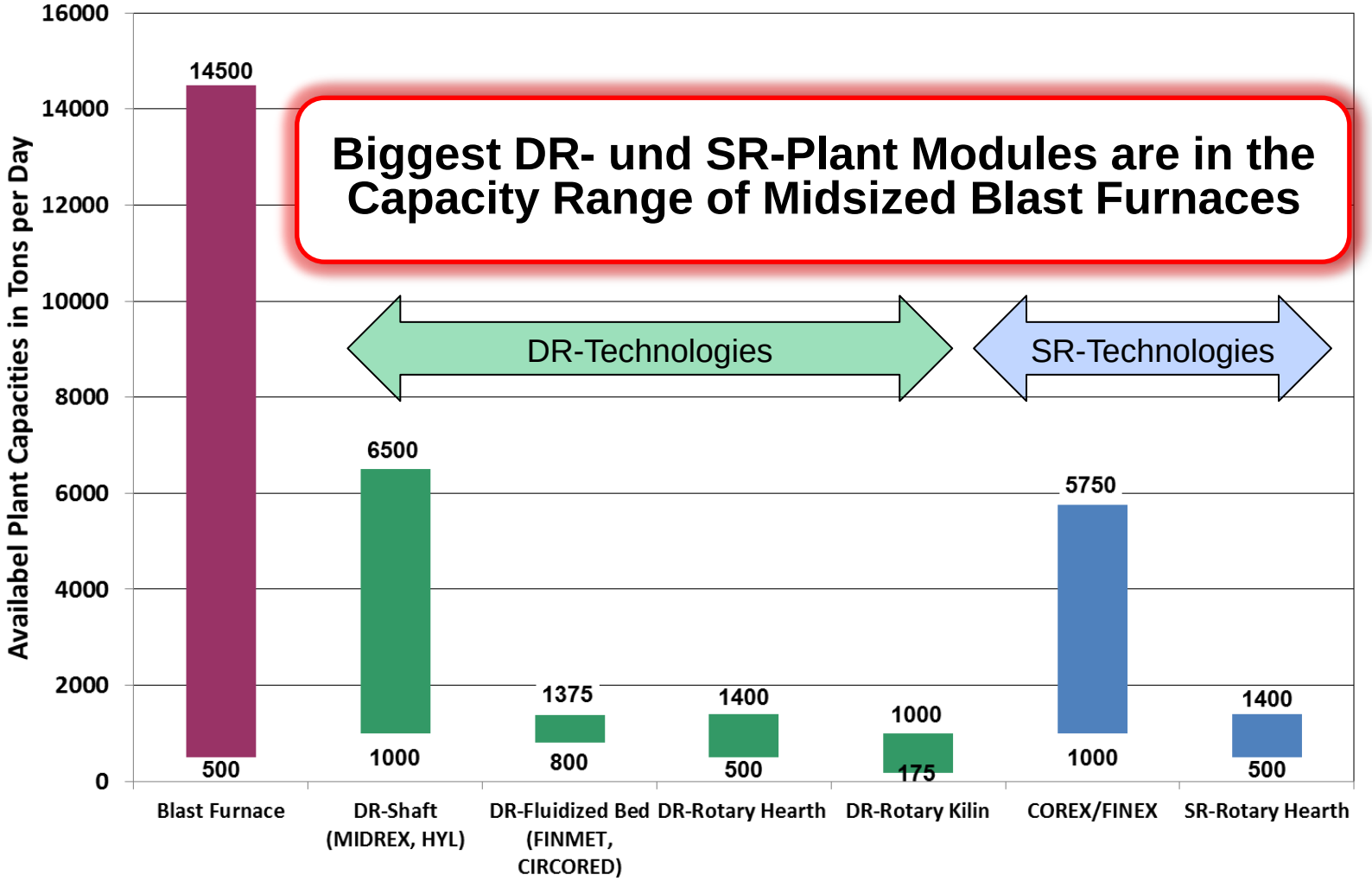
**) Idled 2014

***) Idled 2012 and (to be) relocated from Shanghai (Baosteel) to Xinjiang (Bayi Steel)

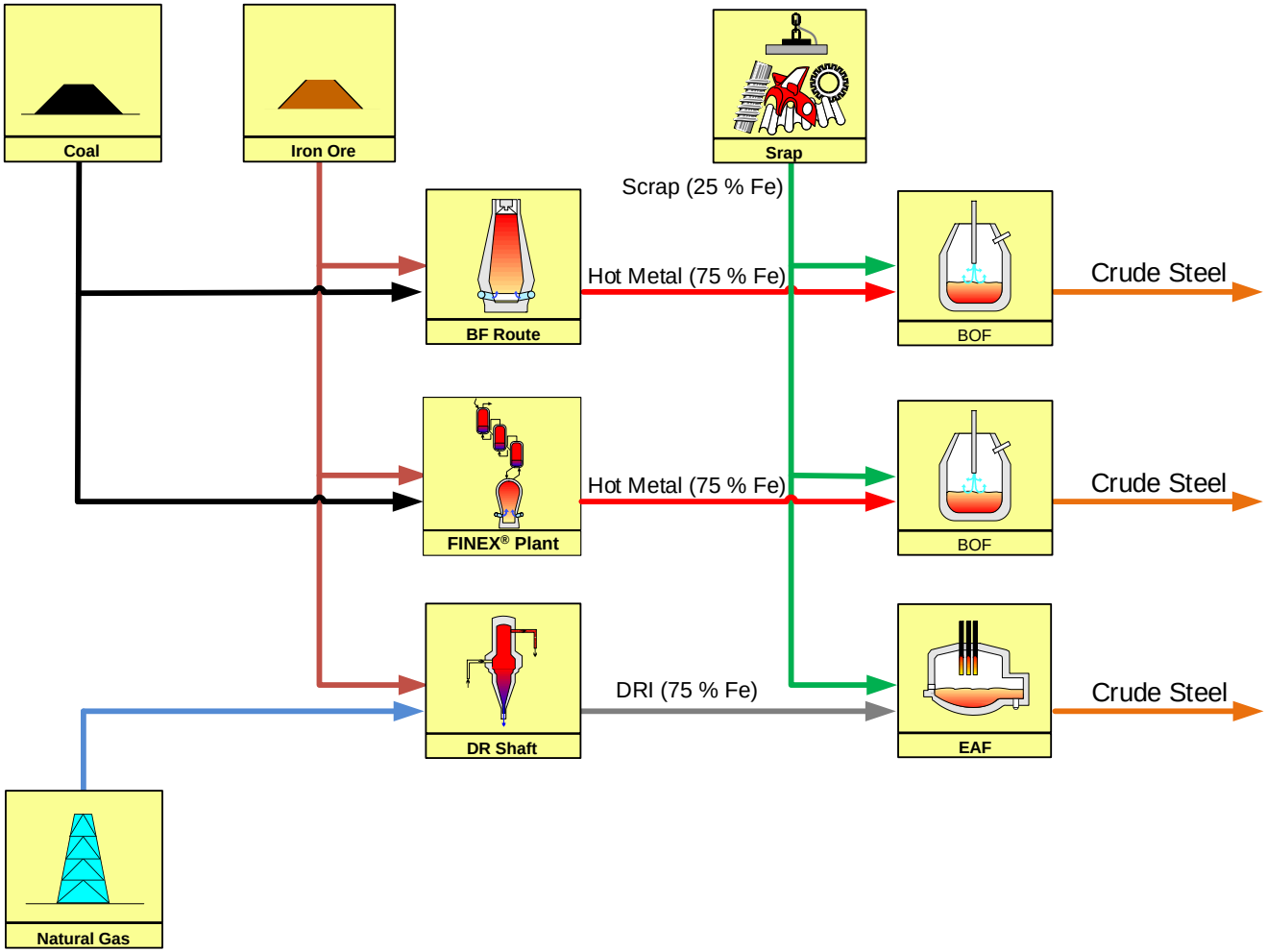
****) Relocated from Shanghai (Baosteel)

Source: Primetals

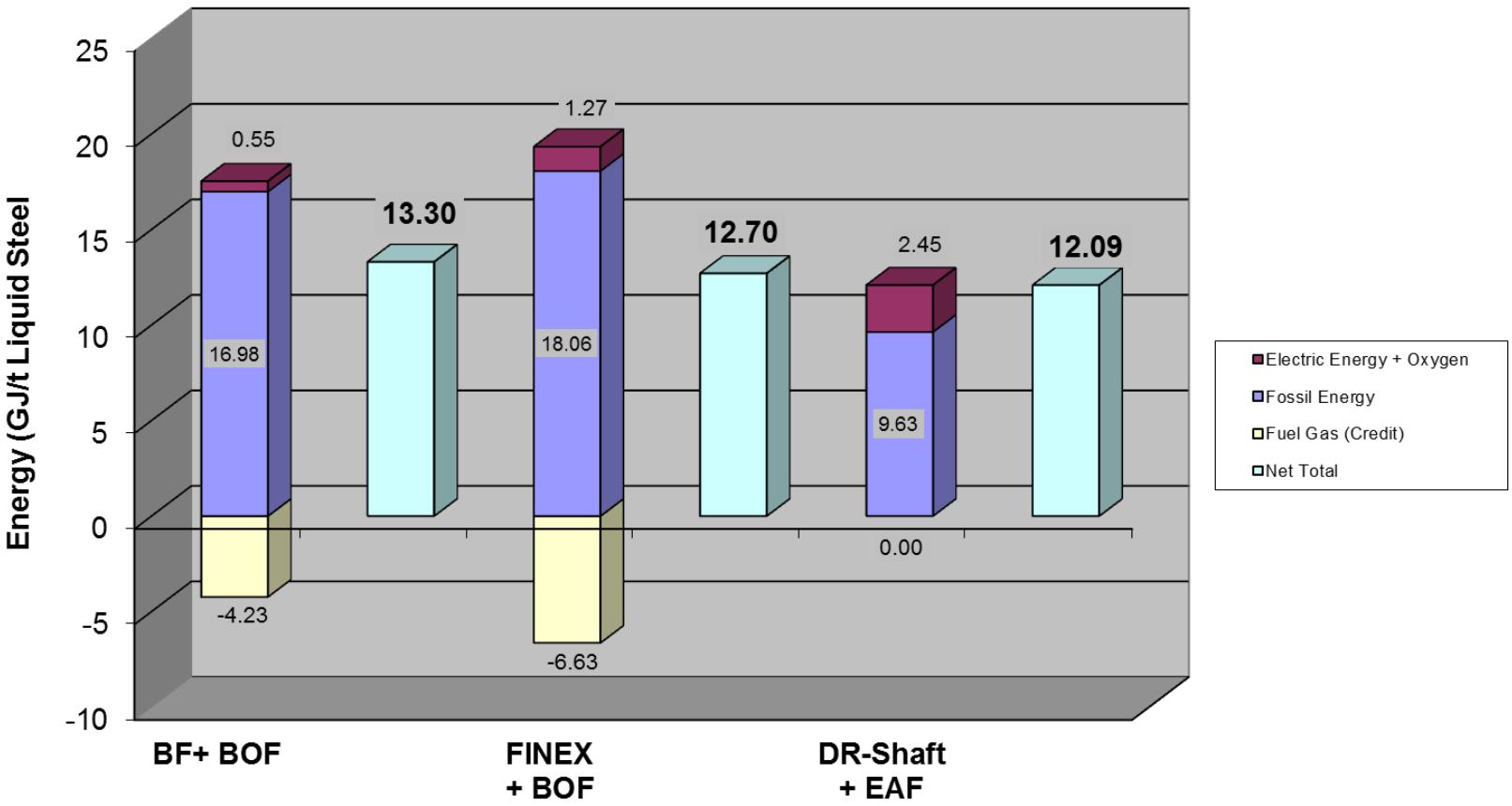
Available Plant Capacities for Ironmaking Technologies



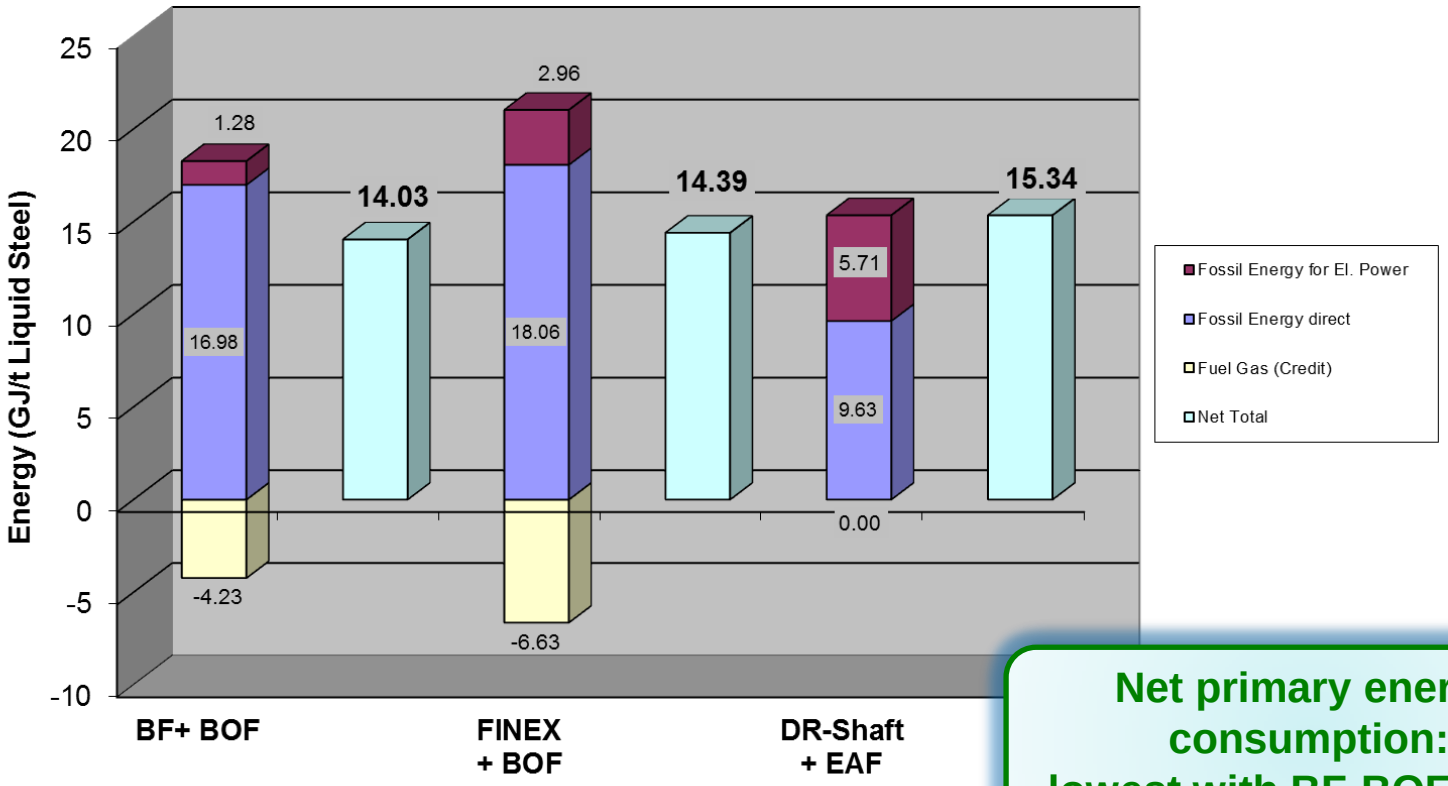
Primary Energy Use – Comparison of Routes



Energy Balance for Steel Production

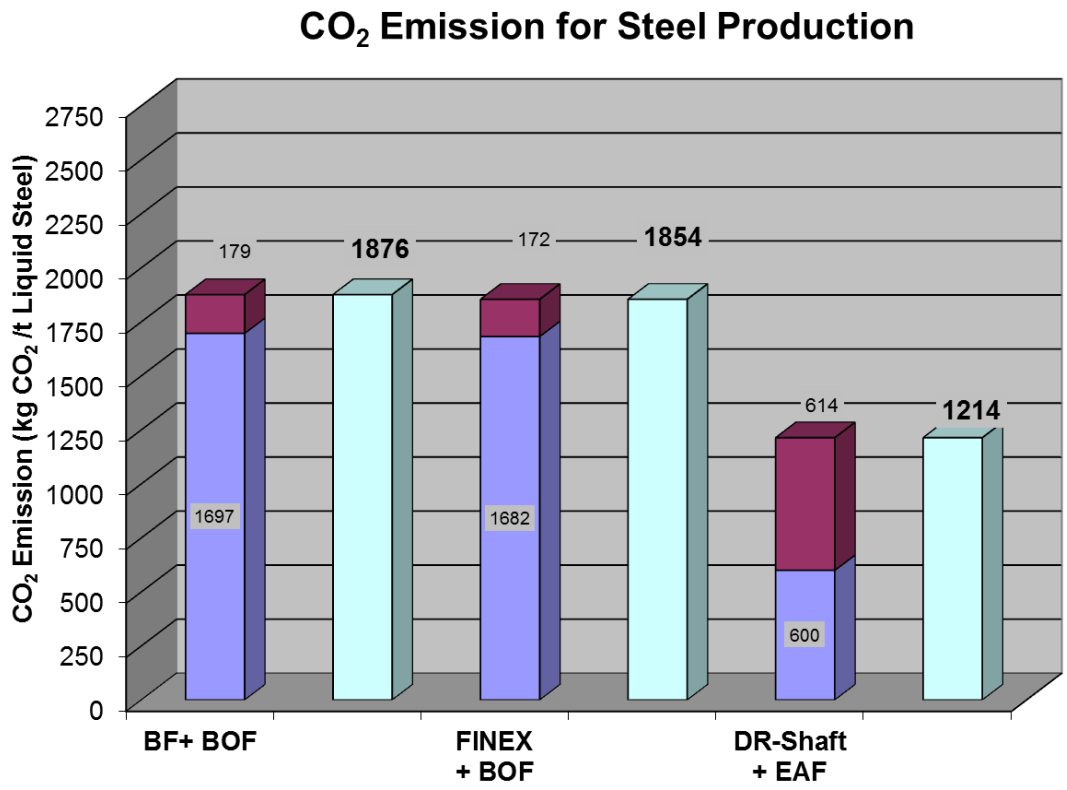


Primary Fossil Energy Resources for Steel Production incl. Electric Power Generation (43 % Efficiency Factor)



Net primary energy consumption: lowest with BF-BOF route

Remark: The average conversion efficiency in Germany for electric energy production from fossil fuels was 43 % in 2013 (Source: Deutsches Bundes Umweltamt)



Indirect CO_2 Emissions:

- **0 kg CO_2/kWh (BF + FINEX)**
- **0 kg CO_2/Nm³ O_2 (BF + FINEX)**
- **0,6 kg CO_2/kWh (DR+EAF)**
- **0,3 kg CO_2/Nm³ O_2 (DR+EAF)**
- **162 kg CO_2/t Pellet**
- **1400 kg CO_2/t Burnt Lime**

Indirekt
Direkt
Net Total

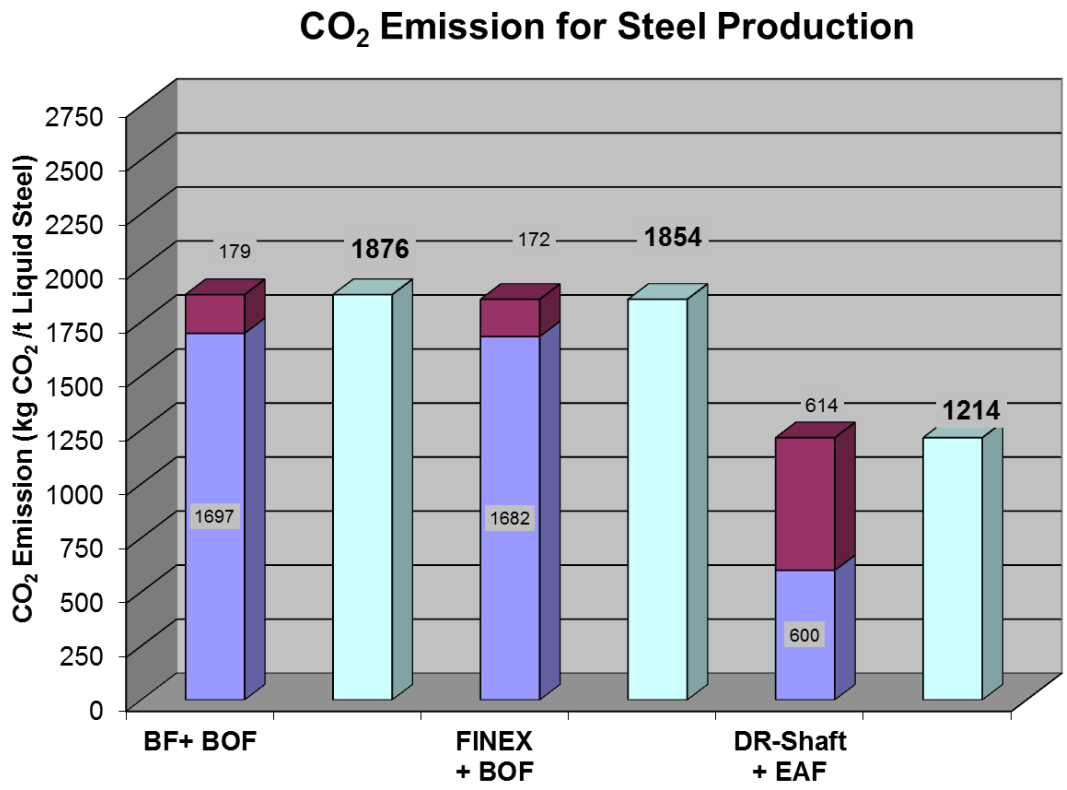
Substantial lower CO_2 emissions for DR-Shaft + EAF Route
Total: ~ 35 %
Direct: ~ 60 %

Direct Emissions

- Conversion of fossil carbon and calcination in the process (no credits considered)

Indirect Emissions

- Production and transport of raw materials (pellets, sinter, coke, burnt lime)
- Production of electric energy and oxygen



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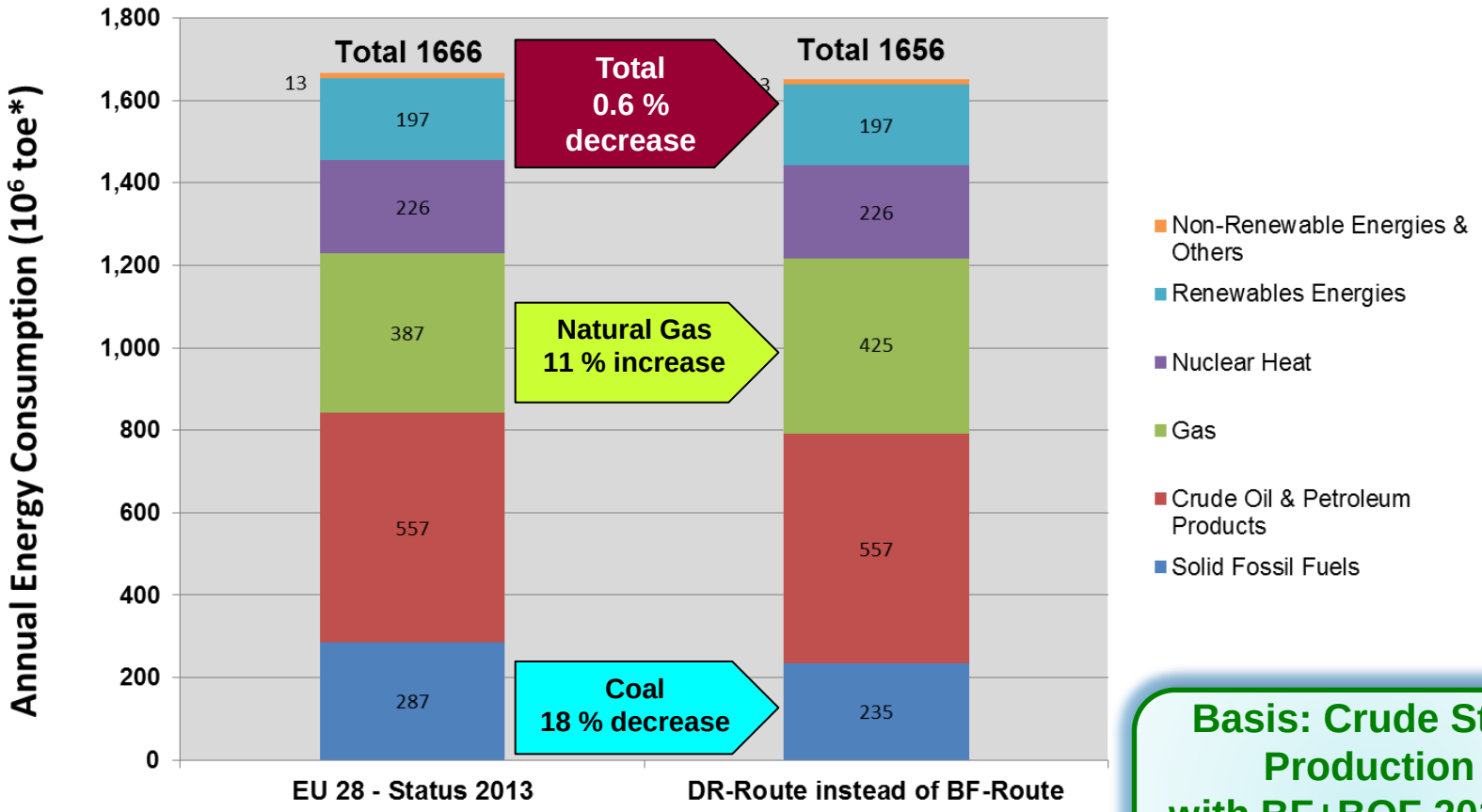
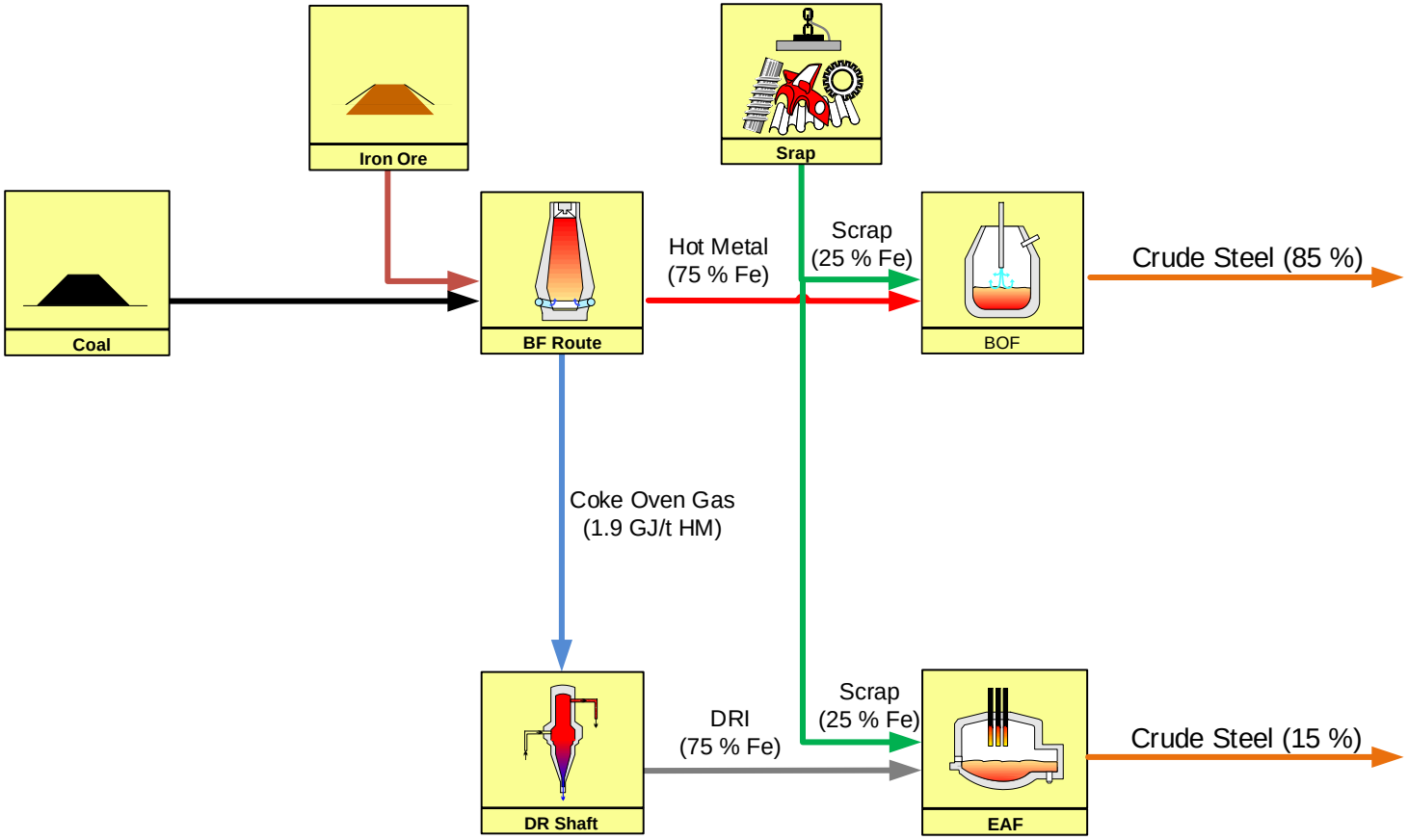
Conversion of Crude Steel Routes from BF+ BOF to DR-Shaft+EAF
Effect on Overall Energy Consumption in EU28



* 1 toe = 41,867 GJ (= 10^7 kcal)

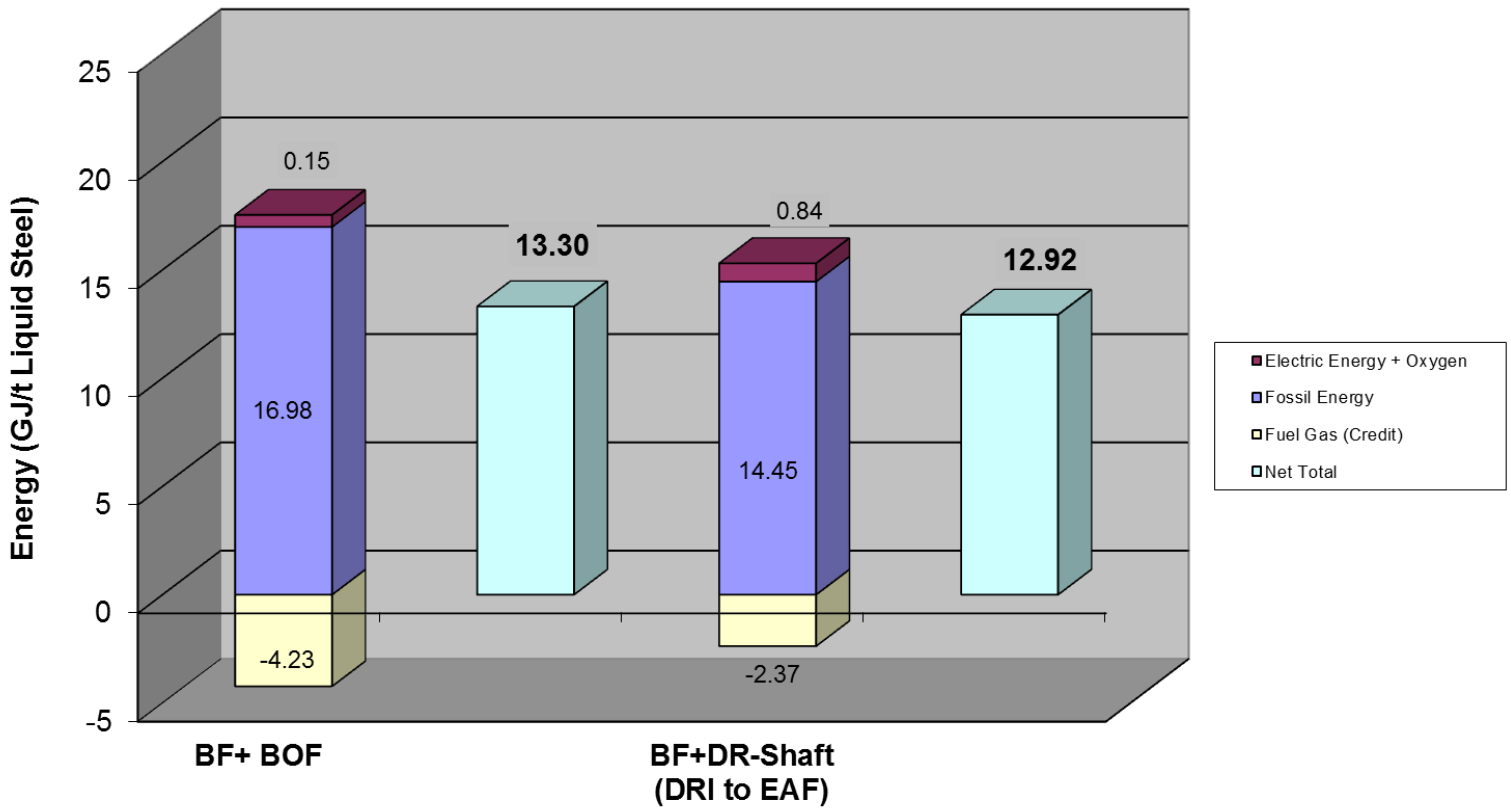
Basis: Crude Steel Production with BF+BOF 2013 in EU28
103.2 million tons

Use of Coke Oven Gas for DRI Production in Integrated Route



Case Study:
100 % of Coke Oven Gas is utilized for Steelmaking with DR-Shaft – EAF Route

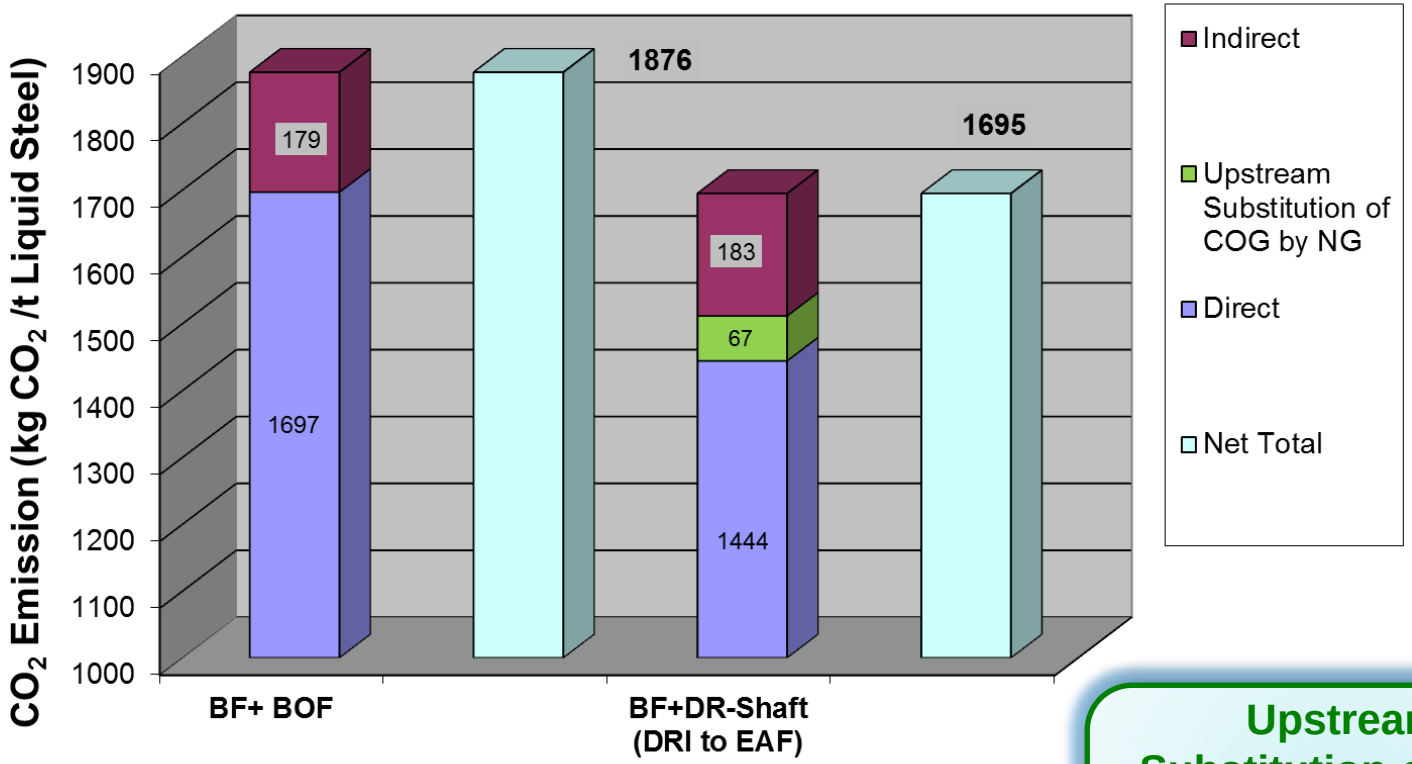
Energy Balance for Steel Production



Overall Effect for Integrated Steel Works by Utilization of COG for DR-Shaft-EAF

- 3 % lower total energy consumption
- 15 % lower fossil energy consumption
- Production increase by 17 %

CO_2 Emission for Steel Production

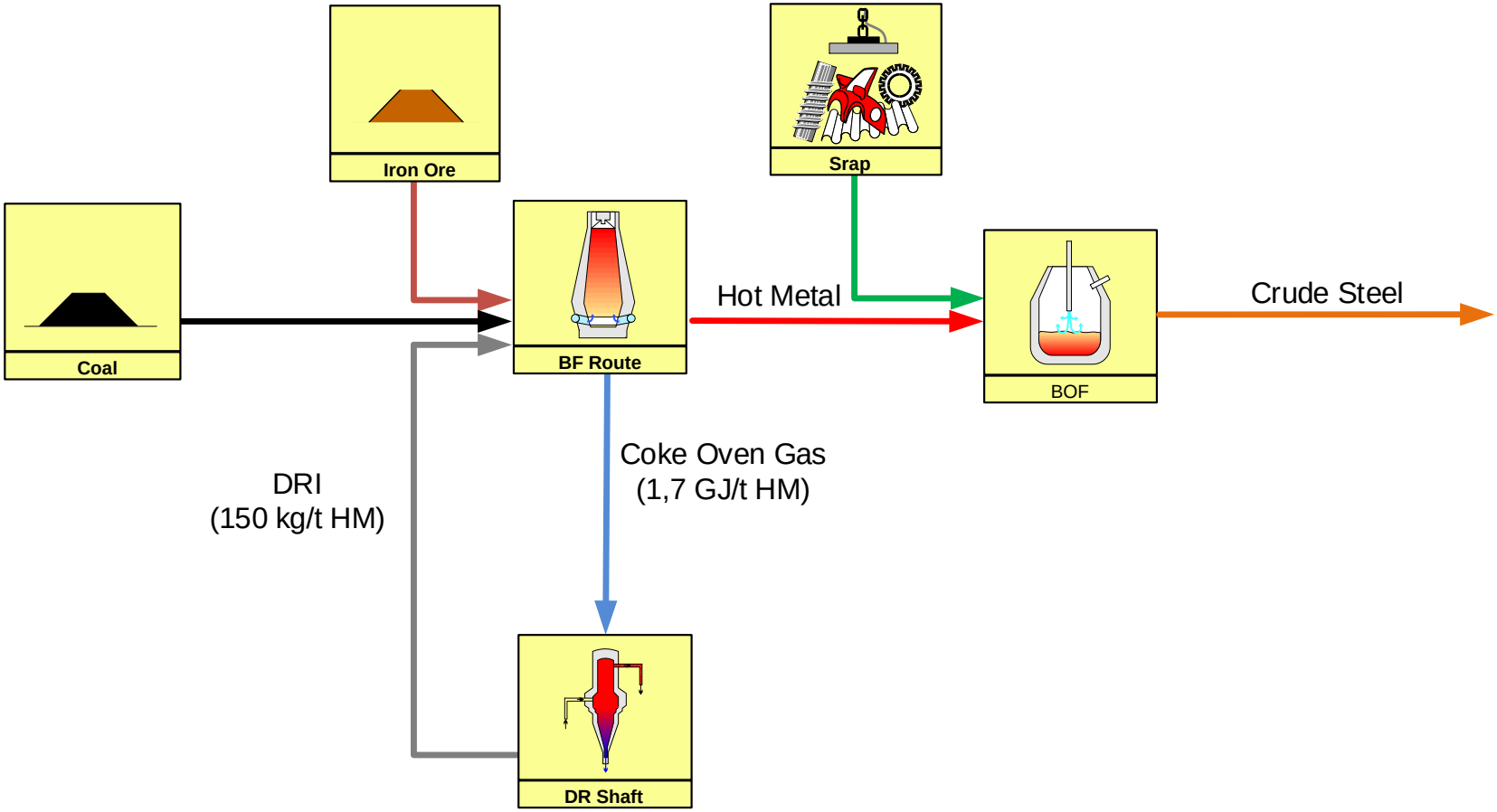


Upstream Substitution of COG by NG for hot rolling is considered in CO_2 Balance

Overall Effect for Integrated Steel works by Utilization of COG

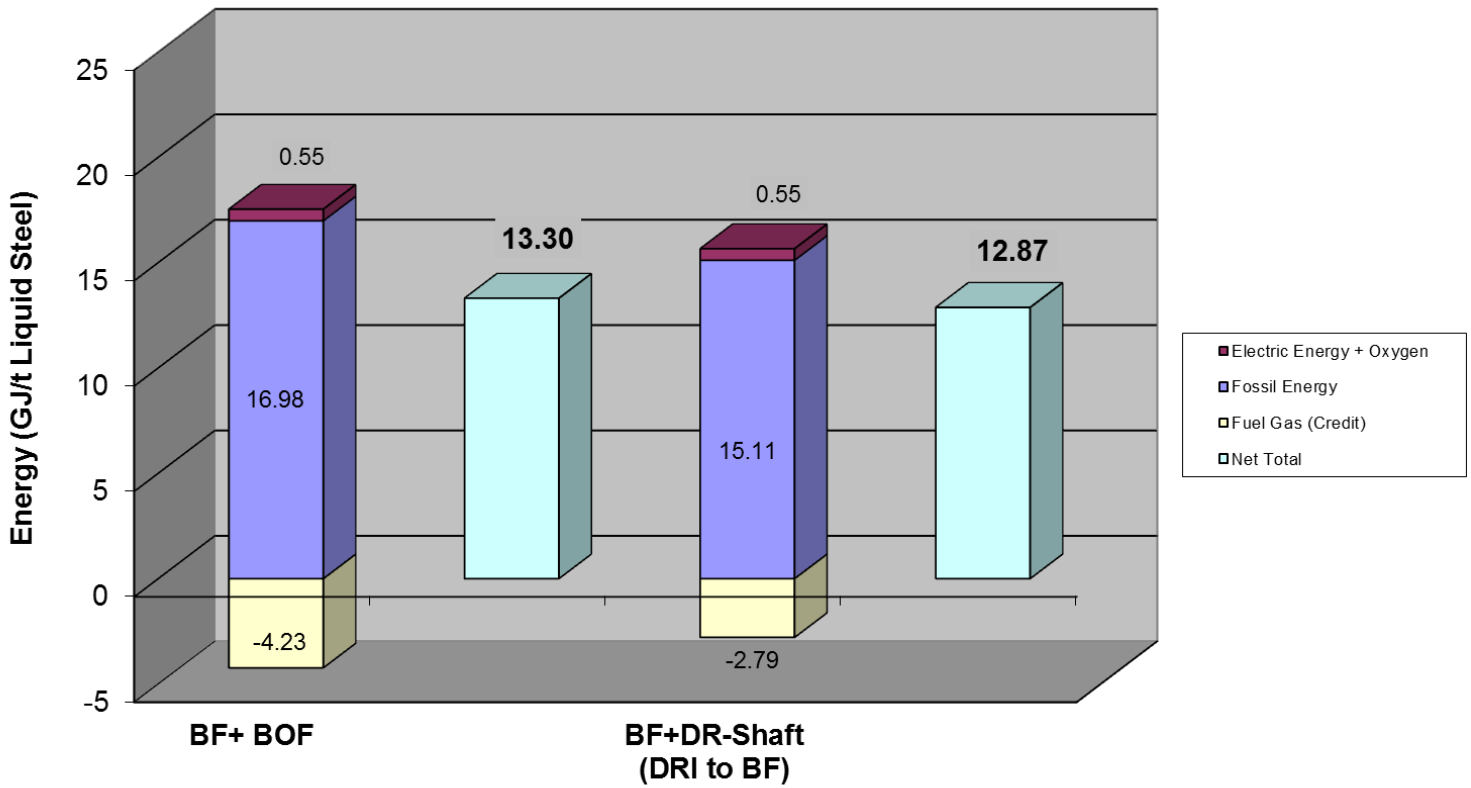
- 11 % lower direct CO_2 Emission
- 10 % lower total CO_2 Emission

Use of Coke Oven Gas for DRI Production in Integrated Route



Case Study: Use of DRI in BF
100 % of Coke Oven Gas is utilized for DRI Production for BF

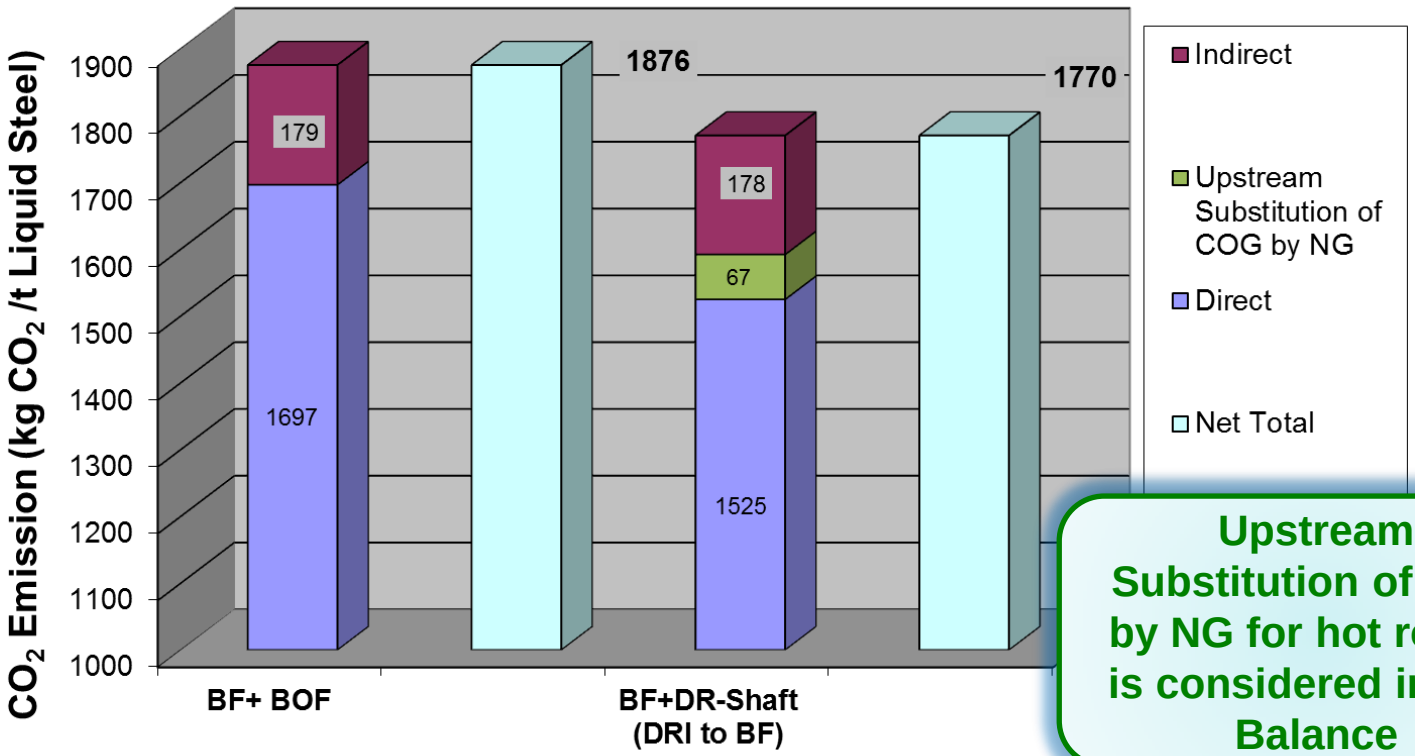
Energy Balance for Steel Production



Overall Effect for Integrated Steel Works by Utilization of COG to produce DRI for BF

- 3 % lower total energy consumption
- 11 % lower fossil energy consumption
- Production increase by 5 to 7 %

CO_2 Emission for Steel Production



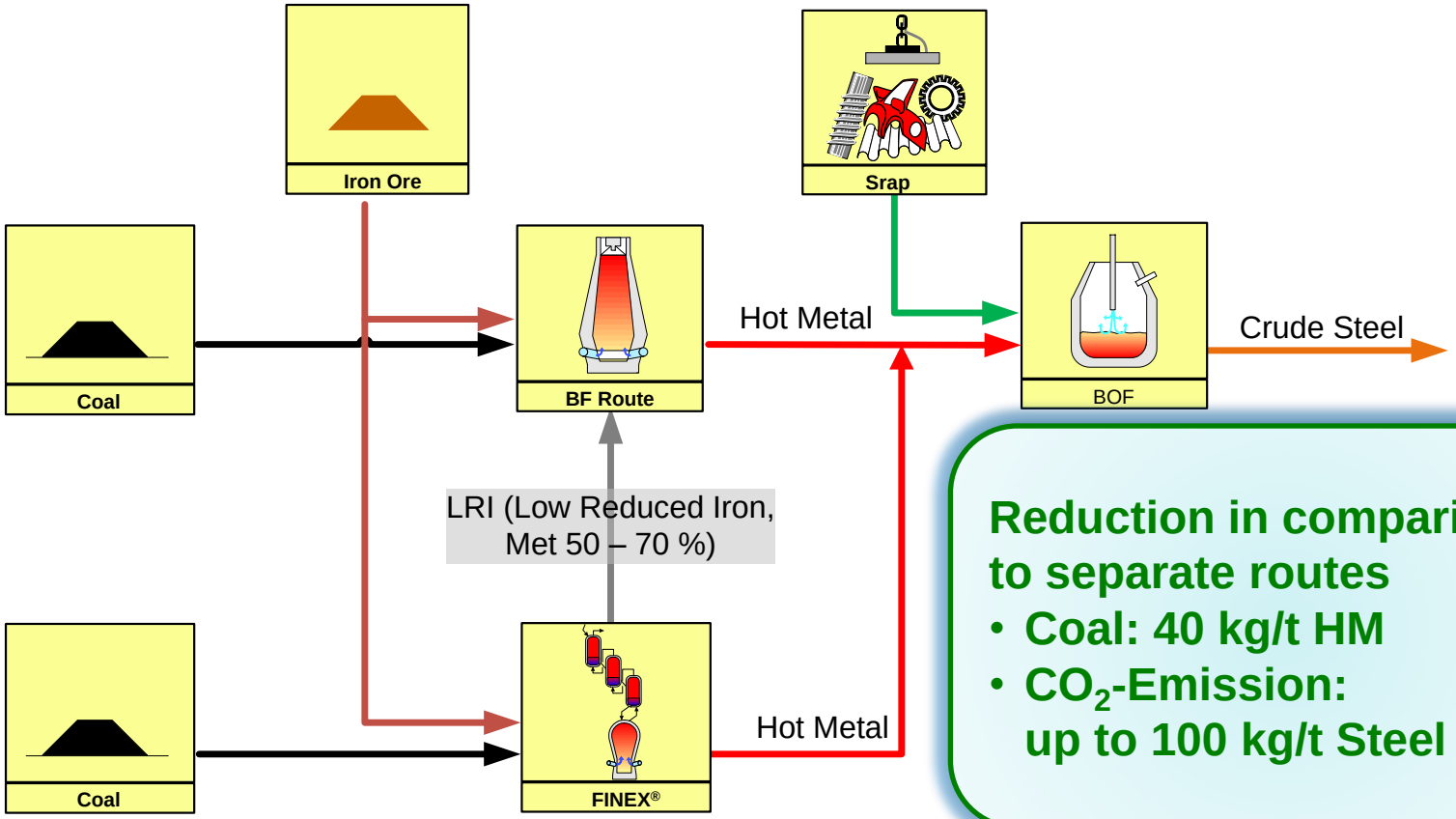
Upstream Substitution of COG by NG for hot rolling is considered in CO_2 Balance

Overall Effect for Integrated Steel Works by Utilization of COG to produce DRI for BF

- 6 % lower direct CO_2 Emission
- 6 % lower total CO_2 Emission

Combination of BF-Route and Smelting Reduction

Use of LRI (Low Reduced Iron) produced in FINEX as substitute for Sinter in Blast Furnace

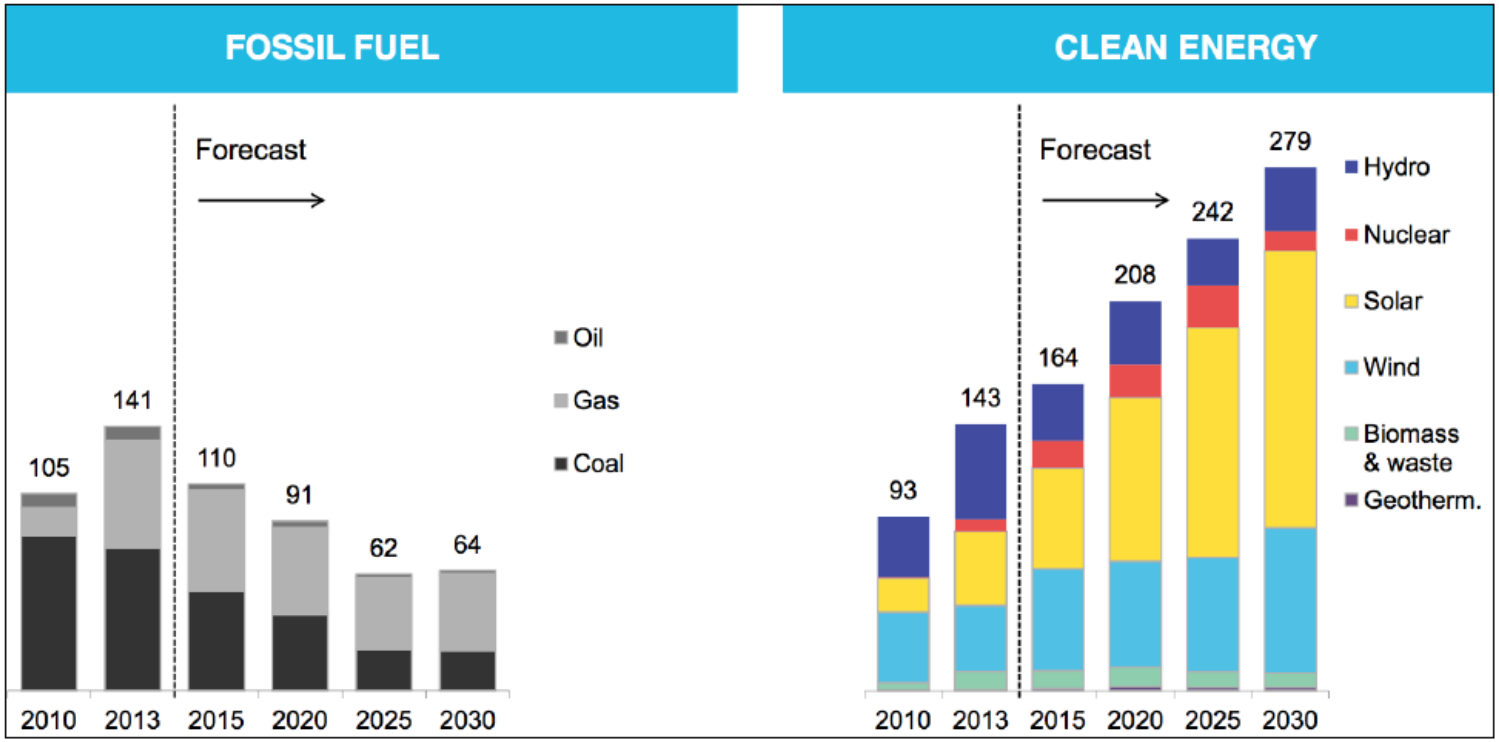


Reduction in comparison to separate routes

- **Coal: 40 kg/t HM**
- **CO_2-Emission: up to 100 kg/t Steel**

Race Between Fossil Fuels and Renewable Energies

In 2013 the world has added more capacity for renewable power each than coal, natural gas, and oil combined for the first time.

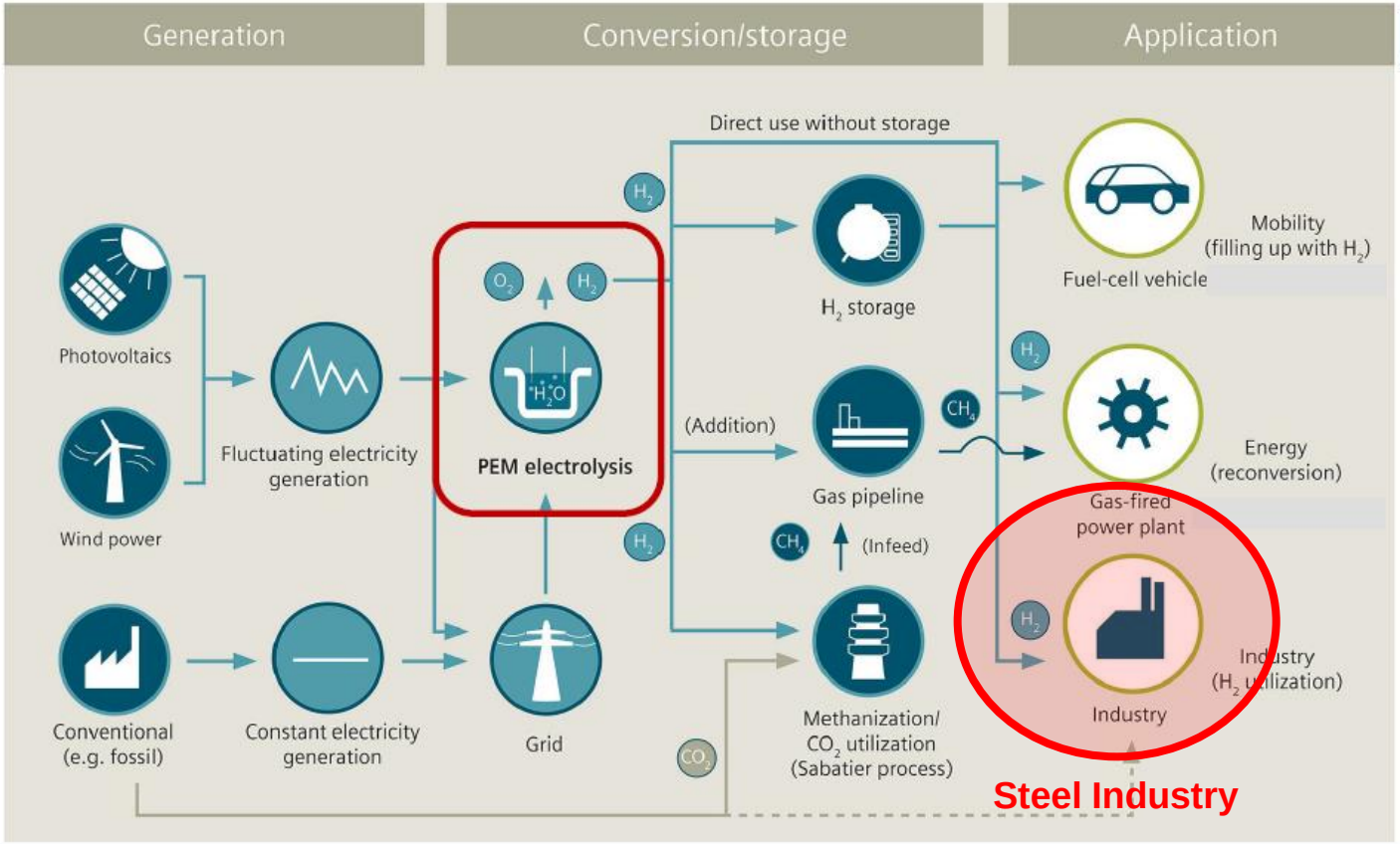


Power generation capacity additions (GW)

Source: Bloomberg New Energy Finance 2015 (http://www.bloomberg.com/news/articles/2015-04-14/fossil-fuels-just-lost-the-race-against-renewables

Source: Siemens, Presentation at VDEh, WG "Efficiency increase and CO2 mitigation along the value added chain steel“, Oct. 12, 2015

Conversion of Energies into Chemical Power



App. Focus

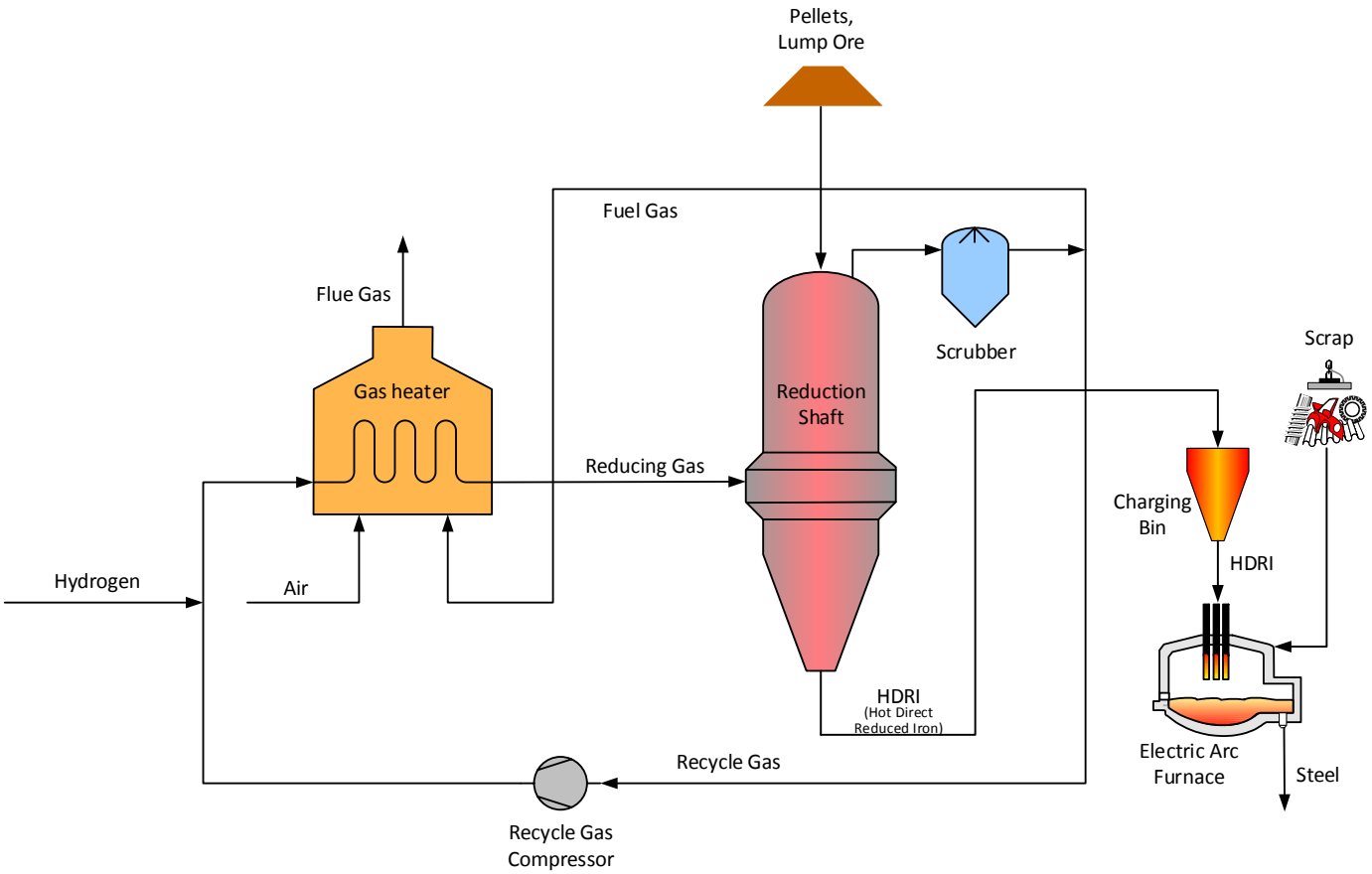
- Refueling station for cars & busses
- Hydrogen conversion for Wind & PV parks
- On-site production and use

H_2 drives the convergence between energy & industry markets

Source: Siemens, Presentation at VDEh, WG "Efficiency increase and CO2 mitigation along the value added chain steel“, Oct. 12, 2015

Production of Steel on Renewable Energies

Process Concept of DR-Shaft and Electric Arc Furnace was investigated in ULCOS
Direct Reduction Shaft Process is operated with 100 % H_2



Summary and Conclusions

- Annual production of DRI/HBI and hot metal in SR plants corresponds to 5.3 % of world steel production
- Overall energy consumption of the steelmaking routes (BF + BOF, FINEX + BOF and DR-Shaft + EAF) are nearly the same
- Steelmaking route of DR-Shaft + EAF has significantly lower CO_2-emission as BF + BOF and FINEX + BOF
- Prospective for DR- and SR-Technologies in Europe:
  Integration of BF + BOF route with DR- und SR-Technologies
  - Reduction of specific energy consumption
  - Reduction of CO_2 emissions
  - Increase of capacity and productivity of existing plants
- Growth of electric power production from renewable energies will drive the convergence between energy market and industries.
  - Supply of hydrogen enables low CO_2 steel production
  - Steel industry in Europe has to become prepared for the challenges and chances of this change in the next decades

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THANK YOU FOR YOUR ATTENTION

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