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EAF Efficiency

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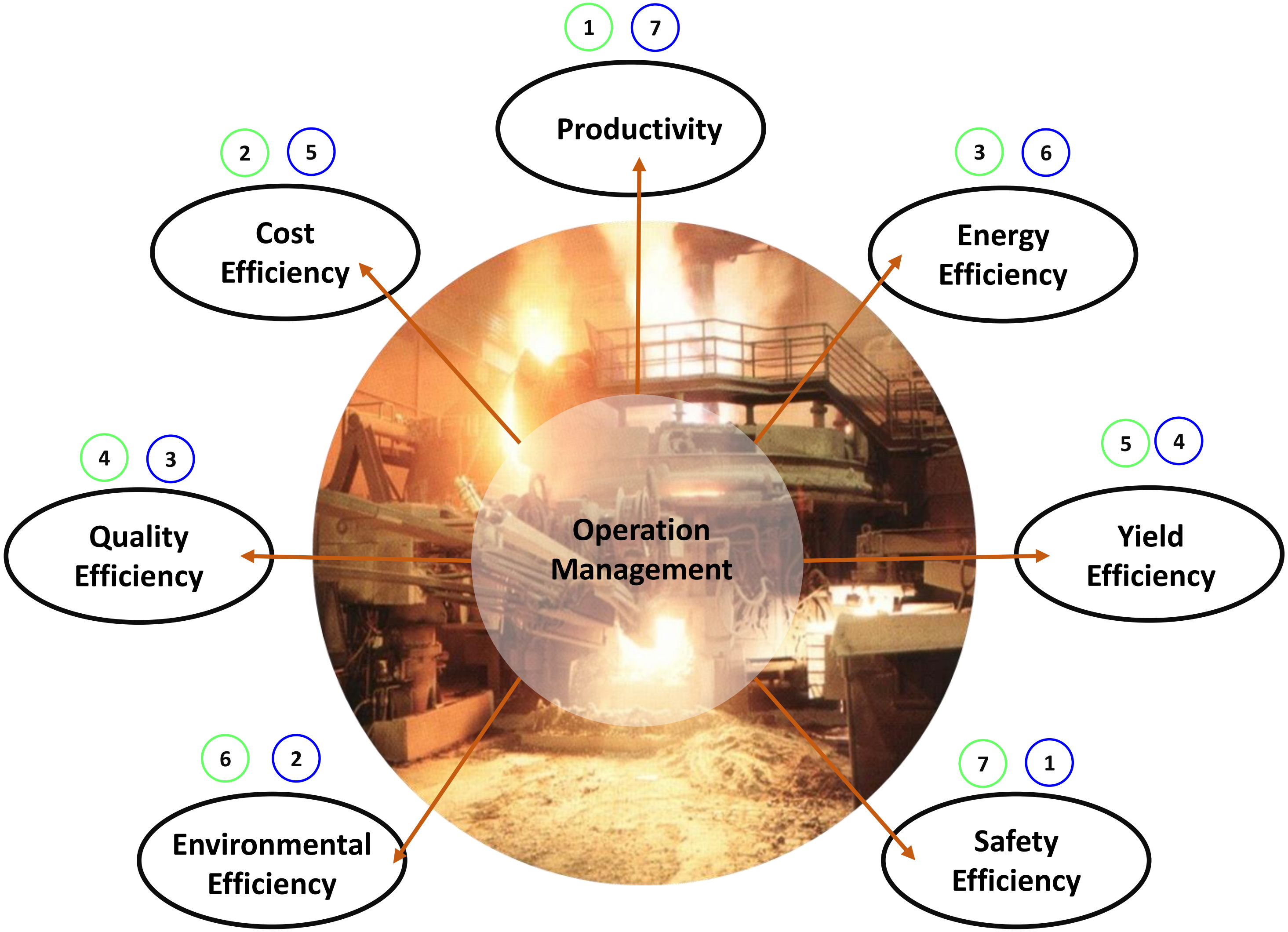
Agenda

- Introduction
- Productivity
- Yield Efficiency
- Energy Efficiency
- Cost Efficiency
- Quality Efficiency
- Safety Efficiency
- Environmental Efficiency
- Conclusions

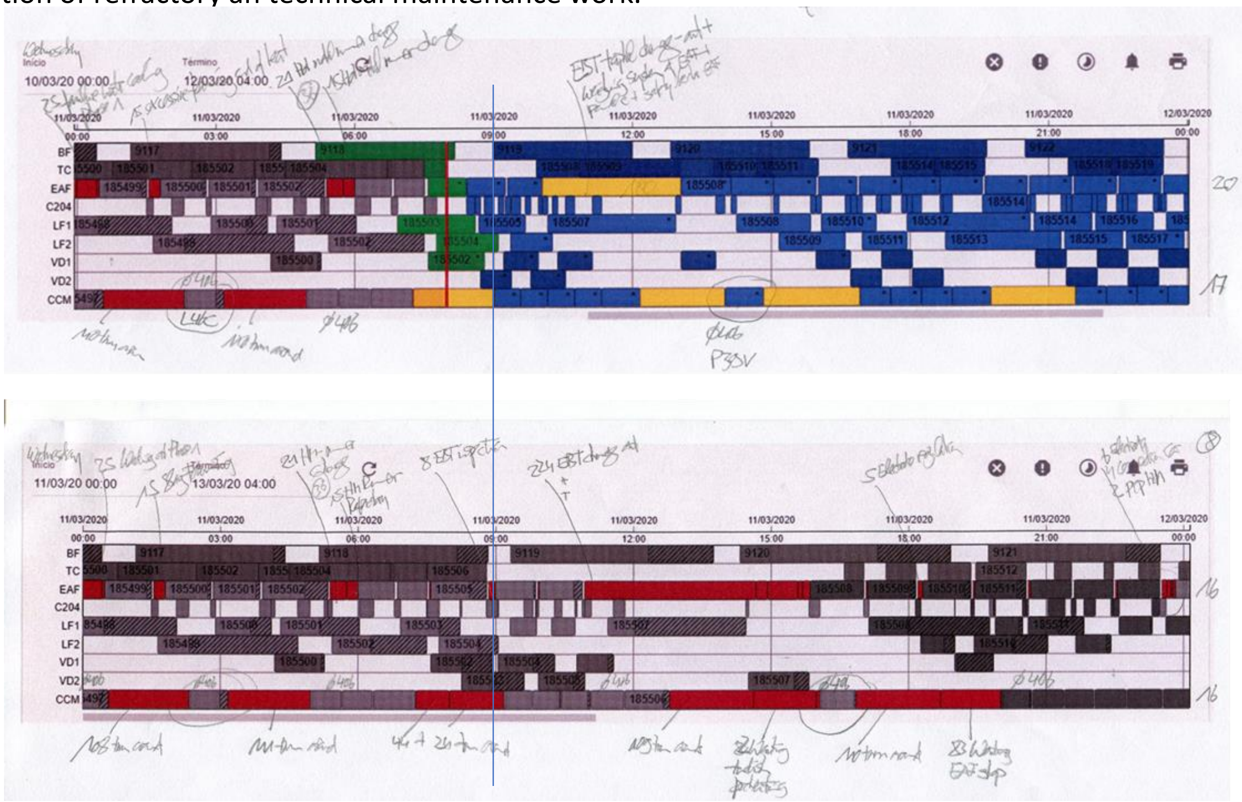
Efficiency in EAF Operation

Efficiency of EAF steelmaking can be measured in various parameters. Since it is a result of the operations it is influenced by the operations management. The relevance/importance of the parameters depends on the view (blue number inside view, green numbers outside view.



Productivity

Productivity is measured in t/h. Typical values today are between 130 – 180 t/h for a single EAF. The productivity is depending on the tap-weight in t/heat, the process quality losses in kg/t and the process speed (P-ON, P-OFF, delays) in min/heat. It requires maximum possible utilization of vessel sizes and crane capabilities, maximum availability of all other aggregates in the plant and proper organization of refractory an technical maintenance work.



- The graph shows a schedule from an single furnace EAF shop. On the top the plan is shown, on the bottom the reality. One delayed big stop for EBT change has resulted in several extended waiting times after turn around at the CCM.
- In the planning stage there was a mismatch of three heats between EAF and CCM.
- In the reality the EAF lost 4 heats, the CCM cast all heats tapped.
- The single heat at the CCM caused two long turn around breaks.

Source: Example

Yield Efficiency

The yield efficiency is measured in % or kg/t raw material input compared to good products delivered to the rolling mills. The Fe-losses during the process chain are the impurities of the metallics (scrap, hot metal, DRI), the losses with the by products (slag, dust, skull, scale) and the quality losses between tapped steel and good products delivered to the rolling mills.

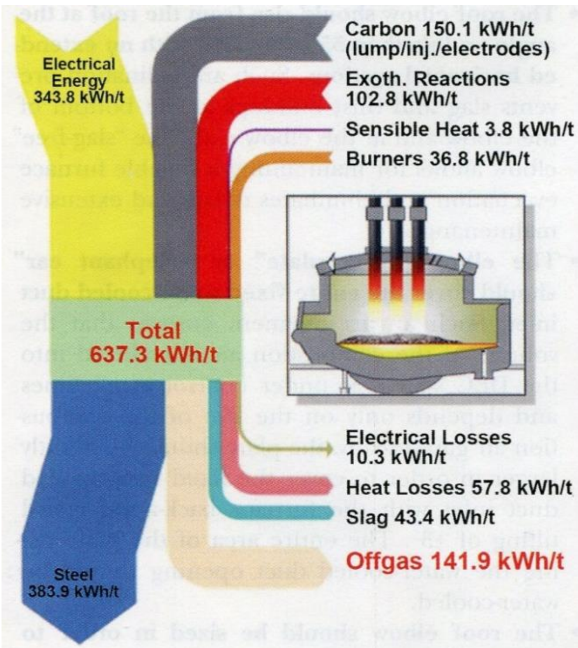
Position	Example	Example	Yield	Total Yield	Comments
	kg/t	t/heat			
Metallic Charge	**1.123,6**	**150,494**			
+ Alloys	26,0	4,026			alloys from SekMet
EAF + SekMet losses	-108,0	-16,720			slag, dust, skull
Liquid Steel to CCM	**1.041,6**	**137,800**	90,6	90,6	
Ladle rest	-4,0	-0,551			liquid returns from CCM
Tundish skull	-6,2	-0,854			
Cast Steel	**1.030,4**	**136,394**	98,9		
Head scrap	-18,9	-2,578			increased length for quality reasons
Tail scrap	-6,1	-0,832			center void depending on size and speed
Length correction	-0,3	-0,041			
Cutting burrs	0,0	0,000			burrs are causing surface laps on product
Other	0,0	0,000			
Total CCM process losses	-25,4	-3,451			
Cast billet send to RM	**1.005,0**	**132,944**	97,5	87,4	
Length correction	-0,8	-0,080			
Cutting burrs	-0,3	-0,040			burrs are causing surface laps on product
Open casting	-0,5	-0,066			start of cast without LS
Reoxidation downgrades	-0,1	-0,013			shrouding issues
Tundish level violation	-0,3	-0,040			LS not immerged during ladle change
Strand stops	-1,2	-0,160			
Billet bending	-1,7	-0,226			
Other	0,0	0,000			
Total quality losses	-5,0	-0,651			
Good billets	**1.000,0**	**132,292**	99,5	87,0	
Quality scrap on finished products	0,0	0,000			
Good billets	**1.000,0**	**132,292**	**100,0**	**87,0**	

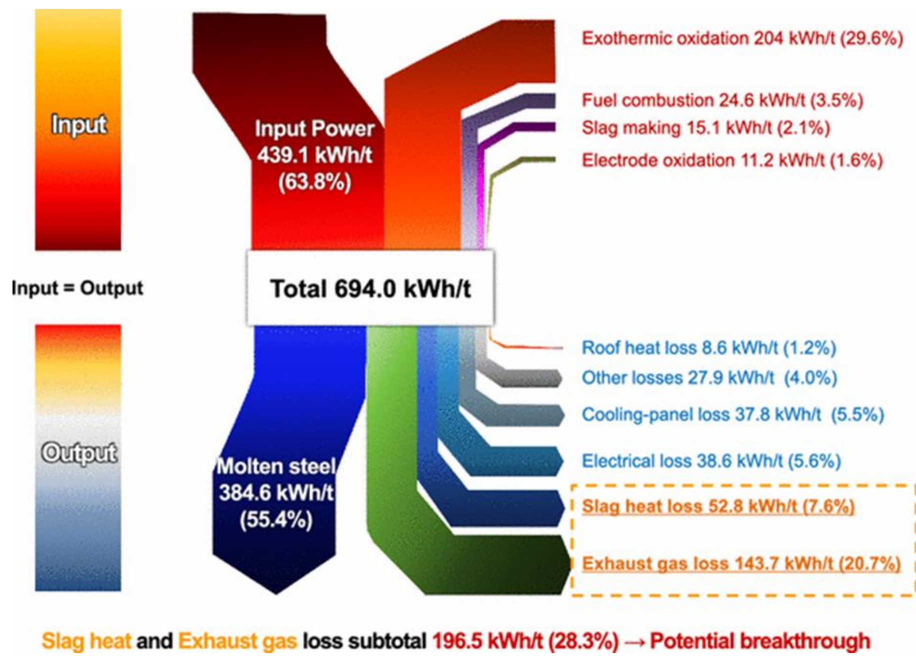
The table shows an example with a total yield of 87% which is quite good due to processed raw materials and controlled process and quality losses. Weak point is increased head scrap due to quality issues in products rolled from the first CCM billet layer in the sequence.

Source: Example

Energy Efficiency

The energy efficiency is measured in total kWh/t for EAF + LF + CCM + auxiliary equipment (Cranes, GCP, other). The power consumption of the utilities is usually included in the utility prices (compressed air, water, Oxygen, Ar, N_2). The power consumption of the rolling mills is separated. Usually power and heat consumption (ladle and tundish preheaters, RHF) are monitored separately.





Σ losses: 253,4 kWh/t **Δ 56,0 kWh/t** **Σ losses: 309,4 kWh/t**

0,7 balance difference

The energy consumption of an EAF is about 650 kWh/t_{LS} (2,34 GJ/t_{LS}). The power consumption varies upon raw materials and process conditions between 350 and 600 kWh/t_{LS}. The total energy consumption including the power generation is between 5,5 – 5,9 GJ/t_{LS} (1,53 – 1,64 MWh/t_{LS}).

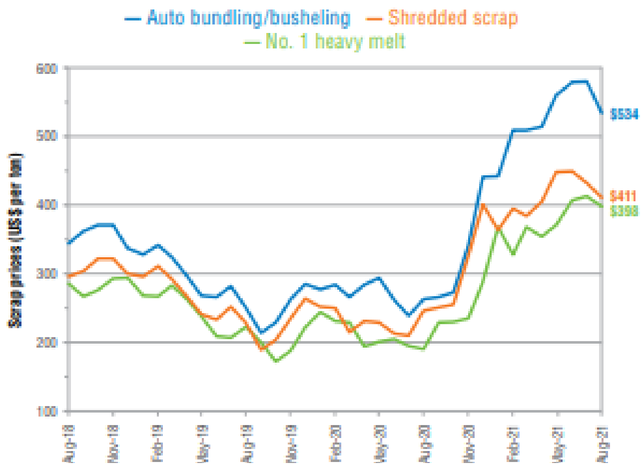
Source : Iron and Steel Technology, 2015

Cost Efficiency

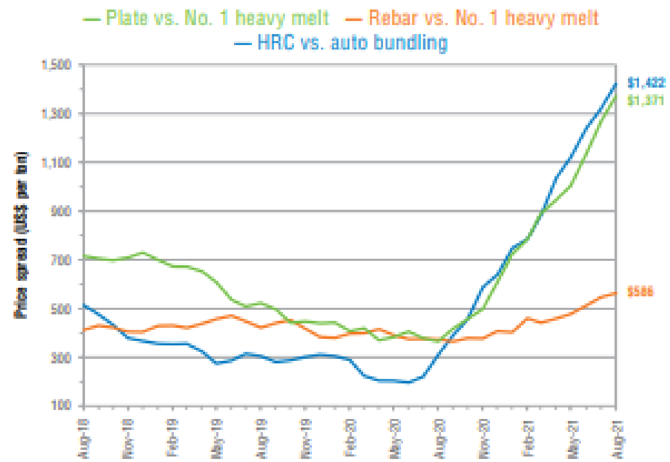
The cost efficiency is measured in currency/t and is the result of all economic factors related to the production of steel. It is calculated from the specific consumption of all purchased materials and services multiplied with their purchase price and the fixed cost (labor, contracted services, maintenance and capital cost). It should be pointed out that not always the lowest price will result in the lowest cost. For this reason all purchases should be evaluated as TCO or value in use.

Item	unit	factor	unit price ($)	% fixed	Costs ($ per tonne)		
					Fixed	Variable	Total
Steel scrap	tonne	1.117	371.01	0%	0.00	414.42	414.42
Steel scrap transport	tonne	1.117	5.00	0%	0.00	5.59	5.59
Pig iron/DRI	tonne	0.000	406.00	0%	0.00	0.00	0.00
Pig iron/DRI transport	tonne	0.000	14.00	0%	0.00	0.00	0.00
Industrial gases	cubic m	56	0.11	0%	0.00	5.95	5.95
Ferroalloys	tonne	0.021	1588	0%	0.00	33.34	33.34
Fluxes etc	tonne	0.068	149.41	0%	0.00	10.16	10.16
Electrodes	tonne	0.001	4000	0%	0.00	5.96	5.96
Refractories	tonne	0.001	1314	0%	0.00	1.23	1.23
Other costs	unit	1	19.62	25%	4.91	14.72	19.62
Thermal energy	GJ	-0.068	8.32	0%	0.00	-0.57	-0.57
Electricity	MWh	0.444	102.61	15%	6.83	38.73	45.56
Labour	hours	0.291	41.97	25%	3.05	9.16	12.21
Capital charges	unit	1	17.31	100%	17.31	0.00	17.31
Total					32.10	538.69	570.79

Steel scrap	72,6%
Power + electrodes	9,0%
Ferroalloys	5,8%
Other cost	3,4%
Capital Charges	3,0%
Labour	2,1%



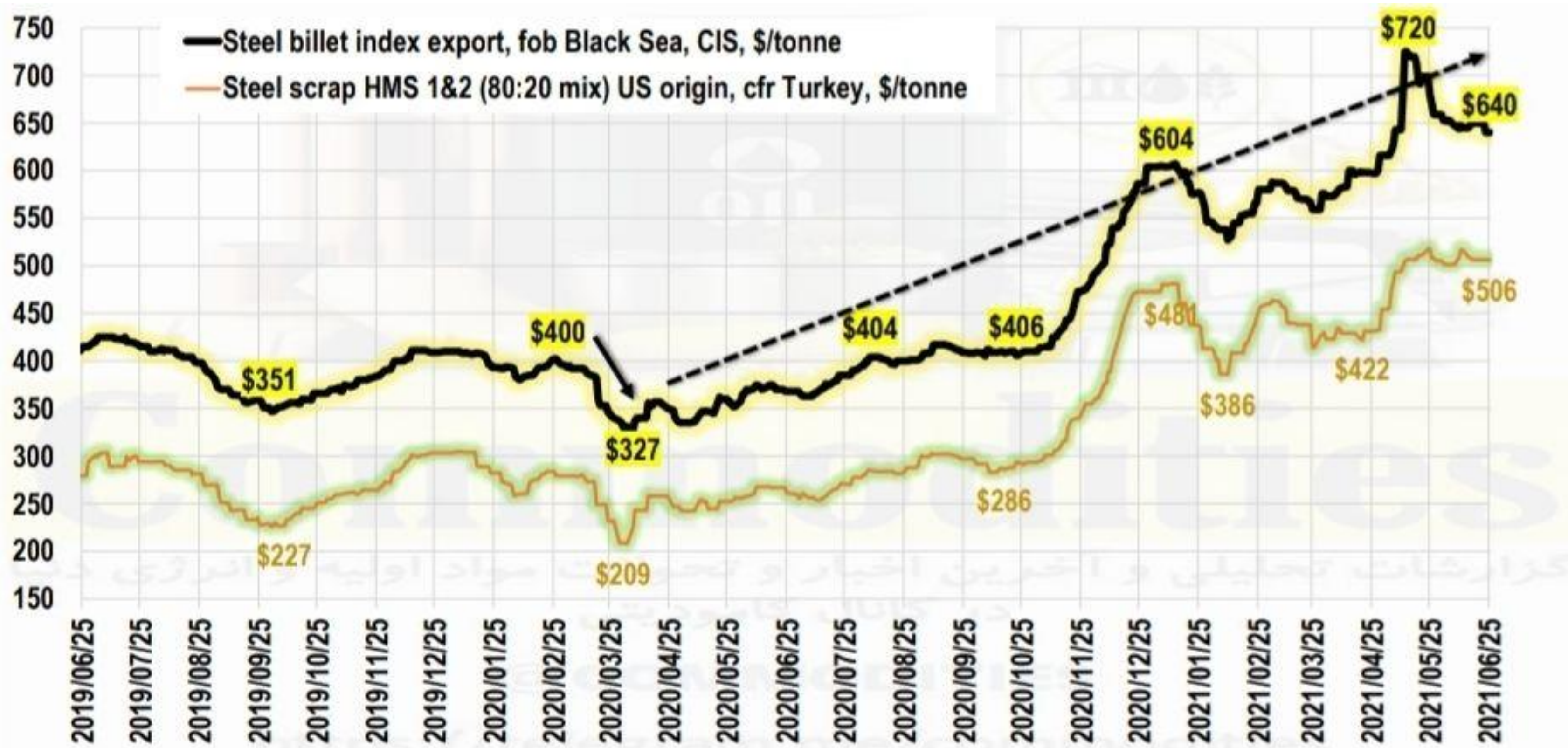
US scrap prices



US metal spread

Source : www.steelonthenet.com and Iron and Steel Technology November 2021

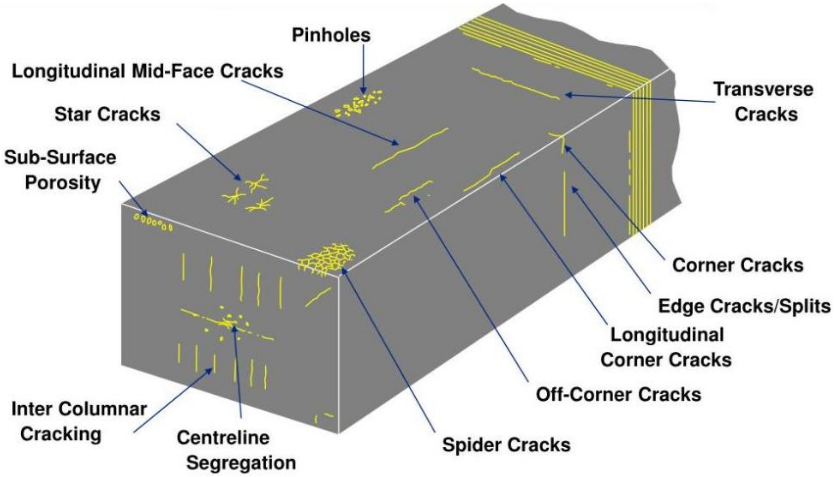
Cost Efficiency: MENA Situation



Quality Efficiency

The quality efficiency is measured in % or kg/t detected defects during the production. Usually the quality losses are linked to surface and internal defects on the final products, but also the process losses of the steel production (liquid steel returns, ladle skulls, slag skulls, tundish skulls, head and foot scrap, scale, cutting losses, downgrade scrap) can be considered as quality losses. The advantage of these losses compared to slag losses is, that they can be recovered as charge material for the EAF so that the loss is limited to the conversion cost, other than slag losses where the Fe included is a total loss.

Defects on cast products



- As shown in the graph on the left, numerous possible defects are possible in the CCM process.
- Proper equipment (shrouding systems, tapered mold, hydraulic oscillator, controllable spray water loops, MEMS, FEMS, soft reduction) must be installed to avoid these defects for the entire product portfolio.
- CCM maintenance must focus on misalignment.
- Cast product must be inspected before delivery to the rolling mill. All surface defects passing the automated removal devices must be removed manually.
- Casting process must be monitored (shrouding status, mold level, stopper/valve position, casting speed, irregularities).
- Casting process must be monitored by statistical process control.

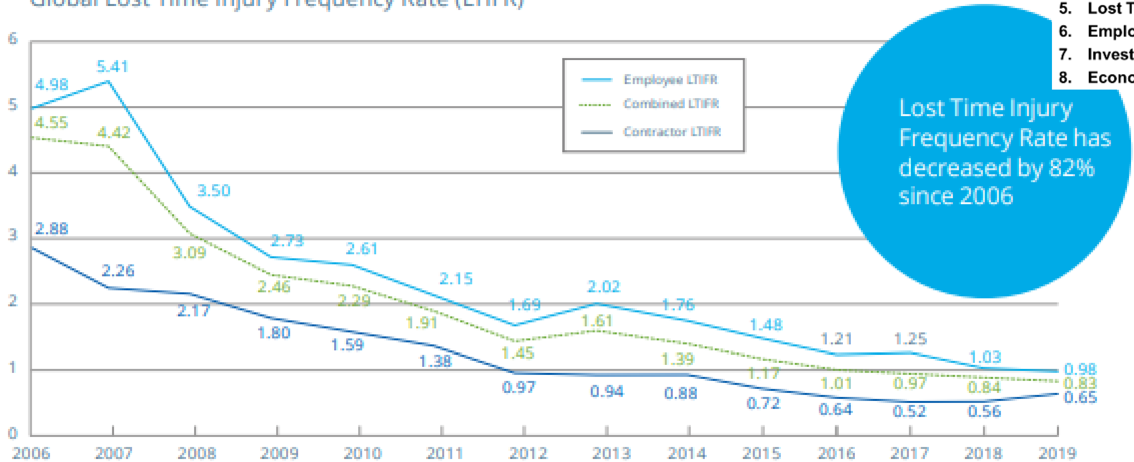
As already shown in the yield table, the quality losses (including the CCM process losses) can be as high as 11 -25 kg/t. This is a substantial loss. Today automated quality rating systems control the cast material quality online. The systems must be feed by plant inspection results in the beginning. Toda machine learning tools are available to support this task.

Safety Efficiency

The safety efficiency is measured in injuries/million working hours and is a self-obligation of all companies and their work staff to avoid impairment of human health or even death, for staff and neighbors of the production facilities. It is upon others one of the most important indicators of steel industry sustainability indicators defined from the world steel organization. The performance indictor is measured in injuries per million working hours and includes fatalities.

1. Greenhouse Gas Emissions
2. Energy Intensity
3. Material Efficiency
4. Environmental Management Systems (EMS)
5. Lost Time Injury Frequency Rate
6. Employees Training
7. Investment in new Process and Products
8. Economic Value distributed

Global Lost Time Injury Frequency Rate (LTIFR)*



*A Lost Time Injury (LTI) is an incident that causes an injury that prevents a person from returning to their next scheduled shift or work period. Lost Time Injury Frequency Rate (LTIFR) is the number of Lost Time Injuries per million man-hours. LTIFR includes fatalities.

The steel industry is committed to achieving the goal of zero harm - an injury-free and healthy workplace for employees and contractors.

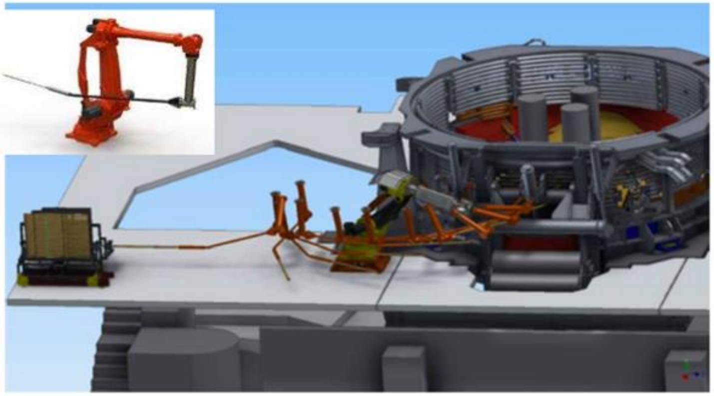
After 25 years of forced activities to improve the “Lost Time Injury Frequency Rates” the worldwide standard has fallen below 1,0, coming from over 50 in the 1980ies and 40 in the 1990ies. This achievement was possible due to technology and also organizational improvements.

Worldsteel.org: „Safety and Health in the Steel Industry“, Public Policy Paper, 2020

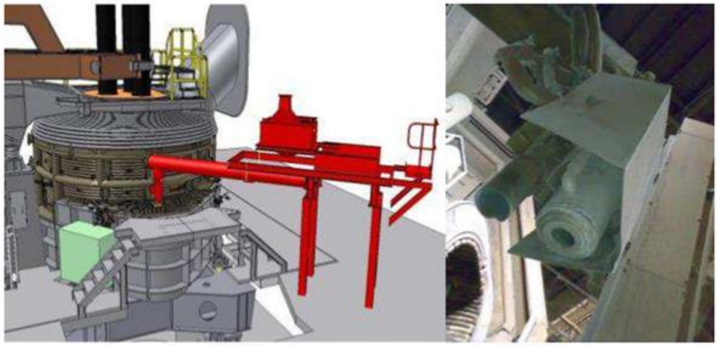
Safety Efficiency: The Man less EAF

- Proposals for automated EAF platform operation were presented by the OEM's already 5 years ago.
- The proposals include:
  - Pulpit with HMI and camera control
  - Robotized temperature and sampling
  - Automated tapping
  - Automated EBT-Oxygen lancing
  - Slag detection and control during tapping
  - Hot heel management
  - Automated EBT cleaner
  - Automated EBT sanding
  - Automated slag door cleaning
  - Automated electrode slipping device
  - Electrode nippling robot
  - EAF wear inspection and automated gunning
  - Ladle tracking system
  - Automated scrap loading crane
  - Automated scrap bucket charge
- Most of the system are already industrialized but an application using all proposed systems could not be identified.
- It should be mentioned that automation increases safety but also complexity. E.g. maintenance efforts are increasing and operation speed is declining.
- CAPEX and maintenance cost for the additional equipment must be taken into account.

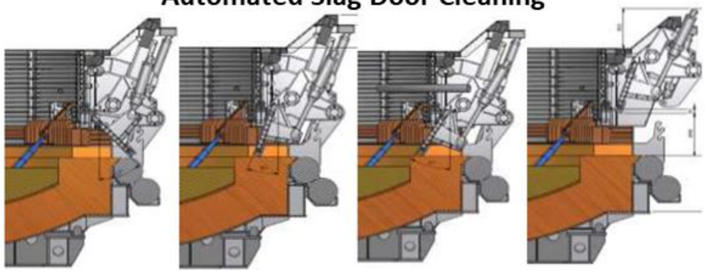
Automated ROBO-sampling



Automated EBT Sanding



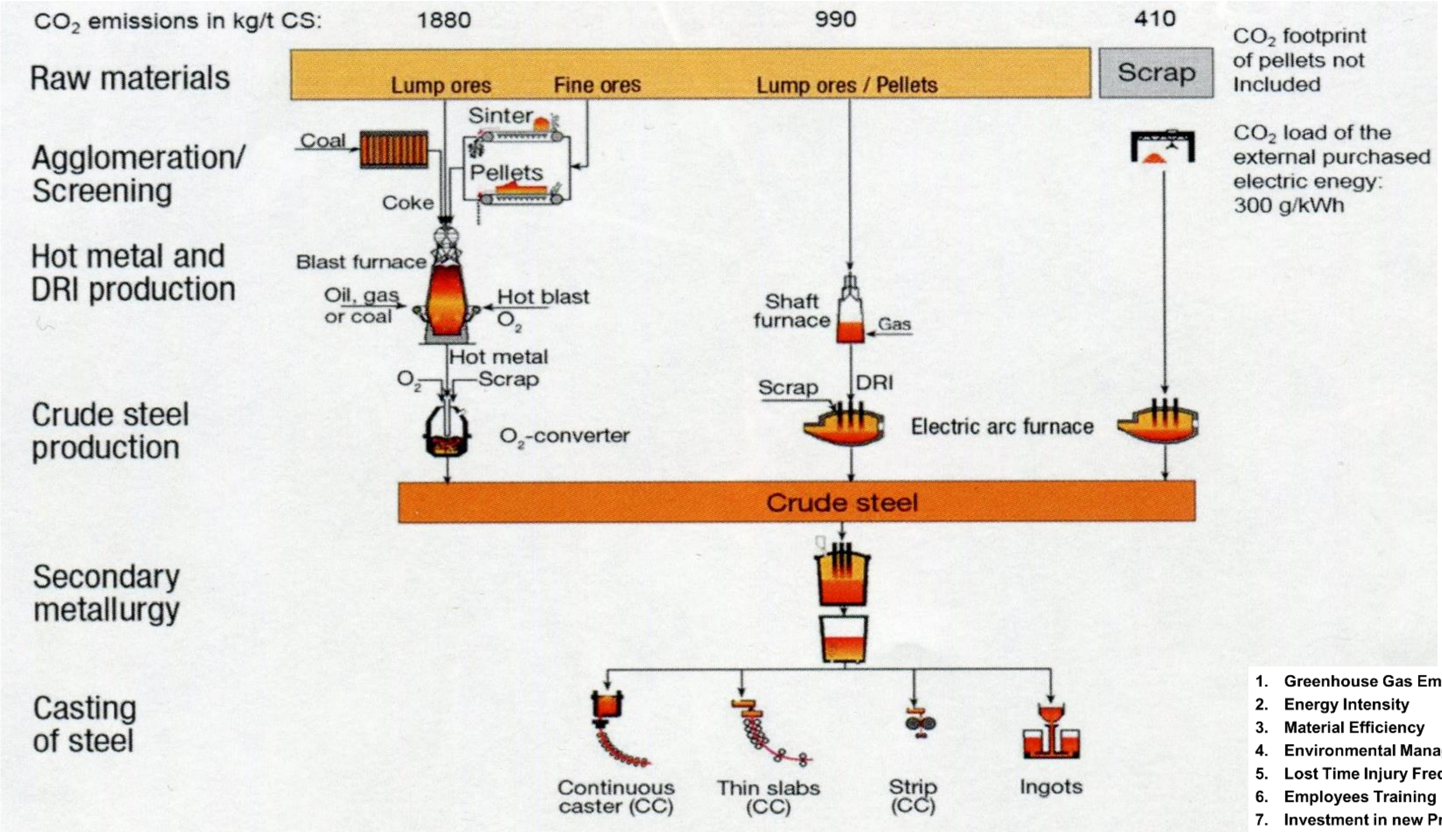
Automated Slag Door Cleaning



J.A. Vasquez, F. Memoli: „Fully automated melt shop: better safety, control and savings

Environmental Efficiency

The environmental efficiency is measured in kg/t, g/t, g/l, mg/m_n^3/ppm/decibel units and is related to visible pollution of air, water and ground. But also not visible pollution like noise and smell must be taken into account. Environmental efficiency is one of the seven sustainability indicators of the world steel organization. In the present fight against global warming in the meantime the greenhouse gas emissions became the most important one.



1. Greenhouse Gas Emissions
2. Energy Intensity
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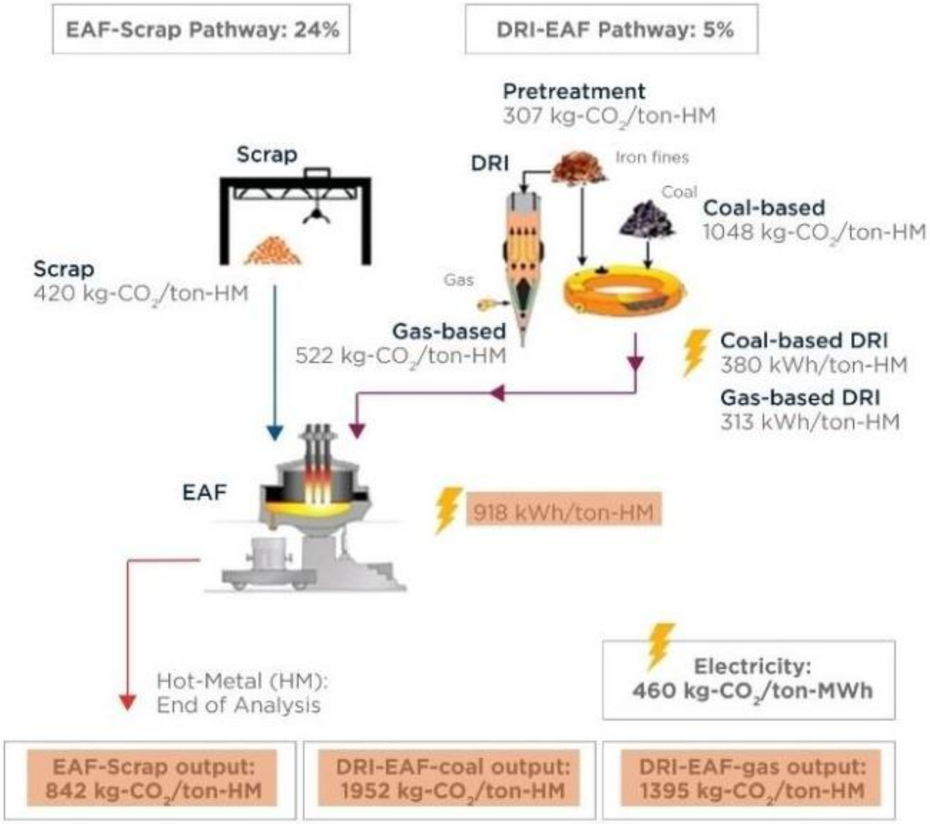
Although EAF steelmaking is considered to be more green house gas emission friendly compared to integrated steelmaking the Carbon footprint is not "zero" (black/grey power, LNG, other C-based materials, footprint of lime, other). This requires initiatives from the producers.

H.B. Lüngen: „Schlüsselwege zur CO2-Minderung", Stahl und Eisen März 2021, S. 45-52

Environmental Efficiency: Life-Cycle based Pathways for EAF Operation Variants

I this model calculation electricity and also scrap is evaluated with a Carbon footprint resulting from the effect, that also scrap is produced from virgin iron before recycling. In the DRI balance the production of Pellets, fired with natural gas is considered. In this approach the scrap-route ends up at 45% of emission reduction compared to BF-BOF and the DRI-route at 73%.

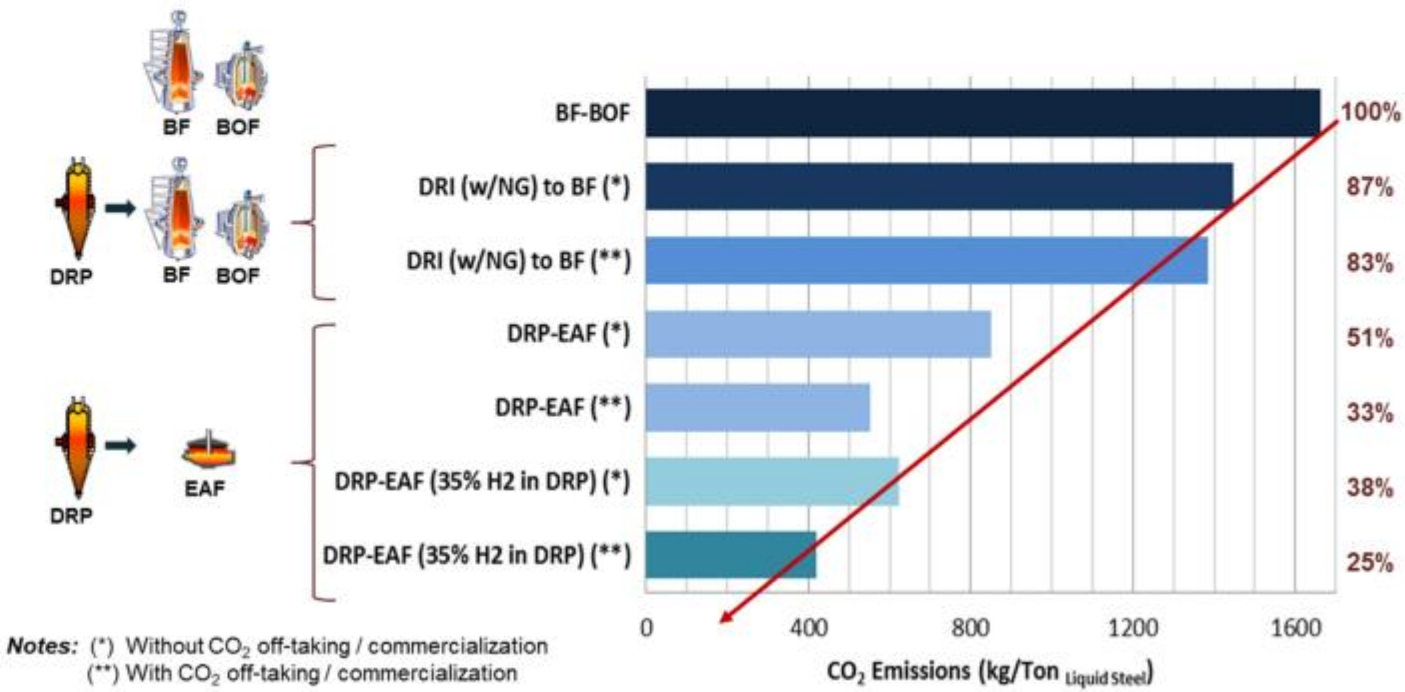


This can be improved by switching the DRI-process to Hydrogen and source electricity from "green" sources. The footprint will only reach to the desired levels if also the firing of the DRI-pellets is switched to Hydrogen. Still the result is not "zero". The resulting Carbon-leak requires further initiatives from the producers.

www.energypolicy.columbia.edu

Effects on CO_2 Emission derived from the Use of H_2 for Steelmaking

As soon as the Hydrogen comes into the game, DRI-EAF based steelmaking, even if grey power is considered, can reach below the CO_2-emissions possible in scrap based EAF teel production. But still the production is not CO2-free as shown in the graph below. Only the use of 100% of H2 in the DRP plus green power, as aimed in Europe will result in a Carbon footprint which is not “zero” (but is considered as “zero” ?).



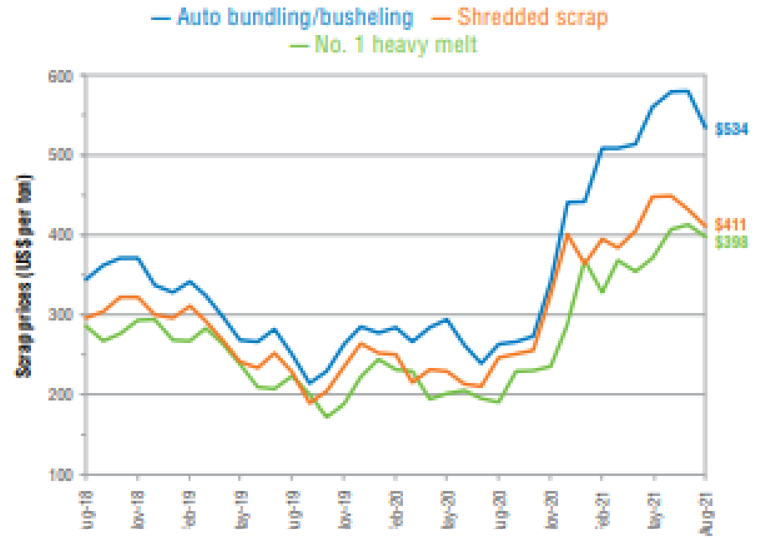
Power: 0,54 kg CO_2/kWh

Today the commitment for H2-use in DRI plats is already at 70-% and 100-% seems possible. This will reduce the Carbon footprint for DRI further. Nevertheless it is still not “zero”. This requires initiatives from the producers.

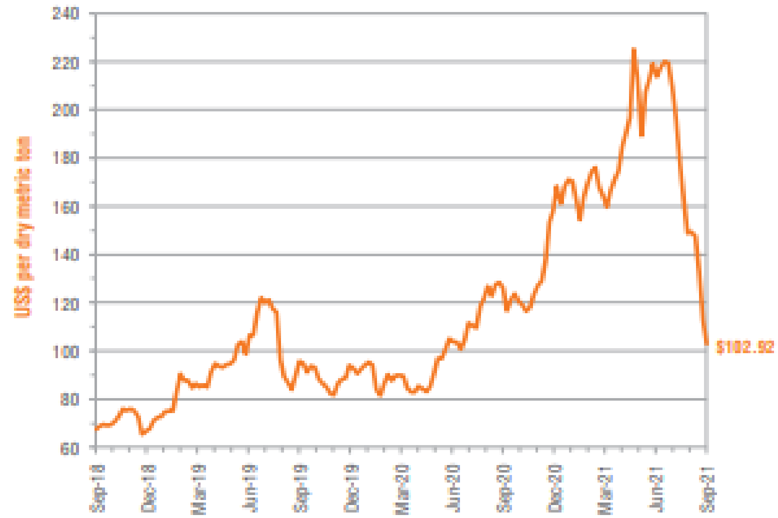
J. Martinez, P. Duarte: „Improving Performance and Decreasing CO_2-Emissions in BF using High-Carbon DRI/HBI“, HYL News, May 2017

Environmental Efficiency: Raw Material Availability and Prices

- Processing scrap is considered as a green steel technology.
- As soon as the prices/taxes for CO_2-emission certificates are rising, the run for scrap will start.
- EU today is one of the major scrap exporters together with USA and Japan. This scrap feeds regions with scrap undersupply like MENA/Turkey and South Korea.
- It can be expected that the developed regions will introduce export taxes on scrap and other recycling materials to keep it inside the region and to enhence domestic consumption.
- Raw material sourcing and prices will become the dominant issue in the next decade.
- Iron ore availability and price is sufficient but eco friendly scrap is not. Scrap quality will deteriorate because especially the large integrated producers rely on the high grade types when they reduce their hot metal ratio.



US scrap prices (Platts)

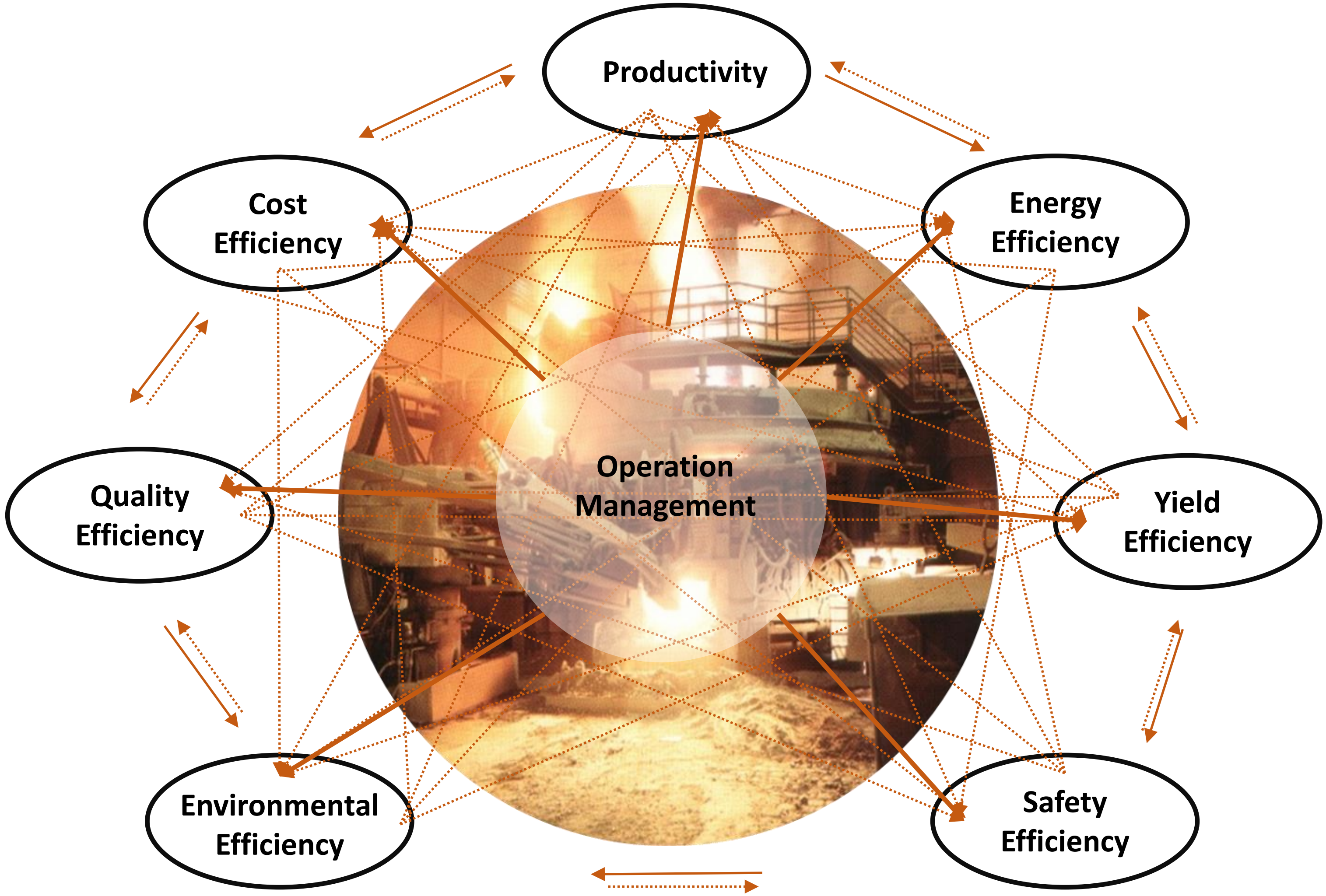


Iron ore price indicator (Platts)

Iron & Steel Technology, November 2021 issue, P. 16-17

Efficiency in EAF Operation

The operation of an EAF steel plant is a complex task with multiple uniform and controversy interacting parameters. Efficiency always is a total optimum, to bring all parameters to the best available bench mark values is not possible.



Thank You very much for your attention!

Qualified EAF operation

Non-qualified EAF operation