# Influence of Metallics and EAF Type on Specific Consumptions and Productivity

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## INTRODUCTION

There is an important variation in scrap quality and alternative iron sources depending on country and region. Besides, a variery of furnace designs are available. This paper intends to look at the influence of metallics type and EAF design on specific consumption of energy, oxygen and other inputs, as well as on some productivity indicators, based on a survey of published figures of EAFs around the world. The results obtained are analyzed in detail.

The data base was selected from publications in technical journals and presentations in conferences, since 2010 to February 2017. All furnaces included are intended for production of rolled products: EAFs for steel castings, forgings and powder are not included, as well as furnaces producing exclusively stainless and tool steels. Also excluded are furnaces with heat capacity lower than 30 t.

The universe surveyed includes 190 furnacess. Twin shell furnaces are contabilized as one furnace (including the CONARC furnaces). All steelmaking regions are included (figure 1). Charge types include from 100% scrap to 40% pig iron, 60% hot metal, 100% DRI/HBI and 100% hot DRI. Products include merchant long products, SBQ, flat products (coil and plate) and seamless pipes.

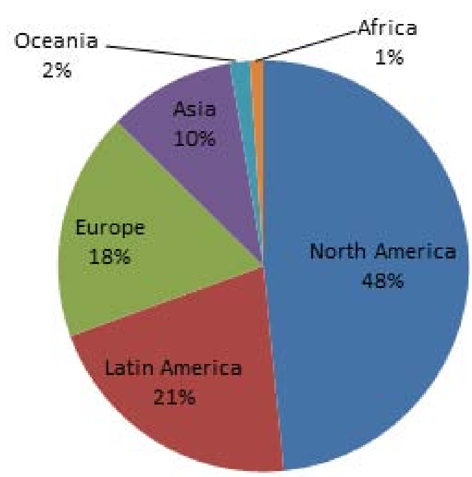


Figure 1. Distribution of the surveyed furnaces by region.

The survey includes 28 DC vs. 162 AC furnaces. Regarding tapping system, there are 16 furnaces equipped with spout, and 174 with EBT. 31 furnaces have some form of scrap preheating (15 Consteeel, 5 shaft and 11 twin shell furnaces), while the other 159 furnaces have no scrap preheating at all. In terms of charging, 9 furnaces are known to be single bucket. In figure 2, the distributions of these furnace features within the survey are shown.

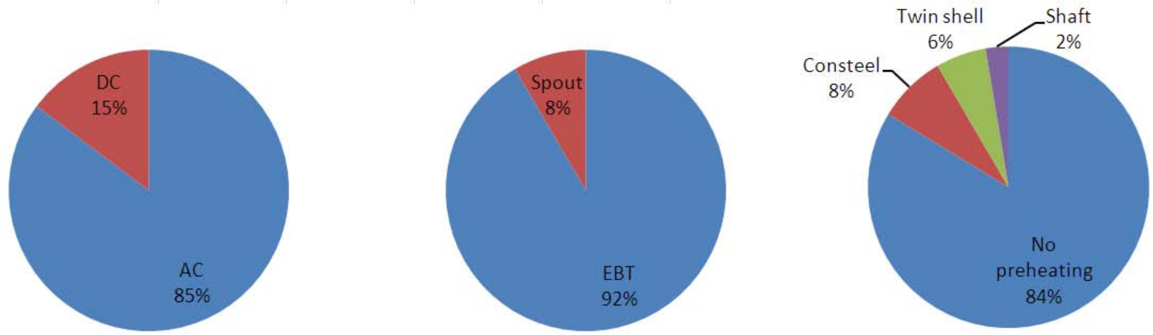


Figure 2. Distribution of furnace type within the survey. Left: electric current type; center: tapping system; right: no preheating and preheating systems.

The relation between transformer power and heat capacity within the survey is shown in figure 3. The line in the figure shows the 1:1 ratio.

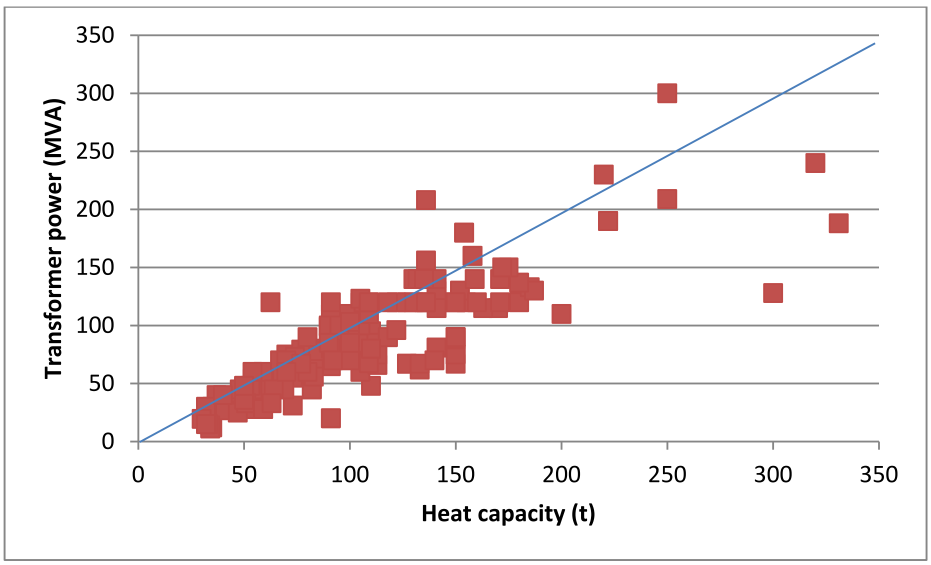


Figure 3. Transformer power and heat capacity (steel in the ladle) for the surveyed furnaces. The blue line indicates a 1:1 ratio.

## SURVEY

Specific consumptions are expressed in terms of metric tons of liquid steel in the ladle. The data included are: company / group; plant name; country; EAF type, heat capacity; transformer (power in MVA); electrode diameter; productivity; tap to tap tine; power on time; power consumption, oxygen consumption; injected carbon consumption; natural gas consumption; electrodes consumption; metallic yield; charge type; product type; published reference.

The sources of the information can be found in the references of this paper [1-46]. It is obvious that published data corresponds usually to a specific operation period, and consumption figures as well as productivity times change depending on demand and other situations that may vary along time.

## POWER CONSUMPTION

For the population of surveyed furnaces, the specific consumption of electric energy depends first of the raw materials, and the thermal state of them when charged (hot DRI, hot metal). Of the ten top EAFs with the lowest energy consumption (<300 kWh/t), nine charge more than 20% of hot metal (table 1 and figure 1). In these cases, energy is consumed in the blast furnace, and EAF $CO_2$ emissions are larger than usual.

The furnaces charging an important share of pig iron, as well as those charging scrap that are managed more efficiently, have a specific energy consumption of 300 - 400 kWh/t (figure 4).

Then, those furnaces of intermediate efficiency with scrap-based metallic charge, as well as those charging hot DRI, are located in the range of 400 – 450 kWh/t (figure 4). Higher energy consumption (more than 450 kWh/t) is typical of high cold DRI/HBI share or of low efficiency scrap-based EAFs.

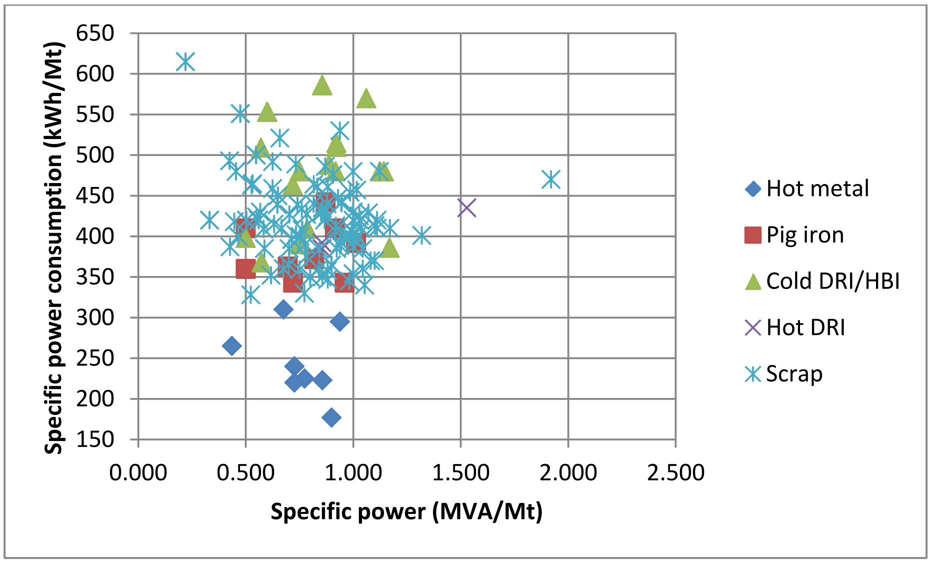


Figure 4. Specific power consumption for furnaces with different metallic charge. Scrap-based EAF applies for furnaces charging more than 80% scrap. Hot metal charging furnaces are considered those charging 20% or more hot metal.

Table 1. Top twenty furnaces regarding power consumption. HM: hot metal; PI: pig iron; cDRI: cold DRI. LS: Long special; LC: Long carbon; SP: Seamless pipes; FC: Flat carbon.

| Country | Heat capacity (t) | Current | Type | Transformer (MVA) | Tap to tap (min) | Power cons. (kWh/tls) | $O_2$ ($Nm^3$/tls) | Met. other than scrap (%) | Product |
|---|---|---|---|---|---|---|---|---|---|
| China | 50 | AC | Standard | | 67 | 132 | | 54 HM | LS |
| China | 100 | DC | Standard | 90 | 44 | 177 | 47 | 57.5 HM | LS |
| China | 110 | AC | Standard | 80 | 33 | 220 | 33 | 30 HM | LS |
| Russia | 175 | AC | Standard | 150 | 45 | 223 | 34 | 22 HM | LC |
| Taiwan | 155 | AC | Twin Shell | 120 | 44 | 225 | 37 | 35 HM | LC |
| China | 110 | AC | Standard | 80 | 35 | 240 | 33 | 30 HM | SP |
| China | 110 | AC | Standard | 80 | 35 | 240 | 33 | 30 HM | SP |
| Brazil | 110 | AC | Standard | 48 | 43 | 265 | | 30 HM | LC |
| Brazil | 80 | AC | Standard | 75 | | 295 | 31 | 25 HM/5PI | LC |
| Singapore | 80 | AC | Shaft | | 48 | 295 | | 0 | LC |
| Turkey | 195 | AC | Standard | | 47 | 300 | 38,5 | 0 | LC |
| South Africa | 170 | AC | Conarc | 115 | 57,5 | 310 | 43 | 50 HM/ 50 cDRI | FC |
| India | 180 | AC | Conarc | 137 | 57,5 | 310 | | 50 HM/50 cDRI | FC |
| Korea | 120 | AC | Shaft | | 49 | 314 | 31 | not known | LC |
| Vietnam | 63 | AC | Consteel | 33 | 54 | 328 | | 10 HM | LC |
| Mexico | 110 | AC | Standard | 85 | 90 | 330 | | 7 cDRI | LC |
| Italy | 95 | AC | Standard | 100 | 42 | 340 | 20 | 10 PI | SP |
| Brazil | 50 | AC | Standard | 36 | | 343 | 60 | 30 PI | LC |
| Brazil | 50 | AC | Standard | 48 | | 343 | 60 | 30 PI | LC |
| Mexico | 56 | AC | Standard | 55 | 55 | 345 | | 7 cDRI | LC |

A favorable influence of scrap preheating is observed (figure 5). Consteel, shaft furnaces and twin shell furnaces are located within those with lower power consumption, sharing this position with the more efficient conventional EAFs. For this purpose, to eliminate the aforementioned influence of the metallic charge, only those EAF charging 80% of scrap or more were considered.

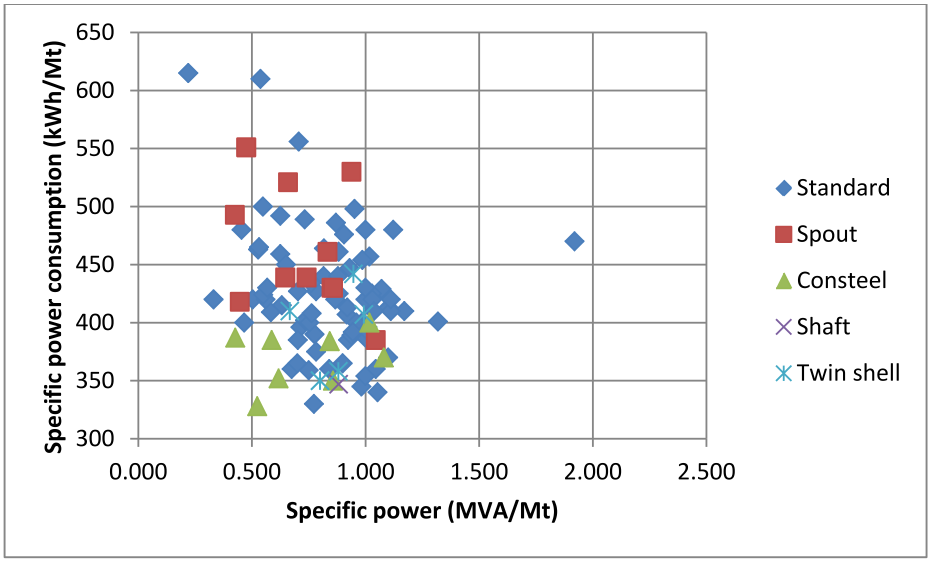


Figure 5. Specific power consumption for scrap preheating and conventional furnaces. Only furnaces charging 80% scrap or more are considered.

## OTHER FACTORS

**Oxygen consumption.** The distribution of specific oxygen consumption in the surveyed furnaces is shown in figure 6. More than half of the surveyed furnaces consume 30 to 40 $Nm^3/t$ of oxygen. This reflects the advance of chemical energy, due to productivity and power cost. From a technological point of view, this is associated to the use of injectors instead of lances, as well as the changes in injector design to allow for large oxygen flow rate.

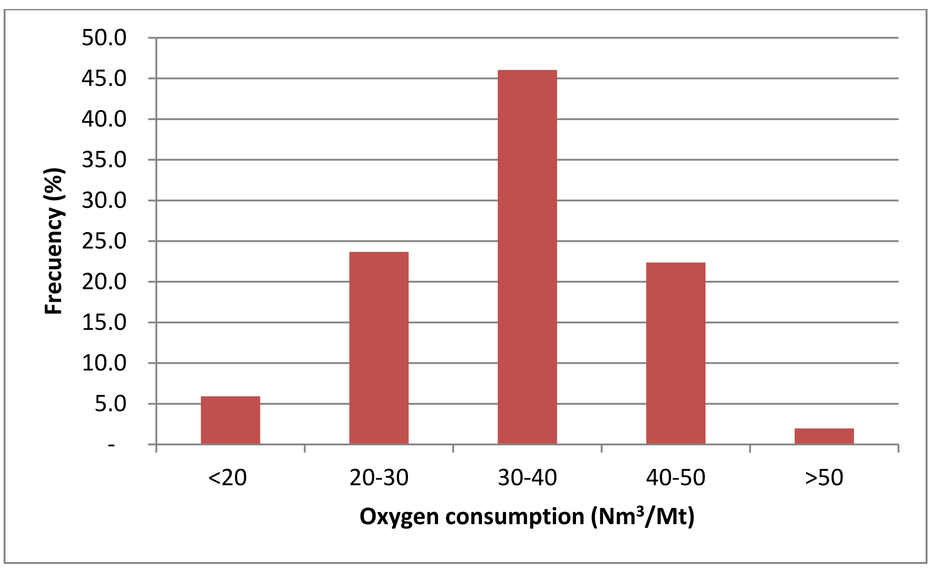


Figure 6. Specific oxygen consumption in $Nm^3/t$ for the EAF surveyed.

Although there is a large dispersion, it is worth to mention the average oxygen consumption related to the metallics charged:

- 20% or more of hot metal: 36,3 $Nm^3/t$
- 20% or more of pig iron: 43,3 $Nm^3/t$
- 20% or more of DRI/HBI: 31,7 $Nm^3/t$
- 80% or more scrap: 31,7 $Nm^3/t$

**Electrodes.** As is to be expected, the higher the heat capacity, the larger the electrode diameter (figure 7). But two other aspects can be mentioned:

- There is a big concentration of furnaces using 610 mm diameter electrodes, tapping from 70 to 200 t per heat.
- DC furnaces, with one or two electrodes, present the larger diameter, for a given heat capacity.

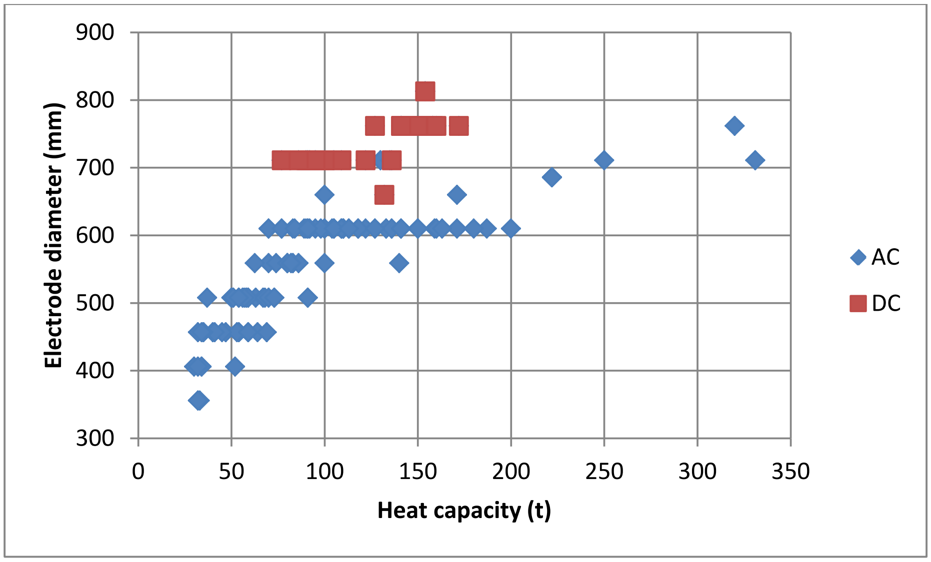


Figure 7. Electrodes diameter vs. heat capacity, for AC and DC furnaces of any design and metallic charge.

As is to be expected, there is a trend to increased electrode consumption for higher power consumption (figure 8). DC furnaces display a lower electrode consumption.

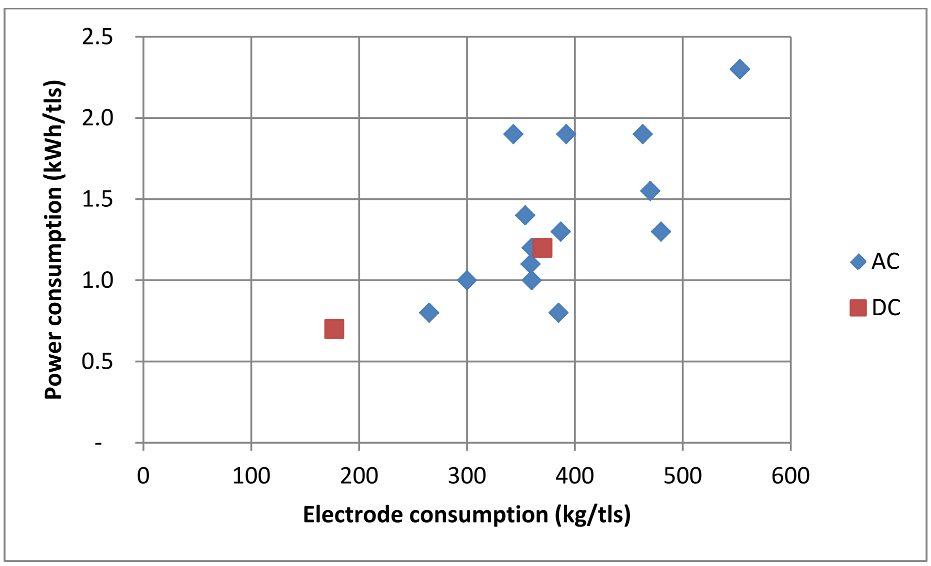


Figure 8. Electrode consumption vs. energy consumption for AC and DC furnaces.

**Productivity.** Productivity per hour is linearly related to the heat size, although other factors influence, too (figure 9). Seven of the ten top EAFs in productivity per hour are feeding slab casters.

 

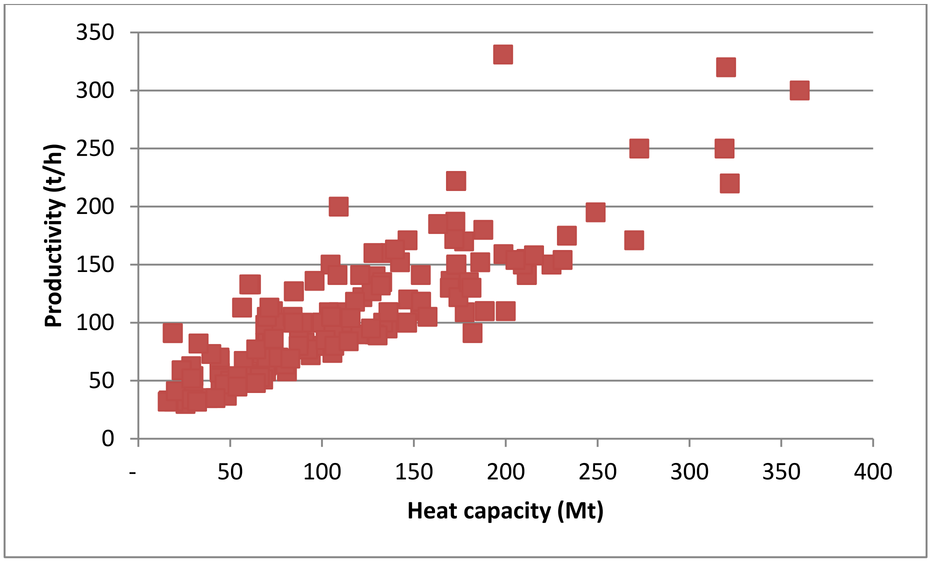

Figure 9. Hour production versus heat capacity, for all EAFs.

Regarding power on time, the twenty top EAFs have a varied heat size (35 to 220 t); sixteen of them are dedicated to merchant long products. The logic behind this situation is that in general, this furnaces are linked to billet casters equipped with metering nozzle and oil lubrication, characterized by casting speeds well higher than those used for SBQ, for the same billet size. Long sequences are usual for these casters, most of them equipped with automatic nozzle changer. SBQ casters, instead, have limited sequence length because of shorter SEN life and a larger variety of steel grades. See table 2

Table 2. Twenty plants in the survey, with the shorter power on time. HM: hot metal; PI: pig iron; cDRI: cold DRI. LS: Long special; LC: Long carbon; SP: Seamless pipes; FC: Flat carbon.

| Country | Heat cap. (t) | Current | Type | Transformer (MVA) | Tap to tap (min) | Power on (min) | Power cons. (kWh/tls) | $O_2$ ($Nm^3$/tls) | Metallics other than scrap | Product |
|---|---|---|---|---|---|---|---|---|---|---|
| Spain | 130 | AC | Standard | 140 | 43 | 29 | | | SC | LC |
| Germany | 100 | AC | Standard | 90 | 41 | 30 | 365 | 38,6 | SC | LC |
| Germany | 100 | AC | Standard | 90 | 41 | 30 | 365 | 38,6 | SC | LC |
| Belgium | 90 | DC | Standard | 99 | 42 | 31 | 370 | 44 | SC | LC |
| Russia | 175 | AC | Standard | 150 | 45 | 32 | 223 | 34 | HM | LC |
| USA | 35 | AC | Consteel | 30 | 55 | 32 | 350 | 31 | SC | LC |
| USA | 171 | AC | Shaft/ Twin | 140 | 38 | 32 | 372 | 50 | PI | FC |
| Brazil | 110 | AC | Standard | 48 | 43 | 33 | 265 | | HM | LC |
| Norway | 89 | AC | Consteel | 75 | 41 | 33 | 384 | 26 | SC | LC |
| Turkey | 220 | AC | Standard | 230 | 41 | 35 | 360 | 35 | SC | LC |
| USA | 154 | DC | Standard | 180 | 40 | 35 | 386 | 41 | CDRI | FC |
| USA | 154 | DC | Standard | 180 | 45 | 35 | 386 | 41 | CDRI | FC |
| Luxemburg | 160 | DC | Twin Shell | | | 35 | | | SC | LC |
| China | 100 | DC | Standard | 90 | 44 | 36 | 177 | 47 | HM | LS |
| Brazil | 80 | AC | Standard | 75 | | 37 | 295 | 31 | HM | LC |
| Korea | 100 | AC | Standard | 100 | 45 | 37 | 354 | 29 | SC | LC |
| France | 92 | DC | Standard | 72 | 54 | 37 | 375 | 44 | SC | LC |
| UAE | 152 | AC | Standard | 130 | 64 | 37 | 392 | 35 | HDRI | LC |
| Belarus | 110 | AC | Standard | 95 | | 38 | 386 | | SC | LC |
| Qatar | 85 | AC | Standard | 78 | 50 | 38 | 480 | 35 | CDRI | LC |

## CONCLUSIONS

There has been four ranges of power consumption according to the metallic charge:

1. <300 kWh/t: furnaces charging more than 20% of hot metal
2. 300-400 kWh/t: furnaces charging an important share of pig iron, as well as those charging scrap that are managed more efficiently
3. 400 – 450 kWh/t: furnaces of intermediate efficiency with scrap-based metallic charge, and those charging hot DRI
4. >450 kWh/t: furnaces with high cold DRI/HBI share or low efficiency scrap-based EAFs.

Regarding furnace type, it is clear the favorable influence of scrap preheating, with transporter, shaft or twin shell. DC EAFs do not differ much on power consumption, but are in the low range of electrode consumption.

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