Energy efficiency: a non-criterion in industrial processes

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Abstract

A calculated comparison between gas and electrical aluminium melting, from an energy efficiency as well as from a CO_2 emissions point of view, shows that there is a certain "imbroglio" concerning energy efficiency as a strategy for industrial processing in climate change mitigation. Energy efficiency seems to be used by many governments as a way of running with the hare and hunting with the hounds: pretending measures against climate change, and safeguarding at the same time the possibility for industrial growth. It is argued that "CO_2 emissions" or "life cycle analysis" are more relevant assessment tools to evaluate the impact on climate change of an industrial process. Moreover, in industry it is production efficiency – defined as the ratio between production yield and production efforts – what really matters, and not energy efficiency as such. And also from a pure theoretical, thermodynamical, point of view it is exergy efficiency that can point out the possible economies in an industrial process.

Consequently, for industrial processing it seems wise to make a split between the process itself and what is usually called "utilities". By "utilities" secondary but essential resources are meant as there are: compressed air, speed drives, lighting, refrigeration, steam, hot water. For these "utilities", standardized devices and practices can be designed. This standardization makes it rewarding to have a primary concern for their energy efficiency. For the process itself, however, industrial experience learns that the first concern is to have the process running.

Nevertheless, it can be forecasted that in the energy supply system of the future, energy efficiency will regain its importance as an evaluation criterion, not in the context of impact on climate change, but more as a performance parameter for the energy management of an industrial process.

Introduction

Energy efficiency is an important concept in all reasoning about rational use of energy. Experience learns however that in industrial practice energy efficiency is not a first line criterion for the assessment of a process. E.g. labour cost is in many occasions far more preponderant than concerns about energy efficiency.

Reference can be made to a recent study on hot spots on the construction parts of a channel induction furnace for the melting of aluminium[1]. This study was introduced by industry as a problem of prematurely material ageing, entailing high labour costs. It is clear that the occurrence of hot spots on the construction parts of a high power device for industrial thermal processing represents a lot of energy losses. However, these losses only came into the picture after calculations have been made. Once industry came aware of these losses, measures on energy efficiency are welcomed indeed. This study anecdotally shows that energy efficiency is not at all a bottom-up concept in industry. It only comes to the fore in a-posteriori calculations or when it is imposed top-down to satisfy environmental regulations[2].

1. Hectors D., Van Reusel K., Driesen J., *Solution of a Hot Spot Problem in the Housing of a Channel Induction Furnace*, International Congress on Electricity applications in modern world (UIE 2008), Krakow, Poland, May 18-21, 2008.

2. E.g. in Belgium production licences are only issued if energy efficiency criteria are met.

Table 1: Comparison gas – induction melting of aluminium scrap.

	Gas	Induction
Natural gas [GJ]	3	
Electricity [GJ]		1.8
Oxidation losses [kg]	18	6
Specific (primary) energy use [GJ/t]	3.080	4.527
CO_2 emission (1) [kg/t]	175 +132 = 307	156 + 43 = 199

(1) calculated as the sum of two terms: term 1: CO_2 emission linked to the primary energy use (for electricity, the primary energy equivalent is calculated for the Belgian generation mix for the year 2002); term 2: CO_2 emission linked to the energy associated with the oxidation losses.

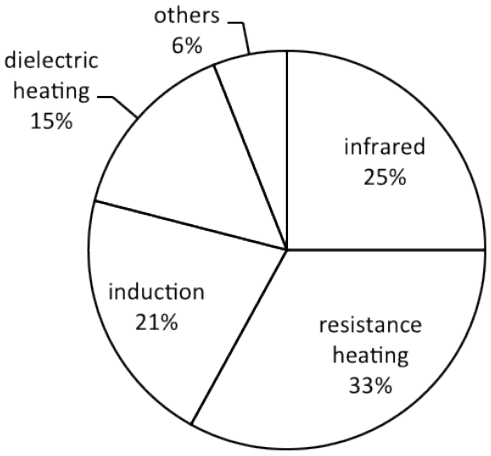


Fig. 1 Share of each electroheat technique.

A polemic title has been chosen for this paper in order to initiate the debate by a challenging position. The real purpose of the paper is to show, that energy efficiency as a concept can be useful in industrial practice, on the condition that a distinction is made between utilities and the process itself.

An industrial case: the energy efficiency "imbroglio"

To lay bare a certain "imbroglio" concerning energy efficiency as a strategy in climate change mitigation, it is very instructive to make a comparison between gas and electrical aluminium melting, from an energy efficiency as well as from a CO_2 emissions point of view. Take the situation[3] of 1 tonne (t) of aluminium scrap melted in a gas and induction furnace respectively. The values for the energy consumption and for the losses are found in literature[4], where the broad range in numerical value for these data is acknowledged, especially for the oxidation losses[5].

Gas turns out to be more (primary) energy efficient. But in climate change concerns, CO_2 emission is the point. To meet the international agreements (Kyoto at the time, followed by the Copenhagen agreements) many governments express industrial exploitation conditions in terms of energy efficiency, in spite of the fact that CO_2 emission is the real issue. The example summarized in Table 1 clearly shows the contradiction in decision taking concerning the choice between gas and electricity: from the viewpoint of (primary) energy efficiency gas should be preferred, however, if CO_2 emission is the main concern – which it really is in climate change –, electrical induction melting should be preferred. Moreover, for a smartly designed furnace[6], also hot spots – which not only give rise to premature deterioration of the construction parts, but are an important source of energy losses as well – can be avoided when using electricity. Electricity has the advantage indeed that it is more than a mere carrier of energy. The particular physical characteristics of electricity enable a quite exact deposition of the energy in the material to be heated.

The more general viewpoint: "energy efficiency" as a motive for the use of electricity in industrial thermal processing

After this anecdotic reference, laying bare the "imbroglio" concerning energy efficiency, a more general viewpoint has to be taken now, in order to avoid missing the forest for the trees. To validate on a more general level the conclusions already suggested by the findings of the particular case in the previous paragraph[7], the files of 30 years feasibility studies of the electroheat department of LABORELEC[8] are investigated looking for the motives that brought industry to consider electricity as energy vector for thermal processing. As thermal processes are huge consumers of energy, electroheat technologies give a good chance indeed to assess the importance of the energy efficiency motive in the choice of the most appropriate technology for thermal processing. The time span 1970–2000 covers the years – after the oil crises of the seventies – in which energy consumption exactly was a major issue in the industrialized world.

3. See also LABORELEC presentation by K. Van Reusel (+ information gathered and calculated by R. Stiens) at a KVIV workshop on 12th May 2005: "Ervaringen met energie-audits" ("*Energy audits experiences*").

4. E.g. E. Baake, U. Jörn, A. Mühlbauer, Energiebedarf und CO2-Emission industrieller Prozeßverfahren („Energy need and CO_2 emissions by industrial processing"), Vulkan-Verlag, Essen, 1996, table A7, p. 141.

5. Ibidem, p. 49.

6. Cfr. Hectors D., Van Reusel K., Driesen J., *Solution of a Hot Spot Problem in the Housing of a Channel Induction Furnace*, International Congress on Electricity applications in modern world (UIE 2008), Krakow, Poland, May 18-21, 2008.

7. To show that not all swans are white, it suffices to indicate one specimen that is blackly feathered. However, the message of this paper aims at a more general level of validity. Therefore, an inductive way of arguing is left for a more overall viewpoint.

8. LABORELEC is the technical competence centre of the Belgian electricity sector.

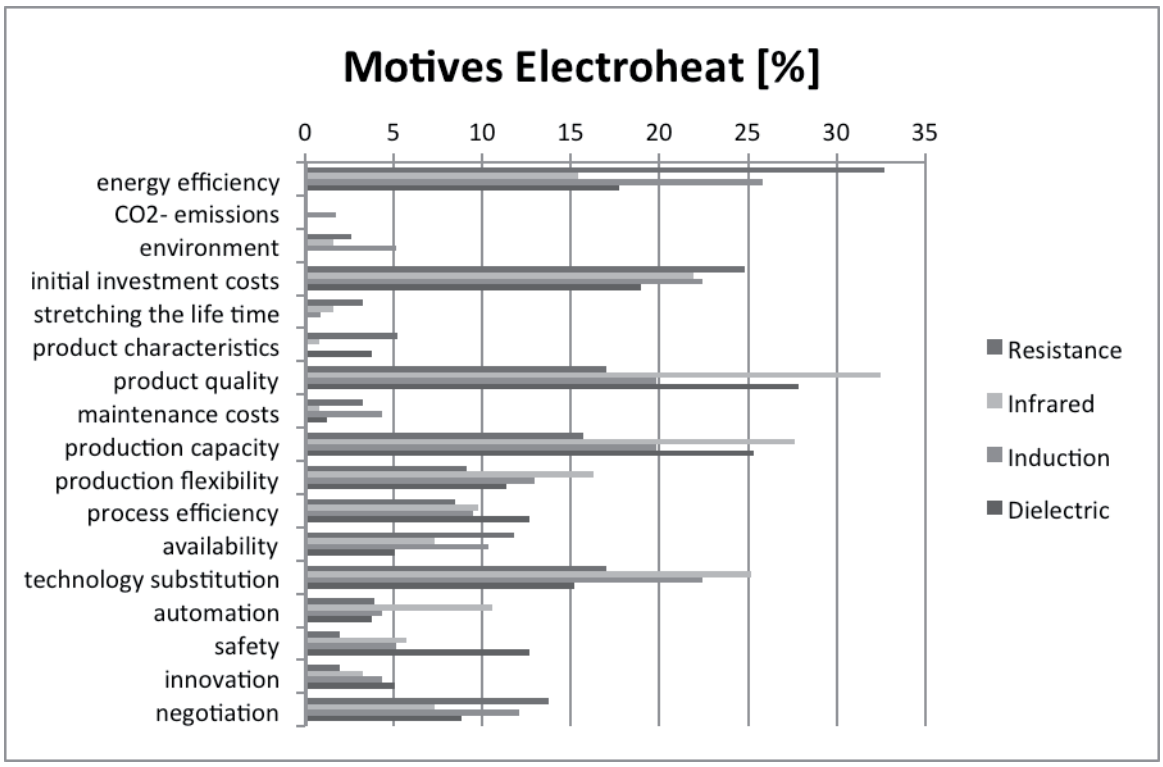


Fig. 2 Motives for electroheat.

Four electroheat technologies are investigated: resistance heating, infrared heating, induction heating, and dielectric heating[9]. Fig. 1 gives the share of each electroheat technique in the electroheat feasibility studies done by LABORELEC in the years 1970–2000.

The LABORELEC files are scrutinized on the motives that bring industry to make an appeal to the electroheat facility for a feasibility study on each electroheat technique. Each time a motive seems to be present in a specific report, the counter for that motive is increased by one. At the end the total number for the respective motive is divided by the total number of reports on the respective electroheat technique in order to obtain a relative value, expressible as a percentage. This relative value facilitates the mutual comparison of the four investigated electroheat technologies. The results are given in Fig. 2.

It is no surprise that for resistance heating energy efficiency is the main motive for calling upon the service of an electroheat facility, as indicated in Fig. 2. Indeed, resistance heating is typically a substitution technology, where a switch is made from a combustible fuel fired process to an electrical process. This switch has to be justified by a study on investment and exploitation costs. This brings the issue of energy efficiency to the foreground when considering resistance heating substituting a fossil fuel fired process by an electrical process.

Also for induction heating energy efficiency is an issue to study because the processes in which induction heating is used are generally highly energy intensive.

In dielectric heating the energy efficiency is studied because of the intrinsic low efficiency of the dielectric technology. Studies have to be done to optimize the overall process by a combination of different techniques.

For infrared heating energy efficiency is good, and is not really a major subject of investigation. As a partial conclusion of this enquiry, it can be firstly stated that the concern for energy efficiency[10] is dependent on the technology. Secondly, and more importantly to the main conclusion of this paper, the multiplicity of motives makes it clear that energy efficiency has never been the only criterion in the choice of the most appropriate technology. Moreover, a more indepth analysis of the LABORELEC reports shows that energy efficiency is rarely the decisive motive to consider technology switch. The energy efficiency criterion is taken into consideration after other motives for technology choice are already met[11]. Therefore, the statement can be made that energy efficiency is a typical issue of energy policy as used by governments. Energy efficiency seems to be used indeed by many governments as a way of running with the hare and hunting with the hounds: pretending measures against climate change, and safeguarding at the same time the possibility for industrial growth.

Historically, it is the context of primary energy supply and scarcity of fossil energy resources that brings energy efficiency to the fore in the nineties of the last century. The context of climate change makes energy efficiency to an operational concept

9. By "others" (fig. 1) techniques as ultraviolet, plasma, air knife, are classified. Due to the only marginal occurrence of these techniques in the LABORELEC files, no further attention will be paid to them.

10. CO_2 seems not to be a motive at all in the LABORELEC files. In the time span of the investigation, the years 1970–1995, the CO_2 item was not an environmental issue yet.

11. Cfr. PhD thesis K. Van Reusel, Context and technology bound motives for the use of electricity in industrial thermal processing. From 'Electroheat' to 'Electromagnetic Processing of Materials', Universtiy of Leuven, 2010.

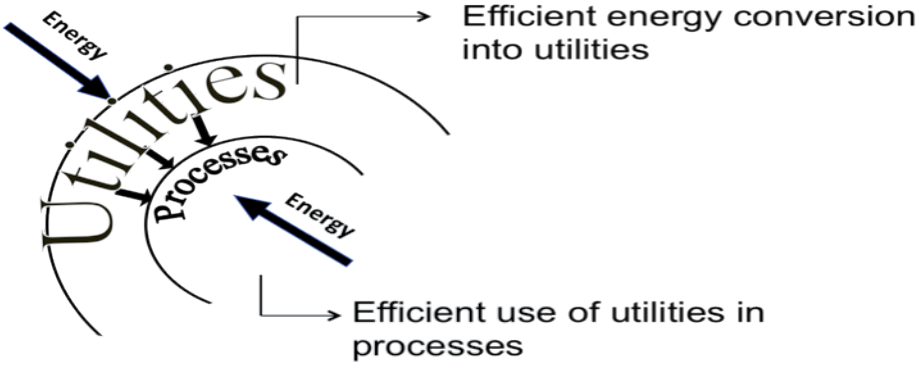


Fig. 3 Rational use of energy in industrial processes.

in a governmental policy to meet the environmental concern as well as to safeguard the possibility of industrial expansion. In a real concern for climate change, the energy efficiency criterion should be corrected towards more appropriate assessment tools as "CO_2 emissions" and "life-cycle-analysis".

A necessary split between "utilities" and "process"

Industrial practice learns that the real point of interest in industrial processing is not as much energy efficiency but production efficiency, which can be defined as the ratio between production yield (including better quality) and production efforts (including maintenance). Energy efficiency is an excellent evaluation concept for all mass products and for those electrical applications that are used in great number as there are lighting applications and drives. Here, the law of great numbers prevails. For industrial processing however it seems wise to split industrial processing between the process itself and what is usually called "utilities". By "utilities" secondary but essential resources are meant as there are compressed air, speed drives, lighting, refrigeration, steam, hot water. Fig. 3 articulates the rational use of energy in industrial processes.

For "utilities", standardized devices and practices can be designed which makes it rewarding to have a primary concern for their energy efficiency. For the process itself, however, industrial experience learns that the first concern is to have the process running.[12] This is the point of vital importance for which other considerations, including energy efficiency, have to give way. Moreover, the fact that energy consumption is mostly directly proportional to production volumes makes it very easy to impute it proportionally in the production cost. This is another reason why energy efficiency plays a minor role in most decisions on technology choice. At the moment of decision taking, considerations of investment costs, reliability, safety, and working environment are mostly preponderant.

Exergy analysis is the real assessment tool for identification of possible energy savings

For an assessment of a process, it is in fact exergy, more than energy, which should be considered. Exergy is defined as the maximum work potential of a material or of a form of energy in relation to its environment. From a thermodynamical point of view, exergy indicates the reversible part in the total energy content. More than energy efficiency, the notion of exergy efficiency, is capable of indicating the possible energy economies. Exergy analysis reveals the irreversible energy conversions in a thermodynamical process. This can be illustrated by the example of a gas boiler system. As indicated in Fig. 4 the energy efficiency is 96.7 %. If the assessment stops here, the conclusion is that the gas boiler is an excellent energy conversion system. However, when the exergy efficiency is calculated it turns out that the exergy efficiency is not more than 8.4 %[13]. This can be intuitively appreciated by considering that in fact it makes no sense to use a gas flame of around 800 °C for low temperature heating (e.g. 70 °C for the water used for room heating).

Unfortunately, for an industrial process, the exergy analysis turns out to be quite laborious[14]. Specialized consultancy is required, which makes it hard and expensive to use it as a tool for efficiency assessment in industry.

Energy efficiency as a performance criterion in the energy supply system of the future

It can be stated however, that it is likely to happen that energy efficiency will regain a position as a performance criterion in industrial processes. The electricity supply system of the future will be a system of distributed generation. It is inherent to this future situation that the supply in power is for some geographical areas more limited. To have enough power delivered to the process, will be a most important issue in industrial processing. Therefore, energy efficiency will become more important than ever as a performance parameter. Not as much to save energy – there is "enough" renewable energy –, but more as a way to ensure that sufficient energy can be supplied to the application.

12. Reference can be made to the cited article Hectors D., Van Reusel K., Driesen J., *Solution of a Hot Spot Problem in the Housing of a Channel Induction Furnace*, International Congress on Electricity applications in modern world (UIE 2008), Krakow, Poland, May 18–21, 2008. This research has been initiated by industry. However, the first point of concern was not the energy losses caused by the hot spots, but rather the fact that these hot spots involved premature material ageing and consequent production stops.

13. Cfr. "What is Exergy exactly?", http://www.exergie.nl/whatis.html.

14. Cfr.R.L. Cornelissen, Thermodynamics and sustainable development. The use of exergy analysis and the reduction of irreversibility, Ph.D. thesis, 1997, University of Twente.

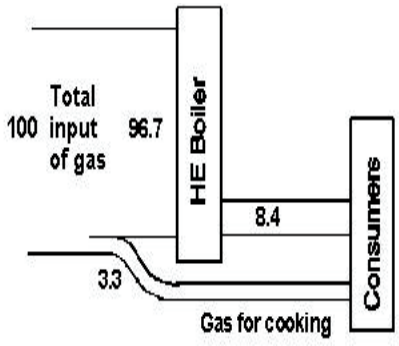


Fig. 4 Energy versus exergy efficiency.

Conclusion

It can be concluded that energy efficiency is in the current state of affairs a non-criterion in industrial processes. In fact it makes only poor sense as a measure for CO_2 reduction of industrial processes. "CO_2 emissions" or even more "life cycle analysis" are the more relevant assessment tools to evaluate the impact on climate change of an industrial process. In industry it is production efficiency, not energy what really matters. From a thermodynamical point of view it is exergy efficiency that can point out the possible economies in an industrial process.

It can be forecasted that in the energy supply system of the future, energy efficiency will regain its importance as an evaluation criterion, not in the context of impact on climate change, but more as a performance parameter for the energy management of an industrial process.

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