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Long Term Energy Efficiency Improvement

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Abstract
The opportunities for long term energy efficiency improvement in industry have been studied. Three studies are described. The first study was directed at making a preliminary survey of technologies that might reduce the end-use demand of industrial processes on the long term. The second study focused on the development of a methodology to make a more profound analysis of the long term potential. The third study describes a database for energy efficient technologies. It is concluded that, after technologies that are currently technically feasible have been implemented, there still exists a considerable (new) potential for improvement.

1. INTRODUCTION

A major option to reduce CO_2 emissions is efficiency improvement of energy end-use and energy conversion processes. Often it is stated that the ultimate potential of energy efficiency improvement in the western world is several ten percents. A large number of studies showed that this potential is technically feasible within 10 years [see e.g. Lovins and Lovins, 1990; Pilavachi, 1993; ETSU, 1984; Giovannni and Pain, 1990]. However, it is also claimed that in the longer run this potential is much larger, i.c. more than 80% or even 90% [see e.g. Ayres, 1988; Jochem, 1991].

In this paper an overview is given of work performed to assess the potential of efficiency improvement on the long term. The results can be of use in R&D priority setting, developing CO_2 mitigation strategies, and long term energy infrastructure planning. Three studies addressed the opportunities of long term energy efficiency improvements. The approach and results of these studies will be described in this paper.

2. SURVEY OF ENERGY EFFICIENT TECHNOLOGIES IN INDUSTRY

The first study is directed at making a preliminary survey of technologies that might reduce the end-use demand of industrial process on the long term [Smit et al, 1994]. The technology descriptions are based on readily accessible literature, where necessary supplemented with data provided by experts on the specific sector or technology. The descriptions are divided into two sections. The first section gives a description of the reference technology and the new, energy efficient technology. Also information on state-of-the-art, ongoing R&D, and applicability of the technology is presented. The second section gives preliminary economic and energetic parameters. In table I some results of this research are presented. It must be emphasized that the results are based on a limited literature research, in some cases supplemented with consultation of experts. A more thorough analysis of the energy efficiency improvement potential is topic of the second study.

3. DEVELOPMENT AND TESTING OF A METHODOLOGY

The second study focuses on the development and testing of a methodology to make an accurate analysis of the long term energy efficiency improvement potential.

The methodology developed so far starts with the determination of the minimum energy requirement to perform a certain energy function and of the energy losses associated with performing the energy function with the current technology. The question posed is, can these losses be reduced without changing the current technology? And, if such is not the case, are technologies perceivable that can reduce the energy losses? After having compiled a list of efficiency improvement technologies, an assessment of the possible technological development is made. A list of determinants of technological development is filled out on the basis of a literature review and consultation of experts.

A study following this line of research has been conducted for the sector 'paper and board' industry. Furthermore, two studies are underway for the sectors 'iron and steel industry' and 'cement industry'. Here we will present some results of the studies for the paper and board industry and the iron and steel industry.

Theoretically, the minimum energy demand for making paper out of wood pulp is very small (compared to a present average primary energy demand of about 10 GJ/ton paper). The operation with the largest energy losses is the steam generation (in a CHP-unit or boiler). Steam is mainly required for drying of the paper against steam heated driers. Elimination of these losses is only possible by making paper without the addition of water. However, this has a large negative effect on the product characteristics. Five technologies were selected that have the opportunity to reduce the energy losses.

Table I: Selection of long term energy efficiency improvement technologies. All figures are based on the Dutch industry. It must be emphasized that these results are based on a limited literature research, in some cases supplemented with consultation of experts.

Proces/application	**Current technologies**	**Currents SEC*** **(GJ/tonne)**	**Long-term technology**	**Long-term SEC (GJ/tonne)**
Milk powder	Two-stage drier	3.95	Condi-cyclone	2.3
Paper	Steam heated cylinders	9.9	Impulse drying	7.8**
Ethylene	Naphtha steam cracking	61***	Selective steam cracking	55
	Cryogenic distillation	61***	Membrane separation	56
Chlorine	Membrane electrolysis	9.9 electricity 1.2 steam	Improved membrane electrolysis	7.5 electricity - steam
Bricks	Roller kiln	2.2	Tunnel kiln	1.8
Cement	Standard kiln (dry process)	3.4	Fluidized bed	2.7
Iron making	Blast furnace	17.6 (tonne pig iron)	Converted blast furnace	10.6
Steel casting	Casting and rolling	1.64 (tonne crude steel)	Strip casting	0.24
Aluminium	Hall-Heroult	51.1 electricity 16.3 fuel	AlCoA	33.1 electricity - fuel
			Inert cathodes and anodes	42.1 electricity - fuel
Cross-cutting technologies	**Current technology**	**Best practice efficiency**	**Long-term improvements**	**Long-term efficiency**
Combined generation of heat and power	Gas turbine with waste heat boiler, or combined cycle	34-36%	Increase turbine inlet temperature; improvement of gas turbine cycle.	about 50%
High temperature applications	furnaces	Energy demand: 200 PJ/year	Heat recovery with ceramic recuperators	Energy demand: 170 PJ/year

* SEC = specific energy consumption; in this table primary energy is meant, unless indicated otherwise

** Savings on steam demand are 50-75%; however, the electricity demand increases. Therefore, savings on primary energy are smaller.

*** Including use of fuel as feedstock (43 GJ/tonne).

The third step of the methodology, assessment of the technological development, resulted in the selection of two technologies that are most promising for reducing the energy consumption of a paper mill: condensing belt drying and impulse drying. R&D to these technologies is concentrated in Finland and the USA. Also in Italy, Sweden and Germany research is being conducted. These technologies have the ability to reduce the specific steam demand by 50-75% [Beer et al. 1993].

For the iron and steel industry only the first two steps and part of the third step of the methodology have been performed so far. The specific energy requirement of an efficient integrated steel plant (Hoogovens, the Netherlands) is 19.7 GJ/ton crude steel. On the short term a reduction to 16.8 GJ/ton is technically feasible. However, the thermodynamical minimum energy requirement for the reduction of iron oxide is only 6.2 GJ/ton. An exergy analysis of an integrated steel mill revealed that the room for improvement of the current process is limited. Larger improvements seem only feasible when another production route is chosen. Several technologies are outlined: an increased share of secondary steel making, advanced iron making processes (e.g. plasma processes), direct steel making (in-bath melting of iron, ore-to-powder steelmaking), near shape casting, and using hydrogen as reductant. The largest efficiency improvement is achievable with more secondary steel making. Taking into account an improved efficiency of electric arc furnaces and a higher energy demand for scrap benification a specific primary energy demand of about 7 GJ/ton steel seems possible in the long term. A combination of efficient technologies for primary steel making might reduce the specific primary energy demand to about 12 GJ/ton steel [Beer, 1994].

4. A DATABASE ON ENERGY EFFICIENT TECHNOLOGIES

A database (called ICARUS) on the potential and costs of energy efficiency improvement measures that can be applied in different sectors of the Dutch economy between 1990 and 2000 has been constructed [Beer et al, 1994]. Data were acquired using a sectoral, bottom-up approach. In figure 1 the results are summarized in a supply curve. The figure indicates a technical potential for efficiency improvement for the period 1990-2000 of 36%. If only those measures with a positive net present value are taken into consideration, the potential is 29% (we call this the economic potential).

It is also possible to collect data on long term energy efficiency improvement technologies in a database like ICARUS. We have done this for technologies that probably will be commercially available before the year 2015 [Beer et al, 1994]. The results are also summarized as a supply curve, see figure 1. Of course, on this longer term the uncertainty in the data is larger than for the period 1990-2000.

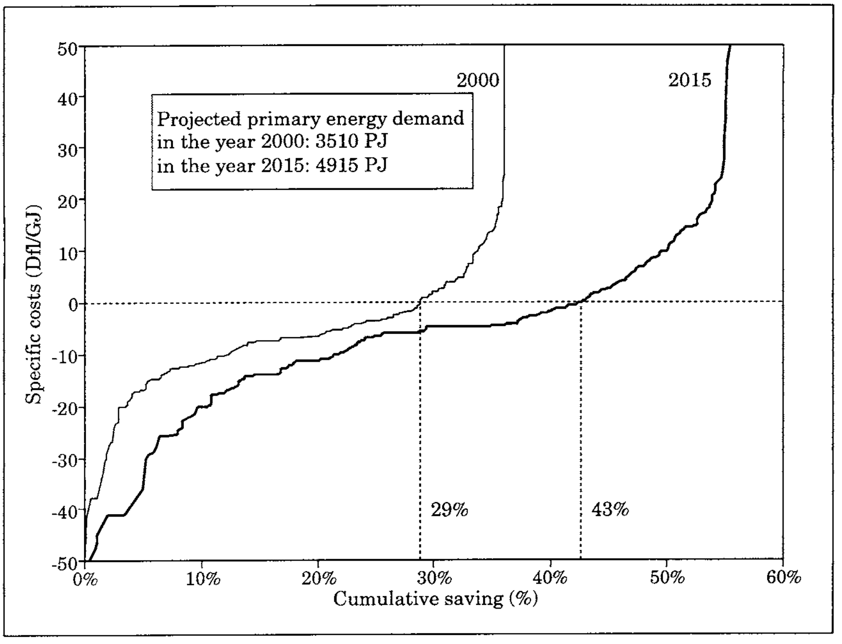

Figure 1: Supply curves of energy efficiency improvement measures for the periods 1990-2000 and 1990-2015. On the horizontal axis the cumulative improvement potential is given as percentage of the projected energy demand without efficiency improvements. The European Renaissance scenario is used with growth figures based on physical growth. Vertically the specific energy efficiency improvement costs are depicted. Energy prices are taken from [EZ, 1994]. The low energy price scenario is used. A discount rate of 5% is used.

From figure 1 it can be seen that for the period 1990-2015 the technical potential is 56%. This would mean a decrease in specific energy consumption in 2015 of 31% compared to 2000. The economic potential for the period 1990-2015 is 43%.

5. CONCLUSIONS

It can be concluded that the potential of energy efficiency improvement is not limited to the currently technically feasible technologies. In the steel making process, for instance, the long term potential is about three times as large as the short term potential. An assessment of the technological development by filling out a list of determinants of this development, gives insight in the probability that a technology will be commercialized and the time scale for this to happen. This information can be of aid in R&D-priority

setting. For instance, all R&D to innovative drying techniques in paper making is currently concentrated in four or five countries, but not in the Netherlands. Therefore, national R&D-funds can better be applied for the development of other energy efficient technologies.

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