LCA Methodology

A Methodological Approach for the Economic Assessment of Best Available Techniques

Demonstrated for a Case Study from the Steel Industry

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Abstract. The determination and the assessment of Best Available Techniques (BAT) is one of the key issues in the realisation of the IPPC-Directive. While research has already focused on environmental benefits and technical practicability of techniques within LCA, little work has been carried out assessing economic feasibility. A methodology for the economic assessment of BAT in the framework of the IPPC-Directive on a plant level has to comprise all costs that accrue by measures to prevent, to reduce, to utilise or to remove emissions into water, air and soil caused by industrial production processes. The applied cost concept provides a systematic accounting and allocation of decision relevant costs and possibly revenues, that are pertinent to the economic assessment of BAT. The application of the methodology to a case study from the steel industry shows the practical use of the approach.

Keywords: Best Available Techniques (BAT); cost allocation; decision relevant costs; economic assessment; electric steelmaking; emissions; investment related costs; IPPC-Directive; Life Cycle Assessment (LCA); operating costs; steel industry

Introduction

The Council of the European Union issued on September, 24th 1996 the Directive on Integrated Pollution Prevention and Control (IPPC-Directive) [1]. The purpose of this Directive is to achieve integrated prevention and control of pollution arising from many relevant industrial activities, which are defined in Annex I of the IPPC-Directive. To achieve this goal, the Directive demands the implementation of an integrated licensing procedure for the operation of concerned industrial installations within all member states of the European Union. A main prerequisite to get a permit for an installation is to obey certain basic obligations by the operator. The primary obligation is to take all the appropriate measures against pollution, in particular through the application of the Best Available Techniques (BAT) (Art. 3, [1]).

This concept of BAT plays a very important role within the IPPC-Directive. For this reason, the Commission of the European Union started an information exchange on BAT for all concerned industrial activities. Aim of this exchange is to obtain Reference Documents on BAT (BREFs), which contain all relevant information on BAT including descriptions of the corresponding industrial sectors, main consumption and emission data on a sector level, as well as the BAT and related achievable inputs and outputs on a plant level. For a couple of industrial activities. BAT have already been either proposed and published, or are in the ultimate stage of discussion in the Technical Working Groups (TWG) which are concerned with the collection and processing of information on BAT for specific sectors. BREFs have been issued for the cement industry and for the iron and steel industry, for further industrial activities, like non-ferrous metal processes and ferrous metal processing, the work has advanced pretty much and will be completed most likely in the near future. As a result, descriptions of the corresponding industrial sectors including figures on mass and energy streams related to the respective industrial activities are available. The BREFs, which are elaborated by the European Integrated Pollution Prevention and Control Bureau (EIPPCB) in Seville, of course also contain the identified BAT and related achievable input/output data.

One problem which has been discussed in the context of the IPPC-Directive is the general problem of determining and selecting these BAT, which are suitable to prevent or, where that is not practicable, to reduce emissions and the impact on the environment as a whole [2]. Another important task in this framework is the determination and consideration of economic aspects of BAT in the course of their selection, as this is also required by the IPPC-Directive (i.a. Art 2 and Annex IV, [1]). For reasons of transparency and comparability, it is indispensable to employ a sound methodology for the economic evaluation of proposed techniques to consider in the determination of BAT, such that meaningful statements on economic aspects can be made. The methodology proposed in the following section is based on a techno-economic approach. It can be easily adapted to the tools discussed in Life Cycle Assessment (LCA) developed and applied for ecological assessment.

1 Proposal of a Methodology for the Economic Assessment of BAT

A very common approach to assess the economic performance of technical measures is the determination of costs

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related to these technical alternatives. The methodology proposed in this paper also bases the cost concept. If costs of technical measures need to be determined ex ante, it is very often necessary to estimate shares or even all of the cost components. The exactness of cost estimations can vary from a preliminary, coarse estimate to a very detailed estimate, depending on the availability of information and time as well as the purpose of the estimation. An exact economic assessment of BAT by means of costs will require consistent and complete data for all processes that are considered. If detailed cost data for these processes are not available, missing or inconsistent data will have to be estimated or data from similar processes will have to be considered representative or will have to be adapted by up scaling or down scaling, for instance [3].

1.1 Cost definition

The determination of costs caused by techniques to consider in the determination of BAT requires a general delimitation, which costs are to be taken as decision relevant. Two alternative definitions of decision-relevant costs may be distinguished [3]:

(a) Decision-relevant costs are defined to be costs for the additional input of resources for the production process, which are caused by newly installed measures to prevent or control emissions.

(b) Decision-relevant costs are defined as in case (a), however, not only the additional but the entire input (including already installed technologies) is taken into account.

Whether definition (a) or (b) applies, depends on the situation under consideration.

1.2 Delimitation Problems

The definition of costs requires thorough consideration, in particular in case of the assessment of integrated measures. If a measure is used both for production and emission reduction purposes, or if productivity of the production process benefits due to technical progress, cost allocation becomes difficult if not impossible. For instance, if an older technology is replaced by a new technology equipped with integrated measures, this may not only result in a better environmental performance, but also in improving production conditions. This may cause reduced costs for labour protection and safety measures or higher production capacities and higher profit margins. In this case, the determination of costs for emission reduction measures would require detailed knowledge about that part of the integrated measures, which are relevant for emission reduction and the other part, which is relevant for the improvement of production conditions. Whether this delimitation is possible objectively is highly questionable, as it is the well known problem of cost allocation for joint-products.

Another delimitation problem is related to the consideration of technical progress. For instance, suppose an old installation is replaced prematurely, which means that the depreciation time is not fully exhausted, by a new, more powerful (concerning productivity) and more efficient (with respect to environmental performance) installation, instead of retrofitting the old installation. The difference in investment (old/new installation) has then to be split up unambiguously in an investment due to technical progress and an investment due to better environmental performance. Whether this can be done is also very uncertain. Being aware of these mentioned delimitation problems, an approach for the determination of costs related to techniques to be considered in the determination of BAT is proposed in the following.

1.3 General approach

A general approach to evaluate costs of proposed techniques to consider in the determination of BAT should comprise the following steps:

I. Delimitation of measures to evaluate (definition of system boundaries)
II. Analysis of decision relevant costs (i.e. costs related to investments, operating cost)
III. Determination of costs related to investments (if required)
  III.a Determination of required investments (e.g. units, machines, plants, etc.)
  III.b Determination of investment related costs (e.g. depreciation, maintenance, etc.)
IV. Determination of operating costs (if required)
  IV.a Determination of relevant material and energy flows (related to the assessed measures, including expendables, emissions, etc.)
  IV.b Determination of costs related to these relevant material and energy flows (including expendables, emissions, etc.)
  IV.c Determination of other decision relevant costs and revenues (e.g. personal costs, follow up costs, overhead, revenues for products of recycling measures)

These listed steps will be characterised in the following. Step I should provide a sensible delimitation of the proposed measures of the BREF, bearing in mind the delimitation problems discussed in section 1.2, such that a meaningful economic assessment is possible. Thus, Step I defines the system boundaries.

In Step II, the relevant cost components of the assessed measure need to be identified. Following the approach suggested in the VDI Norm 3800 [4], the proposed cost concept includes the components covered in the following equation:

$$K^{BAT} = \underbrace{K_{I}^{BAT}}_{\text{Investment-related costs}} + \underbrace{K_{ME}^{BAT} + K_{Process}^{BAT} + K_{Other}^{BAT}}_{\text{Operating costs}} \qquad (1)$$

with

K^{BAT}: Annual total costs for the evaluated measure [EUR/a]

K_{I}^{BAT}: Costs related to investments [EUR/a]

K_{ME}^{BAT}: Costs for inputs and outputs induced by material and/or energy flows [EUR/a]

$K_{Process}^{BAT}$: Process costs for relevant unit operations [EUR/a]

K_{Other}^{BAT}: Other decision relevant costs [EUR/a]

The determination of the annual total costs, K^{BAT}, which include both investment related costs and operating costs, corresponds with Step III and Step IV of the proposed methodology.

1.3.1 Determination of investment related costs of BAT

Step III determines the costs related to necessary investments that are caused by the measure assessed. In Step III.a, the required investments for machines, plants, etc. will have to be determined or estimated. The investment is defined as the accumulated expenditures e until the start up of the measure under consideration at $t = t'$ [5]:

$$I = \int_{t=0}^{t=t'} e(t)\, dt \tag{2}$$

As the determination or estimation of investments is an arduous task itself, it will be assumed in the following that figures for investments are available.

Step III.b includes the determination of investment related costs (K_I^{BAT}). Annual costs, that are usually related to the initial investment I_j of an investment j, include costs induced by depreciation, by interest charges, by repair and maintenance, by insurance and business risks, as well as by taxes. Formally, the annual share of these investment-related costs for an investment I_j can be summarised by a parameter v_j, which is made up by the sum of respective shares v_{jk} ($v_j = \sum_k v_{jk}$) as expressed in equation (3):

$$v_j = v_{jD} + v_{jS} + v_{jM} + v_{jR} + v_{jX} \tag{3}$$

with

v_{jD}: Depreciation [1/a]
v_{jS}: Interest charge related to investment j [1/a]
υ_{jM}: Repair and maintenance related to investment j [1/a]
υ_{jR}: Insurance and imputed business risks related to investment j [1/a]
υ_{jX}: Taxes related to investment j [1/a] (e.g. trade tax on capital or real property tax)

Investment-related costs for the considered BAT concept can then be calculated by means of the following equation:

$$K_I^{BAT} = \sum_j \sum_k \upsilon_{jk} \cdot I_j^{BAT} \tag{4}$$

with

j: Index of different investments, $j \in \{1,\dots,J\}$
k: Index of different cost items, $k \in \{D,S,M,R,X\}$
υ_{jk}: Percentage for the determination of item k, which is related to the investment j [1/a]
I_j^{BAT}: Investment, e.g. for unit-operation j, for the measure under consideration[1] [EUR]

Two shares commonly considered in more detail in the determination of investment-related costs are depreciation and interest charge. For the calculation of depreciation, different time horizons are often applied, e.g. for balance sheet policies or for tax purposes. However, a detailed analysis of different depreciation scenarios in the framework of this approach is not intended, for this reason the straight-line depreciation method is applied. Thus, the rate of depreciation can be calculated by:

$$v_{jD} = \frac{1}{T_j} \tag{5}$$

where T_j denotes the depreciation time or expected service time, respectively.

The calculation of costs related to interest charges is commonly based on the average capital requirement, which can be taken as being approximately half of the investment (excluding those items which are not subject to depreciation). The interest rate i, which has to be applied, can be set by taking the opportunity costs of a similar investment, which aims at long term capital market interest rate and might be corrected by a certain risk factor. Thus, the share of cost-related interest charge v_{jS} can be obtained by

$$v_{jS} = \frac{i}{2} \tag{6}$$

Now, the sum of these two terms stating interest charge and depreciation can be expressed by the capital recovery factor, which is a result from theoretical investment analysis[2]. This is advantageous, as the capital recovery factor gives better information on the costs related to depreciation and interest, although it requires the same input data [18]:

$$\left(\frac{1}{T_j} + \frac{i}{2} \right) \approx \frac{(1+i)^{T_j} \cdot i}{(1+i)^{T_j} - 1} \tag{7}$$

As a result, K_I^{BAT} can be defined as follows:

$$K_I^{BAT} = \sum_j \left(\frac{(1+i)^{T_j} \cdot i}{(1+i)^{T_j} - 1} + \upsilon_{jM} + \upsilon_{jR} + \upsilon_{jX} \right) \cdot I_j^{BAT} \tag{8}$$

1.3.2 Determination of operating costs of BAT

In Step IV, the operating costs ($K_{ME}^{BAT}, K_{Process}^{BAT}, K_{Other}^{BAT}$) related to the measure are determined. The determination of operating costs of assessed technical measures requires first of all an analysis of relevant mass and energy flows within the system boundaries (Step IV.a). Once these flows have been determined, the relevant inputs and outputs can be valued with corresponding prices (Step IV.b). Next to these costs, other costs or also revenues can be considered in Step IV.c. Steps IV.b and IV.c are explained in more detail in the following.

Costs for input/output materials K_{ME}^{BAT}:
Costs for inputs and outputs of assessed technical measures are induced by material and/or energy flows. These costs include costs for the procurement of the input materials, as well as sales revenues or costs for output materials. The valu-

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[1] Additions and/or reductions of the investment I_j for the determination of some investment related costs (eg. determining depreciation, the investment has to be reduced by the expenditure for land) are neglected here.

[2] This approximation is inter alia derived in [18], p. 156ff.

ation of the procurement of expendables (input materials) can be done on the basis of the market prices. Output materials may be associated with revenues if products or by-products can be sold on the market. Costs arise if, for instance, a technique produces outputs like waste or residues which have to be dumped or sent to further processing facilities. Thus, costs for inputs/outputs can be evaluated as follows:

$$K_{ME}^{BAT} = \sum_i p_i \cdot m_i + \sum_o p_o \cdot m_o - \sum_s p_s \cdot m_s \qquad (9)$$

with

p_i: Costs for input material or expendable i (procurement) [EUR/QT]
p_o: Costs for output material o (to be dumped, processed, etc.) [EUR/QT]
p_s: Revenues for output material s (sales) [EUR/QT]
m_i: Technical amount of consumption of expendables of type i in units [QT] per annum (e.g., m^3 process water p.a.)
m_o: Technical amount of output material o (residue) in units [QT] per annum
m_s: Technical amount of output material s (product) in units [QT] per annum

The technical amounts of input and output materials result from the process design and can be obtained from energy and material balances.

Process costs of relevant unit operations $K_{Process}^{BAT}$:
Process costs can be estimated using the formula below:

$$K_{Process}^{BAT} = \sum_j A_j^q \cdot p_j^{P,q} \qquad (10)$$

with

A_j^q: Manpower requirement of qualification q for unit-operation j [man-year]
$p_j^{P,q}$: Specific employment costs assigned to personal requirement l [EUR/man-year]

Process costs may also include costs for energy if not already considered in the calculations according to equation (9).

Other decision relevant costs, K_{Other}^{BAT}:
Other decision relevant costs comprise costs not covered elsewhsere, which allocation to any other term is not common or sensible, e.g. overhead (share), costs for measurement and safety monitoring, etc.

2 Case Study: Steel Industry

In the following, a case study from the steel industry is introduced. The proposed methodology for the economic assessment of BAT will then be applied to the electric steelmaking on the basis of available data in section 4.

2.1 Relevance of the industrial activity

The industrial activity electric steelmaking is listed under item 2.2 in Annex I, IPPC-Directive. This activity is of substantial industrial and environmental relevance, as 38.1% of crude steel in the European Union and 34.2% of the 771 million tons of world-wide steel production have been produced in electric steelmaking plants in 1998 [6]. **Fig. 1** shows the development of the number of Electric Arc Furnaces (EAF), which are the central production units in electric steelmaking plants, in the EU between 1989 and 1997.

Fig. 2 shows the development of electric steel production for the same period. Together, the two figures indicate a trend

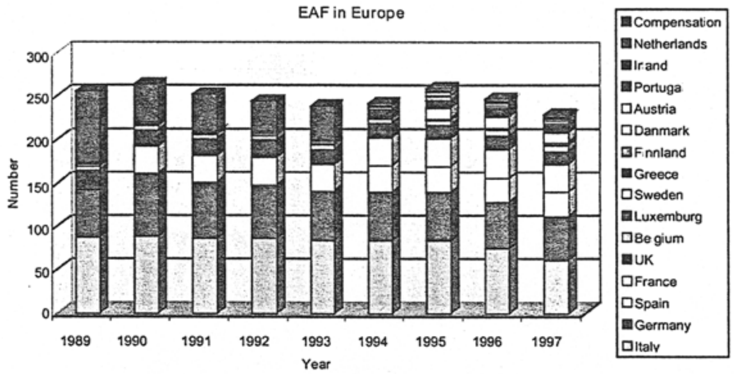

Fig. 1: Number of EAF in the European Union (respective territory)

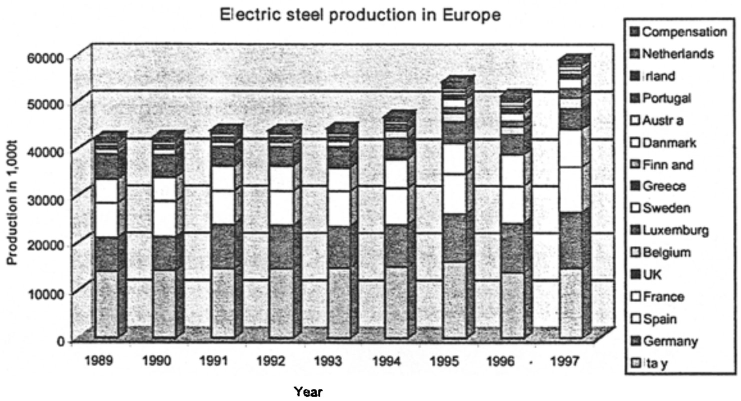

Fig. 2: Production of electric steel in the European Union (respective territory)

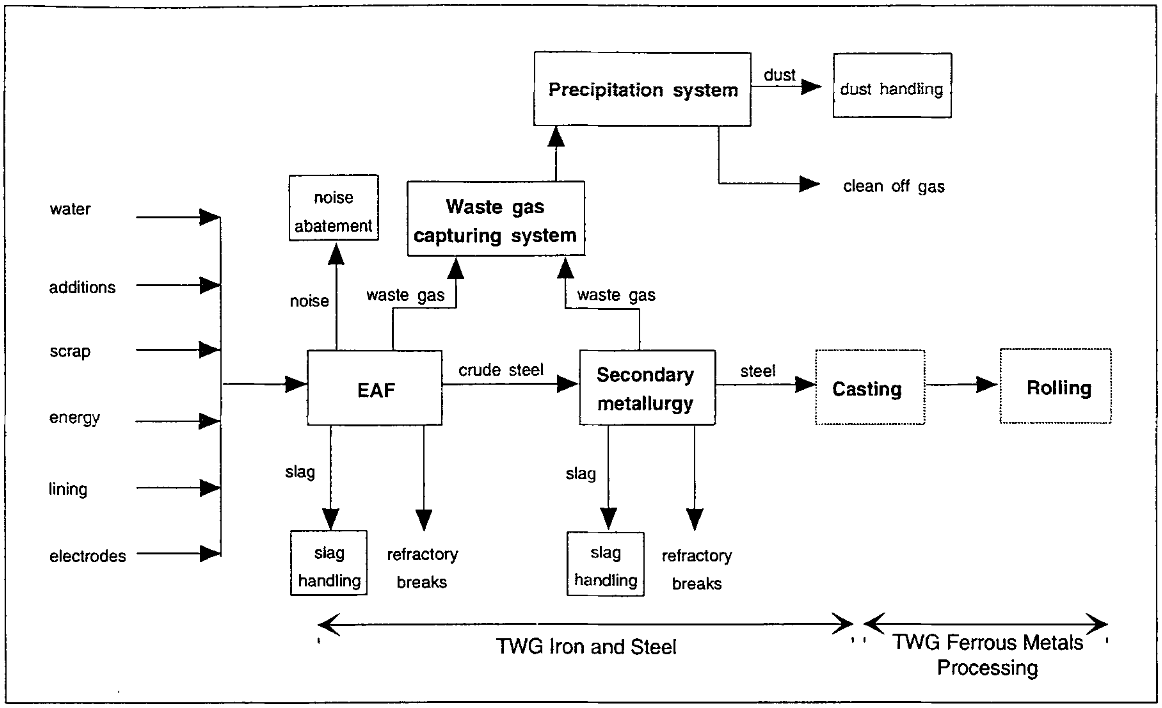

Fig. 3: Diagrammatic overview of the electric steelmaking process including emission reduction measure

towards production facilities with higher capacities and higher productivity within the last years, as the number of EAF stayed the same or even decreased, while production increased by over 30%.

2.2 Description of the production process

Within the next paragraphs, the processes related to electric steelmaking are characterised and important inputs and outputs are illustrated. Fig. 3 shows an overview over inputs and outputs of the electric steelmaking process as well as common emission reduction measures. Also the scope of the TWG Iron and Steel, and Ferrous Metal Processing with respect to electric steelmaking is indicated (cf. [7]).

The prerequisites for the production of electric steel are the provision of the inputs scrap, additions, fluxes, and electrical energy, as well as the regular preparation of the furnace, i.e. its lining with different types of refractory material to protect the furnace shell against high temperatures and chemical and physical strain caused by inputs, heat and slag. Steel scrap is the major iron containing input for electric arc furnaces and has an iron-content of 80-100% [8]. About 1,130 kg scrap per ton of crude steel are charged into the electric furnace, sometimes the scrap is substituted by sponge or direct reduced iron (DRI). The energy input for electric steelmaking is mainly supplied by electrical energy. Specific electrical energy input commonly ranges between about 300-500kWh/t [9].

The furnace is usually charged in batches, although some systems also permit continuous scrap charging: two or three buckets with, possibly sorted, scrap are inserted in succession through the open top into the furnace to use the capacity of 80-150 ton/charge of modern furnaces. According to the desired steel quality, fluxes (e.g. lime) and additions (e.g. carbon, chromium) are added. During the melting phase, when the movable roof has been closed, the graphite electrodes[3] (introduced through the roof) have been lowered and the electric arcs ignited, at the hottest spots temperatures up to 3,500°C arise. In addition to the electrical energy also electrode burn-off and exothermic reactions (e.g. burning of oils and greases or coal) serve as energy sources [10]. To lower the consumption of electrical energy and to accelerate the melting process, oxygen or fuel-gas mixtures can be injected by special types of lances or by oxy-fuel burners to generate process heat.

During the melting and the following oxidation phase, a slag is formed on top of the heat. The slag helps to remove tramp elements. Besides this positive metallurgical effect, a foamy slag on top of the melt is also important for achieving an efficient energy transfer and in particular for the protection of the furnace shell. Another positive effect of the foamy slag is a reduction in noise caused by the EAF process. Typical noise levels for electric arc furnaces, given by the sound power level, are between 125 and 139 dB(A) [11]. Usually, at the same time to the injection of oxygen, also pulverised coal is injected by lances into the furnace to intensify the boiling. After the melting and the tapping steps, tapping follows. The tapping step starts with the tilting of the furnace to tap the slag, as the highly oxidised slag is not desired in the following secondary metallurgy processes. On average about 100-150 kg slag per t crude steel are tapped in electric steelmaking plants producing carbon steel; in stainless steel plants, however, much higher amounts of slag may arise [12]. After slag tapping, the raw steel is tapped at temperatures of about 1,600 to 1,680°C. In practice, eccentric bottom tapping (EBT) is commonly used nowadays. This system allows a slag-free tapping and small

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[3] Dependent on the applied technology (DC/AC), there may be one or three graphite electrodes in use.

Table 1: Typical specific inputs and outputs for EAF plants

Inputs			Outputs		
Scrap	kg/t	1,080-1,130	Steel melt	kg/t	1,000
Total energy	kWh/t	650-750	Slag	kg/t	100-150
Of that:: Electrical energy Oxygen Natural gas	kWh/t m^3/t m^3/t	345-490 24-47 n.a.	Particulates (total precipitated)	kg/t	10-20
Graphite electrodes	kg/t	1.5-4.5	Of that obtained at:		
Lime	kg/t	30-80	Primary dedusting	g/m^3	3.4-33.9
Coal	kg/t	13-15	Secondary dedusting	g/m^3	0.15-0.275
Lining	kg/t on average	1.9-25.1 8.1	Refractory breaks	kg/t	n.a.
Water	Closed loop		Plant scrap	kg/t	n.a.
			Noise	DB(A)	125-139

tapping angles of about 12°, which are favourable for cost savings (caused by the reduction of tap-to-tap times, reduction of heat losses, shorter power cables) [13].

During melting, oxidation and following tapping arise emissions into the air, which are commonly captured by means of direct extraction from the furnace, hoods above it or by a furnace enclosure. Examples of directly extracted waste gas dust contents for several plants range from 13,300 to 33,900 mg/m³ (STP) [14,15].

In general, secondary metallurgical processes, e.g. in a ladle furnace, follow the tapping step. Some refining may also take place in the EAF itself, but nowadays the fine adjustment of the desired steel quality is mostly done in an extra vessel. **Table 1** [14,15] summarises amounts of typical inputs and outputs of electrical steelmaking.

3 Application of the Proposed Methodology to the Case Study Electric Steelmaking

The BAT Reference Document (BREF) on the Production of Iron and Steel was finished by the EIPPCB in July 1999. Techniques mentioned in the BREF with respect to electric steelmaking are divided into the two categories of process-integrated measures (PI) and end-of-pipe techniques (EP). The techniques listed in the BREF are either particular single techniques or combinations of techniques. These techniques are presented in **Table 2** ([16], supplemented by [9]), which shows a detailed overview over the headlines of techniques or combinations of techniques that are included in the BREF.

Fig. 4 [7] gives a diagrammatic view of inputs and outputs of EAF plants, emission-receiving media as well as techniques that are employed to prevent or reduce emissions, or the use

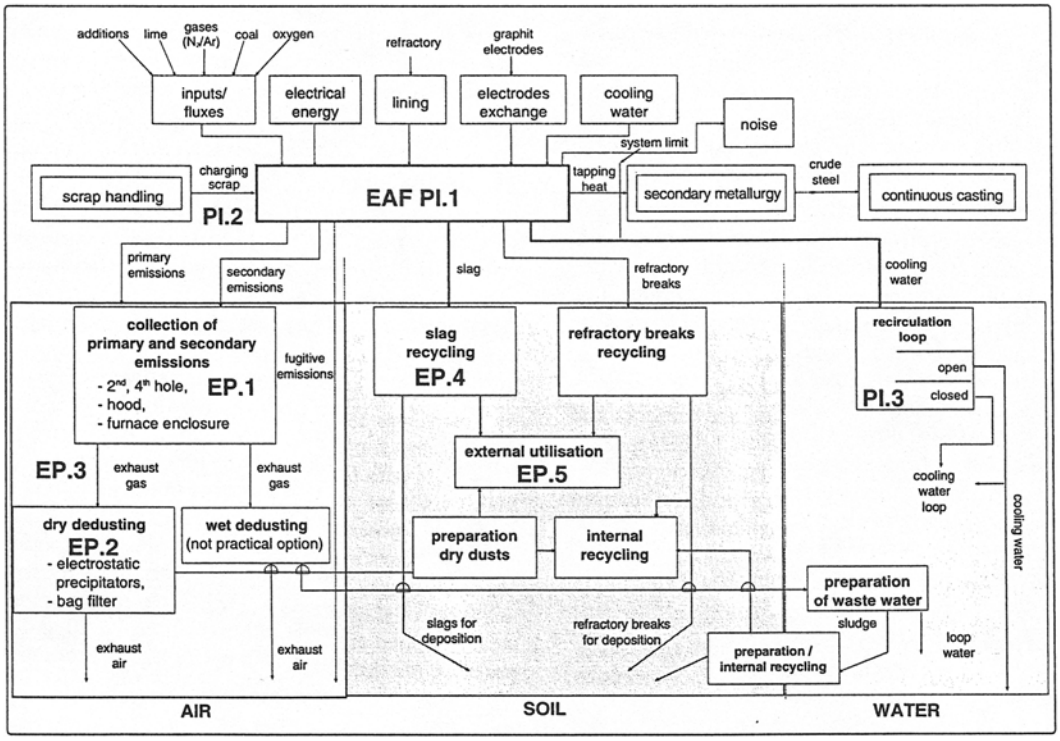

Fig. 4: Inputs, outputs and selected technologies related to the EAF processes

Table 2: BAT for Electric Steelmaking according to BREF Iron and Steel (I/S)

Symbol	More detailed specification	Soil	Water	Energy	Air	State of Art	Retrofit
PI	***Process-Integrated Measures***	x: special relevance of technique for category					
PI.1	*EAF process optimisation*						
	(Ultra) High power operation (UHP)			x		x	
	Water cooled side walls and roof		x	x		x	
	Oxy-fuel burners/oxygen lancing			x	x	x	x
	Eccentric bottom tapping					x	
	Foaming slag practice					x	
	Ladle or secondary metallurgy					x	x
	Automation					x	
PI.2	*Scrap preheating*			x	x		(x)
PI.3	*Closed loop water cooling system*		x			x	x
EP	***End-of-Pipe Measures***	x: special relevance of technique for category					
EP.1	*Advanced emission collection systems*						
	Direct extraction of process fumes (2nd/4th hole)			x	x	x	x
	Hood system			x	x	x	x
	Furnace enclosure (dog house)				x	x	x
	Total building evacuation			x	x	x	x
EP.2	*Efficient post-combustion in combination with advanced off-gas treatment*						
	Post combustion of waste gases			x	x	x	x
	Cooling of waste gases (quenching)			x	x	x	x
	Electrostatic precipitator	x		x	x	x	x
	Bag filter	x		x	x	x	x
EP.3	*Injection of lignite coke powder for off-gas treatment (adsorbants)*				*x*	*x*	*x*
EP.4	*Recycling of EAF slags*						
	Use in construction (EAF slag)	x				x	x
	Processing to lime fertiliser or recycling to EAF (Secondary Metallurgy)	x				x	x
EP.5	*Recycling of EAF dusts*						
	Recycling of precipitated dusts	x		x		x	x
	Waelz process (commercial steel dust)	x				x	x
	DK-process (commercial steel dust)	x				x	x
	Imperial Smelting Furnace	x				x	x
	Treatment by submerged EAF (high grade steel dust)	x				x	x
	Scan dust process (high grade steel dust)	x				x	x
	BSW-process (commercial steel dust)	x					
Emerging Techniques							
	Scrap sorting and cleaning			x	x	x	x
	Comelt EAF			x			
	Contiarc furnace			x			

of resources. Also the techniques to consider in the determination of BAT are indicated.

These techniques mentioned in the BREF are the alternatives to evaluate with respect to economic aspects. The selection of a corresponding particular technique or a combination of techniques then covers Step I of the proposed methodology. The following two figures show examples for process integrated and end-of-pipe measures. **Fig. 5** illustrates a diagrammatic view of an EAF with process integrated measures. **Fig. 6** shows a diagrammatic view of an EAF equipped with end-of-pipe measures.

In the following, the methodology proposed in paragraph 1 is applied to a measure from the BREF on the Production of Iron and Steel. The respective steps are demonstrated by an example from the case study of electric steelmaking on the basis of available data (cf. *Table 3*).

Given these stated figures, the total costs including dust disposal for a bag filter as a part of the measure EP.2 are:

$$K^{BAT} = \sum_{j=1}^{1}\left(\frac{(1+i)^{T_j}\cdot i}{(1+i)^{T_j}-1}+\upsilon_{jM}\right)\cdot I_j + \sum_{i=1}^{2} p_i \cdot m_i + \sum_{o=3}^{3} p_o \cdot m_o$$

$$\approx 213{,}000 \text{ EUR/a} + 293{,}000 \text{ EUR/a} = 506{,}000 \text{ EUR/a}$$

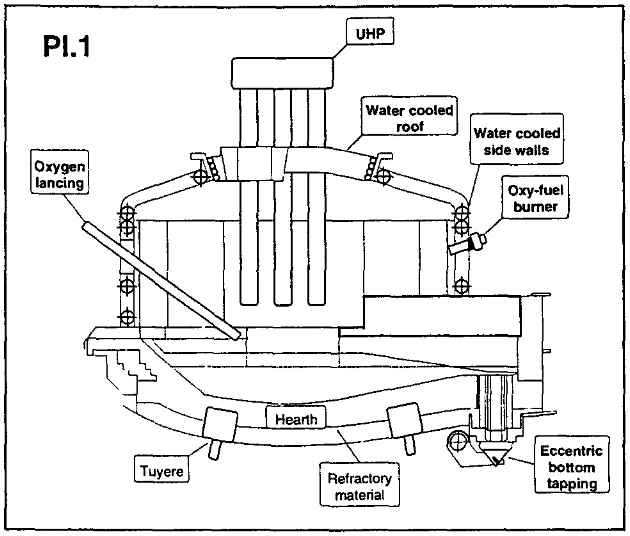

Fig. 5: Electric arc furnace equipped with modern technology (Pl.1)

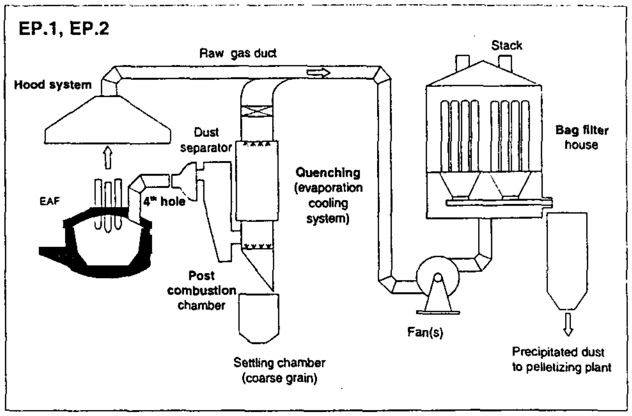

Fig. 6: Electric arc furnace equipped with modern gas cleaning system (EP.1, EP.2)

Table 3: Case study advanced off-gas treatment (bag filter) in electric steelmaking

Step	Content	Value
I.	**Delimitation of measures to evaluate** The BREF Iron and Steel lists in the chapter on electric steelmaking measure (EP.2): EFFICIENT POST-COMBUSTION IN COMBINATION WITH AN ADVANCED OFF-GAS TREATMENT. Here we investigate the economic consequences related to the OFF-GAS TREATMENT (BAG FILTER). Post-combustion and quenching are not investigated for reasons of simplicity.	
II.	**Analysis of decision relevant costs** Relevant cost types for this example are: • costs, dependent on the investment (DEPRECIATION, MAINTENANCE, INTEREST) • operating costs (COSTS FOR INPUTS/OUTPUTS)	
III.	**Determination of costs, dependent on the investment (coarse estimate)**	
III.a	*Determination of required investments* Relevant components of filtering separators are [14]: housing, dust hopper, dust discharge, filter elements, regeneration device; furthermore, a fan is required to build up the necessary pressure. Design of separators and corresponding costs related to the investment depend on several parameters which have to be determined in the planning stage for the particular case. General data are [14]: type of the process for which the separator is to be used, working method of the site, properties of the particles; specific data are: height of the installation above sea level, data on the gas to be cleaned (e.g. temperature, composition, moisture, desired clean gas dust concentration) and data on the particles (e.g. mean concentration in the crude gas, minimum concentration in the crude gas, maximum concentration in the crude gas, particle size distribution, density, composition by material constituents, etc.). A coarse estimate for the investment bag filter can be done on the basis of the off-gas volumetric flow rate: reference values for an average off-gas volumetric flow rate of about 200,000 m^3/h would be in the range from 5 to 7.5 EUR/m^3 [17], i.e. a bag filter with a capacity of 200,000 m^3/h would require an investment in the range from 1 million to 1.5 million EUR.	I_1≈1 million EUR
III.b	*Determination of investment related costs* For this example we assume an interest rate of 10%, a depreciation time of 10 years and a maintenance rate of 5 % (including bag replacement).	i=0.1 T_1=10 v_{1M} =0.05
IV.	**Determination of operating costs (coarse estimate)**	
IV.a	*Determination of relevant material and energy flows* Important material and energy flows in this case study are the required electricity for an operation of the fans, pressure air for regeneration and arising precipitated dusts. Technical amounts of inputs / outputs are coarsely estimated; electrical energy (m_1): 1,120,000 kWh/a, pressure air (m_2): 800,000 m^3/a, precipitated dusts (m_3): 3000 t/a.	Inputs: m_1=1.12·10^6 kWh/a m_2=8·10^5m/a p_1=0.05 EUR/kWh p_2=0.015 EUR/m^3
IV.b	*Determination of cost related to relevant material and energy flows* Prices for technical amounts of inputs and outputs are estimated the following way; electricity (p_1): 0.05 EUR/kWh, pressure air (p_2): 0.015 EUR/m^3, handling of precipitated dusts (depends strongly on type of handling, p_3): 75 EUR/t.	Outputs: m_3=3000 t/a
IV.c	*Determination of other decision-relevant cost and revenues* None	p_3=75 EUR/t

4 Conclusion and Future Outlook

The consideration of economic aspects in the determination of BAT is an indispensable, but also difficult task. A fundamental basis for an economic assessment of techniques to consider in the determination of BAT is a sound methodology that takes into account all decision relevant facts. The methodological approach presented in this paper employs a cost concept that includes decision-relevant, investment-related costs and operating costs. Crucial steps to assess the economic aspects of proposed technical measures from the BREFs are a sensible delimitation of the system boundaries and a careful definition of decision-relevant shares of investment-related costs and operating costs. The application of the methodology to the case study of electric steelmaking shows the practical use of the approach.

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