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BAT According to Climatic Neutrality of Production of Steel Products

V. G. Lisienko, Ya. M. Shchelokov, Yu. N. Chesnokov, and A. V. Lapteva

Institute of Radio Electronics and Information Technologies, Department of Information Technologies and Automatics, Ural Federal University, Yekaterinburg, Mira str. 32, 620002 Russia

Abstract

The purpose of this article is to estimate the best available technologies for values of the following technological numbers: fuel, ecological, depreciation, greenhouse and their sums. All these numbers have power dimension: t of conditional fuel/unit of production that allows to put them. The fuel technological number characterizes power consumption of production. The technological ecological number transfers a payment of the enterprise for environmental pollution to power units. The technological depreciation number transfers depreciation charges from rubles to power units. The technological greenhouse number translates a payment of the enterprise for emissions of greenhouse gases in power units. Technological numbers have through character – from extraction of raw materials before receiving finished goods. The best available technologies are characterized by the smallest sum of all technological numbers.

Keywords: through power-ecological analysis, power ecological capacity of production of steel products, technological fuel ecological greenhouse number, best available technologies, climatic neutrality

Corresponding Author:
V. G. Lisienko
lisienko@mail.ru

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1. Introduction

Main conclusion which should be made, comparing ferrous metallurgy of the Russian Federation and the European Union (EU), consists in what domestic metallurgical complex, having passed into market system of economic coordinates, continues, already three decades to underestimate power ecological opportunities of metallurgical technologies. It prevents ensuring stable decrease in a power ecological capacity of production of cast iron and steel. In the EU power consumption of production there were about 18 GJ/t of liquid steel, in the Russian Federation this indicator about 26 GJ/t. Moreover, high power consumption of production of ferrous metal is the reason of a number of obvious branch environmental problems (greenhouse effect, growth of

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waste, used water volumes, etc.). The time of creation of best available technology (BAT) in the form of a uniform method of definition in the Russian Federation of a power ecological capacity of production of steel products has ripened. Now in the Russian Federation practically each author uses exclusive technique of definition, both power consumption, and a power ecological capacity.

Climatic neutrality – sometimes it is called by a 'carbon neutrality', a zero clean indicator or clean zero – is nothing else as restoration of balance on the planet, from the point of view of emissions, and her return to the previous state prevailing one and a half centuries ago [1].

2. Main Body

For further development of the existing technique of the through power ecological analysis (TPEA), as well as when determining power consumption of production [2–5], and definition of issue of harmful emissions through approach to assessment of specific emissions of greenhouse gases is applied. Through analysis means that all his parameters are defined from moment of production and transportation of resources. Besides, also by analogy with issue of harmful emissions, for purpose of possible comparative assessment of damage from emissions of greenhouse gases with an power ecological capacity of production it is offered to express this damage in power units. It gives chance to compare earlier defined power consumption of production of considered productions taking into account damage from emissions of greenhouse gases.

Analysis of energy consumption does not allow to find indicators of use of heat power resources on end products in technological processes of the existing techniques of determination of thermal power balances of separately taken repartitions. Here carrying out through total calculations of power consumption of a technological product is required. In the most representative look such technique (a method of calculation of technological fuel numbers (TFN)) has been in details developed, further developed successfully and applied in works of scientists of USTU-UPI and Ural power ferrous metallurgy (Lisienko V. G., Rozin S. E., Shchelokov Ya. M.) in the eighties 20th century. The developed technique has a number of features distinguishing it from other techniques and allowing to carry out objectively power analysis or analysis of efficiency of use of energy practically in any technological process.

At choice of BAT and/or when comparing several BAT it is necessary to consider many parameters: power consumption, harmful emissions, emissions of greenhouse gases, pollution of water resources, etc. It is possible to consider each parameter separately, but at the same time reliability of the choice is lost.

Concepts TFN, technological ecological number (TEN) [2], technological depreciation number (TDN) [5], technological greenhouse number (TGN) [5] and their combinations are entered, in each indicator the fuel equivalent of natural gas is used.

For the purpose of allocation from full power consumption of production yet not authentically defined power consumption of human work the indicator of through power analysis (TPA) – TFN – equal to total expenses of all types of energy in given and in all previous productions of technological processes counted for primary fuel, necessary for their receiving, minus TFN formed by secondary energy resources (SER) has been entered. The technique of use of TFN of process allows to compare specific power consumption of separate types of production on various industries, to define main sources of losses of energy, direction her economy, objective results of energy saving actions in separate technological processes.

TFN of natural fuel is defined as (further m^3 is given at n.c.):

$$\mathrm{TFN} = 1,1 \cdot 10^3 \cdot \frac{Q^{\mathrm{w.}}_{\mathrm{l.}\,n.g.}}{\mathrm{Q}^{\mathrm{w.}}_{\mathrm{l.eq.f.}}}, \tag{1}$$

where 1,1 – the coefficient considering production, transportation and preparation of fuel; 10^3 – the coefficient serves for translation of dimension of kg eq. f./kg pro in kg eq. f./t pro; Qrn. ave. of – lowest working heat of combustion of natural gas, MJ/m^3, Qrn. eq. f. – lowest working heat of combustion of conditional fuel, MJ/kg eq. f.

TFN of a product is defined by a formula which fuel TFN – a resource (1) enters:

$$\mathrm{TFN}_{\Sigma} = \Sigma\Psi_i \cdot \mathrm{TFN}_i; \tag{2}$$

where Ψ_i – resource i expense coefficient; TFN_i – TFN_i of a resource, kg eq. f./product unit.

The structured technique of TPA considers the following structure of TFN [2, 3]:

$$\mathrm{TFN} = E_1 + E_2 + E_3 - E_4, \tag{3}$$

where E_1 – energy of fossil fuel (kg eq. f./unit pro) taking into account costs of his production, preparation or enrichment, transportation, etc.; E_2 – derivative energy, for example, electric power, steam, compressor air, oxygen, etc.; E_3 – hidden energy in initial materials, equipment, capital constructions of this process and also in operations on maintenance of equipment in operating state, for example, repairs, etc.; E_4 – energy of secondary energy resources (coke, blast-furnace gas, etc.).

TDN parameter when calculating TFN considers costs of depreciation of equipment presented in power units spent in previous processes – E_3. In a technique of TPEA it is offered to lead depreciation charges (DC) to a power form by means of TDN. By definition, TDN is amount of energy (kg of conditional fuel, GJ), equivalent size of DC on unit of products and size E_3 used when determining for accounting of degree of wear of equipment in each technological repartition. The TDN value is calculated by a formula

$$\mathrm{TDN} = \frac{A}{P_{\mathrm{n.g.}}} \cdot \frac{Q^{\mathrm{w.}}_{\mathrm{l..n.g.}}}{Q^{\mathrm{w.}}_{\mathrm{l.eq..f.}}}, \tag{4}$$

where A – size of DC in a money equivalent, \$ USA/unit pro, $P_{n.g.}$ – price of natural gas; \$ USA/m^3. Size $P_{n.g.}$ is accepted equal 0,55 \$ USA/m^3; $Q^{w.}{}_{l.n.g.}$ = 35.8 MJ/m^3, $Q^{w.}{}_{l.eq.f.}$ = 29.33 MJ/kg eq. f. Taking into account numerical values TDN = 2.231·A kg eq. f./unit pro.

In work of Roments V. A. [6] data on depreciation expenses for some repartitions are provided. In the same place adjusted price of natural gas operating at that time – $P_{n.g.}$ = 0.08 \$ USA/m^3. Taking into account these data TDN values for various repartitions of ferrous metallurgy are given in table 1.

Table 1: TDN values for blast furnace and four repartitions of ferrous metallurgy.

Parameters	Repartition				
	Blast furnace	Romelt	Midrex	HyL-3	Corex
DC, \$ USA/t pro.	3.62	4.36	8.04	10.05	10.72
TDN, kg eq. f./t pro.	55.3	66.6	122.8	153.5	163.7

Received TDN values are from 55,3 kg eq. f. (1,62 GJ) up to 163,7 kg eq. f. (4,796 GJ) on unit of finished goods. DC on products unit on basis of which TDN was calculated have values from 3,62 \$ USA to 10,72 \$ USA, as in conditions of the EU, and the Russian Federation. The provided data are generalized indicators, concrete values will depend on a state, extent of use of equipment, observance of technological modes of his work.

TDN of blast furnace has the smallest value as blast furnace has 'big between-repairs period, ability to work continuously for years without stops for repair'.

TPA has gained further development with development of a technique of complex TPEA for power technological objects and processes.

The technique of power analysis has significantly been improved and complemented with a technique of ecological analysis, as was center, the so-called, integrated TPEA.

Idea of technological ecological number (TEN) is entered into TPEA. TEN is defined as:

$$\text{TEN} = m_s \cdot K_{ve}, \tag{5}$$

where m_s – specific specified lot of harmful emissions (t c. emiss./unit pro); K_{ve} – conditional indicator characterizing extent of compensation of ecological damage in kg eq. f./t c. emiss. According to [2] size m_s can be defined by a formula:

$$m_\pi = \sum_k \left(M_k \cdot A_k\right)$$

where M_k – actual specific lot of harmful emissions of k of pollutant, t выбр./unit pro for repartition i; A_k – coefficient of aggression of k of pollutant, t c. emiss./t выбр.

Size A_k at each hierarchical step for the same harmful emissions can change as for local impact on A_k values sanitary and hygienic standards influence more, for removed – ecological. Coefficient of translation K_{ve} of cost assessment of damage to assessment is equal in conventional power units

$$K_{\text{B}\varepsilon} = \frac{C_{\text{B.B.}}}{\text{C}_{\text{n.g.}}} \cdot \frac{Q^{\text{w.}}_{\text{l.n.g.}}}{\text{Q}^{\text{w.}}_{\text{l.eq.f}}}$$

where C_{vv} – a payment of user of nature for super limit environmental pollution, $ USA/t c. emiss. As normalizing equivalent different types of fuel can be used: oil, diesel, gas. It is expedient to apply a gas equivalent to the Russian Federation, that is, price of natural gas is agreed for cost of fuel. Size C_{vv} is accepted equal 0,045 $ USA/t c. emiss. As a result size of measurement of TEN – kg eq. f./unit pro. Taking into account numerical values K_{ve} = 0.101 kg a eq. f./t c. emiss.

TFN and TEN parameters have identical dimension therefore concept of technological fuel ecological number (TFEN) – total assessment of power ecological expenses at production of products into kg eq. f./unit pro has been entered:

$$\text{TFEN} = \text{TFN} + \text{TEN}. \tag{6}$$

The less this sum, the is better power ecological parameters of analyzed technological process. Through power expenses pay off in form of TFN.

The formula (6) is expanded and presented in form of technological fuel ecological greenhouse number (TFEGN) which represents assessment of climatic neutrality of production of ferrous metallurgy:

$$\mathrm{TFEGN} = \mathrm{TFN}_{\Sigma} + \mathrm{TEN} + \mathrm{TGN} = \Sigma\Psi_i \cdot \mathrm{TFN}_i + \mathrm{TDN} + \mathrm{TEN} + \mathrm{TGN}, \qquad (7)$$

where TFN_{Σ} – total TFN; Ψ_i – resource i expense coefficient; TFN_i –TFN of *i* resource. Introduction of new concepts TDN and TGN has improved a technique of through power ecological and greenhouse analysis. TFEGN defines through power ecological and greenhouse characteristic of process. TFEGN value at process is less, the less it causes its power consumption and smaller damage to environment. In this parameter it is expedient to choose BAT for introduction.

Definition and analysis of sizes TEN have been given in a number of the previous works [2]. For this reason a formula (7) it was possible to simplify and consider technological fuel greenhouse number (TFGN) as an indicator of climatic neutrality of production of any steel products:

$$\mathrm{TFGN} = \mathrm{TFN}_{\Sigma} + \mathrm{TGN}. \qquad (8)$$

Calculations of TFN of technological processes with a product yield in form of crude steel are generalized in table 2. At the same time according to [7] size of through power consumption was determined by a formula (3) as TFN as a part of primary, derivative, hidden energy and energy of SER.

Secondary resources E_4 have negative values, it shows a special role of SER in total volume of power consumption of production, depending on structure of fuel energy balance of concrete technological scheme.

Comparison of processes on receiving cast iron and iron has shown that structure of their power expenses has considerable differences (table 2). Hidden energy (E_3) is available in balances of all compared processes. And this type of energy in blast furnace, Midrex, HyL-3 prevails. Minimum power-intensive processes are Midrex and HyL-3. In table 2 technological chains are located on increase in TFN values. As we see, the most priority processes on TFN value are combinations of repartitions of HyL-3 + EAF and EAF on scrap.

By analogy with TFN and TEN concept TGN of technological process and a product (through TGN) is entered. TGN is defined by number of kg eq. f., necessary for repayment of cost of economic damage from emissions of greenhouse gases on products

Table 2: Ranging of processes on power consumption of steel.

Rank on TFN	Technological chain	Repartition	Product TFN, kg eq. f./t	Making TFN, kg eq. f./t			
				E_1	E_2	E_3	E_4
1	EAF on scrap	EAF	441.0	30	242	147	0
2	HyL-3 + EAF	HyL-3	769.5	458	40	294	0
		EAF	629.7	29	209	392	0
3	Corex + EAF	Corex	931.0	1 010	163	353	–592
		EAF	632.3	29	148	445	0
4	Blast furnace + EAF	Blast furnace	936.0	749	181	240	–234
		EAF	633.8	29	158	446	0
5	Midrex + EAF	Midrex	798.4	458	45	295	0
		EAF	639.2	29	209	401	0
6	Romelt + EAF	Romelt	1 078	1 154	–249	172	0
		EAF	680.6	29	158	493	0
8	Blast furnace + Oxygen converter	Blast furnace	936.0	749	181	240	–234
		Oxygen converter	916.6	0	14,5	902	0

unit. TGN will transform rubles to kg eq. f., that is, economic parameters in power. It allows to say about power economy which operates with more stable sizes. At the same time for cost of fuel price of natural gas is agreed [7]:

$$\mathrm{T}GN_{\pi i} = K_{B\pi} \cdot \sum_{k=1}^{N} M_k^{n \cdot 2.}, \tag{9}$$

where K_{vp} – coefficient of translation of cost assessment of damage to assessment in conventional power units (kg eq. f./t gr. g.); $M_{kgr \cdot g.}$ – actual specific lot of emissions of greenhouse gases, t выбр./unit pro for i repartition; N – amount of considered greenhouse gases (emission only of carbon dioxide, that is, N = 1 is considered here). Size K_{vp} = K_{ve}. Coefficient K_{vp} is presented in the form:

$$K_{\mathrm{B}\pi} = \frac{C_{\mathrm{gr.g.}}}{C_{\mathrm{n.g.}}} \cdot \frac{Q^{\mathrm{w.}}_{\mathrm{l..n.g.}}}{Q^{w.}_{\mathrm{l.eq..f.}}} \tag{10}$$

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Table 3: Productions of an indicator of climatic neutrality of making of steel products.

	Indicator	Definition	Formula
TFN	Technological fuel number	total expenses of all types of energy in given and in all previous productions of technological processes counted for primary fuel, necessary for their receiving, minus TFN formed by SER	$\text{TFN} = 1,1 \cdot 10^3 \cdot \frac{Q^{\text{w.}}_{l.n.g.}}{\text{Q}^{\text{w.}}_{\text{l.eq.f.}}}$ $\text{TFN}_\Sigma = \Sigma\Psi_i \cdot \text{TFN}_i$
TDN	Technological fuel number	number of kg eq. f., equivalent size of depreciation charges on unit of products and size E_3 used when determining for accounting of degree of wear of equipment in each technological repartition	$\text{TDN} = \frac{A}{C_{\text{n.g.}}} \cdot \frac{Q^{\text{w.}}_{\text{l.n.g.}}}{Q^{\text{w.}}_{\text{l.eq..f.}}}$
TEN	Technological ecological number	number of kg eq. f., necessary for repayment of cost of economic damage from emissions of harmful emissions on products unit	$\text{TEN} = \frac{C_{\text{B.B.}}}{\text{C}_{\pi\text{p.}\Gamma}} \cdot \frac{Q_{\text{H}\pi\text{p.}\Gamma^{\text{P}}}}{\text{Q}^{\text{P}}_{\text{H.Y.T}}} \cdot \sum_{k=1}^{N}(M_k \cdot A_k)$
TGN	Technological greenhouse number	number of kg eq. f., necessary for repayment of cost of economic damage from emissions of greenhouse gases on products unit	$\text{TGN} = \frac{C_{\pi.\Gamma}}{C_{\pi p.\Gamma.}} \cdot \frac{Q^{\text{P}}_{\text{H.}\pi\text{ p.}\Gamma}}{Q^{p}_{\text{H.Y.T}}} \cdot \sum_{k=1}^{N} M_k^{n.2.}$

where $C_{gr.g.}$ – considers a payment for emission of greenhouse gases of user of nature for environmental pollution by emissions in atmosphere of greenhouse gases, the value of 0,045 $ USA/t gr. g. is accepted. As a result dimension of TGN – kg eq. f./unit pro. Taking into account numerical values K_{vp} = 0.101 kg eq. f./t gr. g.

Thus, TGN for processes of ferrous metallurgy unambiguously is defined by emission of carbon dioxide.

The size of climatic neutrality of production of ferrous metallurgy is presented in a generalized view in table 3.

3. Summary

Criterion for choice of **BAT** (formula (7)) in form of a uniform method of definition in the Russian Federation of a power ecological capacity of production of steel products is offered. This technique allows carrying out through total calculations of resource intensity of a technological product depending on an objective:

1. in form of power consumption (formula 1, 2),

2. in form of a power ecological capacity (formula 6),
3. in form of an indicator of climatic neutrality of production of steel products (formula 7).

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