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ANALYSIS OF ECOLOGICAL INTENSITY OF METALLURGICAL PRODUCTION

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Ferrous metallurgy is inherently a highly intensive field in terms of energy and raw materials. The impacts of high energy intensity are enormous: the necessary production of larger amount of energy related to high emissions of pollutants and greenhouse gases, associated with increasing negative impacts on the state of the environment and the health of inhabitants. The article suggests the possibility of using the method of structural analysis to calculate direct and complex ecological intensity and to use it as a basis to determine the ecological intensity of the individual metallurgical technologies. The processing of ecological structural model can significantly contribute to the identification of ecologically intensive final products and can improve the decision-making process in this area.

Key words: metallurgical production, structural analysis, ecological intensity

INTRODUCTION

The development of the emission values of basic pollutants in air in the Czech Republic in the period of 2007-2012 show Table 1. [1]

Table 1 **Emissions of basic pollutants in air in the Czech Republic**

year	2007	2008	2009	2010	2011	2012
Emise REZZO 1-4						
Solid substance (thousand of t/year)	67	65	61	63	57	57
SO2 (thousand of t/year)	217	177	175	170	163	157
NOx (thousand of t/year)	283	265	252	238	225	211
CO (thousand of t/year)	508	445	419	398	361	343

Explanation:
REZZO 1 Large sources of pollution
REZZO 2 Medium sources of pollution
REZZO 3 Small sources of pollution
REZZO 4 Mobile sources of pollution

In compliance with § 37 of Act no. 201/2012 Coll., on air protection, the operators of stationary combustion sources in the Czech Republic could apply for inclusion in the so-called Transitional National Plan that determines a transitional period to meet the new emission limits stipulated by the European legislation (see Table 2). [1]

Table 2 **Transitional National Plan in Czech Republic**

t / year	2016	2017	2018	2019
SO_2 (thousand of t/year)	117	99	75	47
NO_x (thousand of t/year)	62	57	51	43
CO (thousand of t/year)	4	4	3	3

There are two main causes of high pollution in the Czech Republic: fourteen obsolete coal power plants as well as energetically inefficient industry. The share of large stationary sources on the total emissions is declining, but the emissions from public power supply and manufacturing industry still account for the majority of emissions, which is one of the causes of high emission intensity of the Czech economy. Power plants and heavy industry were especially responsible for high Czech emissions during the 20th century. When converting the emissions to the unit of GDP, our economy is still highly intensive in terms of energy and, as a result of that, emissions in comparison with other European countries.

There are different emissions limits valid in the Czech Republic, some of them are imposed by the national regulations and legal provisions, while others arise from the international obligations (e.g. the Kyoto Protocol). The emission limits are related to various sources of pollution. E.g., emission limits for large and medium-sized combustion sources are defined for these pollutants: sulphur dioxide, nitrogen oxides, carbon monoxide, organic matters (combustion of wood and biomass) and solid pollutants. The emission limits often have financial impact, not only on the operators of the sources of pollution, but on the public as well.

The most significant change in the field of emissions will take place in 2016, when the directive on industrial emissions (2010/75/EU) will come into force. Significant gradual tightening of emission limits will require

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investment in ecological sphere. Limits for solid pollutants will be reduced to 1/5, NO_x emissions to 1/3 and SO_2 emissions will be reduced to 1/6 of the emission limits valid today. [2]

CZECH METALLURGICAL INDUSTRY AND INDUSTRIAL EMISSIONS

Ferrous metallurgy is inherently a highly intensive field in terms of energy and raw materials. Due to the increasing competition of India and China, falling demand from major consumers of steel as a result of recession, rising prices of energy inputs and, last but not least, environmental pressures, the producers of steel are forced to look for savings in their energy consumption with increasing intensity. The share of European steel industry on the global steel production is 12 %, and the share on greenhouse gases emissions is 10 %.

The statistics of production of emissions in the Czech metallurgical industry have been recorded since 1946. For example, even at the end of 1980s, Czech steelworks produced 80 000 tons of solid pollutants, while now, it is 1 500 tons and, after the execution of current investments, it will be half of that figure starting in 2016. If we added up all the emissions, i.e., NOx, SOx, CO_2 and solid pollutants, we would come to 1 % of the previous state. [3]

Czech metallurgy is located in the Moravian-Silesian Region, which is subject to some of the strictest environmental limits throughout the entire European Union.

The basic concept of the system of emission allowances is defined by the Directive 2003/87/EC and its goal is to reduce the greenhouse gases emissions, while maintaining the economic growth and compliance with the rules of economic competition. The EU Emissions Trading Scheme (EU ETS) was launched in 2005. The Czech smelting plants are also facing uncertainty caused by the cost of purchase of the emission allowances. The forecast for 2020 shows that the metallurgy segment will spend 7 billion crowns for allowances.

Despite the continuous improvement of the parameters of the energy intensity of economy, and especially industry, the CR is still well above the level of energy intensity of highly developed EU countries. The impacts of high energy demands are huge: the requirement for production of higher amount of energy related to high emissions of pollutants and greenhouse gases, connected with increasing negative impacts on the state of the environment and health of inhabitants.

Given that the long-term strategic objectives of energy policy, not only in the CR, but in the EU as well, include the reduction of energy and raw material demands, the requirement to reduce the consumption of all kinds of energies makes it necessary to identify and know the value of all the energy required to produce a unit of production.

The fact that the problem of the concept of raw materials and energy in the Czech Republic is a very problematic issue is illustrated by a high number of articles and opinions published on the subject. The presented State Energy Policy (SEP), the results of analysis of professional agencies, such as the Czech Energy Agency or EkoWat, the statistic records, such as EUROSTAT or professional databases, such as ODYSSEE, and the professional articles lead to the conclusion that various official sources provide vastly different information about the specific energy consumption necessary to produce 1 ton of steel, in many cases, without presenting the calculation methodology, which makes orientation more difficult and prevents any comparison.

EXPERIMENTAL PART AND RESULTS

Structural analysis has been known for long time and it is quite frequently applied method of chequered table of interdisciplinary relationships. Structural models of Leontief type are capable of expressing the relationships among the individual elements of the system in a complex manner across the entire range of production- consumption links. This property was used in the construction of the model of energy intensity of metallurgical products. The method is based on the creation of matrix A of direct technical coefficients and, consequently, it includes a calculation of the inverse matrix B (see Table 3) to matrix E - A consisting of the so-called complex consumption coefficients, expressing the intensity of the individual sectors in terms of the final consumption, as far as, for example, the energy or the financial demands are considered. The inverse matrix of direct consumption coefficients (and therefore the energy intensity of production in the individual technological stages) was used to calculate the complex consumption coefficients, which, for final metallurgical products, include the energy intensity of not only the final stage of production, but also the energy intensity of all components that enter into the final product from previous production phases, as well as from purchases from external suppliers. These calculations have vital importance for an objective comparison of the energy intensity of the individual products, as well as the individual production technologies. [4]

The assembled integrated structural model of steel production and of final metallurgical products with all production stages is designed as a system combination of a conventional structural model of the links between the basic metallurgical fields and the detail view of the internal structure of „energy intensity“ of selected fields. The developed integrated structural model has the following form:

I. quadrant – direct consumption coefficients of defined fields - metallurgical fields (the selected fields are arranged by technologies)

III.a quadrant – direct consumption coefficients of input fields - items of purchased pig iron, ingots and semi-finished products.

III.b quadrant – calculations of energy intensity according to specified items of a costing model expressed in the units of energy intensity (GJ/t) [4]

Table 3 **The basic part of matrix B**

	coke	Sinter	pig iron	steel converters	steel oxyvit	steel electric furn. 17153	steel electric furn. 52-3
I. quadrant / t							
coke	1	0,05	0,55	0,44	0,43	0,01	0,01
sinter	0	1	1,15	0,89	0,86	0	0
pig iron	0	0	1	0,77	0,74	0	0
steel converters	0	0	0	1	0	0	0
steel Oxyvit	0	0	0	0	1	0	0
steel electric furnaces 17153	0	0	0	0	0	1	0
steel electric furnaces /St 52-3	0	0	0	0	0	0	1
III.a quadrant / t							
purchased steel, ingots	0	0	0	0	0	0	0
Purchased pig iron	0	0	0	0	0	0	0,01
III.b quadrant / GJ/t							
electric energy	0	0,37	0,66	1,32	1,3	7,12	7,12
earth gas	0	0	0	0	0,46	0	0
coke-oven gas	-7,3	-0,39	-4,03	-3,27	-3,15	-0,08	-0,06
coal-gas	0	0	0	0	0	0	0

Source: own calculations

DISCUSSION

A comparison of the calculated values using the designed model shows that the energy intensity of the individual production phases, calculated only from the primary energy inputs to the given phase, is vastly different from the complex perspective that includes both the energy intensity from direct energy media inputs and the energy intensity of previous metallurgical phases and the energy intensity of purchased materials and performances.

Comparable way of thinking, similar to that of energy intensity (phase and complex), may be encountered in case of ecological intensity - for example, when assessing the environmental burden arising during the manufacturing of concrete products by means of concrete technology. During the comparison of, for example, air emissions in the production of burnt and concrete roof covering, we should not abstract them from the ecological intensity of the production of cement etc. There is an opportunity of applying the basic ideas of the construction of energy intensity model during the construction of the structural model of ecological intensity.

The designed structural model of ecological intensity is currently focused only on air emissions (solid substances, CO, NO_x, SO_2), i.e., it is not a complex model that would deal with the analysis of pollution of water courses, soil contamination, solid waste etc. Once the function and the informative value of the basic model are verified, it will be possible to extend it by including the required fields.

The basic problem in the designing and validation of the model of energy intensity of metallurgical production was to obtain any relevant input data. It turned out that it is absolutely necessary to create a uniform database of information, where major industrial companies will supply the necessary data and information that will subsequently be analyzed and used in the required calculations, for example, to determine the energy intensity of the individual industrial fields. The first experience with the application of structural models, used for the calculation of complex ecological burden associated with metallurgical production, confirm the existence of these problems again.

CONCLUSION

We all want to live in healthy and clean environment, we want to breathe clean air and drink clean water. Let us also not forget the overall economic and societal impact on all stakeholders. In addition to direct losses, there is a much higher secondary losses just to the environment and communities associated with these companies.[5] To be able to create such conditions and to maintain them, we must first know the complex and objective information about the causes and sources of possible pollution.

Moreover, the right decisions in this area can support the corporate responsibility of metallurgical producers which can be transformed into a long-term sustainable competitive advantage.

The prepared structural model of complex ecological intensity of metallurgical production may therefore represent an important tool for effective decision-making in this area.

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Note: The responsible translator for English language is Petr Jaroš (English Language Tutor at the College of Tourism and Foreign Trade, Goodwill - VOŠ, Frýdek-Místek, CR