Environmental Impact Assessment for Dismantling an Energetic Complex Using Thermodynamic Concepts

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Abstract: - The paper makes a comparison the ecological and the exergetic balance of industrial processes. The nuisance intensity is defined for each polluting agent. It is expressed as a function of a nuisance unity, called ECOPOINT, according to the OFEFP. A simple method for calculating the total nuisance of any industrial product is defined, as the sum of the number of ECOPOINTS produced by each process of the product manufacture. An application, based on the method proposed for the quantification of environmental effects occurred when dismantling a thermoenergetic group, was realised. The results obtained are graphically represented.

Key-Words: - exergy, ecopoints, ecofactor, environmental impact

1 Introduction

The interactions of any industrial process with the environment are placed either upstream, when considering the rarity of the consumed resources or downstream, when considering the outlet of by products as well as the resulted harmfulness. The quality of the resources is assessed based on specific criteria. Comparing the mathematical expressions of the harmfulness flux of matter resulted from an industrial operation and the flow of residual hot water by using the **intensity** and **natural intensity** notions of a polluting agent respectively the heat **exergy** and **anergy,** an analogy, suggesting that a series of methods developed for the appointment and analysis of exergetic balances may be transposed in ecological balances, can be established. The case of dismantling an energetic group composed of a steam generator, turbines and electrical generator has been chosen as an example.

In [2],[7],[9],[10],[17] environment impact evaluation it was realised by polluting indicators, SWOT analyses or impact matrix.

The analogy ecological balance – exergetic balance was dealt with in [1], realising therefore a correlation between the exergy-polluter and exergy-natural pollution pairs. The ecopoints and ecofactors method was fundamented in [2], [3], [4], [5], [6].

The new elements brought forward by the paper are:

- Adapting a series of exergetic analyses for the elaboration of environmental indicator capable to express the impact dismantling the industrial installations has on the environment;
- The methodology proposed is based on the hypothesis that the impact on the capital of used natural resources, semi-fabricated and finite products is symmetrical (considering the metabolism of waste by the ecosphere) to the impact the dismantling the respective installations has on the environment.

2 Problem Formulation

In order to quantify the environmental impact of dismantling the energetic group the OFEP (Office Fédéral de l’Environnement, des Forêts et du Paysage) – Switzerland was used. The method is based on appointing a series of ecopoints for different components of an installation; ecopoints which amplified to the reference unit of measure of the considered component lead to an ecofactor capable of numerically quantify the environmental impact. The calculations carried out for the major elements of an energetic group equivalent to a 110

MW installed power: namely steam generator turbine and electric generator.

$\dot{m}$ is considered the mass flow of matter resulted from an industrial operation containing as well an environmental polluting "agent" [1][7].

Considering g_i to be the intensity of the pollutant, the flow of harmfulness shall then be:

$$G_i = g_i \cdot \dot{m} \qquad (1)$$

g_{io} is considered to be the natural intensity of the polluting agent in the receiving environment. It corresponds for instance to the balance concentration between "naturally" produced SO_2 and the one absorbed by the marine environment. Equation (1) may therefore be written:

$$G_i = \underbrace{(g_i - g_{i0}) \cdot \dot{m}}_{polluting\ fraction} + \underbrace{g_{i0} \cdot \dot{m}}_{nonpolluting\ fraction} \qquad .... \ (2)$$

The expression of $\dot{m}$ is extracted from equations (1) and (2):

$$\dot{m} = \frac{G_i}{g_i} = \left(1 - \frac{g_{i0}}{g_i}\right) \cdot \dot{m} + \frac{g_{i0}}{g_i} \cdot \dot{m} \qquad (3)$$

In order to realise a parallel between the polluting equation with agent $\dot{m}$, and thermal pollution of residual hot water, the heat flux $\dot{Q}$ resulted from hot water is:

$$\dot{Q} = \underbrace{\left(1 - \frac{T_0}{T}\right) \cdot \dot{Q}}_{exergie} + \underbrace{\frac{T_0}{T} \cdot \dot{Q}}_{anergie} \qquad (4)$$

Considering relations (3) and (4) it is observed that the *thermal pollution flux identifies the exergy flux.*

The mathematical analogy of relations (3) and (4) suggests that a series of methods developed to establish exegetic balances may be transposed to the ecological balances [8].

The above mentioned relations may be quantified with the help of a series of concepts defined by the OFEFP of Switzerland [7][2].

The notions used in the expression the degree of pollution are defined as follows [3].

The actual flux - F expresses the limits of natural supportability (ecological saturation); the actual flux exceeds the critical flux ($F > F_k$) when an overexploitation of resources is realised.

The critical flux - F_k, represents the maximum polluting load which does not produce any irreversible damages within the analysed ecosystems.

Saturation – generally expresses the proportion between the available resource quantity and the realised exploitation. Ecological saturation – or ecological limits express the proportion between the tensions exerted on nature and its capacity to absorb them or to eliminate them.

Ecofactor – the measure of the limit of a natural resource, defined by the proportion between the effective exploitation (F) and the maximum admissible exploitation (F_k). (the "maximum admissible" expression signifies irreversible damage start appearing from this limit onward).

Ecopoint – ecological load unit; result of the calculation of the ecobalance (the highest this number is the more the exerted tension increases). The ecopoint represents the product between the ecofactor and the polluting load.

Different elementary harmfulness need to be standardised, namely expressed through common units to sum them in order to determine the total harmfulness produced by a number of polluting substances. One of the solutions was given by the OFEFP of Switzerland, which defined a harmfulness unit for each pollutant called ECOPOINT, representing the harmfulness of a ton of product at a maximum acceptable intensity. In the end, the form of expression (3) of the harmfulness flux may be written as [1]:

Considering G_i as the harmfulness flux measured in ecopoints/year, the average flux of matter $\dot{m}$ measured in tons per year and the ecofactor g_i measured in ecopoints per ton, the following relation results:

$$G_i = \dot{m} \cdot g_i$$

The ecofactor is determined using formula[3]:

$$f = \frac{1}{F_k} \cdot \frac{F}{F_k} \cdot 10^{12} \qquad (6)$$

3 Problem Solution

Based on the previously presented method and on statistical data regarding the environment in Romania, the ecopoints for different basic elements of the steam generator were determined and in order to have a common term of comparison, the total number of ecopoints for each of the 3 elements (steam generator, turbine, electric generator) was determined.

The results obtained based on the ecofactors of energetic consumption, air pollution, water pollution and soil pollution are presented in figures 1 to 10.

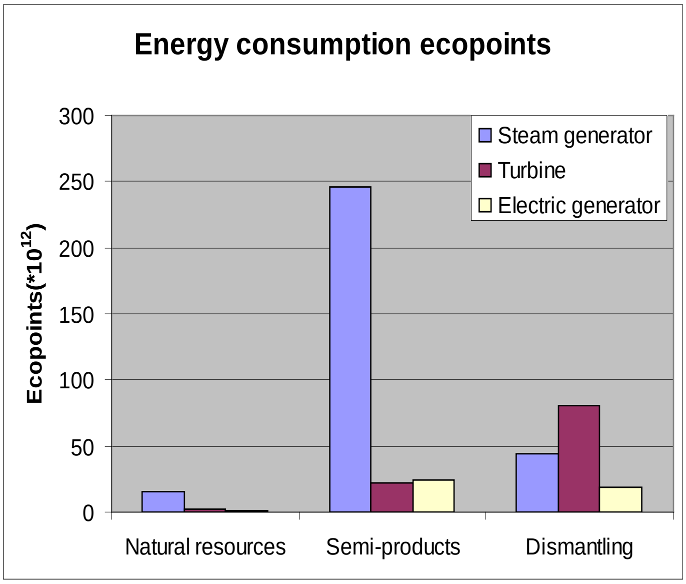

Fig. 1 Energy consumption ecopoints

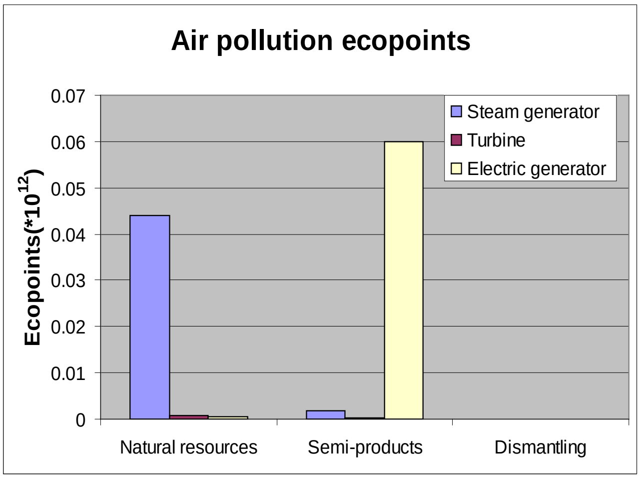

Fig. 2 Air pollution ecopoints

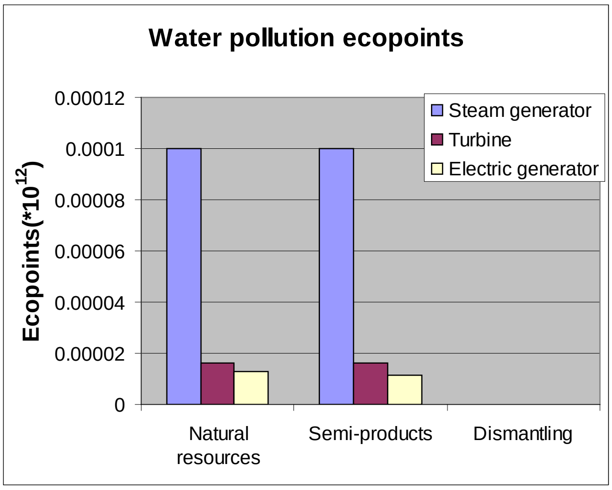

Fig. 3 Water pollution ecopoints

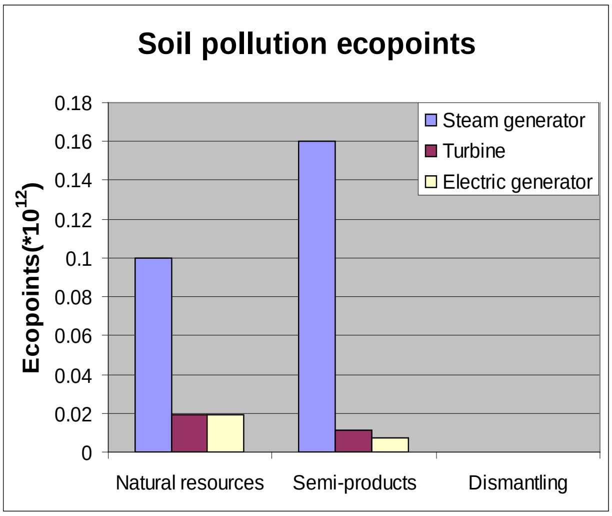

Fig. 4 Soil pollution ecopoints

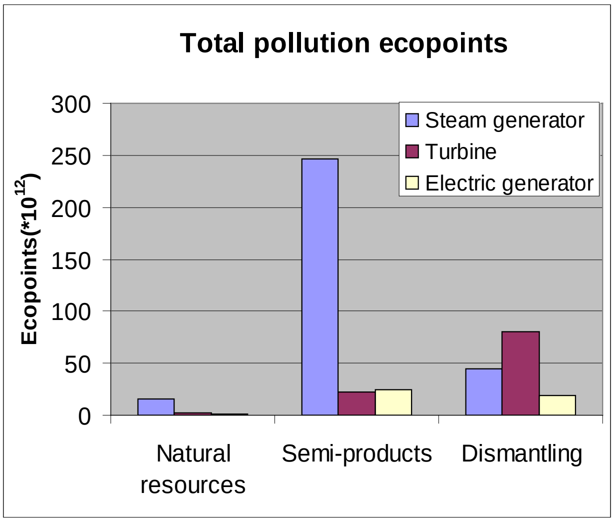

Fig. 5 Total pollution ecopoints

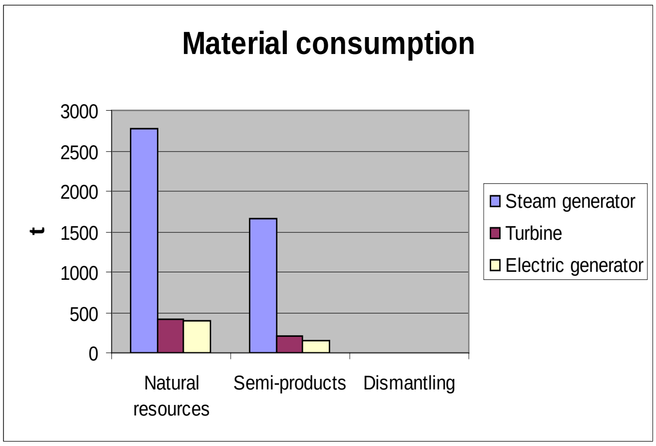

Fig. 6 Material consumption for natural, semi-fabricated and material resources

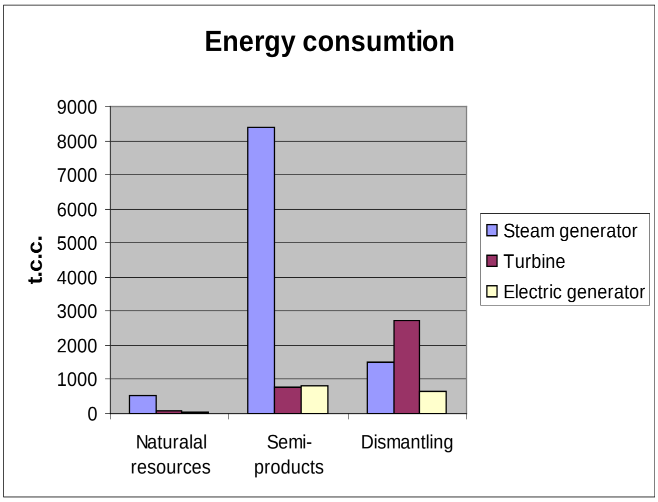

Fig. 7 Energy consumption for natural, semi-fabricated and material resources

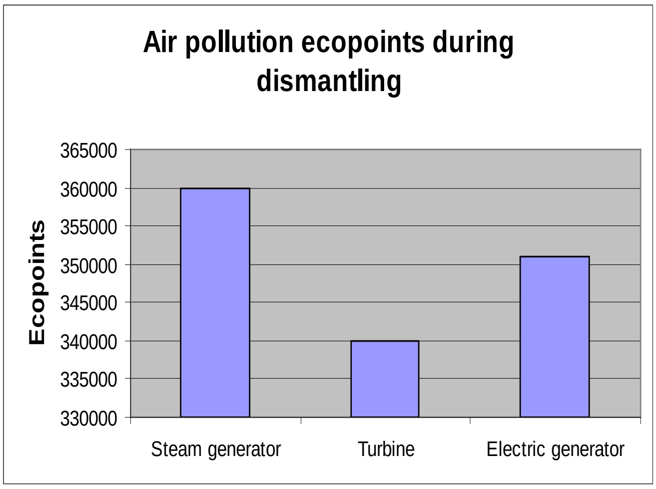

Fig. 8 Air pollution ecopoints during dismantling

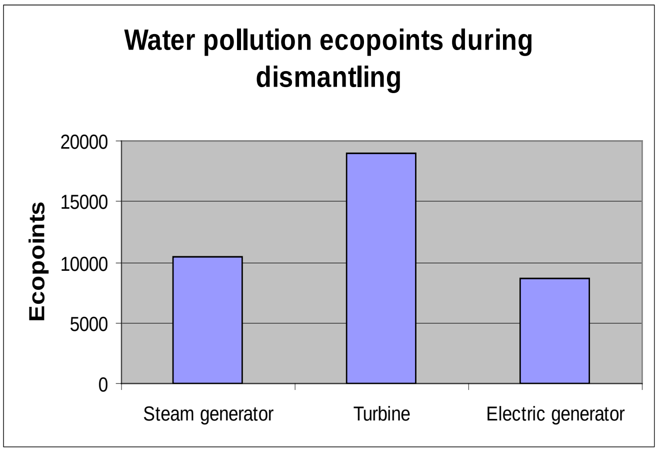

Fig. 9 Water pollution ecopoints during dismantling

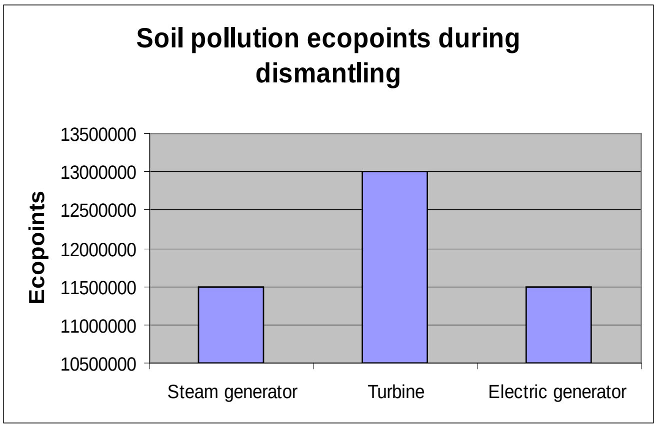

Fig. 10 Soil pollution ecopoints during dismantling

The determination of the ecopoints allows the numerical expression of the environmental impact encouraging graphical aggregation of financial, energetic and ecologic components. The CAREEC diagram highlights the costs for optimisation measures considering economic, energetic and ecologic criteria [1], [7], [9].

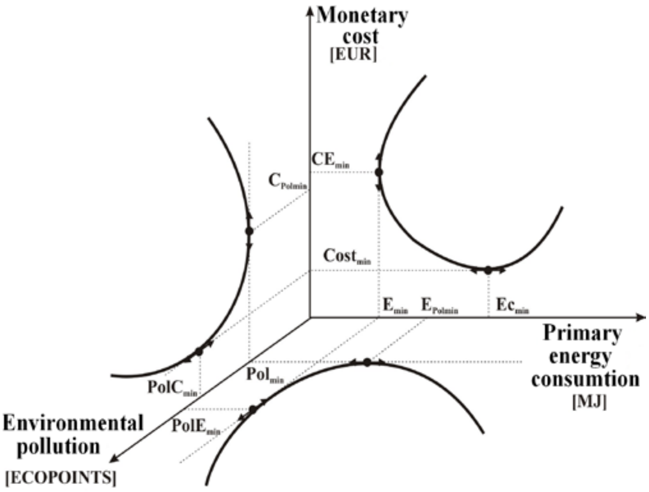

Fig. 11 CAREEC diagram

As it may observed in Figure 11, the following correlations may be realised [6]:

- The Ecmin - E_{min} difference highlights additions energetic costs for the reduction of monetary costs;
- The Epolmin - E_{min} difference highlights additional energetic costs for the reduction of environmental costs (pollution related);
- The C_{Emin} – Cmin difference highlights additional monetary costs for the reduction of energetic costs;
- The Cpolmin – Cmin difference highlights additional monetary costs for the reduction of environmental costs;
- The $PolE_{min}$ - Pol_{min} difference highlights additional environmental costs for the reduction of energetic costs;
- The $PolC_{min}$ - Pol_{min} difference highlights additional environmental costs for the reduction of monetary costs.

Depending on the national strategy and on the international conjuncture different proportions may be assigned to the expenses represented in the diagram and based on optimisation criteria the best monetary energetic and environmental solution may be therefore chosen.

4 Conclusion

The proposed method tries to use a mathematical formulation for the balance of harmfulness through the extension of the classical matter and energetic balances for an industrial procedure..

The difficulties of the method are the following:

- Colleting the experimental data;
- Defining the outline of the system to which the balance is applied. The conclusions are different when analysing a coal operated central heating plant, when it is placed in a depressed area, in a hill area or on a plain area;
- Defining the maximum admissible harmfulness;
- Considering the characteristics of the local environment;
- Harmonizing the national and the international regulation;
- Realising a compromise between the regional and the global interests.

The advantages of this type of approach are:

- The use of concepts and the analytical instrument of exergetic balances;
- Obtaining synthetic values representing the global ecological load exerted by the analysed system on its own environment;
- The method allows the comparison of different solutions for the creation of a product;
- The supply of information regarding the ecological importance of an ecosystem and reaching an alarm threshold;
- Implying consistent amendments it may be comprised by an analytical-experimental apparatus destined for the operationalisation of the concept of sustainable development;
- It offers the possibility of a periodical control of concrete quantifiable environmental protection measures.
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