FORMING ECO-RESPONSIBLE BEHAVIOR OF FUTURE ENGINEERS BASED ON THE STUDY OF CARBON FOOTPRINT

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Abstract: *One of the major problems of humanity is represented by the climatic changes caused by the anthropogenic impact on the environment. Calculating carbon footprint for an activity or for a process is important in the conscious action of fighting global warming by reducing the emission of GHG. Studying carbon footprint (individual, for system or for activity) by the students from the technical education puts them in the situation to analyze the relationship between the environment and their own activity on the one hand and on the other hand of industrial processes and activities, from the point of view of GHG emission*.

Keywords: *carbon footprint, global warming, greenhouse gases emissions*

1. Introduction

Scientific research in the field have shown both the causes, linked especially with greenhouse gases (GHG), and the strategies which must be applied in order to prevent the process of global warming as the main vector of the climatic changes [2]. Successfully applying the strategies in the domain requires the awareness of the entire society which can be made through cultivation, training and education.
The Law on National Education from January 5, 2011, stipulates at article 4: 'The education and the training of children, youngsters and adults have as main finality forming skills which are understood as a multifunctional and transferable assembly of knowledge, abilities and skills necessary for… employment and for participating at the functioning and the development of a sustainable economy.'
In this context, the skills developed during the training programs of an engineer, regardless of his/her specialty must also have in view the sustainable usage of resources, eco-friendly technological processes, sustainable production, ecological design, sustainable consume and the life cycle of products.

2. The concept of carbon footprint

A carbon footprint has historically been defined as 'the total set of greenhouse gas (GHG) emissions caused by an organization, event, product or person.' However, a more practicable definition has been suggested, and namely : 'A measure of the total amount of carbon dioxide (CO_2) and methane (CH_4) emissions of a defined population, system or activity, considering all relevant sources, sinks and storage within the spatial and temporal boundary of the population, system or activity of interest.' [3].
The carbon footprint expresses greenhouse gases by converting them into an equivalent amount of carbon dioxide (CO_2 equivalent or CO_2e), based on the relative global warming impact of each gas. The standardized definition of this parameter can be found in the ISO 14064-1: 2012 standard [7].

3. The calculus and the interpretation of carbon footprint

The calculus of carbon footprint, as it is suggested by the definition, can be made both in personal or familial domain and in all fields of activity: enterprise, company, corporation, authority or

institution [5]. Engineers activate in all these domains. Depending on the domain and the study program, they master in technical superior education professional and transversal skills which can ensure a successful career and mobility on the labor market. Due to the fact that sustainable development has become a worldwide priority both in economic and social areas, the technical university curricula should deepen this subject, especially because the industry and the services have such an important anthropogenic impact [8].

3.1. The usage of the case study in calculating carbon footprint

In order to pass from general to particular and given the life and professional experience of students, the first application in calculating carbon footprint is recommended to be the individual or familiar calculus. In this regard there can be accessed on – line programs which require from the student pieces of information regarding the structure of the family, the endowments of the house and the degree of comfort established individually or with the family, the manner of spending the free time or the holidays etc. The student is thus made knowledgeable in a series of pieces of information regarding household consumption, the consumption of electricity and the consumption of fuel for transport. It is preferable that this study be realized for a period of 1 year.

3.2. Phases in the calculation of carbon footprint of a productive activity

This study can be realized in the period of student practice in different industrial organizations. The period for which the calculus is effectuated is indicated to be of one year. In order to form the ability of calculating carbon footprint, for the beginning processes or activities with reduced complexity are chosen, which eases the data interpretation and the establishing of a coherent action plan in order to decrease the emission of CO_2e.

Step 1. Establishing the field of study

For the results to be accurate, in a first phase a limitation of the field of study should be realized. In this regard, there can be made an approach based on the process with which the students are familiar from ISO 9001:2008 Standard - Quality management systems - Requirements: 'An activity or set of activities using resources, and managed in order to enable the transformation of inputs into outputs, can be considered as a process. Often the output from one process directly forms the input to the next'. For the same purpose, environment aspects with impact from the point of view of GHG will be established thus applying the knowledge gained from the study of the International Standard for Environmental Management Systems EN ISO 14001:2004. The process selected as being relevant for the study will be added with the emissions of equivalent CO_2.

Step 2. Calculating the emissions of CO_2e

2.1. Establishing the types of GHG emissions

GHG emissions are classified as [7]:

a) Direct GHG emissions which are specific to the processed which release GHG into the atmosphere;

b) Indirect energetic GHG emissions from the process of generating imported electricity, heat of steam consumed;

c) Other indirect GHG emissions: coming from the production of purchased raw materials or of basic materials, employee transport and which are generated in the usage phase or the final phase of the life cycle of products and services.

Given the complexity of the field and in order to apply the acquired experience during the case study, emissions will be calculated for categories b, respectively c.

2.2. Selecting the methodology of quantification

For the categories of emissions analyzed it is chosen the calculus method based upon the quantities consumed for the analyzed process. For indirect energetic GHG emissions from the process of generating imported electricity, heat of steam consumed: based upon the 2006/32/EC Directive from April 5, 2006 regarding the energetic efficiency at final users and the energetic services, from annex II, it is established the energetic amount of the fuels which are selected for final usage based upon the conversion table (table 1). Students can create their own work documents or to use the following model, in which kWh was selected as measurement unit.

In the category of other indirect GHG emissions (c) are usually enlisted those coming from the automobile park of the organization, being taken into consideration their route in km of those which are useful for the process.

Table 1. The conversion of the type of fuel in kWh

Type of fuel	Consumed quantity	Units	Units	x	Conversion factor (kWh per unit)		Total kWh
Natural gas		kg	m^3	x	13.1 kWh/kg	7.85 kWh/m	
Liquefied petroleum gas (LPG)		kg	L	x	12.78 kWh/ kg	7.65 kWh/L	
Coal		kg		x	6.65 kWh/kg		
Associated petroleum gas (APG)		kg	L	x	11.75 kWh/kg	9.87 kWh/L	
Wood, moisture 25%		kg		x	3.83 kWh/kg		
Wood pellets/ Wood briquettes		kg		x	4.67 kWh/kg		
						TOTAL	

(Source: www.iuses.eu/materiali/ro/.../Exercitiu_complex_pe_energie)

2.3. The quantification of GHG emissions

For the category of indirect energetic emissions (b) the entry data are obtained either from the bills sent for the respective fuels or from the material or energetic balance of the respective activity. For the quantification of the CO_2 emission, the consumption is amplified with the respective emission factor (table 2).

For the category of other indirect GHG emissions, the route in km is multiplied by the value of CO_2 emissions from the Certificate of Registration of the Vehicle or with the value resulted from consulting, for example, the site http://www.servicii-inmatriculare.ro/emisii-co2-calculator/.

Table 2. Quantifying indirect GHG emissions

Type of energy	Energy consumption, kWh	x	Emission factors		Emissions	
			CO_2, kg/kWh	CO_2e, kg/kWh	CO_2, kg	CO_2e, kg
Electricity from National Electro-Energy System		x	0.5108	0.5387		
Natural gas		x	0.2019	0.2178		
Liquefied petroleum gas (LPG)		x	0.2271	0.2440		
Coal		x	0.3459	0.3470		
Associated petroleum gas (APG)		x	0.2786	0.2800		
Other fuels		x				
				TOTAL		

(Source: www.iuses.eu/materiali/ro/.../Exercitiu_complex_pe_energie)

4. Results and discussion

The obtained results will be compared with the values from specialty literature in order to appreciate the length the measures to reduce carbon footprint should have had [1]. The target should take into consideration the commitment of Romania to reduce greenhouse gases at the level of 2020 with a percentage of 20% as compared with the level of emissions in 1990 [6]. The first measures can emerge from the deduction of the consumption of electric energy on consumers and its pie chart type representation.

The proposals will be synthesized according to table 3. Measures will relate to different types of uses of thermal or electricity power. The measures to reduce carbon footprint must be in correlation with the dynamic of the process and must be within the limits of economic efficiency.

Table 3. Proposals to reduce carbon footprint

Type of energy / Usage	Proposed measures	Economy %	Saved energy, kWh	CO_2 prevented, kg
Thermal	Heating			
	Modernization industrial ventilation systems	25		
	Improvement of the thermal isolation of the buildings	10		
	Assemblage of windows with double glass	5		
	Assemblage of an isolating adherent tape at doors	10		
	Assemblage of devices to close entrance doors	5		
	.....			
Electricity	Lighting and Equipments			
	Replacing the incandescence lamps with fluorescent lamps	15		
	Turning off interior lights during the night	5		
	Closing the monitors of the computers when they are not used	2		
	Putting the computers in 'sleep' mode when they are not used	2		
	Control office lighting with timers and motion sensors	5		
	.....			
	Consumption of hot water			
	Assemblage of solar panels	30		
	.....			

5. The eco – responsibility of future engineers with the aid of carbon footprint

Studying carbon footprint (individual, for system or activity) by the students from technical education puts them in the situation to analyze the relationship between the environment and their own activity on the one hand and on the other hand of industrial processes and activities, from the point of view of GHG emissions. The study of the influence of GHG on the process of global warming and processing a sufficient amount of data regarding the sources that generate GHG emissions leads to an approach through knowledge, understanding, explanation and interpretation of this phenomenon.

Using methods, techniques and instruments of investigation and application that are specific to carbon footprint results in the rise of the awareness of the role that the engineer plays in the process to fight climatic changes. The proposals of measures to reduce carbon footprint must be the result of a brainstorming debate thus ensuring the participation to the individual professional development. Students ought to be encouraged to apply innovative solutions [4]. Principles as 'the polluter pays principle' or 'extended producer responsibility' are better understood and at the same

time increase the personal responsibility in approaching scientific problems which are current and of perspective.
In this process a major role is held by the university teacher who coordinates such a study because he/she must have skills in the field of environmental protection in industry.

6. Conclusions

Calculating carbon footprint for an activity or a process is important in the conscious action of fighting global warming by reducing GHG emissions. In order to be relevant, carbon footprint is calculated periodically, preferably at intervals of one year. The measures to reduce carbon footprint must be adapted to the analyzed process and their effect must be quantified.
For future engineers this is an application which reflects the anthropogenic climate change through the emissions of GHG which can be quantified in CO_2e. The coordinator of this study accommodates the students with data collecting regarding the schedule and the planning of production, the control of the consumption of raw materials, of materials and of energy. Using methods, techniques and instruments of investigation and application which are specific to carbon footprint lead to the awareness of the role the engineer plays in the process of fighting climatic changes.

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