Eco-design of Electric Equipments

Tsutsuianu O.
Romanian National Committee of the World Energy Council
Bucharest, Romania

Abstract. In the last time, some factors and especially the environmental protection requirements have forced to add the ecological criterion for design of electric equipments, within a new Eco-design concept. The essence of this concept consists in the integration of environmental aspects at project phase, taking into account full life cycle of product. The work presents some theoretical and practical aspects of *eco-design* for electric equipments. The actual *eco-design* conception combines *Qualitative Assessment of Life Cycle Criteria* with a quantitative method based on the *Product Carbon Footprint*. The calculation of the last indicator means the quantification of the greenhouse gases emissions ($kgCO_2$ equivalent) during the life cycle of products and services. From the study of the technical literature and its own practical work, the author has found that "maintenance", one of the phases of the life cycle of electric equipment, is not sufficiently analyzed and quantified in terms of negative impacts on the environment, including CO_2 emissions involved in the service performed. As a result, it has achieved himself and in collaboration with other specialists studies and research, with the ultimate objective of establishing environmental performance indicators in this field. Thus, the main objective of this paper refers to the original contribution of the author who has established two such indicators, namely: *1. Absolute indicator "CO_2 emissions involved in service (E_s) [kg CO_2]"* and *2. Relative indicator "Specific CO_2 emissions involved in service (e_s) (kg CO_2 / euro)".*
***Keywords*:** environmental legislation, eco-design, life cycle of product/service, product carbon footprint, environmental performance indicator, CO_2 emissions.
DOI: 10.5281/zenodo.3239204

Eco-proiectarea echipamentelor electrice

Țuțuianu O.
Comitetul Național Român al Consiliului Mondial al Energiei
București, România

Rezumat. În ultima vreme, unii factori și în special, cerințele privind protecția mediului au impus adăugarea criteriului ecologic la proiectarea echipamentelor electrice, în cadrul unui nou concept denumit:*eco-proiectare*.Esența acestui concept constă în integrarea aspectelor de mediu la faza de proiect, luând în considerare întregul ciclu de viață al produsului. Lucrarea prezintă unele aspecte teoretice și practice ale *eco-proiectării* echipamentelor electrice. Concepția actuală de *eco-proiectare* combină criteriul *Evaluarea Calitativă a Ciclului de viață* cu o metodă cantitativă bazată pe *Amprenta de Carbon a Produsului*. Calcularea acestui ultim indicator înseamnă cuantificarea emisiilor de gaze cu efect de seră (kg CO_2 echivalent) pe durata ciclului de viață a produselor sau serviciilor. Din studierea literaturii tehnice de specialitate și din activitatea practică proprie, autorul a constatat că „mentenanța”, una din fazele ciclului de viață a echipamentelor electrice nu este suficient analizată și cuantificată din punct de vedere a impacturilor negative asupra mediului, inclusiv a emisiilor de CO_2 înglobate în serviciul efectuat. În consecință a realizat personal și în colaborare cu alți specialiști studii și cercetări, având ca obiectiv final stabilirea unor indicatori de performanță ecologică în acest domeniu. Astfel, obiectivul principal al articolului se referă la contribuția autorului care a stabilit doi astfel de indicatori și anume: *1. Indicatorul absolut "emisiile de CO_2 înglobate în serviciu (E_s) [kg CO_2]"* **și** ***2. Indicatorul relative "emisiile specific de CO_2 înglobate în serviciu (e_s) (kg CO_2 / euro)".***
Cuvinte-cheie: legislație de mediu, eco-proiectare, ciclu de viață a produsului/serviciului, amprenta de carbon a produsului, indicator al performanței de mediu, emisii de CO_2.

Эко-дизайн электрооборудования

Цуцуяну О.
Румынский национальный комитет Всемирного энергетического совета
Бухарест, Румыния

Аннотация. За последнее время, некоторые факторы и в частности требования по охране окружающей среды добавили экологические критерии при проектировании электрооборудова-

ния, в рамках новой концепции, называется: *эко-дизайн*. Суть этой концепции состоит из интеграции экологических аспектов на стадии проекта принимая во внимание весь *жизненный цикл продукта.* В статье представлены некоторые теоретические и практические аспекты *экодизайна* электрооборудования. Текущая концепция экологического дизайна сочетает в себе *качественную оценку жизненного цикла* с количественным методом, основанным на *углеродном следе продукта*. Расчёт этого последнего показателя означает количественную оценку выбросов парниковых газов (в эквиваленте кг CO_2) в течение жизненного цикла продуктов или услуг. Исходя из изучения технической литературы и собственной практической работы, автор обнаружил, что ”техническое обслуживание”, одна из фаз жизненного цикла электрооборудования, недостаточно проанализировано и количественно определено с точки зрения негативного воздействия на окружающую среду, включая выбросы CO_2. встроенный в услугу выполнено. В результате, он укомплектовал и сотрудничал с другими специалистами в исследованиях с конечной целью установления показателей результативности экологической деятельности в этой области.Таким образом, основная цель этой статьи относится к первоначальному вкладу автора, который установил два таких показателя, а именно: *1. Абсолютный показатель ”Выбросы CO_2, включенный в службе (E_s) [кг CO_2]” и 2. Относительный показатель ”Удельные выбросы CO_2 в службе (e_s) (кг CO_2 / евро)”.*

Ключевые слова: экологическое законодательство, эко-дизайн, жизненный цикл товара / услуги, углеродный след продукта, показатель экологической эффективности, выбросы CO_2.

INTRODUCTION

Few years ago, two main criteria (*cost and reliability into operation)* have been considered for electric equipments design. In the last time, some factors determined even in this sector to add the ecological criterion within a new *eco-design* concept.

The essence of *eco-design* consists in the integration of environmental aspects at project phase taking into account full *life cycle of product,* from raw materials acquisition up to product elimination.

The particle “*eco*” means at the same time economy and ecology [1].

The main objective of this paper is to present theoretical and practical aspects of *eco-design*, with examples in electric engineering.

Of course until now, researchers have studied and documented issues that some results of which are mentioned here on references given in the paper.

In the multiple concerns worldwide, the author comes to personal contributions especially regarding *eco-design* philosophy approach into maintenance phase of electric equipments, an area less studied and treated in the technical literature.

Details of this new, including the proposal of performance indicators based on ”CO_2 emissions included in the activities of maintenance of electrical equipment” will be given to the work at chapter no.VI.

I.INFLUENCE FACTORS OF “ECO-DESIGN”

Eco-design is influenced by some factors shown in the ”Fig. 1”, namely:

1) .Legislation

The globalization of world economy obliged the companies from each country to participate within a large context of regulation and standardization in the energy-environment field. Are mentioned in this respect: ”Montreal Protocol”, ”Kyoto Protocol”, ”Environmental European Standards”, ”Environmental International Standards” (especially ISO 14 000 series), as well as specific regulation for electrical equipments, such as, European Directives WEEE-2 012/19/EU and RoHS-2 011/65/EU [2], [3], [4], [5], [6].

....Important are also the national regulations in the field [7], [8].

2) Market requirements

Because, “environmentally friendly products” (including electric equipments) are encouraged on market competition, they are profitable not only for consumers but for producers too.

3) Economical requirements

Specific environmental requirements may be balanced to prevent supplementary capital costs (investments). For example, an *eco-design* which provides less raw materials or energy

consumptions can obtain a low total cost. According with *life cycle concept*, this kind of design can be considered like economically.

4)Specific environmental requirements

Respecting these specific requirements can be reduced significantly environmental negative impacts associated with electric equipments on their full *life cycle* [9].

5) Social aspects

The electric products of *eco-design* can win an easy acceptance from the large public. In this field already are some successes in applying the new design concept. This matter can have a profitable influence about of society [10].

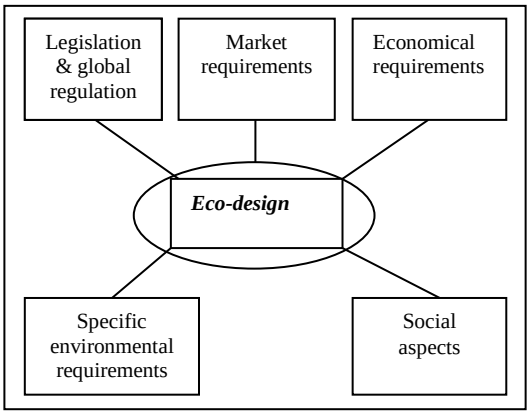

Fig1. Influence factors of *eco-design* [10].

II.RELATIONSHIP BETWEEN ENVIRONMENTAL MANAGEMENT SYSTEMS AND *ECO-DESIGN*

In accordance with EMAS (communitarian environmental management and audit scheme) [11] or with ISO 14001:2015, environmental management systems are based on ”clean” production techniques/technologies having in this respect some common points with *eco-design*.

Therefore, one environmental management system, implemented and certified is a good starting point for products *eco-design* approaching.

Key indicators for measuring the environmental performances base on “production units”.

This kind of indicators can have in the view energy, water, chemical matters consumptions or the quantity of eliminated hazardous wastes [12].

Within a company can’t be a single “eco-designer” because the *eco-design* requires one interdisciplinary work approach. For this reason there are much more “entering points” for *eco-design:*

- *Supply Department* is responsible for dealers selection and for acquisition of components with low contents in hazardous matters;
- *Marketing Department* will identify the market opportunities from category “green is sold better” and will promote “green efforts” of company;
- *Research and Development Department* will take into account environmental aspects like a creative tool for innovation and for identification of efficient possibilities;
- *Environmental Department and Health & Safety Labour Department* will have their specific contribution from environmental protection and respectively, labour security point of view;
- *Quality Department* has missions regarding better products achievement, which gives to him one special place within *eco-design*;
- *Designer or Design Team* if already works within an interdisciplinary framework will have environmental performance only like a supplementary decisional criterion to aide at yours daily activity.

III.“ECO-DESIGN” STAGES

“Eco-design” stages with adequate activities are guided by International Standard ISO/TR 14062/2002, and include [13]:

1.Planning (Design ideas):

- To collect data/proofs;
  To select these in accordance with benefits and reliability; To line their at corporate strategy;
- To take into account “environmental aspects”; To think “life cycle”; To define “environmental requirements;
- To analyse external factors; to choose adequate approach of environmental projects; to check selected approach;
- To perform an “environmental analyse” of referential product.

2. Draft project (Project outlook):

- To set common idea; To perform an "analyse orientated to *life cycle*"; To define "measurable tasks";
- To develop design concept; To fulfil "environmental requirements";
- To materialize within a "specification" and to apply the results from the "analyse of referential product".

3. **Detailed design** (Project solutions):

- To apply project approach;
- To finalize "product specifications ", including "life cycle" considerations:
  - ✓ using *eco-design* instruments and data base;
  - ✓ searching alternatives for materials with problems;
  - ✓ elaborating scenarios regarding "life cycle" for a better understanding of product evolution;
  - ✓ analysing assemblies / disassemblies.

4. Checking/prototype (Prototype):

- To check specifications by prototypes testing;
- To analyse considerations regarding prototype "life cycle":
  - ✓ doing comparison with previous generation of products;
  - ✓ analysing objectives achievement.

5. Production. Launching on the market (Product):

- To publish communications regarding "environmental aspects", the best utilization and elimination of product;
- To take into consideration possible "environmental statement" and its requirements:
  - ✓ promoting to clients groups "environmental excellence" of product;
  - ✓ underlining supplementary characteteristics: quality, costs during utilization;
  - ✓ making the users for "green products".

6.Product analyse:

• To take into consideration and to evaluate experiences, "environmental aspects and impacts";

- ✓ evaluating product success (what arguments really trusted for clients?);
- ✓ identifying possibilities on later improvement for future generation of products; what innovations will appear (within company or on market)? What are doing the competitors?

IV. AN "ECO-DESIGN"STRATEGY

Products optimisation and redesigning are based on 6 **RE** philosophy:

1. **RE**-thinking of product and his functions (for example, how can be efficiently used the product);
2. **RE**-duction of materials and energy consumption during its "life cycle";
3. **RE**-placement of hazardous substances with "environmental friendly" alternatives;
4. **RE**-cycling. It chooses materials which can be recycled and the product is thought thus so that can be easy disassembly for recycling;
5. **RE**-using. The product is designed thus so that theirs component parts to be reused;
6. **RE**-covering (repairing). It thinks one easy repaired product, thus so that he doesn't be too quickly replaced.

Initially it was applied 3**RE** philosophy (recycling, reusing and recovering). Further, *eco-design* strategy can to have in the view:

- To check current stage of products: what market requires, what expectations have the client?
- To identify environmental aspects: which are the relevant environmental aspects of products?
- To establish objectives and involve departments and suppliers chain;
- To choose the instruments, checking lists and appropriate guides; to determine the relationship between environmental arguments and costs;
- To make an analyse of product and to identify potential for improvement;
- To promote innovation aspects [1].

V."ECO-DESIGN " PRACTICE

Eco-design concept application means a processional chain according to flow chart shown in "Fig. 2" [10].

"Environmentally friendly design" for electric equipments is based on *eco-design* of the electrical insulation

systems. In selecting insulation materials should be considered their costs and functional characteristics, as well as, environmental negative impacts, associated with these.

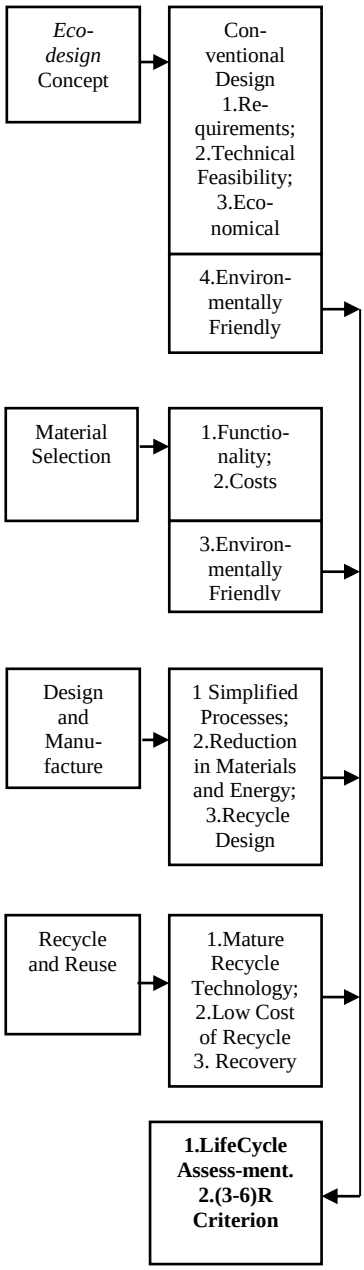

Fig.2. Environmentally friendly design process

A.Selection of materials

Selection of electro technical materials means to make the following steps:

a) Identification of working environment for the insulation components from equipment ensemble (external or intrinsic, such as working voltage) and of common design requirements, such as: temperature, humidity, composition of insulation material, etc;
b) Examination of properties and specifications for "candidate" materials. Elimination of those which not meet respective requirements;
c) Analysis of compatibility for all the insulation components to avoid the risk like electro insulating fluid (gas or liquid) to produce one chemical reaction in contact with other components, such as: washers, insulating films, etc.;
d) Evaluation of manufacturing process, costs, product life and recycling, as well as environmental negative impacts. Choosing the best material on the base of an technical/economical comparative study;
e) Preparation of samples for tests (according with national / international standards) and submit measurements required by these procedures.

B."Environmentally friendly" insulation materials

Evaluation of environmental negative impacts generated by electric equipments is possible by integration of environmental aspects into product design and development [13]. The environmental impacts should be quantified during all stages of material *life cycle* : manufacture, utilization, and disposal. Some organisms from environmental field (such as, EIME/Environmental Information and Management Explorer, from France) developed software which is used to assess environmental impacts generated by electric equipments [14].

One material can be considered like "e*nvironmentally friendly*" if he meets firstly, the "3 R criterion", and namely [10]:

- ✓ Can be easily *recycled* using *a* technology commercially available with minimum costs;
- ✓ So that after reprocessing their characteristics meet further regulated requirements;

- ✓ Can be *recovered* (can reduce of other raw materials consumption by recovery, including repairs of some product/equipment components within is incorporated).

C.Design for "recycle" and "reuse"

A typical design principle for easy *recycle* and *reuse* consists of two elements: avoid the use of components made of mixed materials or use single type of materials.

The key to achieve such kind of design can be considered:

- ✓ Avoiding the use of metal reinforced plastic components;
- ✓ Avoiding the use of metal bolts and nuts and try to promote locking features of the plastic materials;
- ✓ Avoiding the use of glue to prevent environmental pollution during recycling;
- ✓ Using the same type and grade of materials. When this is not possible, should be clearly mark and classify the materials;
- ✓ Avoiding the use of decorating materials, words, paints and protective coatings;

Many years recycling and reusing focused on plastic materials by three methods:

1) Mechanical method

This method is applied for large components, such as external shields and insulation meshes. It involves: classification, decommissioning, identification and pulverising etc.

2) Chemical method

For products of smaller volume, achieved from different materials, their separation isn't easily. In this case can be used a chemical approach, like high temperature decomposition or incineration.

3) Direct conversion

For materials that cannot be reprocessed by the above mentioned methods, direct burning can be used. Although, the application of this method needed a carefully checking of pollutant emission resulted by combustion, it is also a positive environmental impact consisting in fossil fuel saving (especially oil and natural gas).

D.Reduction in the use of materials

To reduce raw materials consumption for electrical products can be take into consideration many aspects. According to "Fig. 3", one change in the packaging design of switchgear can significantly reduce the mass of packaging materials. From Design A to Design B, a one third volume reduction is achieved. In *Table 1*, the changes regarding design concept of packaging are quantified.

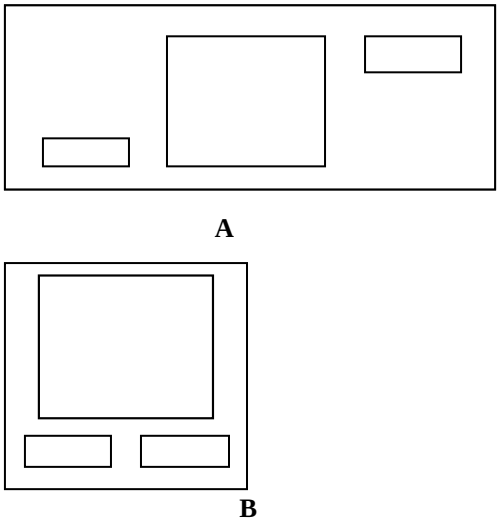

Fig.3. Diverse manners for switchgear packaging [10]

A).Classical; B). "Environmentally friendly"

Table 1

Comparison of Design A and B [10]

Materials	Unit	"Design A"	"Design B"
Timber	kg	15	10
Plastic	kg	6	4
Paper	kg	3	2

The actual *eco-design* conception combines ***Qualitative Assessment of Life Cycle Criteria*** with a quantitative method based on the ***Product Carbon Footprint.*** The calculation of the last indicator means the quantification of the greenhouse gases emissions ($kgCO_2$ equivalent) during the life cycle of products and services [15].

The „state of the art" in the *eco-design* field is includes in the book from reference [16]. This book considers *eco-design*, a major tool for reducing the environmental impacts of products, services and systems in the context of

sustainable development. It covers four key aspects of *eco-design*, applied to electric engineering.

First, it describes current and future methodologies and standards, including regulations, which apply to electric engineering.

In turn, the second chapter is devoted to energy systems and planning, including constraints on the insertion of equipment into the grid. Components such as transformers and cables, their *eco-design* characteristics and impacts, and their potential to improve the environmental impacts of networks are described in the third chapter.

Lastly, the fourth chapter deals with materials in terms of their performance and ecological impact. In the case of electric equipments, the *eco-design* approach is also connected to the development of renewable energies and energy efficiency.

VI. ECO-DESIGN APPLICATION TO THE MAINTENANCE OF ELECTRIC EQUIPMENTS

Since 1990, the author was deeply involved within environmental protection activities of Romania's National Energy System, leading-between 1990-2004 -specialty departments at the Romanian Electricity Authority (RENEL), National Electricity Company (CONEL) and National Company (CN Transelectrica SA).

During this period he also contributed, personal or within teams, to the theoretical and practical activities focused on the following main environmental objectives:

- Improving the manufacturing-environment relationship;
- Implementation of the environmental management system according to the international standard ISO 14 001 in the structures of the Romanian energy companies ;
- Monitoring of environmental impacts and assessment of ecological performance of thermal power plants in Romania];
- Assessing the impact of electricity networks on the environment;
- Environmental Impact Assessment in Energy Equipment Maintenance;
- Knowing and applying *Eco-design* principles;
- Comparison of ecological performance in the repair of power transformers;
- Performance indicators in the maintenance of electric equipment;
- "Green" criteria for choosing materials used in the medium voltage power grid.

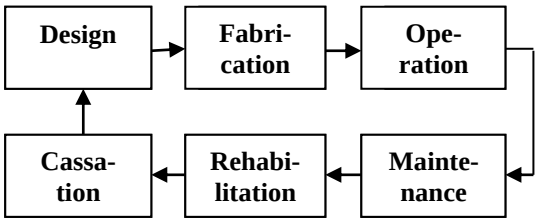

Fig.4. *Life Cycle* phases of industrial equipments [21].

Any industrial equipment traverses a *life cycle* which evolves from *design* to *cassation*, passing through more phases which are shown in ”Fig. 4”.

The *maintenance* (based especially on repairs) has as a purpose to maintain equipments capacity to fulfil designed functions.

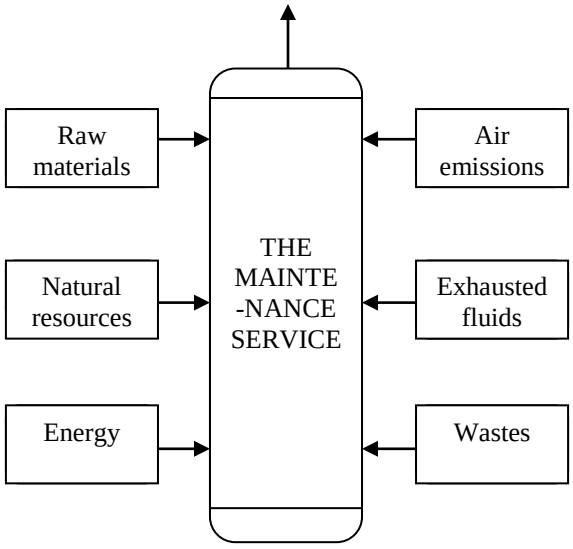

Fig.5. ”Evironmetal- material balance at an organization with maintenance activity [21]

From the study of the technical literature and its own practical work, the author has found that "maintenance", one of the phases of the life cycle of electric equipment, is not sufficiently analyzed and quantified in terms of negative impacts on the environment, including CO_2 emissions involved in the service performed [17], [18], [19] [20].

At an organisation (company) which performs maintenance services, can be distinguished environmental aspects:

-associated to the ”entrances”: raw materials consumption; natural resources consumption; energy consumption;

-associated to the ”exits”: air emissions; exhausted fluids; wastes, etc.

”Environmental balance” for a maintenance service, includes the sum of *environmental impacts* adequate associated *environmental aspects*, caused by material and energy quantities which enter and exit from service contour (”Fig.5”).

Table 2

Elements of „material balance” at transformer 250 kVA, 20/0.4 kV repair [21]

Material consumption [kg]	Energy consumption [kWh]	Wastes [kg]
Oil: 330.6	694.5	Oil:320.2
Rubber: 5.0	-	Rubber: 4.0
Paper:3.0	-	Paper:3.0
Cardboard:6.0	-	Cardboard:6.0
Paint:1.0	-	-
Diluent:1.0	-	-
Cu: 101.5	-	Cu: 95.0

At the present, the most discussed problem at global scale is focused on the „climate changes”, caused by „greenhouse gas (GHG) emisssions”. The largest single human contribution to GHG emissions is carbon dioxide (CO_2). Starting from this reality, the work proposes two indicators for evaluation of environmental performance in maintenance activity of industrial equipments.

The first indicator results from a “power approach” of the “environmental balance” (”Fig.5”) which allows the calculation of “energy involved in service” (**W_s).**

This energy is turn into “equivalent fuel” **(B_s)** and finally into “CO_2 emission involved in the service” **(E_s)**.

The second ones (**e_s**) results by division of “**(E_s)** to the “total financial value of maintenance service” (**Vs**), expressed in euro

A practical application for calculation of these indicators in the case of two power transformers repair, started from the ”material balances” shown in the table 2 and 3. According to the calculation methodology presented above, the comparison indicators **W_s, E_s, V_s** and **e_s** are shown in ”Table 4”.

Table 3

Elements of ”material balance”at Transformer 16 MVA, 110/22 kV repair [21]

Material consumption [kg]	Energy consumption [kWh]	Wastes [kg]
Oil: 12 190	9 737	Oil: 9 634
Rubber: 130	-	Rubber: 120
Paper:1 000	-	Paper: 900
Cardboard: 2 300	-	Cardboard: 1 900
Paint: 24	-	-
Diluent: 20	-	-

Table 4

Elements of ”environmental ”comparison” [21]

Indicators	Transformer 250 kVA, 20/0.4 kV repair	Transformer 16 MVA, 110/22 kV repair
W_s [GJ]	46.7	1 070.5
E_s[kg CO_2]	4 954.7	113 468.3
V_s[euro]	3 343	168 182
e_s[kgCO_2/euro]	1.482	0.675

(E_s) puts in evidence only absolute value of environmental aspects.

(e_s) is relevant because shows practically, ***with what environmental impact (kg CO_2) is obtained each monetary unit ((1 euro) accordingly with performed service.***

From environmental point of view, the repair of second transformer is more efficient because for obtaining of each monetary unit (1 euro) is produced an environmental impact of 0.675 kg CO_2 as compared with 1.482 kg CO_2, corresponding to the first transformer repair.

CONCLUSION

❖ *Eco-design* is a current practice absolutely necessary.

❖ To be truly effective, is needed as involved CO_2 emissions (carbon footprint) to be correctly assessed in all phases of the *life cycle of products or services,* including in the *maintenance phase.*

❖ The advantages of *eco-design* application are: *Creativity and innovation; Low*

manufactured costs; Superior quality of the product; More guarantees; "Green is better sold".

❖ The proposed indicators from this paper can by used on different organizational levels, having two main advantages:

- to assist the Management to find all category of losses (raw material, natural resources, energy) and to take efficient corrective and preventive actions;
- to complete environmental protection data base and to compare environmental performance on different level of maintenance services.

References

[1] Schischke,K., Hageluken, M., Steffenhagen, G. *Eco-Design Awareness Raising Campaign for Electrical & Electronics SMEs*. Fraunhofer IZM Berlin, Germany. Available at: ecodesignarc@izm.fraunhofer.de.(accessed 25.07.2014).

[2] **** Directive 2012/19/EU on the wastes from electric and electronic equipment.*

[3] **** Directive 2011/65/EU on the restriction of the use of certain hazardous substances in electrical and electronic equipment.*

[4] *SR EN ISO 9001:2015. Quality management systems. Requirements*. ASRO, Bucharest (In Romanian).

[5] *SR EN ISO 14001:2015.Environmental management systems. Requirements.* ASRO, Bucharest (In Romanian).

[6] *ISO 45 001:2018. Occupational health and safety management systems. Requirements.* ASRO, Bucharest (In Romanian).

[7] **** Sustainable development.* Infor-mation and Documentation Office for the Environment Infoterra, 2002, Bucharest (In Romanian).

[8] **** Legislation and environmental regulations.* Information and Documentation Office for the Environment Infoterra, 2003, Bucharest (In Romanian).

[9] ******** *SR EN ISO 14040:2007 (Romanian version). Environmental management. Life cycle assessment. Principles and framework.* ASRO, Bucharest, Second Edition, June 2008.

[10] Wenjie, Qi., Shengtao, Li., Falkingham, Leslie., Hassanzadeh Mehrdad., James, Ian. *Environmentally Friendly Design for Electrical Insulation System.* Available at: www.vil.org.uk. (accessed 21.07. 2014).

[11] **** Regulation (EC) No.1221/2009 of the European Parliament and of the Council of 25 November on the voluntary participation by organisations in a Community eco-management and audit scheme (EMAS).*

[12] Tsutsuianu, O. (2006); (2011) *Environmental Performance Evaluation and Reporting. Environmental Indi-cators.* AGIR Press, Bucharest (In Romanian).

[13] ******** *SR ISO/TR 14062/2008 (Romanian version). Environmental management. Integrating environmental aspects into product design and development.* ASRO, Bucharest, First Edition, September 2008.

[14] **** Environmental Information and Management Explorer (EIME).* Avai-lable at*:* www.Codde.fr. (accessed 25.07. 2014).

[15] Sanyé-Mengnal, E., Lozano, R.G., Farreny,R., Oliver-Solá,J., Gasol,C., Rieradevall,J. *Introduction to the Eco-Design Methodology and Role of Product Carbon Footprint*. Available at:www.researchgate.net publication (accessed 27.03.2019).

[16] Bessède J. L .*Eco-Design in Electrical Engineering.* Springer International Publishing AG, Cham, Switzerland, 2018.

[17] **** Romanian Government Decision no. 1043/2007 on eco-design requirements for energy-using products.* The Official Gazette of Romania, 12.09.2007. (In Romanian).

[18] Pralea ,J. *Ecological materials used in eco-design*. (In Romanian*)* Available at www.academia.edu (accessed 12.06. 2019).

[19] Amza, G. *Eco-technology.* Printech, Bucharest, 2007.(In Romanian).

[20]). Vasilescu,E. *Eco-design of processes in materials engineering.* AGIR Bulletin, no.1, 2017, pp.166-170. (In Romanian).

[21] Tsutsuianu,O. *Environmental Perfor-mance Indicators into Maintenance Activity of Industrial Equip-ments.*`„*Calitatea, acces la success"*,["The quality, access to success"-Romanian Magazine] 2015, vol.16, no.144, pp.91-93 (In English).

About author.

Ovidiu Tsutsuianu – PhD, National Romanian National Council on Energy.
Research interests: energy, the overwhelming environment.
E-mail: ovidiu.tutuianu@gmail.com