# ENVIRONMENTAL MANAGEMENT IN DESIGN PROCESS OF MACHINERY

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Nowadays more and more intense discussions of professionals are carried out; they are focused on the issues of global warming. One of the latest documents in the fight against the climate change is the New Global Climate Agreement approved during the Climate Conference in Paris in December 2015. Although the signed agreement does not stipulate any timetable or particular targets for individual countries, it is nevertheless considered to have its impact on the individual spheres of economy, for which there are currently no mandatory environmental requirements. These results in the fact that the existing measures are not sufficient to achieve the objective of 40% reduction in greenhouse gas emissions by 2030 compared with 1990, to which the European Union has already committed itself [EC 2015]. Other measures thus may relate primarily to heavy industry, specifically to the area of machinery, which belongs among large energy consumers [Iskandirova et al. 2014]. The present article covers the assessment of environmental impact of greenhouse gas emissions on designing the machinery. The article describes a proposal of methodology for evaluation of emissions of greenhouse gases released in the production of engineering materials.

**KEYWORDS**

emission of greenhouse gases, design process, engineering material, machinery, Life Cycle Assessment

## 1 INTRODUCTION

Activities devoted to a climate change have been held regularly since 1985 when, under the auspices of the United Nations, the Vienna Convention was adopted. Its purpose was to protect human health and the environment from the adverse effects of ultraviolet radiation (UV-B and UV-C), which penetrates to the Earth via a weakened layer of ozone in the stratosphere (i.e. the ozone hole) [EEC 1988]. The first international treaty to the UN Framework Convention on Climate Change, which outlines the obligations of the Parties to reduce greenhouse gas emissions, is the Kyoto Protocol signed in 1997. The Protocol entered into force on February 16, 2005 and the industrial countries committed themselves to reduce greenhouse gas emissions by 5.2% compared to the year 1990 [UN 2002]. Independently developed by the European Union (hereinafter EU) is an internal objective of achieving a 40% reduction in greenhouse gas emissions by 2030 compared to 1990, where EU committed itself to the policy in the field of climate and energy in 2014 [EC 2014].

A turning point in the fight against the climate change occurred in December 2015 in Paris where the Climate Conference approved a new global agreement on climate change, which was approved by nearly 200 countries worldwide. The agreement applies to all countries of the UNFCCC (Framework United Nations Convention on Climate Change) and obliges them to reduce greenhouse gas emissions at a level that would maintain the global temperature rise by the end of this century below 2°C against the mean long-term monitored temperature. In the second half of this century it will be sought to achieve a balance between the greenhouse gases emitted into the atmosphere and the greenhouse gases removed from the atmosphere and deposited e.g. underground. Thus, the net increase in greenhouse gases in the atmosphere should be zero in the future. [EU 2016]

According to the report of the European Commission, there is a 23% reduction in emissions compared to 1990, and in 2030 this figure will reach only 27%. Therefore, the existing measures are not sufficient to achieve the 40% target, and their expansion is required to those fields of economy, for which there were no mandatory requirements related to the economical attitude towards the environment [EC 2015]. Currently, there is a mandatory environmental legislation in the transport and building industry. Given the above, it can be expected that similar criteria will have to be met by other industries, particularly machinery. The reason for the formation of mandatory environmental legislation in the field of machinery is a high consumption of energy and a great potential to reduce greenhouse gas emissions in this field. [Huzlik et al. 2014]

Current legislation sets no specific limits of GHG emissions for the respective products. However, manufacturers should consider the entire lifecycle of the product and create an environmental profile of the given product, which will indicate the estimates of GHG emissions. This assessment should subsequently be used by manufacturers in the evaluation of alternative product designs when upgrading. Choosing a product design should be realized based on the optimal ratio of environmental aspect in relation to other aspects (e.g. technical or economic).

However, determining the environmental burden throughout the lifecycle of the machinery is quite complicated because it is necessary to collect a large amount of data and to apply a specific evaluation procedure which is not currently available. In this article, we proposed a methodology for determination of GHG emissions produced during the manufacture of basic engineering materials, which largely determine the environmental profile. These issues are described in detail in the dissertation thesis of the author of this article.

## 2 IMPACT OF DESIGN PROCESS ON THE ENVIRONMENT

Lifecycle of machinery can be divided into three basic phases: production (mining of raw materials, manufacturing of materials, manufacturing of the product itself), operation (use and maintenance of the product) and removal (removal of the product from the operation and its potential reuse, renovation or recycling). Each of these stages has an impact on the environment. During the production phase, GHG are emitted as a result of generation of electricity needed e.g. for processing of raw materials, production of materials and machinery itself, burning of fuel through the operation of mining and transport equipment. During the operation of machinery, the environment is affected by GHG emissions produced by electricity generation necessary e.g. for the operation of the equipment, its maintenance and the production of operating consumables (operating fluids). The stage of removing the machinery from operation brings about an environmental burden as a result of fuel burning by waste storage facility for ground disposal and also by electricity generation needed for renovation or recycling of machinery. The overall impact of machinery on the environment throughout its entire lifecycle forms an environmental profile of machinery [Iskandirova et al. 2013].

Fig. 1 shows the lifecycle of the machinery and its impact on the environment.

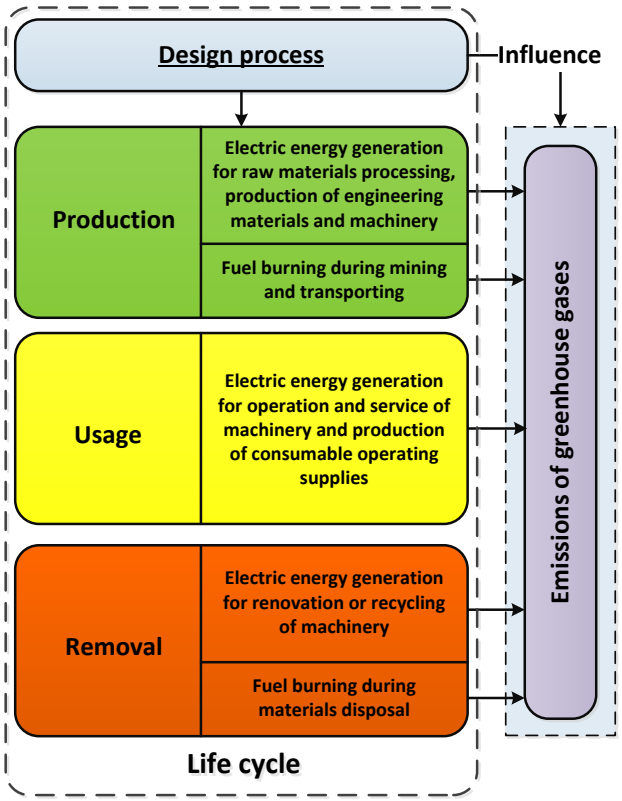


**Figure 1.** Lifecycle of the machinery and its impact on the environment

The ecological profile of the machinery initiates as early as in the phase of its design with determination of parameters and functions of the future facility, its operating conditions and consumable operating materials and also the materials that will be used in the design of the facility. Defining the measures associated with a reduction in environmental pollution must be therefore implemented during the design process. [Auguste et al. 2013]

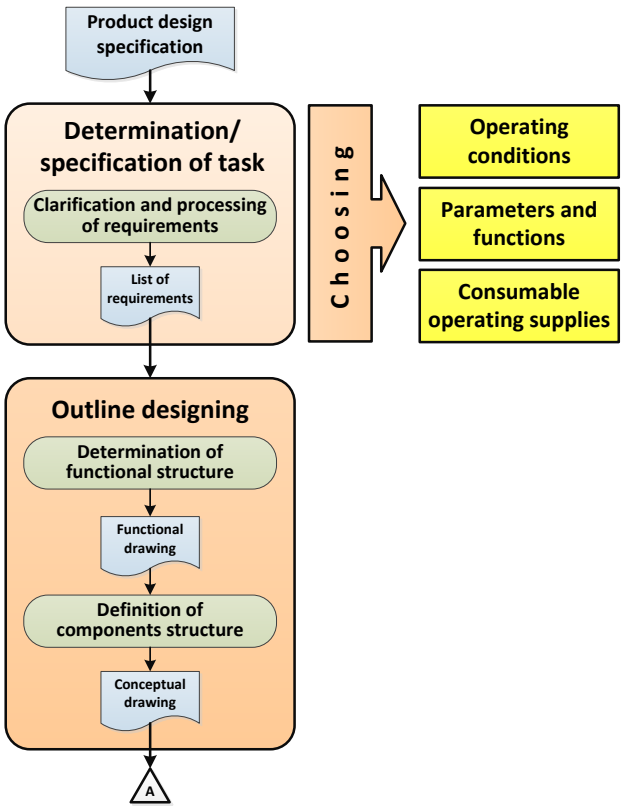


**Figure 2.** Design process of machinery [Blecha 1999]

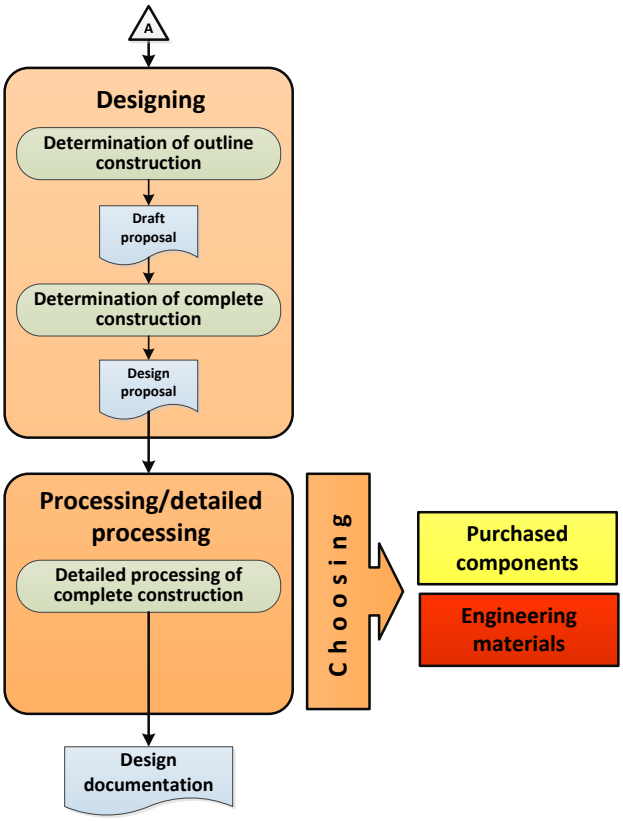


**Figure 2.** Design process of machinery [Blecha 1999] (to be continued)

From the diagram, it is evident that during the first phase of design process "Defining and clarifying of requirements" the approval of requirements for machinery is in progress. During this phase, parameters and functions of future machinery, the operating conditions and the required operating materials are selected. This phase is the first step towards establishing the ecological profile of machinery. The following phases are devoted to a gradual fulfilment of the requirements for machinery by designing and clarifying of its parameters. The last phase of detailed processing of machinery design is a choice of machinery components to be purchased and the materials that will be used for manufactured components. Any selection (parameters and components of machinery, materials, country of production, operating conditions) done during the design process is characterized by a certain amount of energy and raw material resources needed for its implementation, and thus there is a certain impact on the environment.

In terms of impact on the ecological profile of the machinery, the most important parameter of machinery design are the used engineering materials. Their production has relatively large demands on raw materials and energy. In addition, the used materials influence the parameters of the machinery, the conditions of its operation and disposal options.

Fig. 3 shows the influence of engineering material selection on the environment.

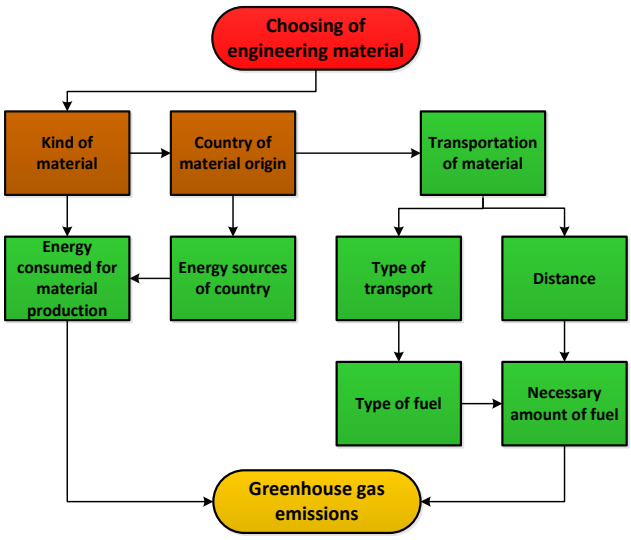


**Figure 3.** Influence of engineering material selection on the environment

When choosing the materials, the choice of both the material itself (material kind) as well as the country where the selected material is produced and wherefrom it will be transported. A selection of certain kind of material affects the environmental pollution by GHG emissions produced through generation of the required amount of energy that corresponds to the energy consumption needed for production of the selected material. When selecting the country of production of the respective material, pollution in the form of greenhouse gas emissions depends mainly on the energy sources mix of the selected country. Each country uses certain energy sources to generate electricity, mostly based on the availability of raw materials, natural resources and the development of transport infrastructure in the country. Electricity consumed for the production of selected material produces, during this process, a certain quantity of greenhouse gases, depending on the sources wherefrom it is generated. The produced material must consequently be supplied to its destination (country), where it will be used to manufacture the component. This is a selection of available type of transport, which will be a basis for the type of fuel used and therefore also the type and amount of emissions produced. Also, the amount of emissions depends on the distance of the respective point (country) of material production from the point (country) of its use for the component production. Ultimately, this determines the amount of fuel needed to transport the material.

## 3 METHODOLOGY FOR DETERMINATION OF GREENHOUSE GASES

The process of machinery environmental assessment starts with setting the goals and scope of the assessment, during which the desired depth and accuracy of assessment are specified, and also the purpose is defined for which the assessment is conducted (for internal purposes, to inform customers, etc.).

In the second step, in the case that the design of the assessed machinery comprises the purchased components, its inventory analysis is carried out. In the analysis, it is necessary to find out whether there are EPD declarations for the purchased components supplied by the manufactures of these components. In the case of delivery of EPD declaration by the manufacturer, it is not required to conduct the assessment of greenhouse gases emitted during the manufacture of the component, since the EPD already contains the data on the product impact on the environment in the form of emissions released to water and air. Collected data from the declaration shall be recorded in the technical report in the form of kinds, amount and the country of origin of components production, which determines the distance and kind of transport, as well as the information about the resources that were exploited in drawing up the declaration.

In the case that the EPD declaration is not available for the purchased component, it is necessary to conduct an assessment of its environmental impact based on the materials contained in its design. The results of the inventory analysis of materials shall be recorded in the technical report. The same procedure must be applied to any components that are produced in the organization conducting the environmental assessment. The inventory analysis of materials is carried out on the basis of design of the considered machinery.

For evaluation of GHG emissions released through the production of engineering material, it is necessary to create a production model of this material (see Fig. 5). In the case that a EPD declaration has been issued for the assessed material, it is not necessary to create a production model. The process of creating the production model is based on the detection of key operations (production of substances, use of energy and transportation means), which constitute the process of material production, and quantities of final product (substance, electricity, fuel) required to obtain the required quantity of engineering material. For this creation, data are needed about the technology of material production available from the manufacturer or from data sources.

The process of creating the production model of material is followed by the process of determining the necessary data on emissions of greenhouse gases released through operations used in the production of the considered material. These data should be the most recent; therefore, prior to the assessment, their update is necessary.

After preparing the necessary data, the evaluation is carried out of greenhouse gas emissions associated with the production model of material. Some data sources already contain the values of greenhouse gases emitted during the production of materials. In this case, the emission data shall be recorded in the technical report. In the case that data on emissions of the assessed material are not available, it is necessary to assess this material on the basis of emissions produced by manufacturing of individual components of the material. If this information is not available, the assessment can be based on the overall energy consumption throughout the manufacturing process or the energy consumption throughout the manufacture of the individual components of the material.

The last option for determination of GHG emissions produced during the manufacture of the material is their estimate using the value of emissions produced through the manufacture of a similar material or energy consumption throughout its production. Provided that it is not possible to determine the greenhouse gas emissions for the material by any of these methods, the material can be excluded from the assessment. However, this decision must be duly justified (e.g. low share of the material in the design of machinery) and shall be recorded in the technical report. If the exclusion of the material is not justifiable, it is necessary to return to the phase of determining the necessary data for the calculation of GHG emissions.

Consequently, it is necessary to calculate the GHG emissions produced during transportation of the material or component (purchased components with EPD) from the point of production to the point of use. After determining the emissions of all assessed materials, GHG emissions produced throughout

manufacture and transportation are added up. If the evaluation of the machinery design proposal is performed with the aim to determine the optimal design, then it is necessary to compare individual design proposals of machinery on the basis of the previous technical reports.

A scheme of the above described methodology for estimating GHG emissions associated with the design proposal of machinery is shown in Fig. 4 below.

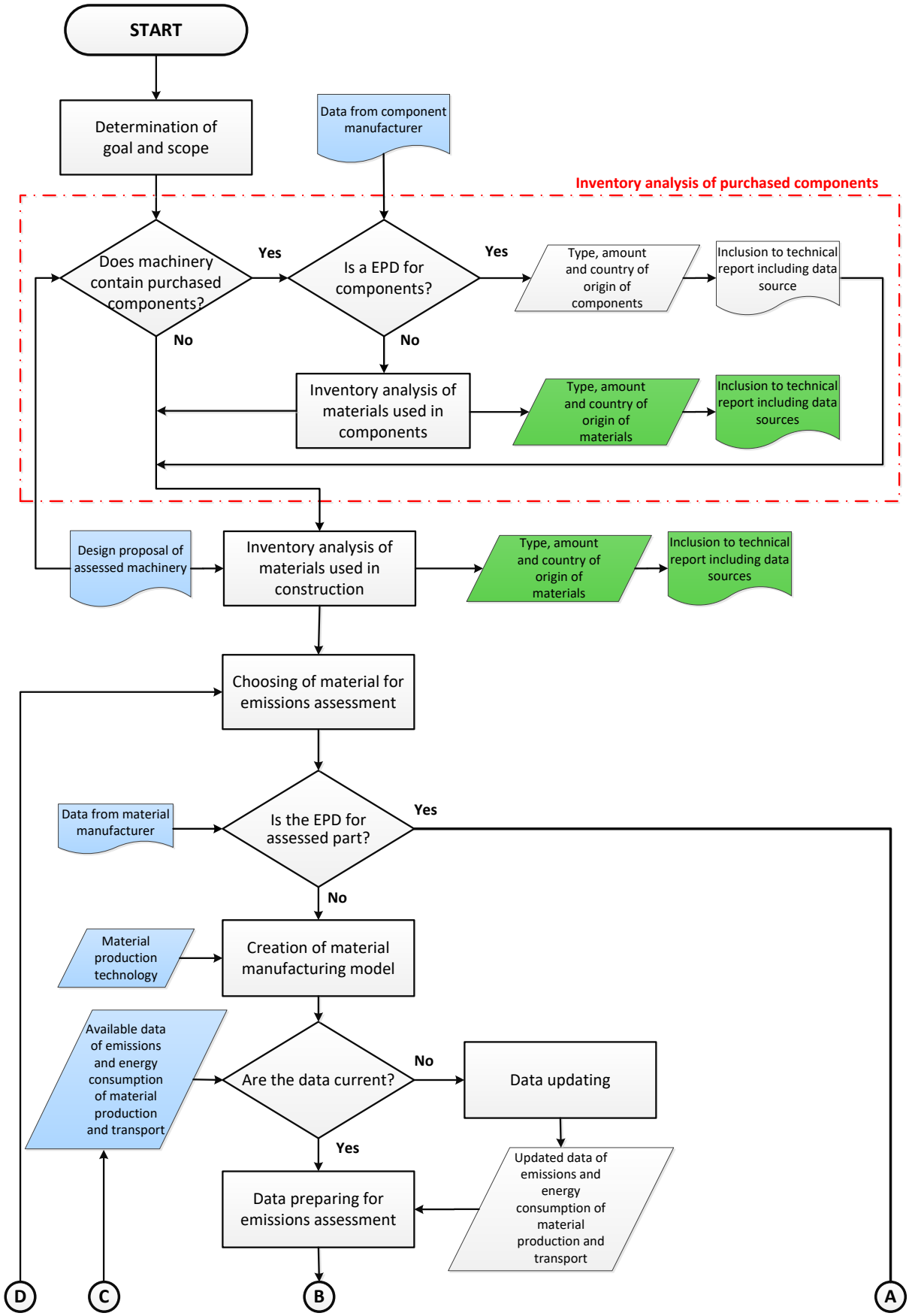


**Figure 4.** Methodology for assessment of GHG emissions released throughout production of engineering materials

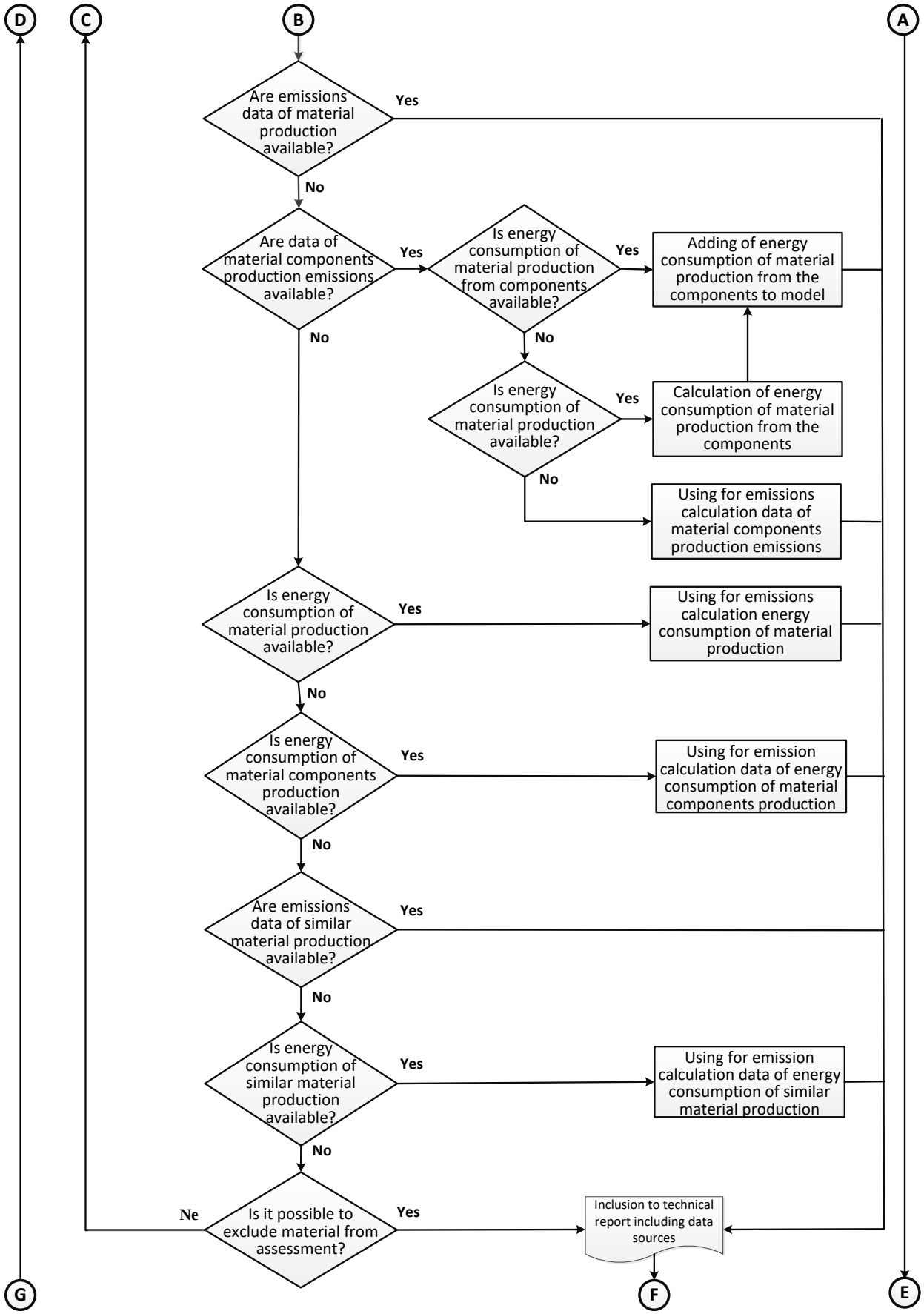


**Figure 4.** Methodology for assessment of GHG emissions released throughout production of engineering materials (to be continued)

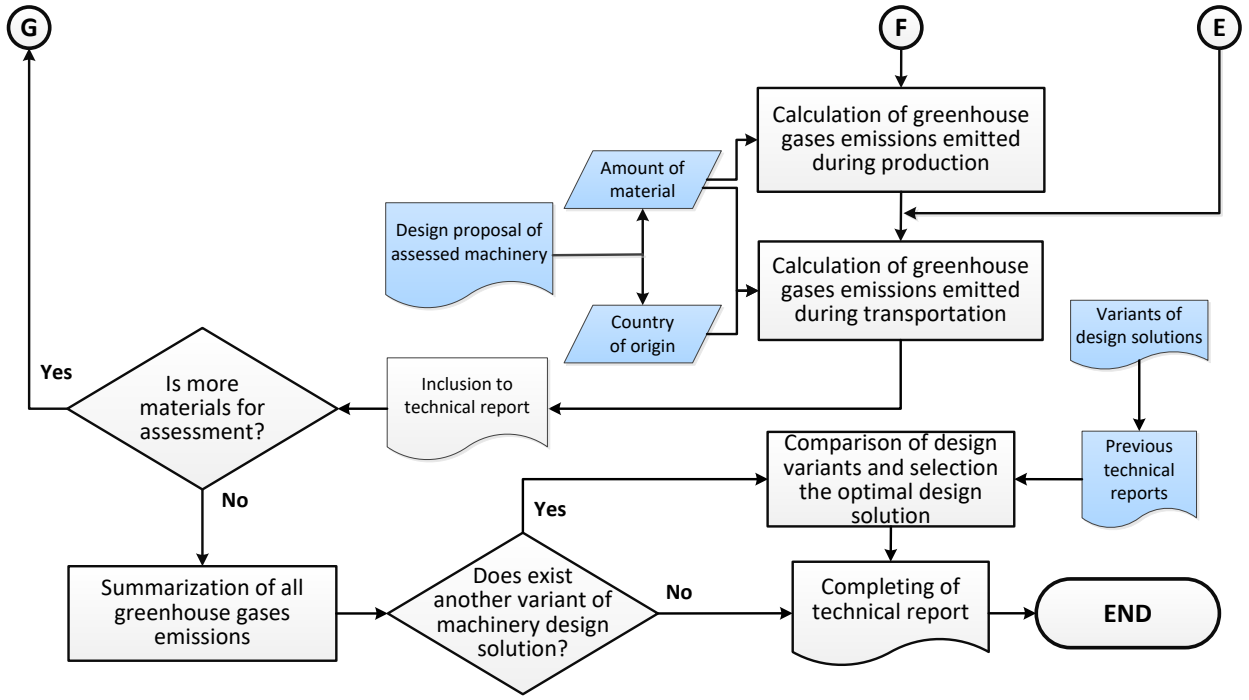


**Figure 4.** Methodology for assessment of GHG emissions released throughout production of engineering materials (to be continued)

## 4 CONCLUSIONS

The present article deals with a system analysis of the impact of the design process of the machinery on the environment. As a parameter that seems to be the most environmentally detrimental were identified materials used in the design of machinery. Based on the above conclusions, a methodology was drawn for estimation of GHG emissions related to the materials used in the design of the machinery.

The drawn methodology can be used by machinery manufacturers for evaluation of individual design proposals of the machinery and the selection of its optimal variant. Manufacturers have the opportunity to already meet the optional requirements arising from the self-regulation of the market and customers' behaviour, and to gradually prepare themselves for compliance with the environmental requirements, which will undoubtedly be obligatory in the near future.


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