European Association for the Development of Renewable Energies, Environment and Power Quality (EA4EPQ)

International Conference on Renewable Energies and Power Quality (ICREPQ'12)
Santiago de Compostela (Spain), 28th to 30th March, 2012

Remodelling of the heating systems of a sports centre based on life cycle assessment. Part I: Boiler replacement.

I. Oribe-García[1], A. Alonso-Vicario[1] and A.M. Macarulla-Arenaza[1]

[1]Deusto Institute of Technology – DeustoTech Energy
University of Deusto
Avda. de las Universidades 24, 48007 Bilbao (Spain)
Phone/Fax number:+0034 94 413 90 00, e-mail: iraia.oribe@deusto.es, ainhoa.alonso@deusto.es, ana.macarulla@deusto.es

Abstract.

Based on existing installations of heating and cooling of the municipal sports centre of Ordizia (Spain) and its operating data, the remodelling of these facilities has been discussed according to new regulations.

In order to facilitate decision-making reform of the facilities, this will be approached from eco-efficiency criteria, i.e. taking into account not only the usual economic and technological criteria (business as usual-BAU), but also integrating the concept of life cycle analysis (LCA) of the installation, allowing therefore to analyze the environmental impact prior to its implementation.

The comparison between two types of boilers, the current diesel one and a high performance natural gas equipment, is presented in this first part. In both cases, the major impact has been found during the use stage compared with the stages of construction and dismantling, due mainly to the use of fuel. Thus, the used fuel has great influence on environmental impact, resulting to be the natural gas boiler the best option.

Key words

Renovation of facilities, Life Cycle Analysis (LCA), renewable energy, natural gas, environmental impact.

1. Introduction

In recent decades, due to economic development and the intese human activity, mankind has led to uncontrolled consumption of natural resources, causing air pollution and depletion of the resources. In many cases its consequences, besides altering the ecosystem, are harmful to human health and make significant loss of quality of life in some areas. Despite the depletion of fossil fuels, future projections show that the energy demand, in the short term, will be supported largely by them, with the consequent increasing of CO_2 emissions and other harmful gases into the atmosphere. Consequently, a series of ecological changes come up with adverse effects.

According to the Intergovernmental Panel on Climate Change (IPCC), about 69 % of all CO_2 emissions are energy related, and about 60 % of all GHG emissions can be attributed to energy supply and energy use [1]. Reduction in CO_2 emissions can be achieved directly via increased efficiency, reductions in the fossil fuel component of the energy mix and the introduction of alternative energy sources [2]. So, environmental degradation is a fact to which, attitudes towards consumption, and other production processes in a perspective of energy and natural resources optimization should be rethinked.

Design for Environment, is a general concept that focus on different approaches of design, which aim is to reduce the environmental impact of a product or process along its all life cycle. Life Cycle Assessment (LCA) is one of the most remarkable contribution of the Design of Environment, which is used to identify, quantify and characterize the different potential environmental impacts associated with each of the stages of product/process life.

In this paper, LCA has been used as decision support tool in order to redesign the installations of the municipal sports centre of Ordizia (Spain). The energy consumption associated with the operation of any sports facility is very large mainly because the requirements in the environmental conditions of temperature and humidity in the air are very demanding, in addition, the pool water must also be heated and there is a very high consumption of domestic hot water (DHW), especially in the showers.

So, the firm that operates the sports centre takes on the remodelling of their heating facilities because the current

ones are obsolete and inefficient, requiring an urgent global new design and remodelling (boilers, pipes, valves, switchboard,...).

Taking into account the ideas outlined above, and prior to the remodelling, different alternatives have been evaluated in order to choose the one that best suits to the sports centre needs and the objectives of the company operator, under economic, ergonomic and environmental criteria.

According to literature, natural gas is the fossil fuel with the lowest environmental impact associated to the extraction, manufacturing, distribution and usage steps [3]. Therefore, in this work and as first step of the remodelling, Life Cycle Analysis (LCA) has been used in order to support the decision to replace the actual diesel boiler by a new gas natural one.

2. Description of current situation

Before describing the two proposals submitted for analysis, a brief description of all the sports facilities before remodelling is presented.

The sports centre consists of the facilities of three different buildings: indoor pools, fronton and sports halls.

A. Indoor Pools

The air conditioning installation of the indoor swimming pools and DHW heating is performed with two diesel boilers. Likewise, these boilers are used for heating the indoor environment, which is also equipped with a dehumidifier. Changing rooms and the sauna have another two air conditioners.

B. Fronton

It is provided with an electric kettle for heating water, a storage tank and a heat exchanger.

C. Sports Halls

This building has three natural gas boilers for environment warming and DHW.

3. Scenario definition

In this work, the replacement of the fuel used for thermal demand has been subjected to study. Therefore, the proposal studied can be summarized as a comprehensive reform of the boiler room of the swimming pools, replacing diesel boilers by high performance natural gas equipment, which carries all the elements associated with this new situation (Cabinet regulation gas, power line, etc) and the replacement of all piping, appropriately lagged, valves and safety features, replacement of the electrical panel, inertization of the old fuel tank and its transfer to treatment plant.

4. Methodology

The LCA studies use a very specific methodology that passes through four main steps:

- *Goal definition and scope of the study:* Define the context in which the assessment is going to be made and identify the boundaries and environmental effects to be reviewed for the assessment.
- *Inventory:* Identify and quantify energy, water and materials usage and environmental releases (e.g., air emissions, solid waste disposal, waste water discharges).
- *Impact assessment:* Assess the potential human and ecological effects of energy, water and material usage and the environmental releases identified in the inventory analysis.
- *Interpretation of results:* Evaluate the results of the previous stages to select the preferred product, process or services with clear understanding of the uncertainty and the assumptions used to generate the results.

In this paper, the study has been carried out with the software SIMAPRO 7.3, developed by *Pré Consultants* according to the recommendations of ISO 14040-44, so that the latest data available in the literature have been used previously adapted to the geographic area and the particular characteristics of the system.

5. Results

A. Goal definition and scope of the study

The study aims to assess and quantify the environmental impacts of the proposed scenario for power generation in the sports facilities in order to select the most accurate one from an environmental standpoint: Reform of the boiler room evaluating fuel switching from diesel to natural gas.

kWh has been defined as the functional unit for the scope of the study, given that it is a well-defined and measurable unit and can be used as a reference for the inputs and outputs, ensuring that the comparison of the systems is carried out according to a common baseline.

The process of converting fuel into electricity is rather similar for all types of fossil fuels [4]. However, in the overall impact of the exercise, the type of fuel and the boiler are also important. Therefore, in this work the manufacturing of boilers and the fuels have been taking into account in order to compare the behaviour of the two boilers.

LCA is limited to the implementation of the proposed scenario, extending it from the extraction of the materials, passing through the manufacture of the devices, their transport to the distributors, their installation and finally to the dismantling of the boilers.

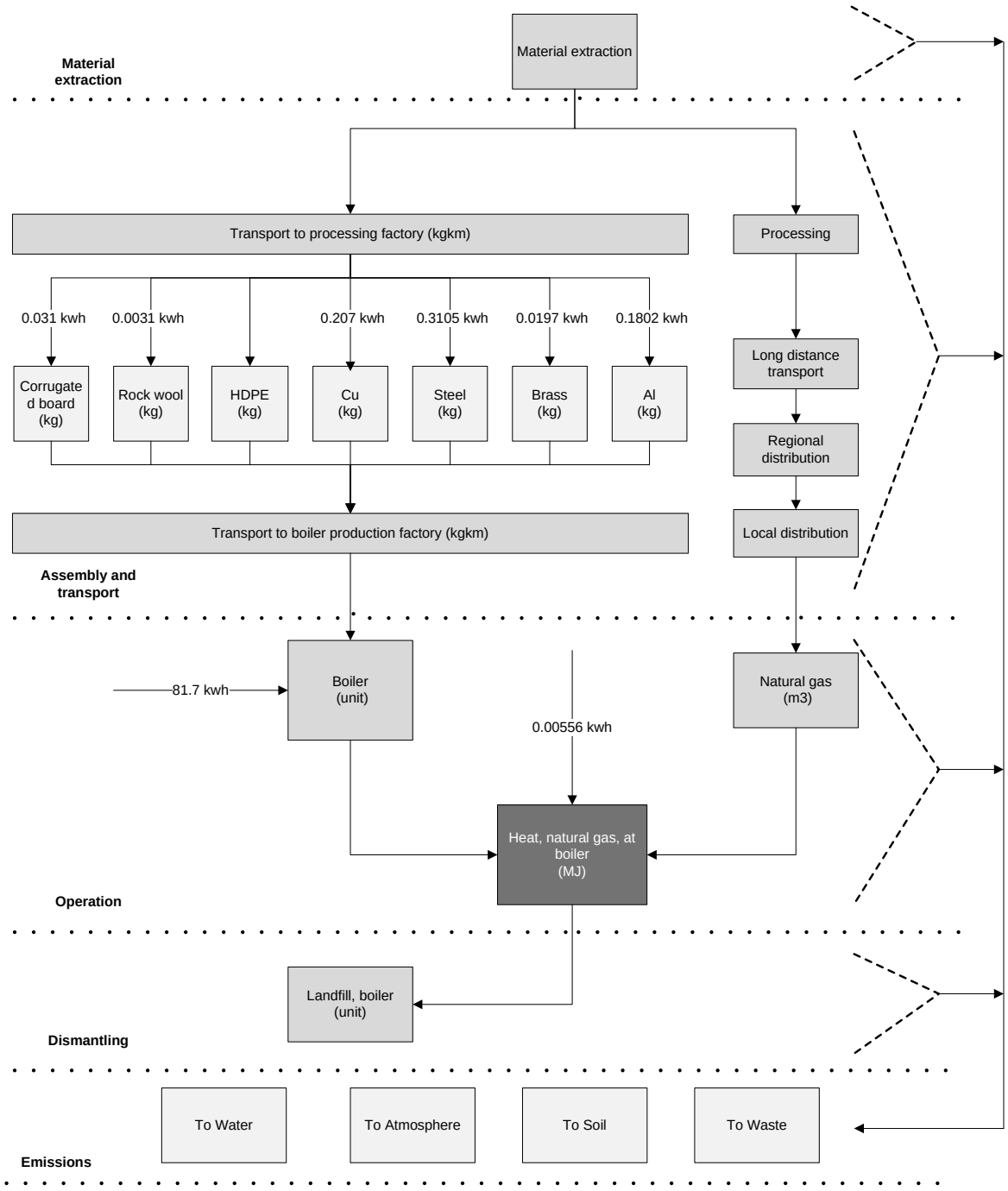

Fig. 1. LCA study structure.

The fuel consumption in a calendar year, together with its extraction, distribution and transportation is also included. The boundaries of the system, outlined in Figure 1, have been chosen according to literature [5, 6].

B. Inventory

This stage consists of the data collection for the quantification of inputs and outputs of matter and energy of the system. The impact of fuel has been modelled using the steps specify in Figure 1.

Assuming that diesel and gas boilers are of similar capacity and require the same energy for their manufacture, a procedure including the details of their manufacture, packaging and delivery, and its final destination has been followed. The main difference lies in the type of steel used.

The data used for this study have been taken from the information provided directly by suppliers, Ecoinvent database version 2.1 and literature [7-8].

C. Impact Assessment

The method used in the evaluation of the impact has been CML 2000 [9]. The categories taken into account for this study, are: abiotic depletion (AD, kg Sb eq), global

warming (GW, kg CO_2 eq.), ozone depletion (OD, kg CFC-11 eq.), toxicity (T, 1.4-kg DBeq.), photochemical oxidant formation (PO, kg NMVOC), acidification (AC, kg SO2 eq), eutrophication (EU, kg PO4- eq)which contribute to the environmental impact on air, water and soil or can directly affect human health. Factors related to the depletion of water and various raw materials, as well as fossil fuels, have also been included.

In Figure 2, it can be seen characterization results of the two heating system.

D. Interpretation of Results

The interpretation of the quantitative analysis of the results has been performed in order to obtaine the main conclusions for the decision-making about what reform to address.

From the results obtained in the characterization phase, and as it can be observed in Figure 2, it can be concluded that in general speaking, diesel boiler shows the highest environmental impacts. As can be seen, GW is reduced by 15%. The reason for this reduction is based on the high H/C relation in its molecules.

On the other hand, it can also be seen, how AC impact category is reduced by 60%. This is because natural gas has sulphur content below 10ppm, so the emission of SO_2 in the combustion phase is smaller than other fuels.

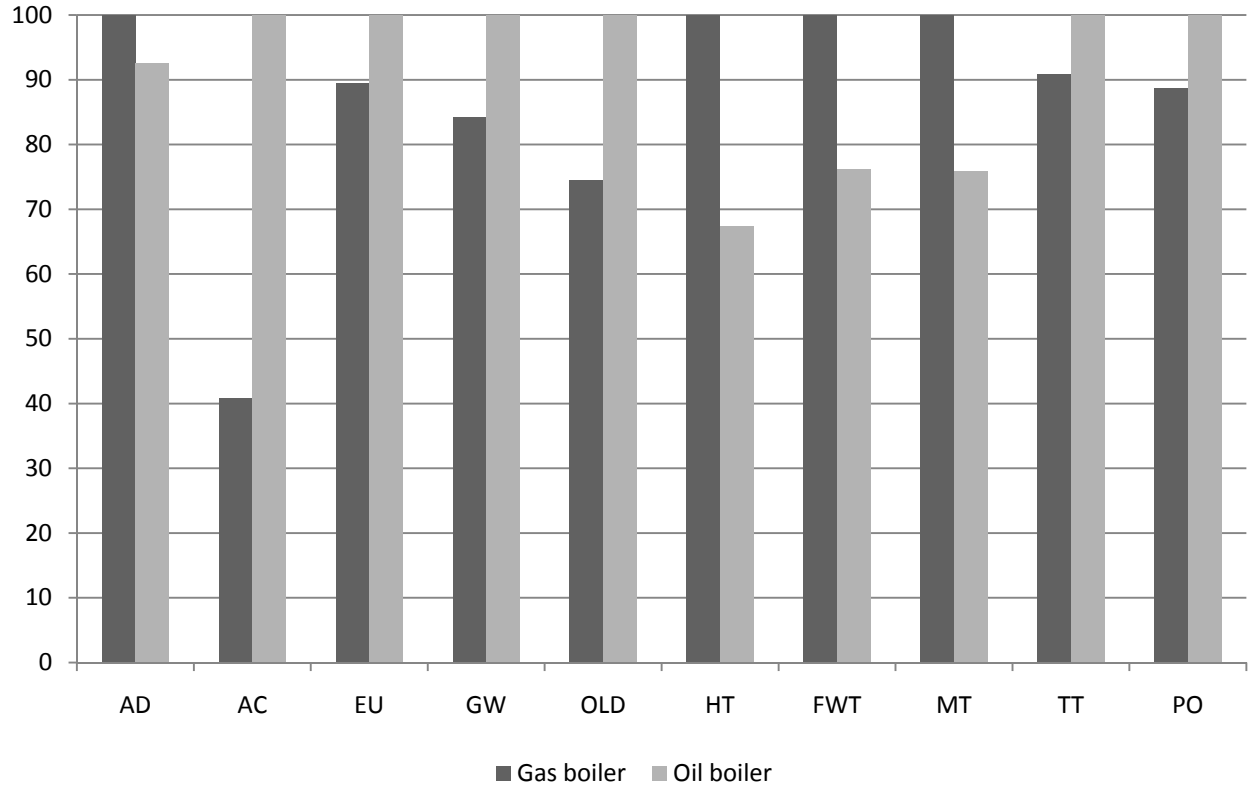

Fig. 2. Characterization of the impact of the boilers.

The normalization step enables to state that in both cases the major impact is over the marine aquatic ecotoxicity, followed by abiotic depletion and global warming, which are mainly due to the use of fuels, as shown in Figure 3 for natural gas boiler. These results conclude that the fuel replacement reduces the environmental impact of the sport installations.

Additionally, it is important to analyze which phase of the life cycle (construction, operation, and dismantling) is responsible for the higher impacts for their minimization.

As illustrated in Figure 3, the mayor environmental impact is obtained in the phase of operation. In the construction phase it has only been taken into account the manufacture of the boiler, not including the necessary infrastructure for the supply of natural gas. The dismantlement phase is the lowest harmful one in comparison with those of construction and operation. In fact, dismantling phase (barely perceptible in Figure 3) is less than 1% of the total impact, whereas the operation and assembly phase account for 88% and 11% respectively.

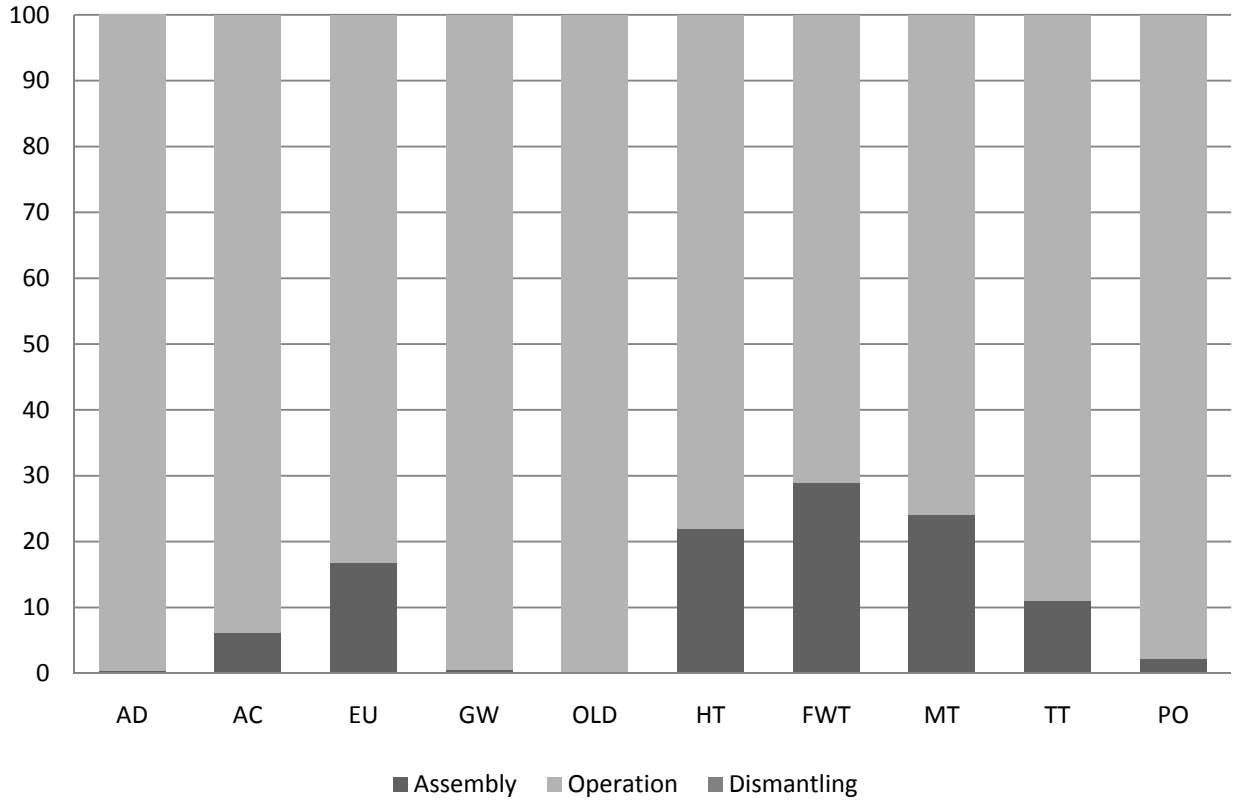

Fig. 3. Contribution of construction, use and dismantlement phases for the gas natural boiler.

6. Conclusions

The results of this study demonstrate that, by analyzing the situation in depth, reduced environmental impact may well be accompanied by an improvement in terms of use, as well as significant reductions in operating costs, most directly associated to energy consumption.

The remodelling of the installation provides significant improvements from the ergonomic point of view, especially by improving the water temperature in all services. The new alternative provides also a reduction in operating costs, specifically by improving the efficiency of the new installation. But the main advantages are derived from the conclusions obtained from the environmental impact assessment:

- The analysis allows to know which of the stages generates more impact, in this case is the use stage
- Fuel switching reduces remarkably the greenhouse gas emissions
- The natural gas boiler has less impact in most categories

Acknowledgement

The authors express their gratitude to Ingeriketa Lantzen, S.L. for allowing us to develop and present this work. The contributions of Iñigo Goitia and Mikel González to this paper are also gratefully acknowledged.

References

[1] Climate Change 2007: Synthesis Report. IPCC, Geneva, Switzerland, 2007.

[2] A. Midilli, I. Dincer, “Hydrogen as a renewable and sustainable solution in reducing global fossil fuel consumption”. Int J Hydrogen energy, 2008, 33, pp 4209-4222.

[3] Gas Natural y Medio Ambiente - El Gas Natural - Energía - Ministry of Industry, Tourism and Trade. Available at: http://mityc.es/energia/gas/Gas/Paginas /gasnatural.aspx.

[4] E. Lazi, E. Verdolini and I. Hascic, “Efficiency-improving fossil fuel technologies for electricity generation: Data selection and trends”, Energy Policy, 2011, 39, pp 7000-7014.

[5] N. Jungbluth, “Life cycle inventories of energy systems: oil”, Ecoinvent, 2007, pp 14-24.

[6] M. Faist, N. Jungbluth, “Life cycle inventories of energy systems: natural gas”, Ecoinvent, 2007, pp 25-46.

[7] R. Dones, C. Bauer, R. Bollinger, B. Burger, T. Heck, A. Röder, “Life Cycle Inventories of Energy Systems: Results for Current systems in Switzerland and other UCTE Countries”. Ecoinvent, 2007.

[8] M. Díaz, A. Rezeau, D. Maraver, F. Sebastián, J. Royo, “Comparison of the Environmental Impact of Biomass and Fossil Fuels Medium-scale Boilers for Domestic Applications Employing Life Cycle Assessment Methodology”, in Proc. 16th European Biomass Conference & Exhibition, Spain, 2008.

[9] CML-IA Software and data. Leiden University. Available at: http://cml.leiden.edu/software/data-cmlia.html.