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Reduction of greenhouse gas emissions resulting from decreased losses in the conductors of an electrical installation

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ABSTRACT

The activities of the electricity sector in production and consumption have implications in almost all environmental problems of today. The main environmental impacts occur during the production of electricity, mainly due to the emission of air pollutants, which is directly linked to climate change that has been observed over time. Ambitious climate change mitigation requires significant changes in many economic sectors, in particular in the production and consumption of energy. Considering that the primary energy consumption has increased, doubling since the 1970s, and in particular the consumption of electricity has had a sharper increase, nearly quadrupling in the same period, all measures that can mitigate environmental impacts on both the supply and demand sides of electricity are of interest. This paper introduces a new software application that analyses efficient investment in street lighting and industrial and domestic electrical equipment, accounting for the reduction of losses in the conductors of electrical installations, which is usually neglected. It also determines the reduction of CO_2 emitted into the atmosphere, which contributes to the reduction of emissions of greenhouse gases from a country or particular product.

1. Introduction

The greenhouse effect is the action that controls and maintains a constant temperature of the earth. This control is regulated by the amount of certain types of scattered gases – carbon dioxide, methane, and nitrogen oxides, among others – known as greenhouse gases (GHGs). When the concentration of these gases in the atmosphere increases considerably, it also increases the average infrared radiation that is retained in the atmosphere, causing various climatic changes, among them, very worryingly, the global warming confirmed by the scientific community.

The use of electrical energy, from production to consumption, during transportation and distribution has implications for almost every major environmental problem nowadays, especially regarding the emission of GHGs into the atmosphere. The electricity sector is responsible for a large portion of GHG emissions, which occur directly in the act of generating electricity, especially from fossil fuels in thermoelectric plants and indirectly in the extraction, transportation, and processing of fuels and raw materials used in the plants' production of electricity from thermoelectric or renewable energy.

If, on the one hand, the production of electricity releases GHGs into the atmosphere, contributing to climate change, and, on the other hand, climate change influences the production of electricity in particular, the use and planning of new power generation plants should be based on the implications of these changes.

In this complex relation and interconnection of influences, various studies have been developed. The influence of climate change on energy production has been the subject of study of various sources, in particular renewable energy sources, which are more vulnerable due to its dependence on weather and climate. For instance, impact of climate change in general on wind power [1], on the water used in nuclear power plants [2] and on the production of hydroelectricity [3], or in specific regions such as the analysis of the vulnerability of wind power to climate change in Brazil [4].

A review of the vulnerability of the energy sector to climate change, in terms of its various aspects, from production, transportation, distribution, and use to energy demand, is presented in [5].

If the long-term concerns regarding the vulnerability of the energy sector to climate change cannot and should not be ignored

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in the present, the influence of the electric sector on the present climate change also cannot be ignored, because the power sector is responsible for a significant part of GHG emissions. In this context it is important to quantify greenhouse gas emissions by developing electricity technology and influencing the decision making of economic and political agents that allow the effective reduction of GHG emissions into the atmosphere.

Quantification is difficult and not always coincident; it depends on the methods of calculation and encompassed components. If only the gas in the central production is counted, the value found is very different from what it might be if we include indirect influences upstream and downstream in order to make an assessment of the lifecycle. It may reach 25% for fossil fuel technologies and 90% for renewable energy technologies [6]. Various studies and methods were analyzed to quantify the direct and/or indirect emissions of GHGs due to the production technology used for coal plants, natural gas, nuclear, biomass, photovoltaics, compiled and explained to the various technologies of electricity and its life cycle in the case of Greece [6–10].

Environmental component uncertainties are very high due to the complexity of the web of relations between natural systems and the various methods of energy production that constitute the electrical systems of a country or geographical region. Various methods can be used in the calculation of GHGs concerning electrical system gases, taking into account the production of electricity or its consumption, resulting in different values [11,12]. Knowing that consumption does not always coincide with the production in the respective country, we have to consider the losses, imports, and exports.

The quantification of emissions is important, as well as the limitation of emissions of GHGs by international laws and protocols, leading to emission reduction, is increasingly relevant and is the object of study.

The electricity sector differs significantly from many other energy sectors, since electricity cannot be stored as such and therefore it is consumed at about the same time as it is produced. The control and reduction of CO_2 emissions involves:

- Reduction of emissions at source through more efficient conversion of fossil fuels (China, for example, the world's largest consumer of coal for electricity generation, could use about 20% less coal if its plants were as efficient as the average in Japan).
- Increasing the use of renewable fuels or decarbonisation of fuels.
- Measures to manage demand and production, environmentally and economically efficient dispatch [13,14], and impacts of distributed generation on the operational characteristics of networks [15].
- Reduction of power consumption in terms of distribution structures and transport at the level of efficient use, such as dimensioning the section of cables to reduce energy consumption and optimizing operating distribution systems [16–18].
- Reduction of distribution losses by reducing reactive power optimization with capacitors placed in the distribution lines [19–21], layout optimization for radial distribution [22], use of superconducting power transmission [23,24], and development of efficient and sustainable electrical equipment, in particular industrial induction motors [25–27], which are responsible for a large share of electricity consumption, as well as efficient lamps [28–32] for industrial and domestic use.

In order to reduce the energy consumption in a domestic or industrial installation, the efficiency of real loads and all losses in the cables of the installation should be thoroughly studied to improve the energy efficiency. Indeed, energy efficiency and reduction of consumption in electrical installations and equipment represent an important line of research, as the decrease in consumption affects the entire energy system and the reduction of greenhouse gases occurs along the entire production chain.

Hence, this paper provides consumers and managers with a new software application that allows them to compare options and choose the best investment in the acquisition and installation of electrical equipment, aiming for both efficiency and sustainability. Three research aspects are connected in an original way: the influence of equipment and the losses caused by it in the installation, the associated economic analysis, and the reduction of GHGs. Previously published works mainly studied the contribution of the reduction of greenhouse gases from the production side. In this paper, the study is focused on the user side, including the reduction of energy losses in an electrical installation as well as the reduction of the greenhouse gas emissions associated in the analysis and choice of efficient electrical equipment.

This paper is structured as follows, Section 2 presents the problem formulation, Section 3 explains the economic evaluation, Section 4 illustrates the new software application, Section 5 provides the simulation results, and, finally, concluding remarks are given in Section 6.

2. Problem formulation

Considering climate change and the limitation of emissions of GHGs at the international level, the control of emissions of air pollutants (mainly SO_2, NO_x, particulates and, more recently, CO_2) has been one of the key aspects for the electric sector. CO_2 emissions responsible for the greenhouse effect from electrical systems cannot be eliminated but can be controlled and reduced. Multiple methods can be used and have been studied in all phases of electrical systems.

The reduction of energy consumption in its various forms is a direct method of reducing the emissions of GHGs, with effects in all phases of the operation of electrical systems. A contribution that is often forgotten is the reduction of losses in electrical installations associated with the use of efficient equipment. To quantify the contribution of the reduction of losses to the reduction of GHGs, the emissions of the final product (gCO_2/kW h) are quantified.

Hence, in this paper we examine how to determine the emissions in gCO_2/kW h of a country or region, present the development steps and calculation of losses in the electrical installations' cables (industrial, domestic, and public lighting), and quantify the reduction of CO_2 emissions into the atmosphere related to the reduction of losses in the conductors of an electrical installation, which is usually neglected.

Various types of power plants using different fuels with different carbonic intensities contribute to the production of electricity in an electrical system of a country. As each type of plant has a different CO_2 intensity we can determine the intensity in the production of electricity by Eq. (1):

$$CO_2\ \text{Intensity} = \frac{\sum(C_i I_i)}{\sum(P_i)} \tag{1}$$

in which:

CO_2 is the intensity of CO_2 in gCO_2/kW h.
i is the fuel source $1,\ldots,n$, which contributes to the production.
C_i is the CO_2 emission factor of each fuel source.
I_i is the fuel input by source.
P_i is the production of energy by source.

Special attention should be given to the contribution of combined heat and power (CHP), since the emission of gases should