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The risks of an energy efficiency policy for buildings based solely on the consumption evaluation of final energy

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ABSTRACT

The concept of energy efficiency is addressed in a way that identifies the risks of policies based strictly on the assessment of the transformation of final energy into useful energy. Considerations of only the efficiency of technologies employed in the final uses may generate distortions in the identification of options that truly preserve natural resources and minimize environmental impacts, especially when different energy sources are used as primary inputs. Herein, the impact of different approaches is discussed through a case study on the regulations of energy efficiency for buildings. The selection of the approach is relevant, especially with regard to a comparative analysis between the use of electricity and other energy sources, such as fuel gases and/or renewable energy. The risks of policies that encourage energy efficiency anchored exclusively in simplified approaches are identified through the analysis of regulations in four countries: Brazil, China, India and Russia. In addition, this work estimates the change in average efficiency of the electricity generation sector for these countries over the period from 1980 to 2008, demonstrating that the assessment of primary energy consumption should guide the policies of energy efficiency.

1. Introduction

The objective of this study is to analyze the risks of an energy efficiency policy based strictly on the transformation of final energy into useful energy. Based on the principle that there is no universal concept of energy efficiency, it presents a case study on energy efficiency policies for buildings. This is relevant for reflection and the application of global energy policy, since many countries are still drafting codes and standards for energy efficiency. It is important that these policies be truly effective.

Energy efficiency policies are an important tool for reducing CO_2 emissions and possible climate changes [1], as well as to contain the rapid growth of energy consumption in the world, contributing to the security of supply and mitigating the depletion of energy resources [2].

Although many countries of the OECD have mature energy efficiency policies for buildings, the vast majority of developing countries are still in the process of implementing codes, standards and regulations for this purpose. The positions of these countries on the issue are either not documented or lack sufficient information, which complicates the analysis of the effectiveness of these policies [3].

Buildings represent a significant portion of the total consumption of primary energy in the world, reaching up to 40% in some countries [2–6]. This situation is further aggravated by rapid growth in the number of buildings built in environments that do not always encourage the use of efficient technologies [7].

The role of energy efficiency policies for reducing total energy consumption cannot be easily measured. According to Brookes [8], Herring [9], and Sorrell [10], increased efficiency may increase, rather than reduce, energy consumption. This fact is due to "rebound effects" caused by reductions in the marginal cost of energy to promote improvements. However, this increased consumption may not be as significant as previously believed because of irreversible efficiency improvements [11]. While this issue is still not completely understood, it is suggested that increased energy efficiency may free up resources for social and economic development, especially in developing countries [12].

The concept of energy efficiency may be anchored in different approaches, according to the types of processes and criteria to be analyzed. A simple definition of energy efficiency considers the relationship between how much energy is introduced into a process and the useful output that the process can generate [13]. This definition reveals the importance of energy in characterizing the usefulness of buildings to human beings seeking comfort and security. Different indicators of energy efficiency can be established. Some of these indicators are limited to the physical evaluation of energy transformations, while others also consider the economic and social dimensions that define the usefulness of a process. The present paper considers only the models that focus on the physical assessment of energy transformations as a criterion for evaluating energy efficiency in buildings.

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Section 2 shows how analytical models can adopt either a simplified, a qualitative or an exergetic approach to the evaluation of how different processes and equipment consume energy. Only through qualitative and exergetic approaches is it possible to compare different technological routes that represent the use of different types of energy in different bioclimatic conditions. The section also presents the final energy conversion factors used in the exergetic approaches.

Section 3 summarizes the international experience in the adoption of these methodologies. The different assessment models for energy efficiency in buildings adopted in Brazil, China, India and Russia were characterized. In this section, there is also an in-depth discussion on the importance of adopting extended or exergetic approaches, which reward reduced consumption of primary energy.

In conclusion, it is shown in this paper that policies to promote increased energy efficiency should form part of a strategic energy approach that is able to meet the particularities of the energy matrices of the countries to which it applies. This approach would avoid the risks associated with simplified assessments that are based strictly on final energy transformation.

2. Expanded and simplified approaches to energy efficiency in buildings

As illustrated in Fig. 1, energy efficiency in buildings can be defined using four distinct perspectives: (i) equipment used in the building, (ii) internal energy processes (e.g., heating, cooling and lighting, because the use of efficient equipment does not necessarily guarantee that the processes are also efficient), (iii) buildings (considering the synergies that can be explored between different internal energy systems) and (iv) the national energy system (linking the analysis of an energy efficiency approach to a supply chain, thus computing the primary source of energy consumption).

2.1. The qualitative approach and the exergetic approach: consideration of primary energy in the evaluation of energy efficiency

The transformation of primary energy into useful energy, with its respective losses, is illustrated in Fig. 2. This approach allows for the evaluation of different technological routes available to obtain a single useful amount of energy, for example: (i) the transformation of an array of primary energies into electricity to be supplied and used to produce useful energy and (ii) the transformation (in GPUs and/or refineries) of primary energy (such as crude oil or natural gas) into fuel gases (LPG or natural gas), fuel oil, diesel, gasoline, ethanol and other energy sources.

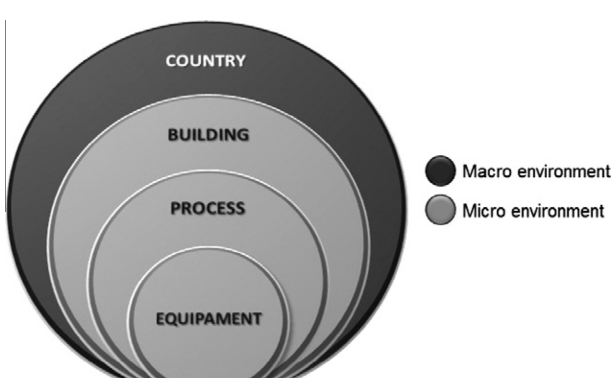

Fig. 1. Different perspectives for the evaluation of energy efficiency.

The exergy analysis considers how useful energy is consumed and, therefore, represents a more robust methodology to account the inefficiency degree of the different components of a system [14]. The consideration of the complete transformation of primary energy into final energy and then into useful energy leads to an extended approach to energy efficiency. Certain equipment, processes, systems and even power sources can be privileged (or penalized) when adapting the concept of efficiency to other key elements of energy policy. Disregarding primary energy consumption associated with the consumption of useful energy can cause the evaluation of efficiency to generate distortions regarding which technologies are actually more efficient, especially when comparing different technological routes operating with different energetic sources.

As an example, Tsekouras et al. (2011) [15] proposes a database system for power system customers that use the efficiency of customer's devices and buildings to determinate the demand curves of different energy sources, like electricity and gas. This methodology starts by considering the end use of energy in order to determinate how energy is consumed in a broader scale.

Two types of expanded approaches have been identified: qualitative and exergetic. The qualitative approach favors or hinders certain types of energy sources according to the objectives of regulation, while the exergetic approach determines the primary energy consumption for each piece of equipment or system in order to identify which alternatives are actually more efficient.

In thermodynamics, the concept of exergy is defined as "the maximum work derived from an energy source with the atmosphere as an infinite heat exchanger" [16]. Fig. 2 shows a practical analysis of this concept, where exergy is represented by the useful energy and energy resources are represented by the primary sources. As previously mentioned, this model is adopted in exergetic approaches.

As the exergetic approaches is based on the calculation of how much energy is really consumed, this model represents the only way to determine how much CO_2 a building is emitting annually according to its energy consumption. It is important to consider this in the developing of climate policies strategies, like Hammons (2006) [17] proposes for Italy.

2.2. A simplified approach: the conceptualization of the transformation efficiency of final energy into useful energy

In Fig. 3, the transformation of final energy into useful energy is illustrated, with the respective losses in processing, transport and storage of useful energy, when applicable. The production of useful energy precedes the supply of needs and consumer satisfaction. Through a simplified approach to energy efficiency, the efficiency of the equipment that performs the final transformation of final energy into useful energy is considered, as well as the efficient use of useful energy. Energy efficiency policies anchored in this approach seek to encourage the replacement of equipment leading to more efficient processes of transformation of final energy into useful energy. This approach may only consider the equipment used in buildings or may be adopted to more systemic views, considering the potential synergies between equipment and internal energy systems. However, this approach becomes less effective when comparing technological paths that originate from different forms of final energy but produce the same useful energy.

For example, Jota et al. (2011) [18] discuss a systemic view of using cluster and statistical data to reshape the building load curve and reduce peak demand. This methodology represents a model where only the transformation of final energy into useful energy is considered.