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A cross-country comparison of the building energy consumptions and their trends

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ABSTRACT

Although it is often stated that the energy consumption in buildings accounts for more than 30% of total global final energy use, only a few studies analyze updated data about the current building energy consumptions or focus on comparing different countries. Similarly, models that predict future trends in building energy demand often use contrasting algorithms which result in diverse forecasts. Scope of this paper is to present and discuss data taken from several studies about the building energy consumptions in US, EU, and BRIC (Brazil, Russia, India, and China) countries and to provide an updated inventory of useful figures. Comparisons among countries are used to show historical, actual, and future energy consumption trends. Data presented by the World Bank, the United Nations Environment Program, the Intergovernmental Panel on Climate Change, and the International Energy Agency are compared with national reports as well as with research studies. The variety of the approaches used in each of the previous sources was considered fundamental to allow a complete review. The paper shows that the total building energy consumptions in BRIC countries have already overcome those in developed countries, and the continuous increase in the building stock of the BRIC countries creates an urgency for promoting building energy efficiency policies in these countries. At the same time, the policies actually adopted in developed countries are insufficient to guarantee a significant reduction in their building energy consumption in the years to come. In the current scenario, at least a doubling of the global energy demand in buildings compared to today's levels will occur by 2050. To avoid this forecast, cost-effective best practices and technologies as well as behavioral and lifestyle changes need to be diffused and accepted globally.

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1. Introduction

The awareness of the worldwide increased population together with the large environmental impacts of current resource depredation, such as energy shortage, climate change effects, and increasing GHG emissions, have raised concerns about the current trends in energy consumption (Wan et al., 2012; Santamouris, 2016). British Petroleum has indicated that the global demand for oil is expected to grow by 30% from 2007 to 2035, while coal and natural gas consumption will increase by 50% (BP, 2010). Meanwhile, the International Energy Agency predicts that unless radical changes in the current patterns are taken, the energy-related emissions of CO_2 will double by 2050 (IEA, 2014). This scenario follows similar forecasts that other third-party models have predicted since mid '1990s (Levine et al., 1996; Ürge-Vorsatz et al., 2007).

In the context of energy saving, the building sector has attracted increasingly attention worldwide, as buildings are responsible for consuming up to 40% of the total energy in some developed countries, with a related emission of 40% of total GHG emissions (IEA, 2013a,b). According to the latest IPCC AR5 WGIII report, in 2010, buildings accounted for 32% of total global final energy use (equal to 117 ExaJoules), 19% of energy-related GHG emissions, 51% of global electricity consumption, 33% of black carbon emissions, and an eighth to a third of F-gases emission (large differences in F-gases data are due to differing accounting conventions) (IPCC, 2014). The IPCC stated that GHG emissions from the building sector more than doubled between 1970 and 2010, reaching a value around 10$GtCO_2$eq/y nowadays (Fig. 1).

A closer look at Fig. 1 shows that most of GHG emissions (6.02 GtCO2eq/y in 2010) are indirect emissions, and these are increasing at a much higher rate when compared to direct emissions. Due to the high contribution of indirect GHG emissions from the building sector, the environmental impacts of buildings vary according to the emission factors of the energy production processes. Although it is not among the scopes of this paper to look at the environmental implications of the building energy demand, it is still interesting to consider the carbon footprint emission to understand the

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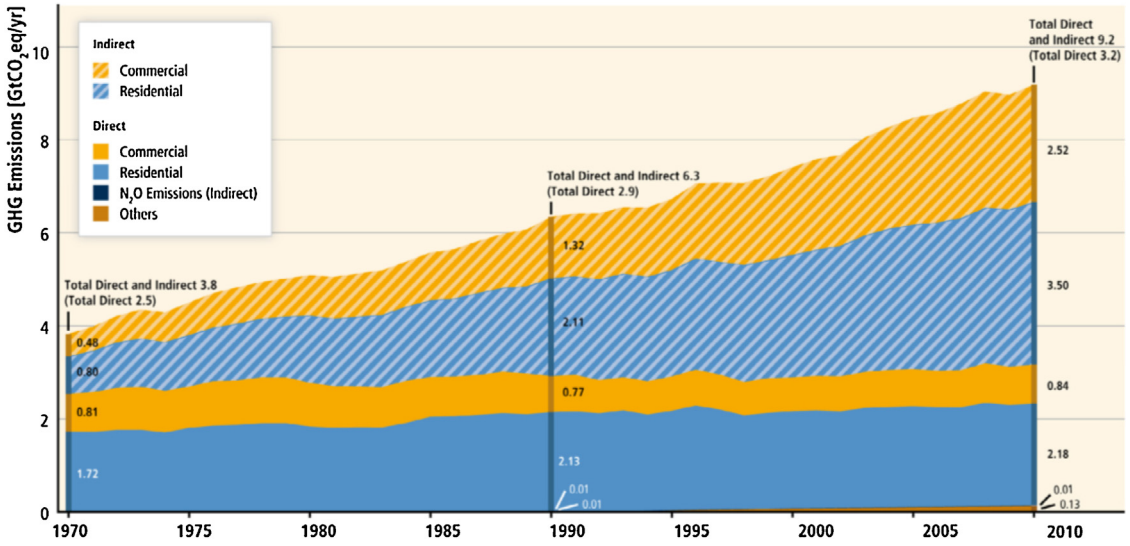

Fig. 1. Direct and indirect (from electricity and heat production) GHG emissions in commercial and residential buildings (source: IPCC, 2014).

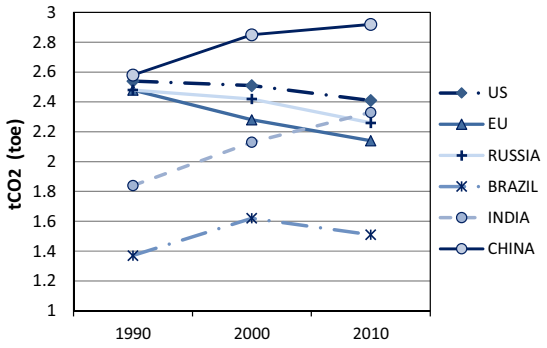

Fig. 2. CO_2 equivalent emissions per primary energy supply through the years in tonne of oil equivalent (data elaborated from EIA, 2014; IPCC, 2014).

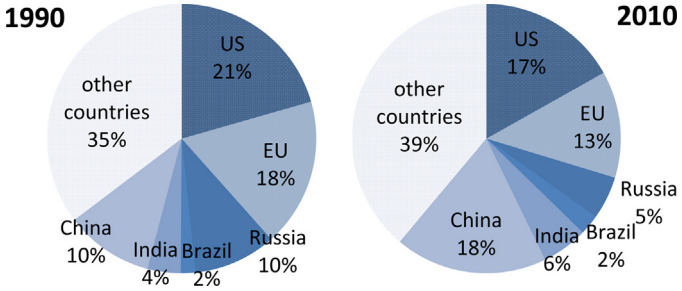

Fig. 3. Percentage of world energy consumption in 1990 and 2010 for different countries (data elaborated from EIA, 2014).

environmental implications in each country. Fig. 2 shows the CO_2eq emission in tonne of oil equivalent through the years, and it helps relating the energy consumption with the corresponding environmental impact. It emerges that the environmental consequences for a unit of energy is lower in countries with a high rate of renewable energy production (for example, the hydroelectric in Brazil), and higher in countries with extensive use of fossil sources (mainly carbon in China). Moreover, this figure shows that the countries where a higher increase in the energy consumption is occurring are those that adopt technologies with larger environmental impacts.

Considering the complexity of energy networks and grids, and the high variability of the real emission factors (Fig. 2), this paper will focus more on the final energy demands than on their environmental implications.

The increasing building energy demand (Fig. 1) requires immediate actions to promote radical changes in current trends (GhaffarianHoseini et al., 2013); in fact, the IPPC recently stated that in contrast to the expected doubling or tripling in final energy compared to today's levels use in 2050, the global demand could stay constant if cost-effective best practices and technologies will broadly diffuse immediately (IPCC, 2014).

Given distinct national conditions, such as economic grow, population trends, and climate characteristics, different policies for energy saving in buildings have been proposed. An international comparison showed that developed countries often have relatively mature policies and coding systems, whereas developing countries have started looking at this topic more recently (Berardi, 2013, 2015). To have a better understanding of the international trends in energy consumption and saving policies in buildings, this paper compares data in selected countries: the United States (US), the European Union (EU), and the BRIC (Brazil, Russia. India, China) countries. The reason for selecting these countries is their overall share of the energy consumption; in fact, in 2010, these countries accounted for more than 60% of global energy consumption (Fig. 3). China is the country with the largest energy consumption worldwide, with a rate of 18% in 2010; the US and EU followed behind, taking up 17% and 13% respectively in the same year; India, Russia, and Brazil are third, fourth and eighth largest energy consumer countries in the world, with a consumption of 6%, 5%, and 2% respectively (EIA, 2014). Fig. 3 also shows the significant relative increase in energy consumption recorded in BRIC countries in the last two decades. In particular, the total world energy use is expected to rise from 13.2 Gtoe in 2010–15.9 Gtoe in 2020 and to 20.7 Gtoe in 2040 (Gigaton of oil equivalent, 1 Gtoe = 11.63 GWh), following an energy consumption growth of 56% between 2010 and 2040; as a result, an increase in energy consumption above 90% can be observed in the non-OECD countries, and around 17% in the OECD countries (Allouhi et al., 2015).

While Fig. 3 refers to the total energy consumption, by breaking down this total demand by sectors, it is possible to depict where energy is mainly consumed (Fig. 4). Although this option should be easy, usually, the building sector does not exist as a unique sector in energy statistics, as many agencies divide the final energy consumption into industry, transport and "other", with this last term incorporating buildings together with agriculture and forestry. Obviously, buildings are responsible for most of the energy

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