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Building energy consumption in US, EU, and BRIC countries

Umberto Berardi*

Department of Architectural Science, Faculty of Engineering and Architectural Science, Ryerson University, Toronto, M5B 2K3, Canada

Abstract

This paper presents and discusses data taken from several studies about the building energy consumption in US, EU, and BRIC (Brazil, Russia. India, China) countries. Most of the current researches about energy consumptions deals with statistics in a specific country. However, international comparisons are useful to discover historical, actual, and energy consumption trends. Data presented in reports of 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. This analysis shows that the BRIC countries have already overcome the total energy consumption of developed countries, and the expansion of their building stock raises an imperative urgency for energy efficiency in buildings. At the same time, this paper shows that the measures actually adopted in developed countries are insufficient to guarantee a significant reduction in their energy consumption in buildings.

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Keywords: Energy consumption; buildings; energy saving; statistical data; BRIC countries.

1. Introduction

The growth of population and the awareness of many environmental and technological issues related to the current resource depredation, such as energy shortage and increase in GHG emissions, have raised many concerns worldwide about current trends in energy consumption. A recent research by BP has indicated that the global demand for oil will grow by around 30% from 2007 to 2035, while coal and natural gas consumptions will grow by

* Tel.: +1-416-979-5000 (ext.3263)
E-mail address: uberardi@ryerson.ca

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50% [1]. Meanwhile, the International Energy Agency predicts that without radical changes, the energy-related emissions of carbon dioxide (CO_2) will double by 2050 [2]. In this context, the building sector has attracted increasingly attention worldwide [3-5]. This sector is responsible for consuming up to 40% of the total energy consumption in some developed countries, with a related emission of 40% of total GHG emissions [6,7]. In 2010, buildings accounted for 32% of total global final energy use (equal to 117 Exajoules), 19% of energy-related GHG emissions, and 33% of black carbon emissions [11]. Given distinct national conditions, such as economic grow, population number, and climate characteristics, different policies for energy saving in buildings have been proposed [8]. An international comparison shows that developed countries often have relatively mature policies and coding systems, whereas developing countries have started looking at this topic more recently.

To have a better understanding of the international trends in energy saving in buildings, this paper compares data in US, EU and BRIC countries. Fig. 1 shows that the selected countries represent the main global energy consumers. Actually, China is the country with the largest energy consumption worldwide, with a rate of 18% in 2011; 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 [6]. Figure 1 demonstrates the tremendous increase in energy consumption recently recorded in BRIC countries and suggests how imperative is to have a global vision to the goal of energy saving.

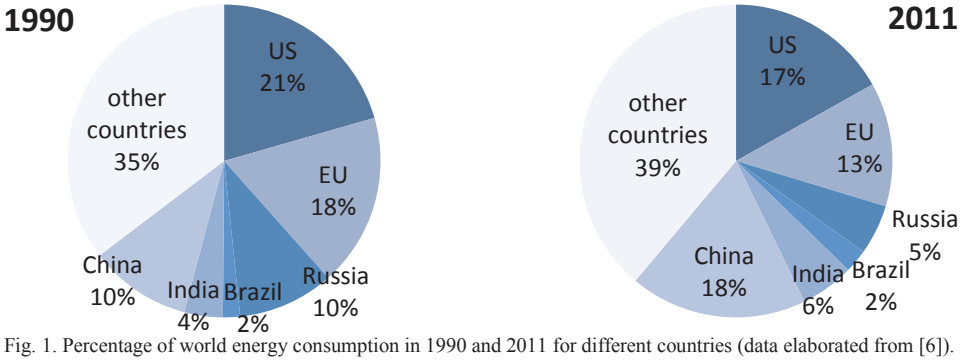

Fig. 1. Percentage of world energy consumption in 1990 and 2011 for different countries (data elaborated from [6]).

Breaking down the energy consumption by sector indicates how energy is consumed and where larger energy savings may occur (Fig. 2). In US and Europe, the increase in energy consumption in buildings in the last years has been modest, but a reduction of the energy consumption in the industrial sector of these countries has occurred since 1990, as a consequence of the shift of their economy from the manufacturing to services. The situation is largely different in BRIC countries, which have experienced a significant energy consumption increase in almost every sector, included the building one.

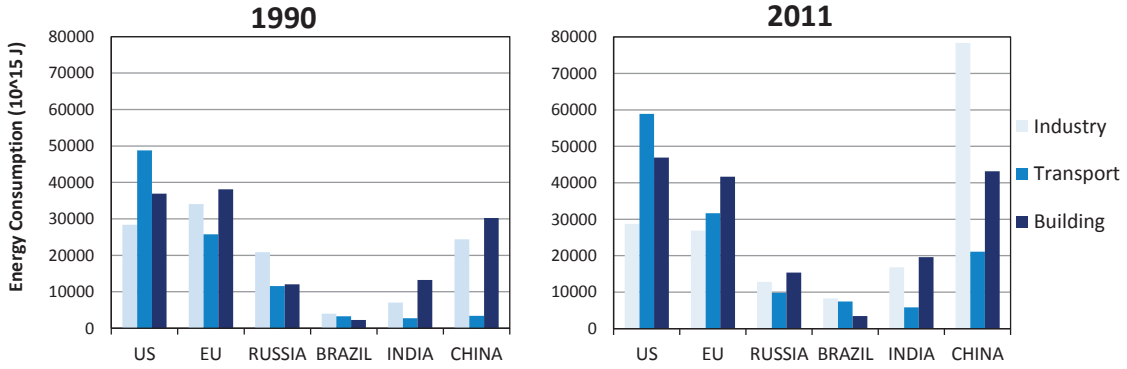

Fig. 2. Energy consumption in different sectors, in 1990 and 2011 (data elaborated from [6] and [9]).

This papers aims to report historical, actual, and forecast data about the energy consumption in the building sector. Most of the historic data for this paper has been taken mainly from reports published by the World Bank, the IEA,

and by the different countries themselves. The forecasts have been taken from the US Energy Information Agency.

2. Energy consumption in buildings

The general approach for energy saving in building includes both high-performance new construction and retrofitting old ones. US and EU have started focusing on this last strategy because their population, urbanization, and housing sector tend to be stagnant (Fig. 3). Although, US and EU expect a replacement rate of new constructions in the future between 2% and 5% only, regulations for nearly zero energy in new buildings have been promoted [7].

On the other side, the grow in energy consumption in developing countries is mainly due to their continuous industrial development and population increase; however, large energy consumptions in the building sector are expected also as a consequence of the growing living standards often following increasing urbanization levels [6,9]. Nowadays only 30% and 45% of population live in cities in India and China respectively, but for both these countries a percentage up to 60% is expected in the next two or three decades [9]. This trend must be considered together with the continuous growth in population; the Chinese population is expected to reach a saturation level by 2030, while India population should grow all the way to 2050. The population of Russia and Brazil is not expected to change significantly in the future; however, the poor and outdated quality of existing buildings and the urbanization process will push the new construction sector in these countries too. As a result, the reduction in energy consumption will need to focus on new buildings in every BRIC country. It is interesting to consider the carbon footprint emission to understand the environmental implications of a reduction in energy consumption in each country. Fig. 4 shows the CO2eq emission through the years, and helps relating the energy consumption with the corresponding environmental impact. This figure shows that countries where higher increases in energy consumption are occurring, are adopting technologies with larger environmental impacts.

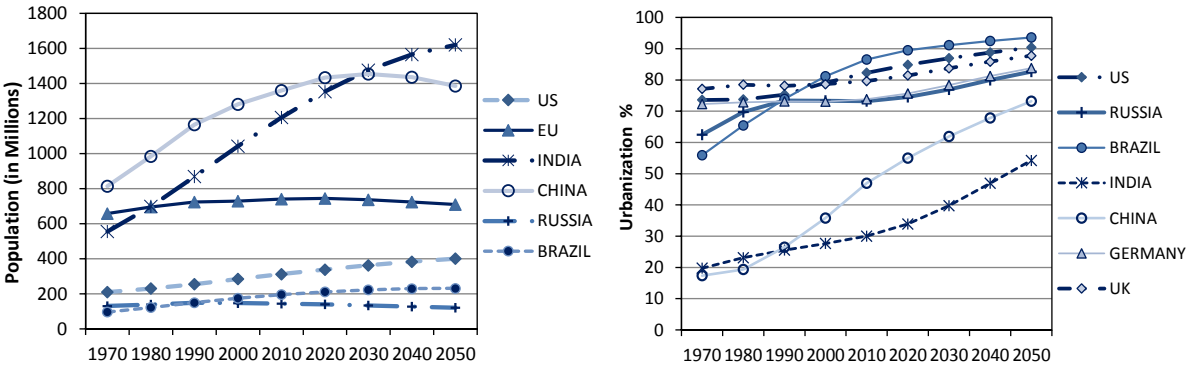

Fig. 3. Total population and urbanization level between 1970 and 2050 (data elaborated from [6] and [9]).

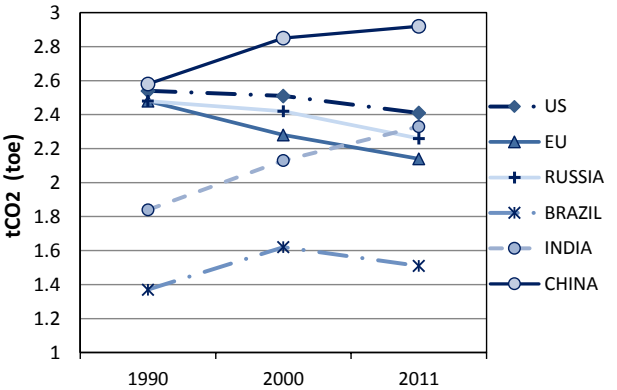

Fig. 4. CO_2 equivalent emissions per primary energy supply through the years in tonne of oil equivalent (data elaborated from [6] and [11]).

Projections of building energy use in developing countries show a large increase with an average annual rate of 2.2% (Fig. 5). In particular, the building energy consumption in China recently surpassed the total US consumption, and it is expected to increase significantly in the next decades, pushed by the high residential demands. The annual growth rates of Russia and Brazil are expected to rise by 0.8% and 2.2% annually respectively [6]. For the developed countries, EU countries, and US, the increases in building energy consumption are supposed to be low in the future, also as a consequence of the promotion of energy saving policies. However, the figure shows that the energy consumption is supposed to increase everywhere, showing that the policies in place are not sufficient to generate a significant reduction of the overall energy consumption in any country.

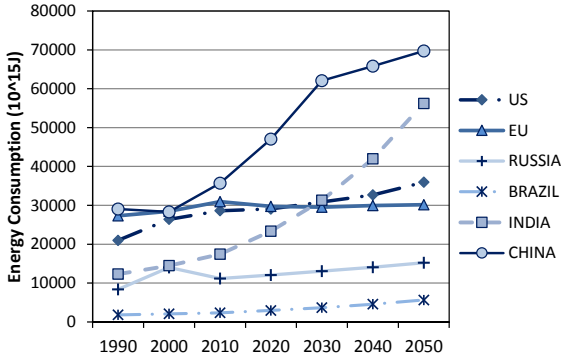

Fig. 5. Residential building energy consumption through the years (data elaborated from [12] and [13]).

The high increase in energy consumption in China is evident considering that in 2050, it will be 15 times higher than in 1970; Brazil and India also stand out, respectively consuming almost four and five times more energy in 2010 than in 1971, and projected to reach in 2050, 11 and 12 times respectively [12,13]. Russia, EU, and US have a different path in energy consumption with an estimated ratio in 2040 equal to 1.2, 0.7, and 1.5 times respectively higher than their 1970 level. This data indicates that there are stable energy consumption countries and rapidly growing energy consumption ones [8]. In some recent reports [3,4], the IEA indicated the priorities for a transition to sustainable buildings: the study shows that some developing countries (such as Brazil, India, and China) should require better efficiency standards for appliances and equipment, but also stronger building codes, whereas advanced envelope design also applicable to building retrofitting is required in US, EU, and Russia. A study about the efficiency of appliances in China showed that at least 21% of residential energy could be saved by using higher efficiency appliances, with as much as 50% possible in some regions [14]; this study made a conservative estimation of 12% reduction in the overall building energy request through the use of high efficiency appliances. Similarly, efficient appliances could reduce the residential energy use by 30% in India [15] and by 27% in Brazil [16].

Another important element for energy saving is the envelope design. The IEA report [3] indicates high performance envelopes as a priority in the cold areas of the US, EU, and Russia, where an overall reduction of 33% in the building energy request could be obtained. More stringent building codes are also important in BRIC countries, especially. China straddles a number of different climate types, from hot-humid tropical in the South to cold harsh dry in the North. Yu et al. [17] found a possible 22% energy saving in the Chinese building sector by improving the code in cities (13% reduction) and rural areas (9% reduction). A study about an enforced energy saving building code in India, found that the energy savings could be between 17% and 42% within urban centres [18]; similarly, Brazil could experience a 15% reduction in the energy consumption by enforcing its energy standards [19]. Russia has a unique situation given to its climate and poor energy efficiency policies; a 42% reduction in energy used for space heating would occur by implementing energy saving policies through the country [20]. Figure 6 shows the change in energy consumption of the BRIC countries assuming new energy efficient standards are fully implemented by 2020. China shows the most drastic savings followed by India, whereas Brazil and Russia would show more modest savings in absolute terms. Obviously, the enforcement of new building codes mainly forces new constructions so in regions with established building stocks, such as Russia, new construction

codes have little effect. Deep retrofitting of the EU and US building stocks could achieve a 33% energy saving [21] and 50% [22] respectively. Figure 7 shows that by 2050 the potential energy saving in developed countries could not be sufficient to compensate the increase in energy needs of developing countries (acronyms refer to the different world regions and can be referred in [11] or [20]).

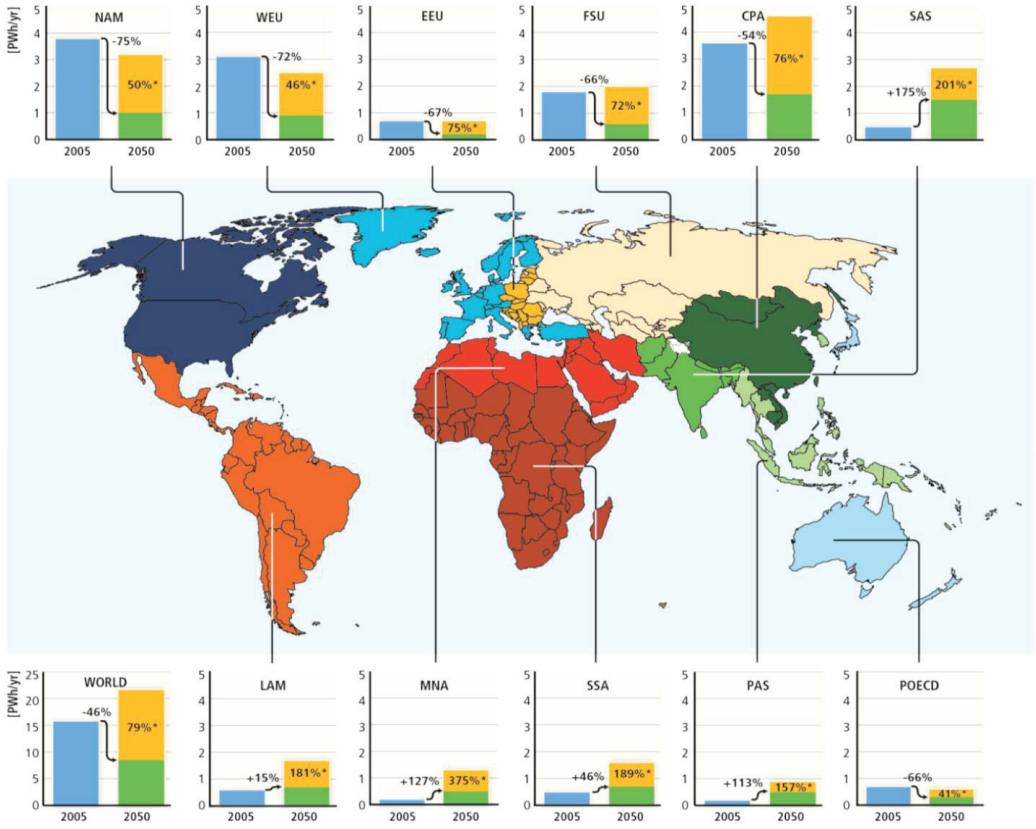

Fig. 6. Building heating and cooling energy use scenarios from 2005 to 2050 according to Global Energy Assessment and IPCC [11,20].

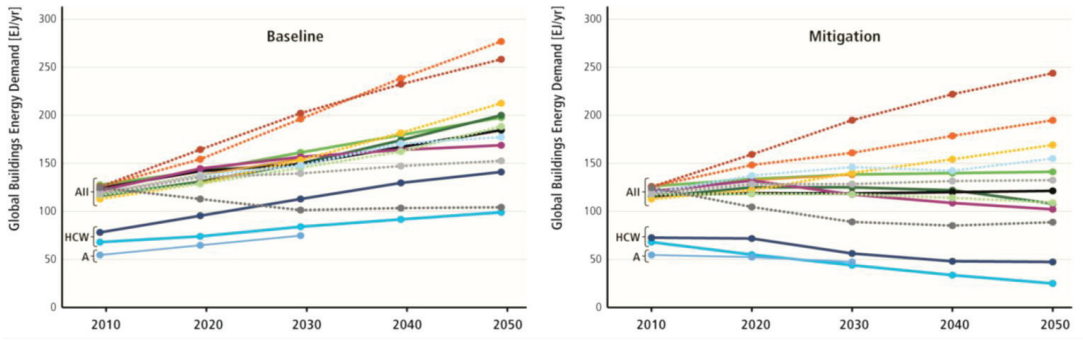

Fig. 7. Building energy demand for several baseline and mitigation scenarios, HCW: heating/cooling/hot water, and A: appliances [11].

3. Strategies for energy saving in the different countries

3.1 United States

After the energy crisis in the 1970s, the US slowly started making efforts in promoting energy saving in buildings by promoting better insulation in building codes [6]. Since the residential energy use is mostly from electricity supply,

it is interesting to see how the energy sources of electricity production have changed: the electricity generated by coal has reduced from 53% to 43% between 1990 and 2011, whereas the percentage of gas has doubled. Despite the improvements achieved in energy efficient products, such as air conditioners, the energy consumption in the US building stock is generally stable (10.01 x 10^{18} J in 1990 vs 10.18 x 10^{18} J in 2009). As figure 8 suggests, the appliances, electronics and lighting energy use in U.S. has increased from 24% in 1993 to 34.6% in 2009).

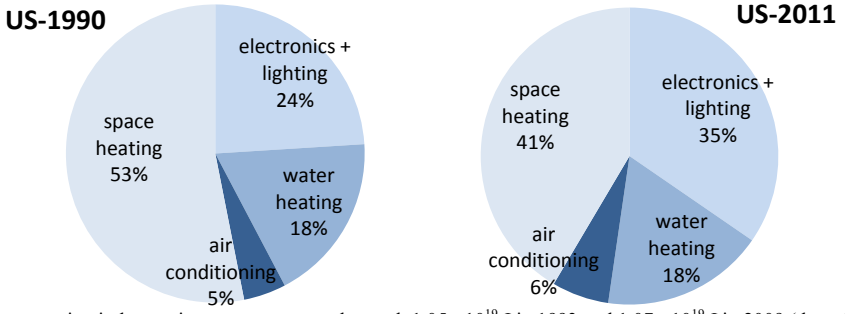

Fig. 8. US energy consumption in homes in percentage over the total, 1.05 · 10^{19} J in 1993 and 1.07 · 10^{19} J in 2009 (data elaborated from [9]).

3.2 European Union

Total energy consumption of the building sector in Europe has increased by around 1%/year since 1990, mainly in non-residential buildings (1.5%/year for non-residential buildings compared to 0.6%/year for households). Electricity consumption has increased more rapidly, by 2.4%/year since 1990 (+60%). Meanwhile, the EU has set an ambitious goal to reduce the level of carbon dioxide by 90% in 2050 compared to that in 1990, and has put a goal for new buildings to be nearly zero energy [23,24]. Data from the European Energy Agency shows that in the last 20 years, the household energy consumption reduced in many countries (above 2%/year in Romania, Poland and Estonia), but it increased in Finland, Hungary, Greece, Croatia, and Cyprus. Fig. 9 reports breakdown data in 2010.

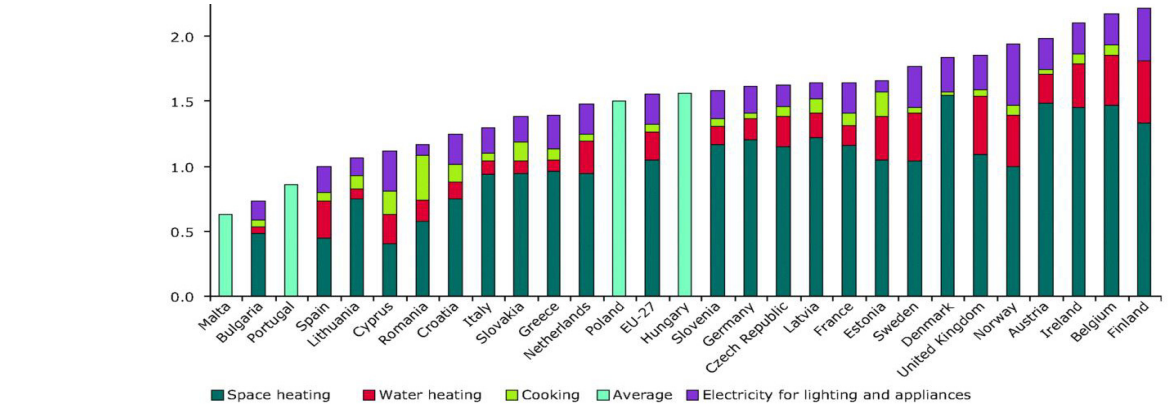

Fig. 9. Final energy consumption in the residential sector in the EU27 in 2010 [25].

3.3 Brazil

The Brazilian energy supply has a large proportion of clean energy thanks to extensive hydro generation, which is the dominant energy source for electricity production (93% in 1990 and 81% in 2011 [6]). Moreover, after the oil crisis in 1970s, Brazil has implemented large programs for biofuel production, using sugarcane ethanol. There are over 9000 large green partnership projects concerning sustainable buildings in Brazil [26]. However, literature shows that poverty is a main factor limiting energy saving practices in Brazilian buildings [27]. Brazil has a voluntary labeling program for commercial buildings, but limited attention to the residential ones [7]. Meanwhile, a mandatory program for electric appliances called “PROCEL” is promoting high efficient equipment [28].

3.4 Russia

Buildings older than 25 years represent over half of total Russian building stock [26]. Due to the long cold season and inefficient heating equipment, the energy consumption for heating represents the most important component of building energy consumption (fig.10). In 2011, the gas proportion has increased to 85% of the total residential energy consumption. However, it should be noted that 78% of heat for buildings is generated by district heating systems. Russia has the world's largest district heating system, which unfortunately has a low efficiency (about 73% versus efficiencies above 90% in European countries). A main detractor to energy saving in buildings is the low energy price. For this reason, Russia has promoted centralized initiatives to improve the efficiency of district heating systems [29].

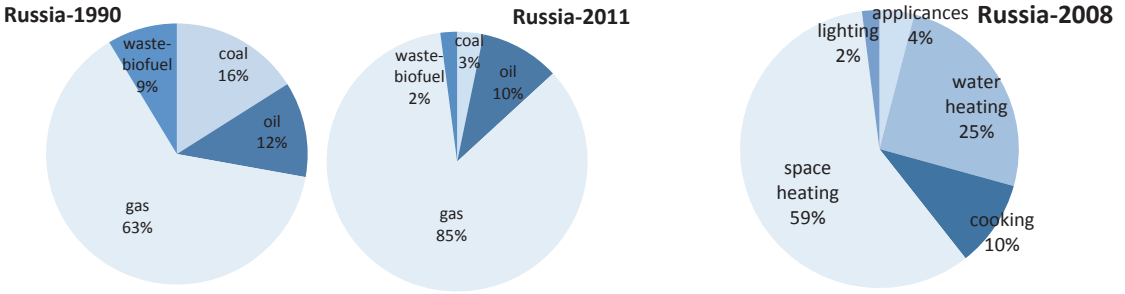

Fig. 10. Russian electricity production by sources (left) [6] and residential consumptions breakdown in 2008 (right) [13].

3.5 India

Even though the development of energy saving buildings is still uncommon in India, the floor area of high performance buildings is rapidly increasing, and it has jumped from 15800 m^2 in 2005 to 1.2bn m^2 in 2013 [30]. Nevertheless, opportunities for energy saving in building sectors are still largely unexplored. Nearly 70% of energy production comes from fossil fuels, but residential energy mainly comes firewood for cooking (fig.11), resulting in widespread deforestation. In spite of the fast urbanization of recent years, most of Indian population still lives in rural areas. Given the hot climate of India, a significant energy saving could come from efficient cooling systems but also could come from the use of the highly available solar resource. This was stressed in the last two five-year plans [31].

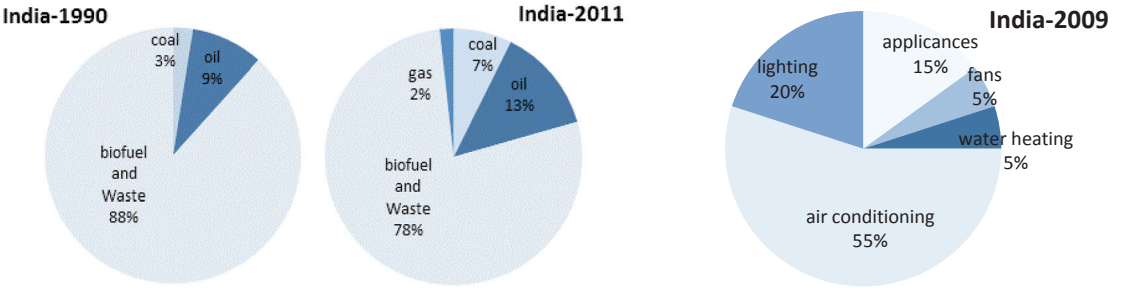

Fig. 11. Indian energy production by sources (left) [6] and residential energy consumption in 2009 (right) [31].

3.6 China

Coal is the major fuel resource of buildings in urban areas, whereas biomass is predominately used in rural areas. The urbanization and GDP growth together with the increase in floor areas per capita and the higher demand for electric appliances will elevate the energy demand in buildings [32]. Although the data in fig. 5 are impressive, fig. 6 shows that a reduction up to 54% is possible in China. Fig. 12 shows the energy consumptions in different scenarios.

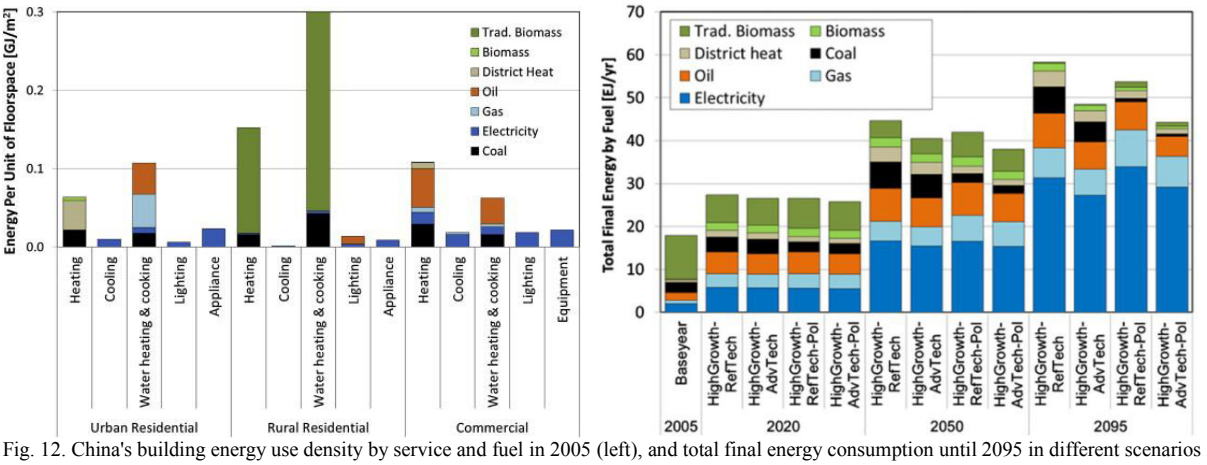

Fig. 12. China's building energy use density by service and fuel in 2005 (left), and total final energy consumption until 2095 in different scenarios divided according to the energy source (right) [33].

4. Conclusions

As the economy, urbanization, and population of developing countries grow, an increasing energy consumption in these countries is expected. Given the quantity of building energy consumption already occurring in these countries, their energy management is critical within a global context. Thus, the development of building energy saving policies together with money-saving devices, or income-generating energy-saving devices, represent a great concern in developing countries. On the other side, developed countries have been devoted in energy saving buildings for more years. These countries earned many valuable experiences in energy efficient buildings. However, it is evident that stricter regulations especially in existing buildings need to be further stressed by focusing on both new technology development and more educationally-related approaches to energy saving.

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