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Global changes in residential energy consumption

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ABSTRACT

The residential energy sector is crucial to achieving CO_2 emission reductions as it has an important energy-saving potential, and its environmental controls are difficult to displace to other countries. Using the latest available data, this short paper provides a concise analysis of residential energy consumption trends for the period 1993–2013 in a double perspective, by main world regions and by per capita gross national income levels in 2013. Residential energy has been divided into three types: non-renewable, direct renewable and indirect renewable. Annual rates of change, energy intensity, energy in per capita terms and some ratios have been analyzed. Notable regional differences and trends were observed in the studied variables. Therefore, different energy policies are recommended for the regions. Eastern and Southern Asian countries, the EU15 and other developed countries, are the regions which should make the greatest effort to reduce residential energy consumption. The promotion of direct and indirect renewable energies is recommended.

1. Introduction

Growing world energy consumption is putting increasing pressure on environmental pollution and global warming. Recently, the Paris Climate Conference (COP21) agreement set out an action plan to avoid climate change by keeping the increase in global average temperature to well below 2 °C (Burleson, 2016). In order to achieve this target, energy consumption and Green House Gas (GHG) emissions must be reduced in all economic sectors.

The residential energy (RE) sector has become key to undertaking rapid emission reductions in a two-fold sense. Firstly, because the residential sector represents around 25% of global energy consumption, and 17% of global CO_2 emissions (IEA, 2016), and therefore has direct significant effects on the world environment (Nejat et al., 2015). Thus, this energy sector has a vital role in mitigating these emissions, because, as stated in IEA (2011), its global energy-saving potential is around $0.48*10^6$ Ktoe per year. Secondly, because the residential emissions productions are difficult to displace to other countries, the applied energy policies are therefore more globally-effective in this sector. In that context, some authors, such as Kanemoto et al. (2014), point out that many countries are reducing their emissions, and even fulfilling their Kyoto Protocol commitments. Nevertheless, they may have achieved these commitments partially because they have displaced polluting industries to other countries, where environmental standards are quite low (Lau et al., 2014). Residential environmental controls are difficult to displace to other countries and therefore energy policies may be more efficient than in other sectors.

Despite the importance of the residential energy sector, there are few studies focusing on its heterogeneity across the world. Some studies refer to a specific part of the world, such as, for example, the EU (Filippini et al., 2014a, 2014b), the USA (Lee and Lee, 2014), China (Zhao et al., 2012) or Lithuania (Štreimikienė, 2014). From a more general perspective, Nejat et al. (2015) review the status and trends of energy consumption in the residential sector globally, and in ten countries. However, very little attention has been given to certain regions, such as Africa, Latin America and the Middle East and to economies in transition. This is despite the fact that, as stated in Mundaca et al. (2013), the causes and/or impacts of climate change are mostly framed in regional terms. Therefore, much more research on geographical differences is needed (Bridge et al., 2013).

On the other hand, most studies referring to residential energy and income are focused on the role of the economic behavior of resident households using micro data. Along this line, for example, the recent study by Gertler et al. (2016) analyses the household decisions to

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acquire energy-using assets in the presence of rising incomes. The findings of this study are consistent with previous work describing an S-shaped relationship between household income and appliance acquisitions, as for example Jamasb and Meier (2010) and Wolfram et al. (2012). These findings suggest that residential energy demand growth may be different, depending on the households' income level. From a macroeconomic perspective, there are much fewer studies. Among them, the study by Auffhammer and Wolfram (2014) presents evidence suggesting that the shape of the income distribution plays a major role in driving household acquisition of energy-using goods in China. These results are consistent with previous work documenting the S-shaped relationship. In that sense, the authors state that there is going to be a large increase in the demand for residential energy in the coming years, as the income grows. Therefore, more research on the relationships between residential energy consumption and income; to link these findings to macro-level trends in energy consumption is needed in order to be able to apply effective energy policies.

The aim of this short paper is to provide a concise analysis of residential energy consumption trends for the period 1993–2013 in a two-fold perspective, by 11 main world regions, and by per capita gross national income (GNI) levels in 2013, covering 4 groups. The results of the paper may be taken as a starting point for additional and deeper analyses regarding regional economies.

2. Methodology

Residential energy (RE) consumption world data are analyzed and presented by world regions and by GNI levels. The RE has been divided into three types of energy: non-renewable residential energy (NRRE), direct renewable residential energy (DRRE) and indirect renewable residential energy (IRRE). Additionally, total renewable residential energy consumption (TRRE) has been calculated by adding DRRE and IRRE. Annual changes, energy intensity (ratio of energy consumption to GDP in Purchasing Power Parity - PPP) and energy in per capita terms have been analyzed for these variables. Additionally, the trend of the following ratios has been studied: RE to total energy (TE) consumption, DRRE to RE and TRRE to RE.

DRRE is the renewable energy consumed directly. It is calculated as the sum of biofuels, waste, geothermal and solar residential energy consumption. The data used come from the *balances* topic in IEA (2016).

IRRE is defined as the renewable consumption made by using electricity or heat, which has previously been generated by using renewable energies. It is calculated as follows:

$$IRRE = re * residential \quad Elec \quad consumption + rh * residential \quad heat \quad consumption$$

$$re = \frac{RREE \text{ used in the Elec production}}{Elec \text{ production} + Elec \text{ imports}}$$

$$rh = \frac{RREE \text{ used in the heat production}}{heat \text{ production} + heat \text{ imports}}$$

where RREE refers to renewable energies and Elec to electricity.

RREE used in the electricity production is calculated as the sum of biofuels, waste, geothermal, solar PV, wind, hydro and tide energy used to produce electricity. RREE used in heat production is calculated as the sum of biofuels, waste, geothermal and solar thermal energy used to generate heat. The data used come from the *electricity and heat* topic in IEA (2016).

$$TRRE = DRRE + IRRE$$

NRRE is the non-renewable residential energy. It is calculated as the sum of non-renewable energy consumed directly and non-renewable consumption made by using electricity or heat (INRRE). Non-renewable energy consumed directly is calculated as the sum of coal, oil products and natural gas energy consumption. The data used come from the *balances* topic in IEA (2016). The INRRE is calculated as follows:

$$INRRE = (nre + ie) * resid. \quad Elecconsump. + (nrh + ih) * resid. \quad heatconsump.$$

$$nre = \frac{NRREEusedintheElecproduc.}{Elecproduction + Elecimports} \quad ie = \frac{Elecimports}{Elecproduction + Elecimports}$$

$$nrh = \frac{NRREEusedintheheatproduc.}{heatproduction + heatimports} \quad ih = \frac{heatimports}{heatproduction + heatimports}$$

where NRREE refers to non-renewable energies. NRREE used in the electricity production is calculated as the sum of coal, oil, gas and nuclear energy used to produce electricity. NRREE used in the heat production is calculated as the sum of coal, oil, gas and nuclear energy used to generate heat. All electricity and heat imports are considered non-renewables energy. The data used come from the *electricity and heat* topic in IEA (2016).

The world has been divided into 11 regions: the European Union's first 15 members (EU15), new European Union members (EU+), other developed countries (ODC), economies in transition (ET), Central African (CA), Southern African (SA), Middle Eastern and North African (MENA), East Asian (EAS), Southern Asian (SAS), Latin American (LAC) and The Caribbean (CAR) countries. Additionally, four groups have been considered by dividing the world according to GNI in 2013: High income (HI), upper medium income (UMI), lower medium income (LMI) and lower income (LI) countries (See Appendix).

The time period analyzed is 1993–2013, for which there is sufficient data availability for all sample countries.

3. Results

3.1. Residential energy consumption, world status in 2013

Fig. 1 shows TE and RE in 2013 by world regions (colors) and by per capita GNI levels (plots). The area of the outer pie shows the TE in the region, while the area of the inner pie shows RE, the latter being divided into DRRE, IRRE and NRRE. By world regions, it may be highlighted that the highest TE is observed in EAS, ODC and the EU15. It is also worth noting the high RE with respect to TE in CA, and in a lesser proportion in SA. The CA region is also highlighted due to its high percentage of DRRE with respect to RE, which may be related to charcoal consumption. Among the regions with the lower percentage use of this renewable energy are the ET, ODC, MENA and EU regions, which is related mainly to direct and indirect oil fuels consumption. LAC, the EU15 and ODC stand out in IRRE, due to the high production of electricity by using wind, biofuels and hydroelectric energy.

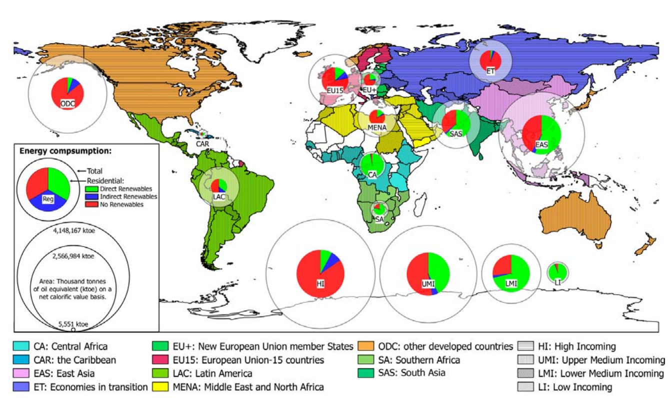

Fig. 1. Total and residential energy consumption in 2013.
Source: Own production from IEA (2016). Maps © EuroGeographics for the administrative boundaries.