CEE CLIMATE POLICY FRONTIER

Between Regional Best Practices and Paris Agreement-compatibility in the building sector

April 2020

Title: CEE Climate Policy Frontier. Between Regional Best Practices and Paris Agreement-compatibility in the building sector

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The European Climate Initiative (EUKI) is a project financing instrument by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). Its implementation is supported by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. It is the overarching goal of the EUKI to foster climate cooperation within the European Union (EU) in order to mitigate greenhouse gas emissions.

Supported by:

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

European Climate Initiative EUKI

Based on a decision of the German Bundestag

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B2DS Scenario	The Beyond 2°C Scenario
BAU Scenario	Business-As-Usual Scenario
ESR	Effort Sharing Regulation
IPCC	Intergovernmental Panel on Climate Change
PA Scenario	Paris Agreement Scenario
RBP Scenario	Regional Best Practice Scenario
SIAMESE	Simplified Integrated Assessment Model with Energy System Emulator

1. Introduction

Decarbonisation of the building sector is essential to reach the EU's emissions neutrality by 2050 goal (European Commission, 2018). Due to the longevity of the building stock, measures to reduce emissions, both in the new and existing buildings, need to be taken now. The report illustrates the impact of different drivers, such as activity, energy consumption, and emissions intensity of this energy, on the emissions levels.

This assessment is done for six Central and Eastern European countries: Bulgaria, Czechia, Hungary, Poland, Romania, and Slovakia. After the economic transformation and joining the European Union all of these countries experienced significant economic growth and, in most cases, an improvement in the quality of life. In the residential building sector this found expression in increasing space per capita and energy consumption for heating.

Despite these changes, between 1990 and 2017, direct greenhouse gas emissions from residential buildings in the selected countries combined decreased by 25% and by the end of that period constituted 8% of all emissions. There were, however, significant differences between the countries analysed, with on one hand Bulgaria, Czechia, Slovakia, and Hungary where emissions decreased by between 49% and 63%, and on the other Poland and Romania where emissions remained largely unchanged.[1]

In this report we assess what was driving these emissions reduction and what would be the impact of a universal adoption of these drivers in all the other countries. For this purpose we divide the sources of emissions in the residential building sector into space and person related, and for each of them identify the main drivers of emissions. On this basis we develop a scenario in which the indicators with the best value from the selected countries are applied universally across these countries until 2030 and compare it with the Paris Agreement compatible levels.

As a result, we present three levels of emissions: the first one reflecting the continuation of past trends until 2030 (BAU Scenario), the second assuming a universal uptake of Regional Best Practice trends (RBP Scenario), and the third one showing the compatibility with the Paris Agreement temperature limit.

The goal of this exercise is not to predict the future. The extrapolation of BAU or RBP trends ignores the potentials for unexpected technological, economic or behavioral changes that could either accelerate, slow down, or even reverse past trends. Rather this exercise aims to illustrate which levers will set the overall trend of decreasing emissions towards Paris Agreement-compatible emissions reduction levels. It may also allow to identify areas in which there is an unused emissions mitigation potential that can be enabled by adequate policy measures.

It must be stated, that while the study only covers *direct emissions* from the residential buildings sector, we also take into consideration energy consumption which leads to *indirect emissions* from the electricity sector. These emissions are not accounted for, as they are covered by the EU ETS and thus are beyond the scope of this study. However, while electrification is one of the major drivers of decarbonization of the building sector, its potential can only be realized if electricity is being generated from carbon neutral sources.

[1] Excluding LULUCF and non-CO2 emissions. Own calculation based on (European Environment Agency, 2020)

2. Methodology

To find out whether the universal adoption of Regional Best Practices would be enough to reduce emissions from the residential building sector to a level compatible with the Paris Agreement temperature limit, we developed two scenarios: one reflecting the universal implementation of the best trends recorded in the selected countries, and another one indicating emissions reduction needed in the residential building sector to be compatible with the Paris Agreement. To assess the impact of the RBP trends, we also looked at emissions levels in a scenario in which past trends are continued until 2030.

The two subsections below explain how each of these sets of emissions pathways was developed.

2.1. Paris Agreement-compatible emissions in 2025 and 2030

In this report, the sectoral Paris Agreement-compatible emissions levels in 2025 and 2030 were scaled down from the Beyond 2°C scenario (B2DS) developed by the International Energy Agency (IEA, 2017). The scenario is a combination of forecasting known trends, and back casting from a specified long-term outcome. This outcome has been defined by the IEA as reducing CO_2 emissions to net zero by 2060 and limiting global average temperature increase to 1.75°C with 50% probability. This scenario can be considered Paris Agreement-compatible under the condition that if the pathway is extended beyond 2060 (the final year in B2DS), it will allow for net negative emissions in the energy sector at a level similar to that in other scenarios assessed by the IPCC. In this case, the B2DS scenario reaches peak warming of 1.6°C and warming drops below 1.5°C before 2100 (Climate Action Tracker, 2018).

Therefore, it can be used as a proxy for Paris Agreement compatible pathway, even though it is from today's perspective conservative in its assumptions about the potential to achieve net zero CO_2 emissions before 2060. At the same time, this is one of few scenarios available at the moment that provides the necessary sectoral granularity to derive the sectoral-based results relevant for this analysis.

The results of the emissions pathway have been scaled down using a tool developed by Climate Analytics called Simplified Integrated Assessment Model with Energy System Emulator (SIAMESE) (Sferra et al., 2019). The Model uses an optimisation approach, incorporating UN population projections and GDP growth projections compatible with the relevant Shared Socioeconomic Pathway (SSP) to create least-cost fuel mix pathways that produce emission reductions necessary to achieve the goals of the Paris Agreement.

Based on historic energy consumption in the residential building sector in the selected countries, this downscaling resulted in emissions levels for 2025 and 2030. These emissions levels are compared with emissions levels resulting from the application of the Regional Best Practices (RBPs).

2.2. Regional Best Practice (RBP) Scenario

The Regional Best Practices in this report are understood as the best (though not necessarily optimal) trends identified in the selected the selected six Eastern and Central European countries from the climate perspective, meaning the impact on greenhouse gas emissions. The study does not account for indirect emissions, which in the EU are covered by other policy measures. This applies especially to electricity and district heating. However, the final energy consumption also for sources which do not result in direct emissions, e.g. appliances or space cooling, are provided for the sake of comprehensiveness and basis for an assessment for other studies.

To cover total *direct* emissions from the residential buildings sector we identified two groups of determinants: space- and person-related. The space-related determinants are space heating and cooling for which three sources of emissions were identified: activity calculated as the amount of space per capita (m^2/person), energy intensity (kWh/m^2), and emissions intensity of the energy (gCO_2 per kWh). Since electricity is used for space cooling, direct emissions intensity from this source is zero, even if it contributes to energy consumption.

The person-related sources of emissions are those for which the space of the dwellings is of little importance. Instead the number of people occupying the space is the primary driver of energy consumption and emissions. These are: water heating, cooking, and appliances. While the role of electricity differs between the first two sources, the last one fully relies on electricity. Similarly as for air conditioning, we provide it for the sake of comprehensiveness even if it does not contribute to direct emissions.

For each of these drivers and selected six countries the annual rate of change in the period between 2000 and 2015 was calculated. This period is determined by data availability from JRC IDEES Project (EU Science Hub, 2019). Two scenarios are developed on the basis of these indicators: the BAU Scenario in which the country-specific past trends are extrapolated until 2030, and the RBP Scenario where the best practices from the selected countries are universally applied to all countries (see Figure 1).

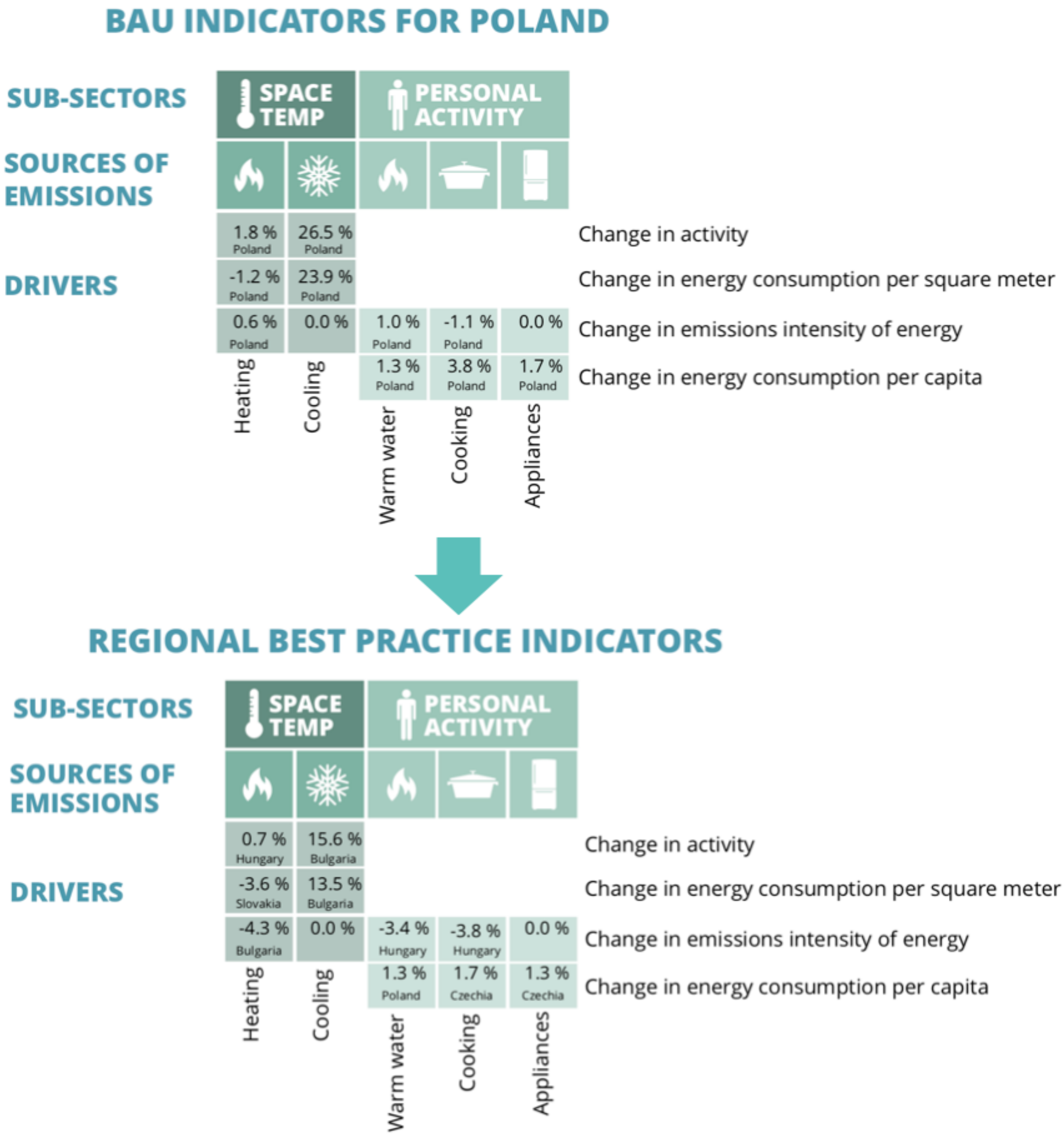

Figure 1: Replacing national indicators (above) by Regional Best Practice Indicators (RBP).

The value of the trend selected as Regional Best Practice is determined by the impact on energy consumption, which - except for cooling and appliances – also has an impact on direct emissions. Depending on the value, this is reflected by the slowest annual increase or the fastest decrease.

3. Context of the residential sector in CEE countries

The residential sector in the countries of Central and Eastern Europe has undergone several changes over the past decades. While there are numerous commonalities between these countries, there are also significant differences that need to be kept in mind when looking at the results of our analysis. This section presents a short overview of these similarities and differences, such as the average household size, energy costs, or the lifestyle factors influencing appliance ownership.

3.1. Size of households

Rising levels of income, emigration, and aging of the society had important repercussions for the type and size of households. In all selected countries the average age of the population increased. The fastest increase took place in Slovakia, where the average age increased between 2000 and 2015 by 6.4 years (See Figure 2). An important driver of this trend in Slovakia, but also all remaining countries, was low fertility rate, which in Slovakia and Czechia was at 1.30 and 1.15, respectively at the beginning of the century. While it increased in the subsequent years, in most of the countries it remained below the EU28[2] average (Eurostat, 2020c). Another factor was emigration of the younger generation to the other EU member states, mostly Ireland and the UK, however this factor has a very limited factor on the official statistics as most of the emigrants remained registered in their countries of origin (European Commission, 2012).

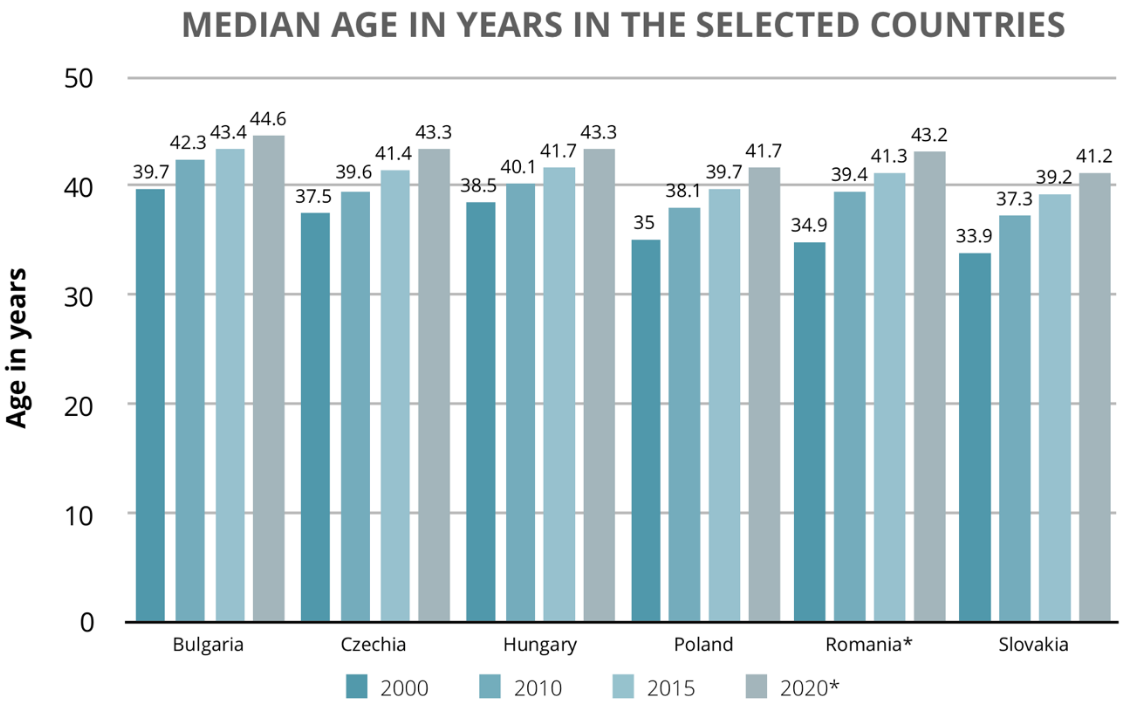

Figure 2: Median age of the population in years in the selected countries (Statista, 2020).

This migration-driven aging and overall decrease in the population influenced residential buildings sector by on one hand decreasing the occupancy in existing dwellings, and on the other increasing the number of new builds the construction of which was financed by remittances from the (temporary) emigrants.

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[2] Whenever reference to EU28 was made, it reflects EU membership between 2013 and 2019.

These trends resulted in an increase in the number of rooms per person in all countries, with the largest increase in Czechia and Hungary (See Figure 3). In the latter, the significant increase took place between 2017 and 2018, which could have resulted from a decrease in the VAT in the residential building sector – see subsection 3.2. Despite an increase, in 2018 there were still only 1.2 rooms per person in Poland, Slovakia, and Romania – much below the 1.7 average in the EU27.

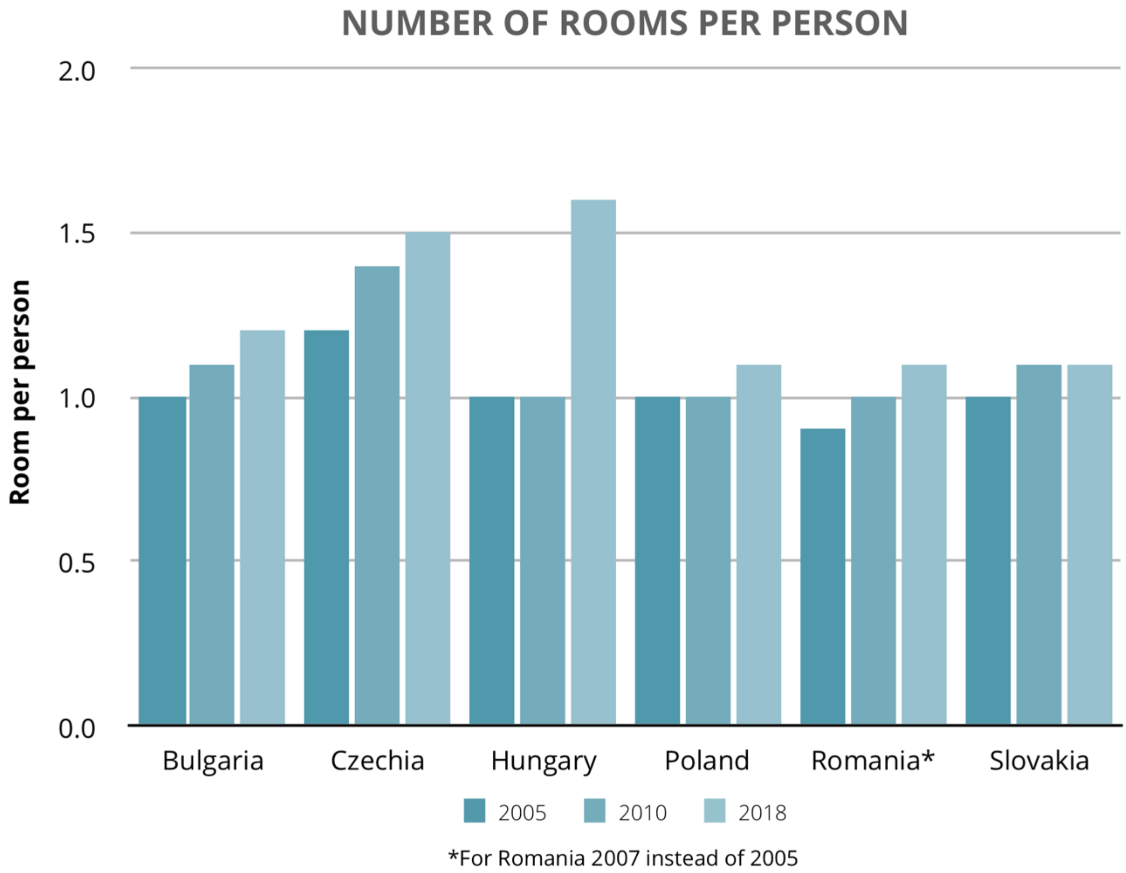

*Figure 3: Number of rooms per person. *For Romania the data for 2007 instead of 2005 (Eurostat, 2019a).*

The increase in the number of rooms per person was also reflected in decreasing share of overcrowded apartments[3] in all countries. The largest decrease took place in Hungary, where in 2000 every second household was overcrowded. In 2018 every fifth household was overcrowded. Despite a significant decrease, 42% and 46% households remained overcrowded in 2018 in Bulgaria and Romania, respectively (See Figure 4). In all countries the rate of overcrowding was higher than in the EU27 on average, where 15% of all households were qualified as overcrowded.

At the same time, the share of people living in under-occupied[4] dwellings was increasing. In 2018, every fourth citizen of Czechia and Hungary lived in such dwellings. In Romania this share was the lowest and amounted to 7%. In all countries this rate remained significantly below the

[3] Overcrowded households are defined by Eurostat based on a number of criteria, including less than one room for each single person aged 18 or one room per pair of children under 12 years of age.

[4] According to Eurostat's definition, a dwelling is defined as under-occupied if the household living in it has at its disposal *more* than the minimum number of rooms considered adequate – thus the opposite of overcrowded. Differently from the case of overcrowding, the rate of under-occupation is reflected in the share of total *population*, not *households*.

average for the EU27, however the gap decreased significantly between 2005 and 2018 (Eurostat, 2020g).

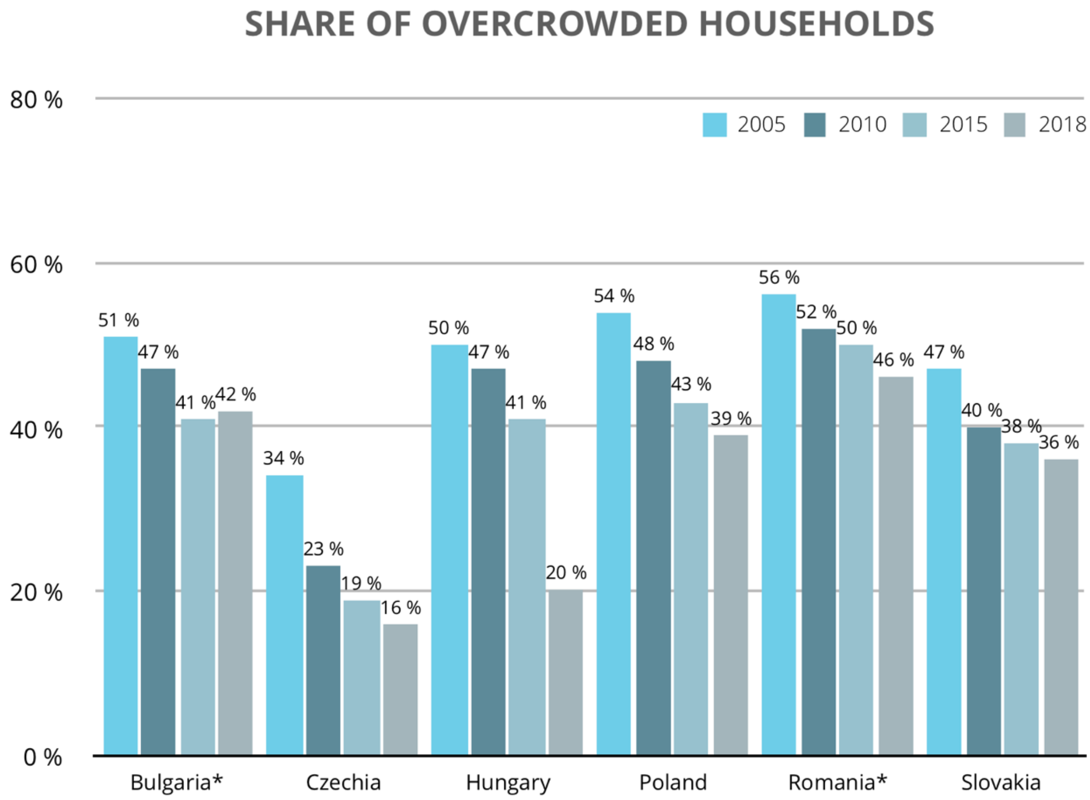

Figure 4: Share of overcrowded households. For Romania and Bulgaria the numbers are for 2007 instead of 2005 (Eurostat, 2020f).

3.2. Dwellings type, age, and ownership

The decrease in the overcrowding was accompanied by an increase in house construction. In all countries, except for Bulgaria and Slovakia, the share of population living in houses – both single and semi-detached – increased (See Figure 5). In some cases this increase was significant: within slightly less than a decade almost 2.3 million Poles and 120 thousand Romanians moved from a flat to a house. This trend was counterbalanced by the opposite change in Bulgaria where over 800 thousands citizens moved to a flat. Nonetheless the weighted average shows that the share of people living in a house increased by 1.8% between 2005 (2007 for Romania) and 2018.

This trend has been accompanied by a move out of the cities in all countries except for Bulgaria (+5%) and to a much lesser degree, Hungary (+1.1%). In some countries the share of the population living in cities fell significantly – by 6.5% in Poland and 8.8% in Romania. The major beneficiary of this trend – accompanied by a move away from rural areas in all countries except for Slovakia – were suburbs and towns. This has important repercussions on one hand for space per capita, while on the other hand availability of access to district heating.

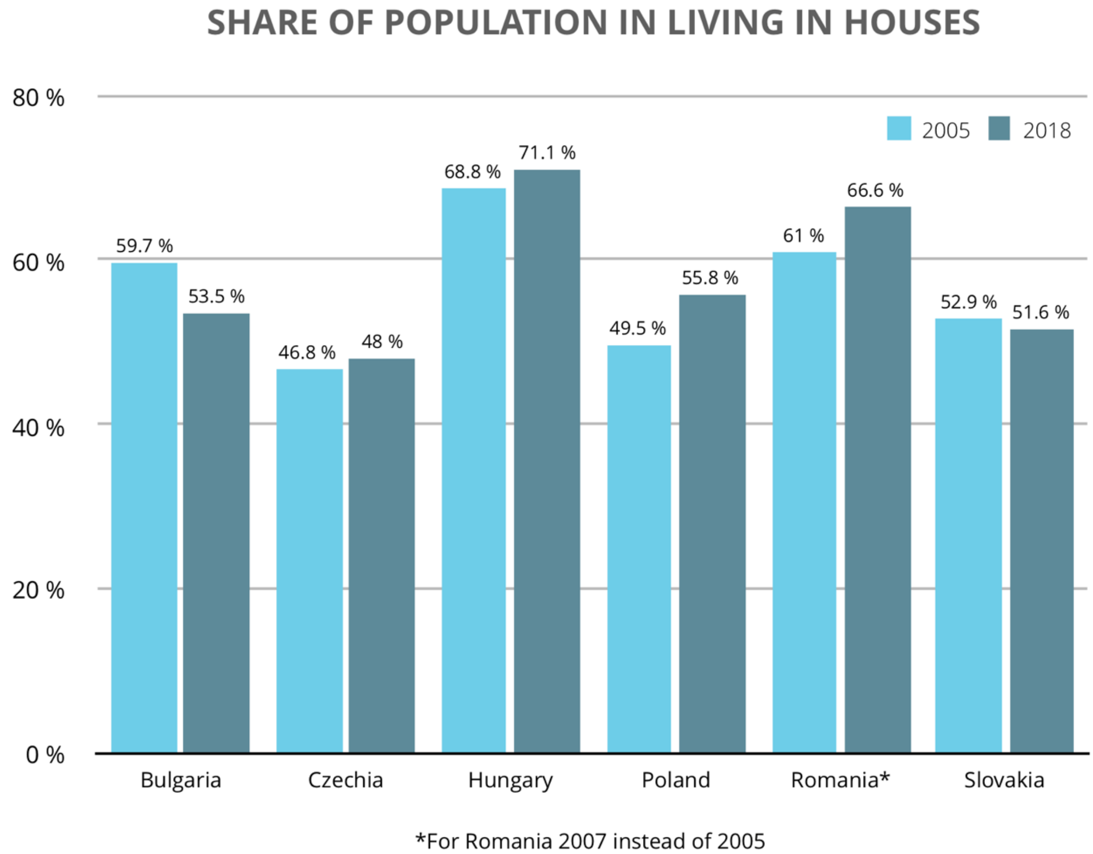

*Figure 5: Share of population in living in houses in 2005 and 2018. *Data for Romania is for 2007 instead of 2005. (Eurostat, 2019b).*

The general trend of moving from a flat in a city to a house in the suburbs was possible due to an increase in the number of new houses. In the first decade of the century the number of new builds increased steadily in all six countries and in Bulgaria and Romania was 1.5-times higher in 2008 than in 2000. Following the economic crisis, however, this increasing trend reverted for all countries except for Poland, where it stabilized (See Figure 6). The drop in new construction in Hungary can be explained by the high VAT rate on new residential construction at 27%. As a result in 2013 only 7,293 dwellings were added in the whole country. Reduction of the VAT rate to 5% led the number of building *permits* to grow significantly and reached 31,559 in 2016 (The Housing Europe Observatory, 2017).

As a result of these trends the highest share of new buildings was in Poland - almost 15% of all buildings in this country were built between 2000 and 2015. In Czechia and Slovakia this share was at around 12%. The lowest share of new buildings could was recorded in Bulgaria where less than 5% of dwellings were built after 2000.

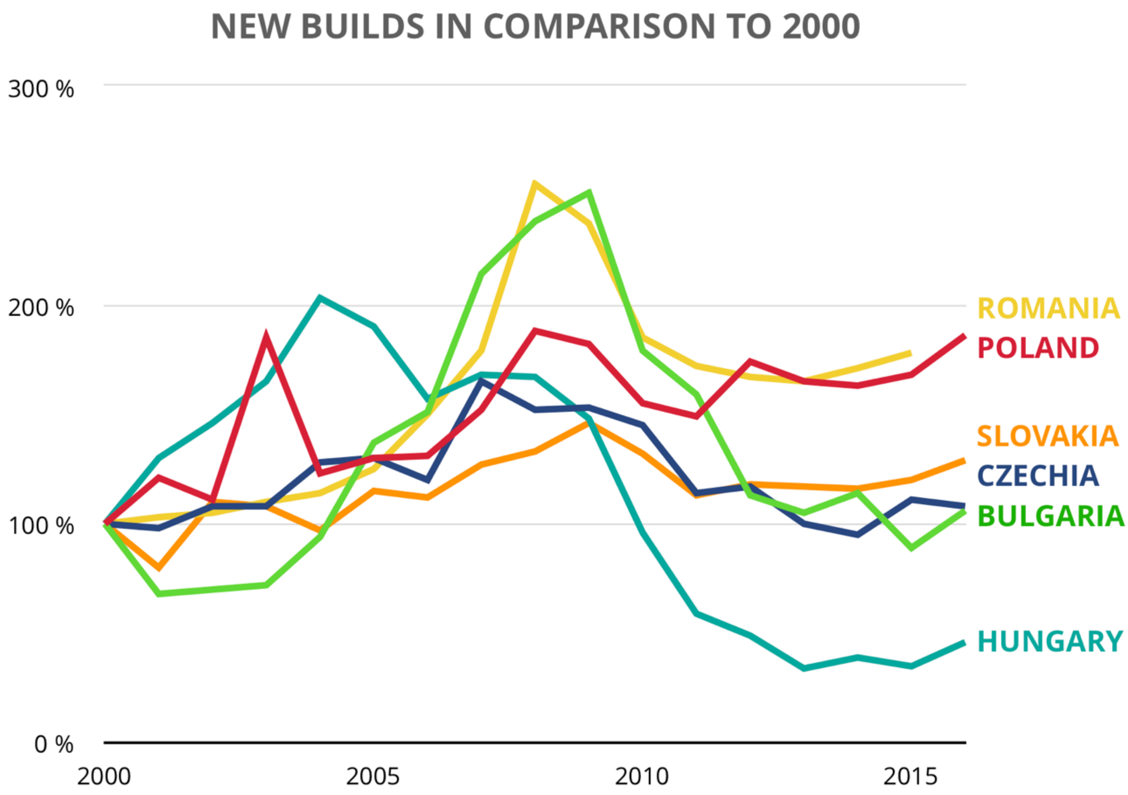

Figure 6: New builds in comparison to 2000 (EU Buildings Observatory).

Despite the increase in the number of new builds – the impact of which was strengthened by decreasing population – significant majority of dwellings in the countries were built before 1990 (See Figure 7). Furthermore, over 35% of housing units are in a dilapidated condition, and are not earthquake resistant (Romania's risk is the highest in Europe) (Mathema & Simpson, 2018). This implies a significant potential for deep renovation to reduce their energy consumption. So far this potential has barely been utilised, with renovation rates around 1% or below (ZEBRA2020, 2020).

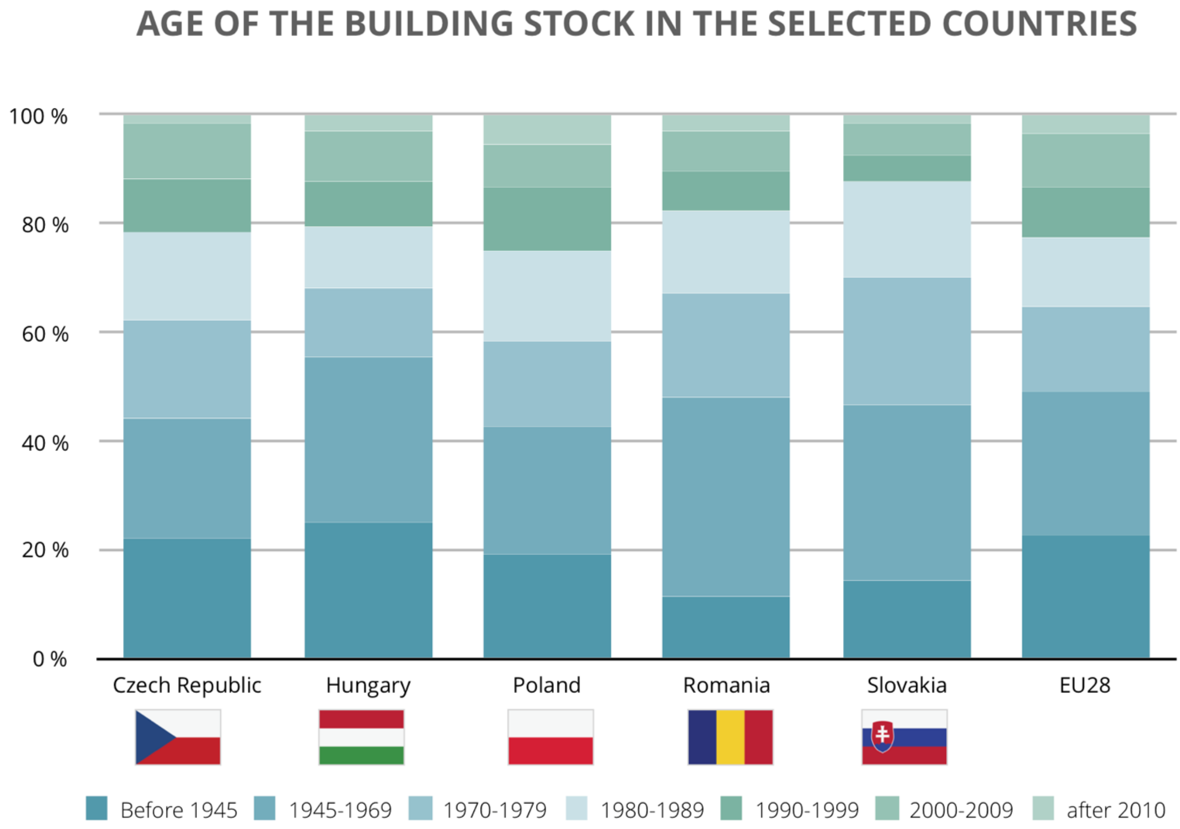

Figure 7: Age of the building stock in the selected countries. Data for Bulgaria inconsistent therefore not shown. Own calculations based on (EU Buildings Observatory).

In addition to increasing levels of income, one of factor that may accelerate investment in retrofitting is a high level of home ownership. Due to split incentive investments in energy efficiency tend to be lower in rented dwellings than in dwellings inhabited by their owners. Owners renting their apartments or homes are reluctant to invest in efficiency measures since the tenant is the only one to benefit (Eurostat, 2013).

This is much less of an issue in the CEE countries where the share of owner-occupied dwellings is especially high and in 2018 ranged from 74% in Czechia to 96% in Romania, compared to an EU28 average of 69% (See Figure 8). One of the major reasons for this high level of owner occupation is the privatization that took place in these countries after the fall of communism. In Romania the state owned 70% of the properties and sold them at an advantageous price resulting from Romania’s devalued currency paired with high inflation. In Poland high levels of home ownership were driven by the construction of homes often financed by remittances from abroad after joining the European Union.

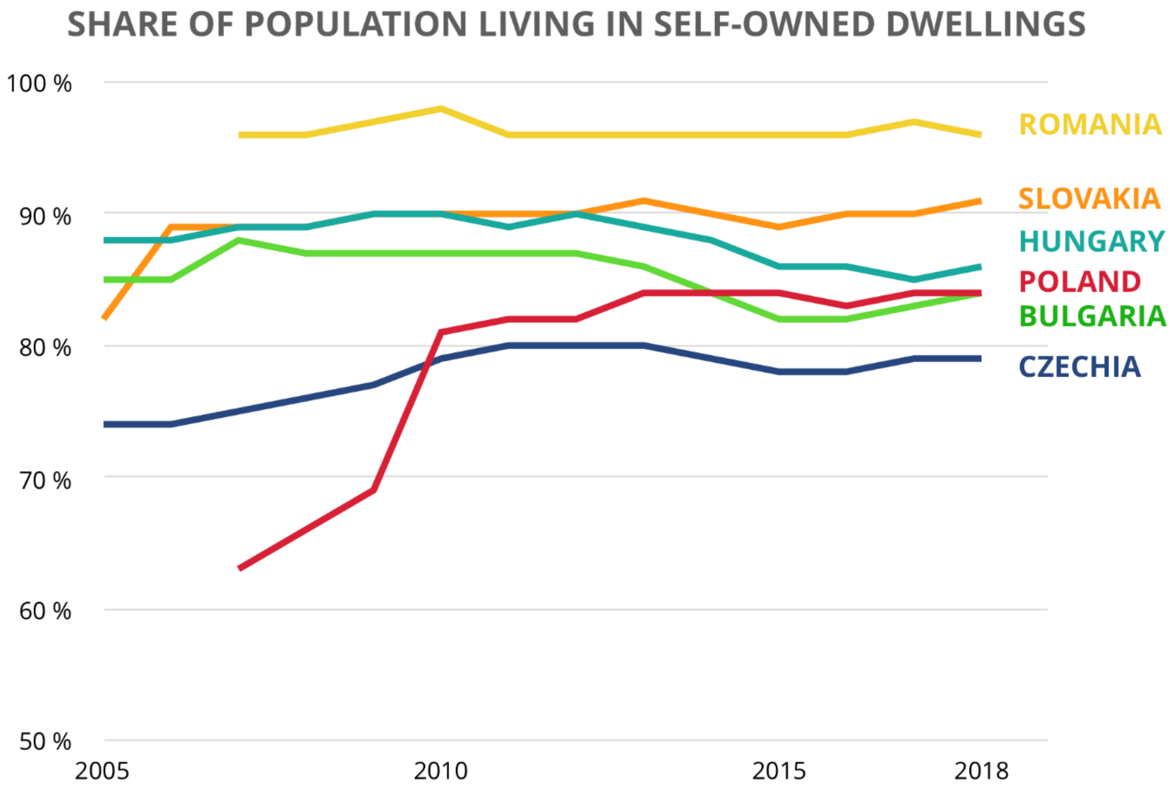

Figure 8: Share of population living in self-owned dwellings (Eurostat, 2020a).

3.3. Energy poverty

The citizens of the CEE countries are among the most affected by energy poverty, which result from a highly inefficient building stock and comparably low income combined with fuel prices. In 2018 over 30% of Bulgarians, 14% of Romanians and 11% of Hungarians were in arrears on their utility bills. Despite this, almost 34% of Bulgarians and 10% of Romanians couldn't afford to keep their home adequately warm (EU Energy Poverty Observatory, 2020).

Citizens in all selected countries benefit from fuel prices below the average of the EU: in 2017 the gas prices were between 51% and 92% of the average EU levels. The household electricity price was between 48% and 72% of the EU levels. However, the lower costs of fuels were more than neutralized by much lower GDP per capita, which in Bulgaria was only a quarter of the EU's average. In all countries except for Slovakia, GDP stands at less than 50% of the EU's average (See Figure 9).

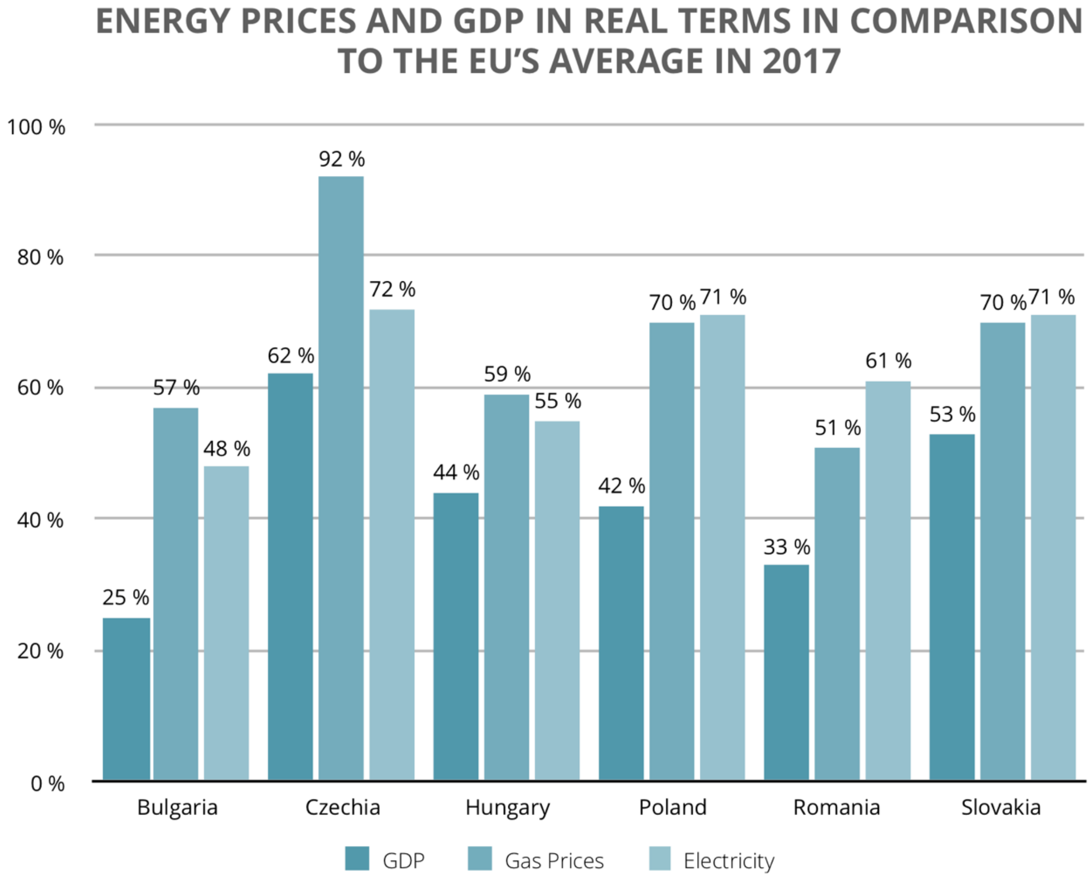

Figure 9: Energy prices and GDP in real terms in comparison to the EU's average in 2017. While the GDP in all countries is below or significantly below the EU average, the prices of energy carriers are only slightly lower. Own calculations based on data from (EU Energy Poverty Observatory, 2020; Eurostat, 2020e).

No comparative data is available for heating oil for the selected countries. However the global market for this fuel allows us to assume similarly that lower prices driven by lower taxation do not fully counterbalance much lower GDP per capita. Data is missing also for coal, which only plays an important role for space heating in Poland. In 2015 over 85% of the coal used in households in all selected countries, was utilized in Poland (Eurostat, 2020d). At the beginning of the last decade 70% of single-family buildings in this country used coal. This amounted to 3.5 million coal-fired boilers, almost 30% of which were more than ten years old. About 3 million were manually fed boilers - an outdated technology that allows waste to be burned, thus resulting in significant air pollution (BPIE, 2016).

The issue of energy poverty has important repercussions for emissions from the residential buildings sector. Solving this problem by increasing incomes or decreasing fuel taxes would result in much higher emissions caused by people's reasonable desire to keep their homes warmer. Introducing measures supporting deep renovation would not only reduce energy poverty but would also reduce emissions and improve air quality, especially in countries highly reliant on coal.

4. Assessing past trends

The energy consumption in the selected six countries combined increased between 2000 and 2015 by 1.7%. However, there were significant differences between the countries with energy consumption decreasing by 23% in Slovakia and 12% Romania, and increasing in the remaining countries by almost 10%, with the fastest increase in Poland. This increase in emissions was also

4.1% faster than the corresponding increase in energy consumption, indicating worsening emissions intensity of the energy consumed.

Around two thirds of energy consumed in the EU in the residential sector in 2015 was used for space heating. However, this constituted a decrease from almost 75% of all energy consumed in 2000. In Bulgaria space heating consumed less than half of the energy consumed in residential buildings sector in 2015. At the same time, it was the country with the highest share of energy used for space cooling. At 0.5% of the total energy share in this country, space cooling played a minute but rapidly increasing role. Water heating was the second major source of energy consumption, and one with the highest rate of increase – by between 1.1% and 8.8%. In addition, the share of energy consumed for cooking and appliances increased by between 0.2% and 2.6% for the former and between 1.1% and 5.6% for the latter (See Figure 10).

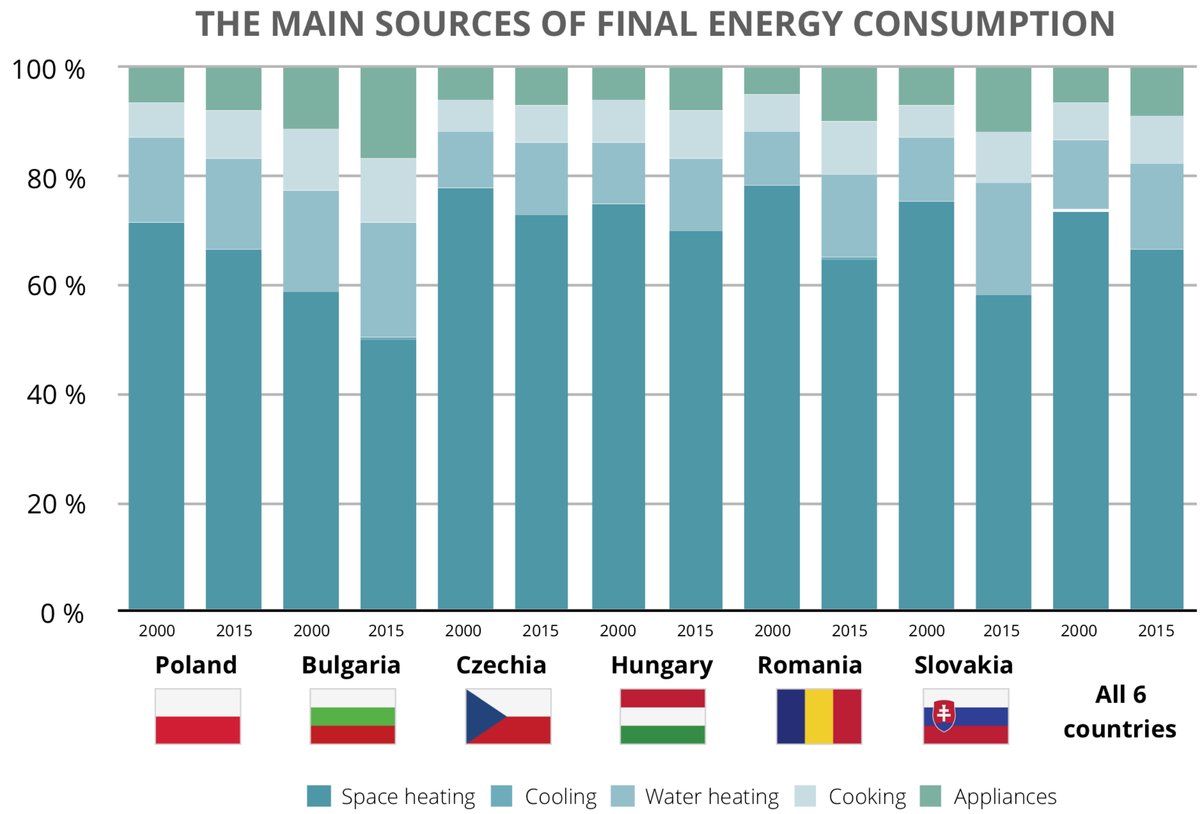

Figure 10: The main sources of final energy consumption in the residential buildings sector in the selected countries. Own calculation based on (EU Science Hub, 2019).

Of the five main sources of energy consumption, only three contribute to *direct* emissions. Cooling and appliances powered by electricity result in *indirect* emissions, which are beyond the scope of the study. Not surprisingly, also for the remaining three sources, space heating plays the most important role and in 2015 was responsible for 69% of total emissions from residential buildings combined in all countries – 6%-points less than in 2000. This share has been taken over and divided equally by water heating and cooking (See Figure 11).

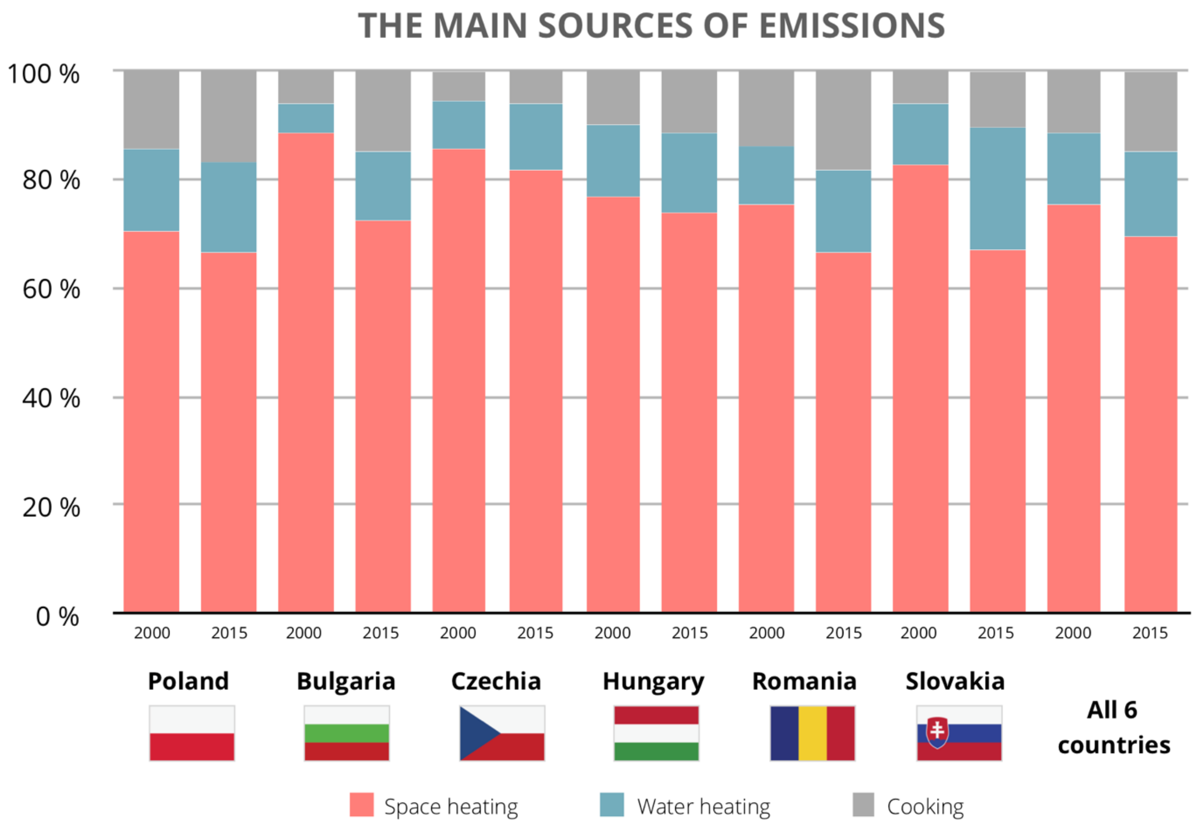

Figure 11: The main sources of emissions in the selected countries. Own calculation based on (EU Science Hub, 2019).

There is a general trend away from space heating towards subsectors in which electricity is used more often (water heating), *much* more often (cooking) or exclusively (space cooling and appliances). This has important repercussions for decarbonization of the buildings sector and of electricity generation.

The following subsections present the main factors driving energy consumption and emissions in the five subsectors.

4.1. Space heating

Emissions from space heating are determined by the activity levels (number of square meters of heated space per capita), energy intensity (energy consumption per square meter), and emissions intensity of this energy.

The activity levels increased in all selected countries at similar speeds: by between 1.2% and 1.9% annually. The major outlier was Hungary, where the increase was only 0.7% annually, which was even below the EU28 average of 0.8% annually. As a result, it moved from being the country with the most dwelling space per capita in 2000 to third position in 2015, behind Czechia and Slovakia. In absolute space per capita Romania was an outlier with only 17.4 m^2 per capita. An average citizen of Romania therefore had around half as much space as an average citizen of Czechia (See Figure 12).

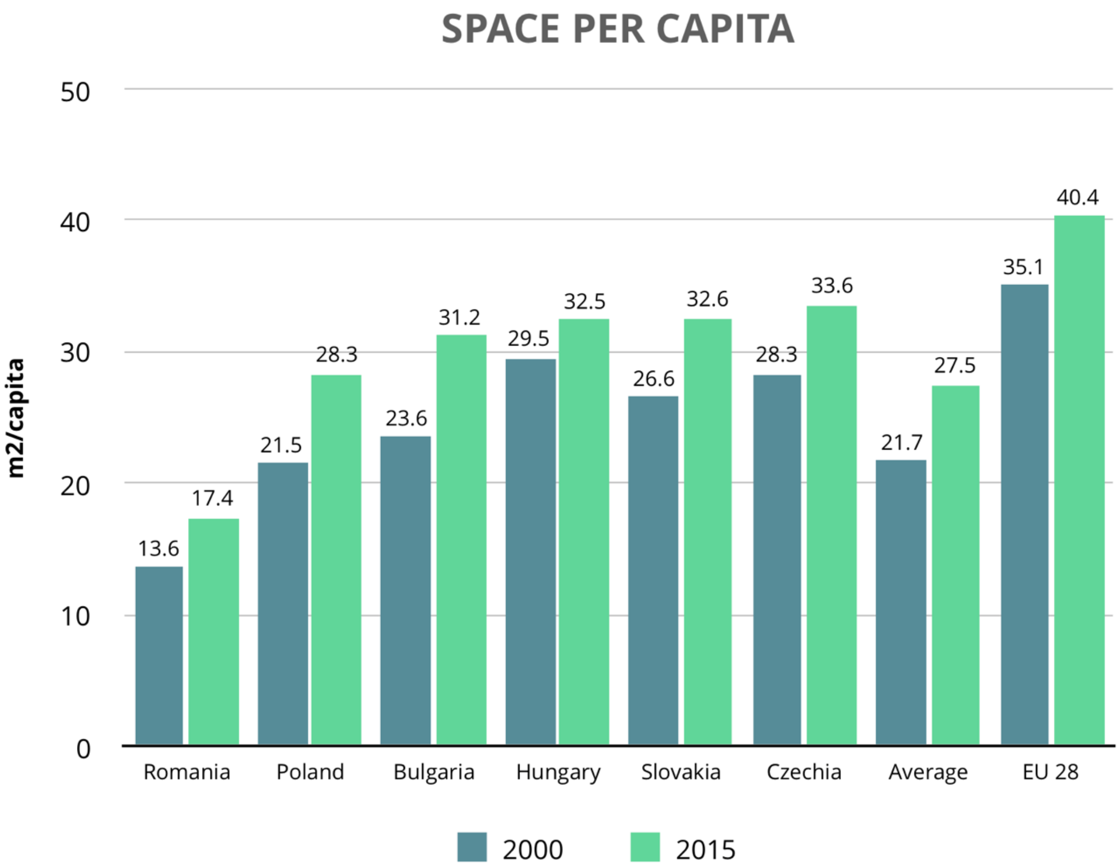

Figure 12: Space per capita in 2000 and 2015 in the selected countries and EU. Source: Own calculation based on (EU Science Hub, 2019).

Despite these increases, the average space per capita in the six analyzed countries was below the EU28 average of 40,4m^2 per capita in 2015. However, the much faster growth rate of the CEE countries decreased this discrepancy slightly: from 13.4 m^2 per capita in 2000 to 12.9 m^2 per capita in 2015. It can be expected that as the income levels in these countries converge with other EU member states, so too will the amount of space per capita.

With the exception of Hungary, the impact of increased space per capita has been counterbalanced by a decrease in energy intensity per square meter. With the exception of Poland, this increase in energy efficiency resulted in an overall decrease in energy consumption from the residential building sector.[5] For some countries this decrease was significant, amounting to 27% in Romania and 41% in Slovakia. In Poland residential sector consumed 2% more energy for space heating than in 2000 (See Figure 15).

Romania and Czechia were the countries with the highest energy intensity at around 160 kWh/m^2. The neighboring countries of Bulgaria and Slovakia consumed the least energy per square meter – 57 and 76 kWh/m^2 respectively. These differences are mainly due to differences in the age of the building stock, renovation rate, and renovation depth, driven by national policies (European Commission, 2019).

[5] While the average annual increase in space *per capita* in Hungary was higher than improvement in energy efficiency, the overall final energy consumption was lower due to a decrease in population by 3.5%. As a result, in 2015 residential sector consumed 0.7% less energy for space heating than in 2000.

In addition, energy demand for space heating has also been driven by the change in the number of heating degree-days (HDD) in the selected countries[6]. The average number of HDD decreased substantially in all selected countries between periods 2000-2005 and 2010-2015. The biggest decrease could be recorded for Hungary and Slovakia – by 6.4% for both countries – indicating decreasing need for space heating. Bulgaria, which witnessed the largest decrease in energy intensity experienced the smallest decrease in the number of HDD, showing that other factors must have played a much more important role in the improvement in energy efficiency. (See Figure 13).

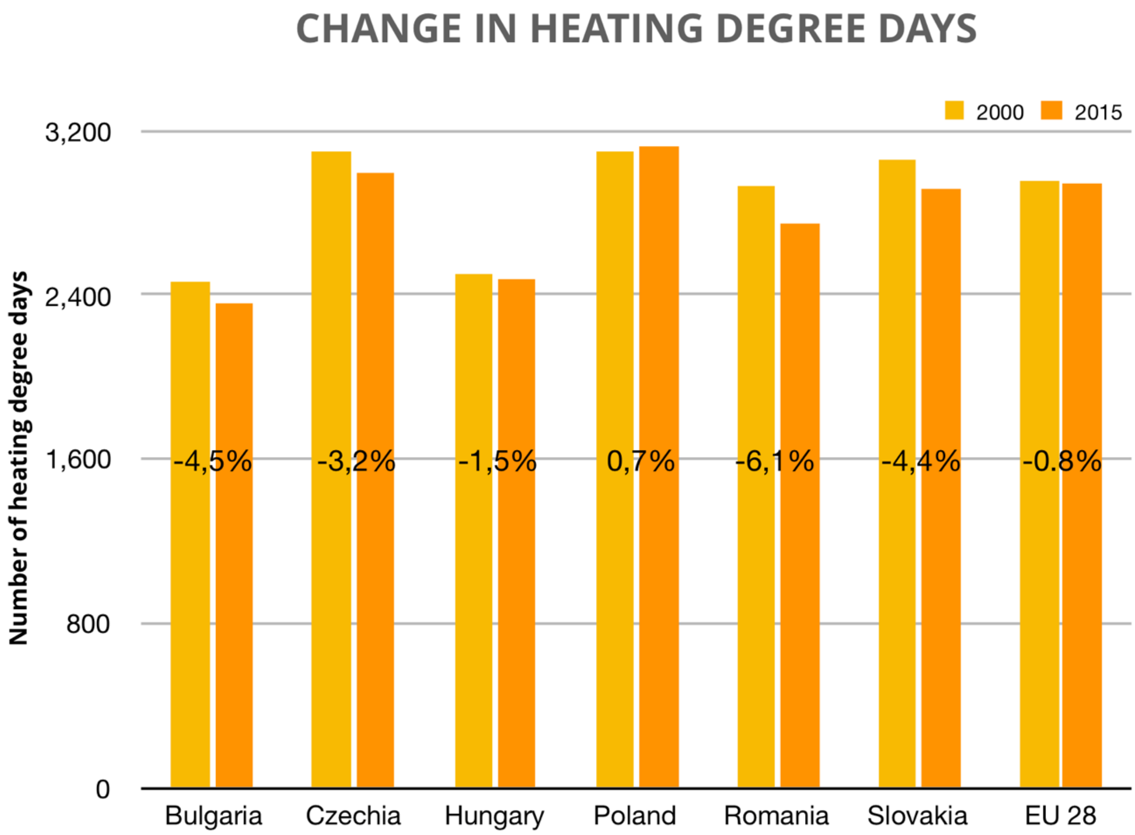

Figure 13: Average change in heating degree days between 2000-2005 and 2010-2015 in the six selected countries. Own calculations based on (Eurostat, 2020b).

[6] The HDD index is calculated by multiplying the **number** of days during which the mean temperature is equal or below 15°C by the **number of degrees** between 18°C and the mean temperature on such days. More information can be found at (Eurostat, 2020b).

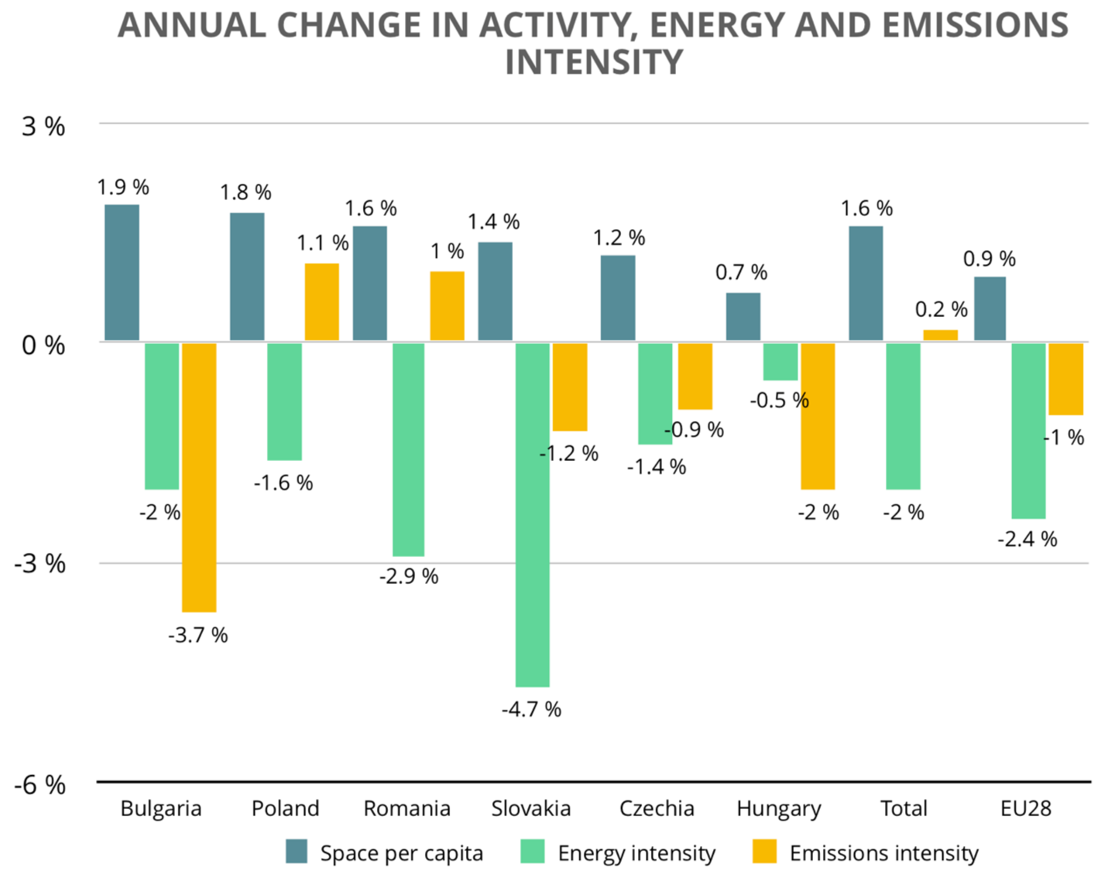

Figure 14: Annual Change in activity, energy and emissions intensity. Own calculation based on (EU Science Hub, 2019).

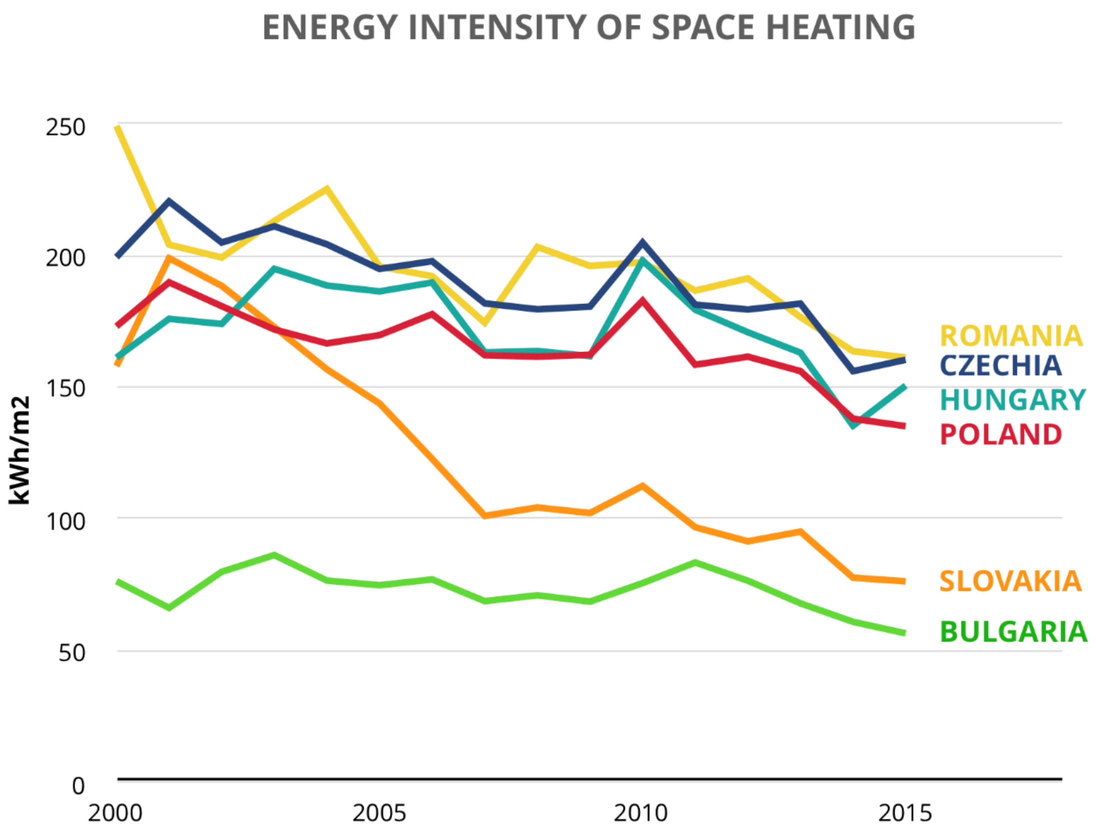

Figure 15: Energy used for space heating for selected countries. Own calculation based on (EU Science Hub, 2019).

In all cases the decrease in *useful*[7] energy consumption was less explicit. Between 2000 and 2015 the amount of useful energy consumed has actually increased in all countries except for Romania and Slovakia. However, the latter country noticed the higher improvement in the ratio between final and useful energy – from 57% in 2000 to 68% in 2015. While an improvement of 4-6%-points could be observed for all other countries, it did not exceed 63%.

A decreasing gap between final and useful energy was the result of greater efficiency of energy generation in the home (e.g. private ovens) and an increasing role of electricity for which no such losses occur. Also the role of heat pumps - for which the ratio of useful to final energy is more than 200% - started increasing in all countries but was still minimal in 2015 (EU Science Hub, 2019).

In four of the six selected countries the impact of an increase in energy efficiency was strengthened by decreasing emissions intensity. The largest decrease took place in Bulgaria, which already in 2000 had the second lowest levels of emissions intensity of final energy at 76 gCO_2/kWh of energy used in space heating. By 2015 it decreased further to 43 gCO_2/kWh, which is by far the lowest level of the selected countries. In Poland and Romania emissions intensity went in the opposite direction and increased on average by 1.1% and 1% annually. Due to Poland's size, this resulted in an increase of the weighted average for all selected countries by 0.2% (See Figure 14 & Figure 16).

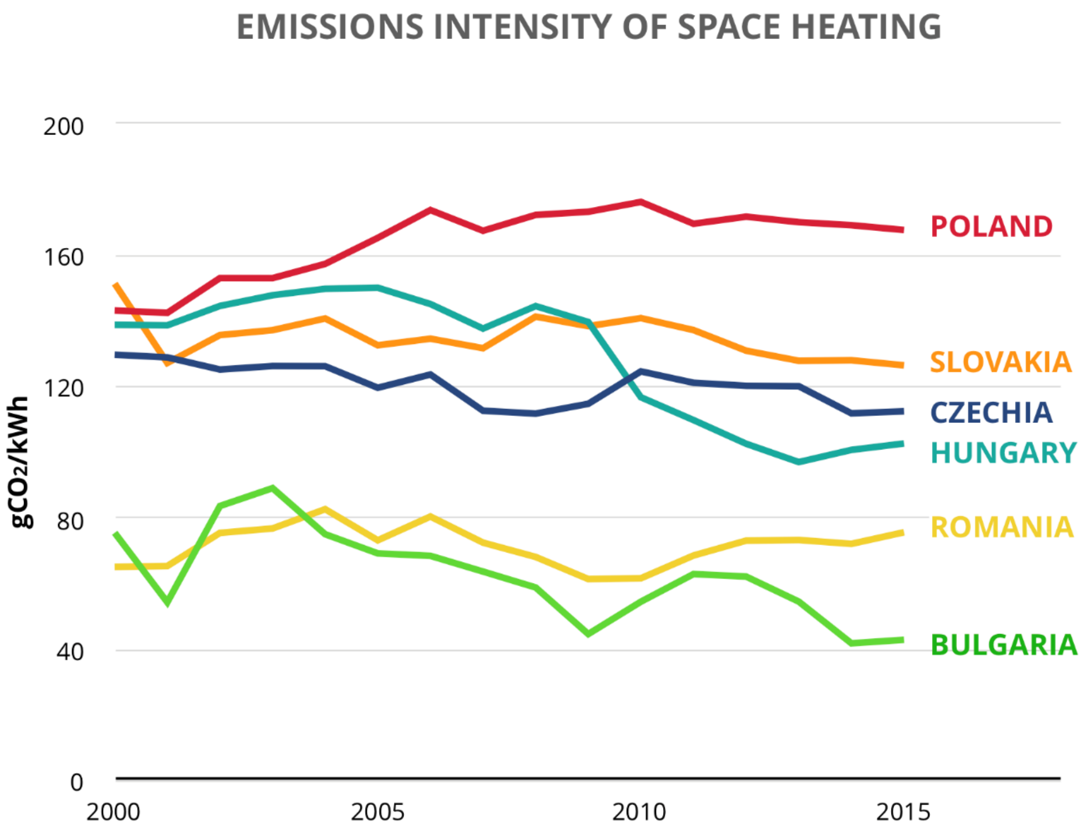

Figure 16: Emissions intensity of energy used for space heating for selected countries. Own calculation based on (EU Science Hub, 2019).

[7] Final energy is energy delivered to final user and thus excludes energy losses during deliveries and transformation. If the energy takes the form of fuel which needs to be combusted (e.g. coal or fuel oil), the losses occurring during the combustion constitute the difference between final and useful energy

These changes in emissions intensity were driven by changes in the fuel mix. Poland and Romania, the only two countries that noted an increase in emissions intensity, were also the only ones in which the share of coal increased. The significant fall in emissions intensity in Romania was driven largely by increasing share of renewables – almost exclusively biomass. When combined with district heating and electricity, 86% of energy consumed for space heating in Bulgaria was coming from sources no causing *direct* emissions. As mentioned earlier, however, this excludes *indirect* emissions in district heating plants and power plants.

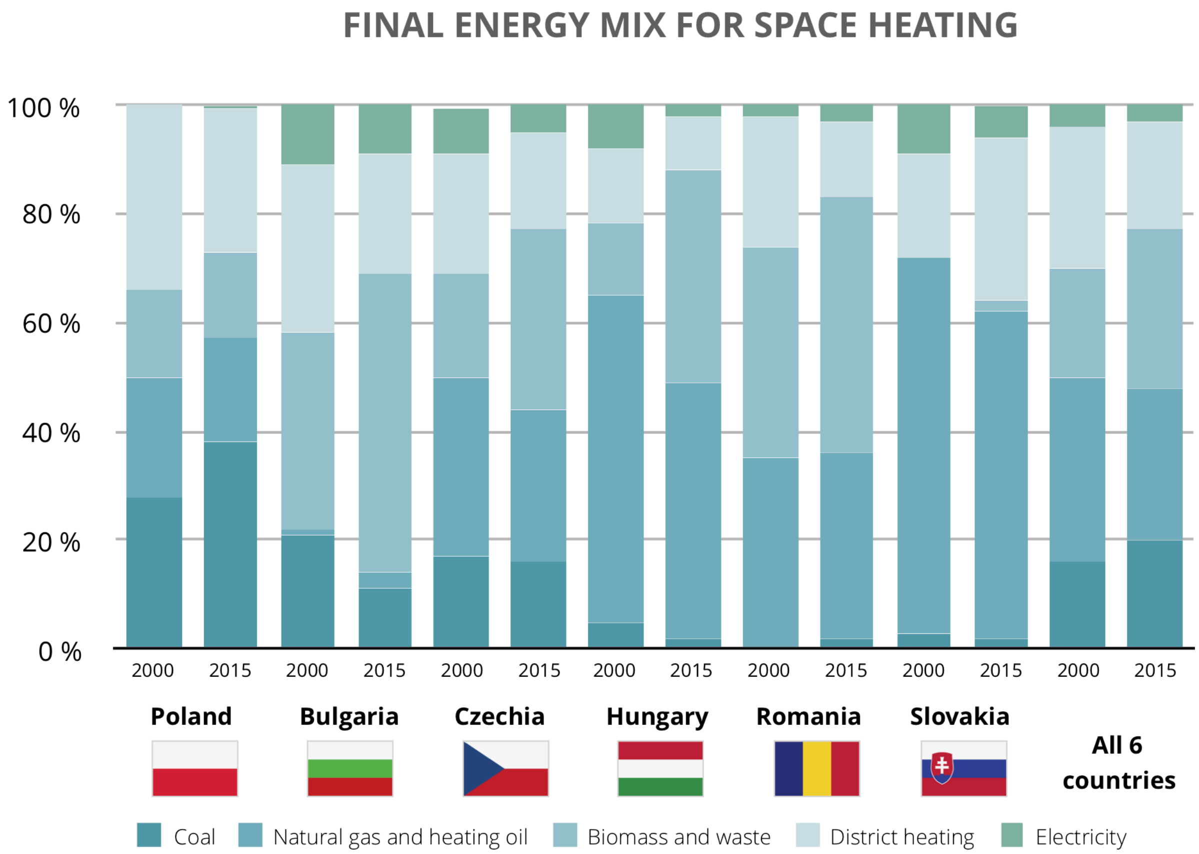

Figure 17: Sources of energy in 2000 and 2015. Fuel used in district heating plants are subsumed under "district heating". Own calculation based on (EU Science Hub, 2019).

The weighted average for all selected countries indicates a major increase in the share of renewables, to a large degree replacing district heating, and to some degree also natural gas (Figure 17). The decreasing role of the latter was also prompted by an increase in the share of coal in Poland. However this development seems to be only temporary – after a peak in 2010 coal consumption for space heating in the biggest country in the region started to decrease and fell by 25% by 2015.

4.2. Space cooling

As it is powered by electricity, space cooling does not contribute to direct emissions. In 2015 it has also contributed to 0.12% of the final energy consumed in residential building sector. However, what is worrying is the dynamic of the increase and the potential for further growth.

Between 2000 and 2015 final energy consumption for cooling increased 6.3-times for all selected countries combined. This increase has mainly been driven by an increase in the cooling space as more and more dwellings were equipped with air conditioning (See Figure 18). As a result in 2015 between 2.2% (Poland) and 10% (Romania) of households were equipped with such a device. At the beginning of the century the share of air conditioned dwellings was less than 1% for all countries, except for Romania.

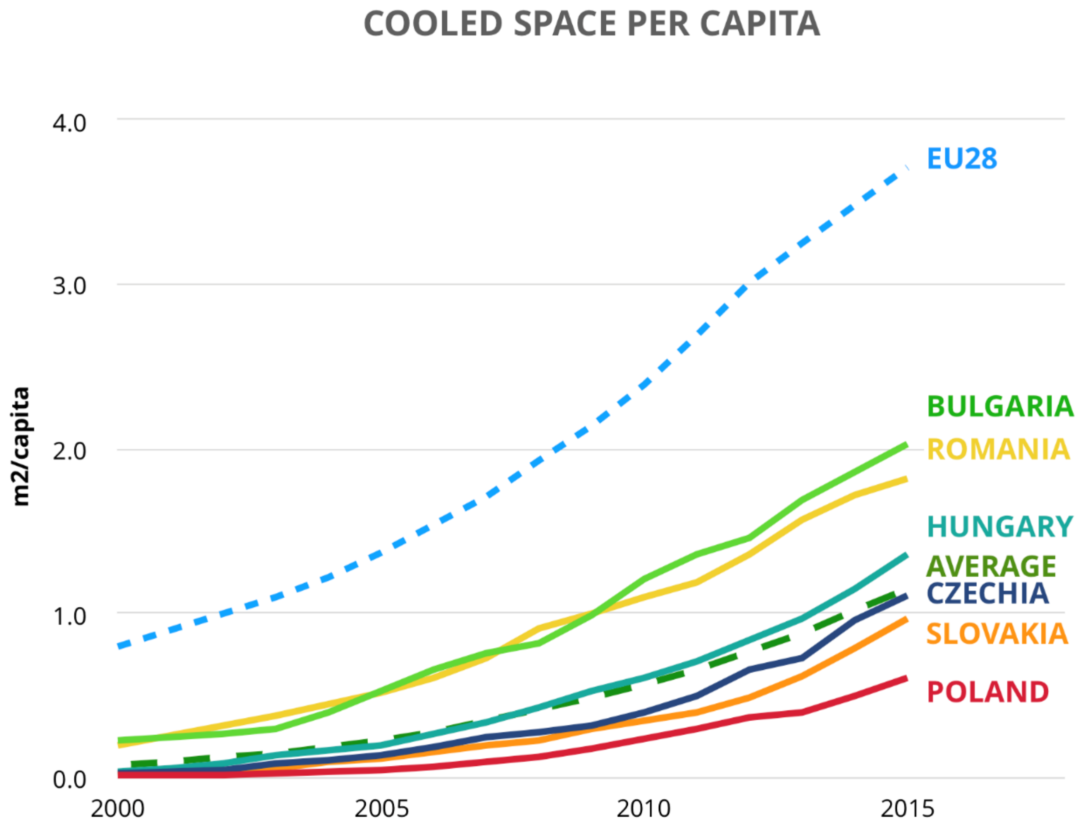

Figure 18: Cooled space per capita in selected countries. Own calculation based on (EU Science Hub, 2019).

This increase in demand can be explained on one hand by increasing levels of income and thus affordability of such an equipment, when made essential by cold weather conditions. On the other hand increasing average temperatures, reflected in the increasing number of Cooling Degree Days (CDD) (See Figure 19) have made cooling equipment more popular also in countries where they were previously very rare, especially Poland, Czechia, and Slovakia. The continuation of both trends - increasing income and increasing need for air conditioning resulting from rising temperatures - make it possible for the rapid increase in energy consumption by space cooling to continue or even accelerate in the selected countries in the coming years.

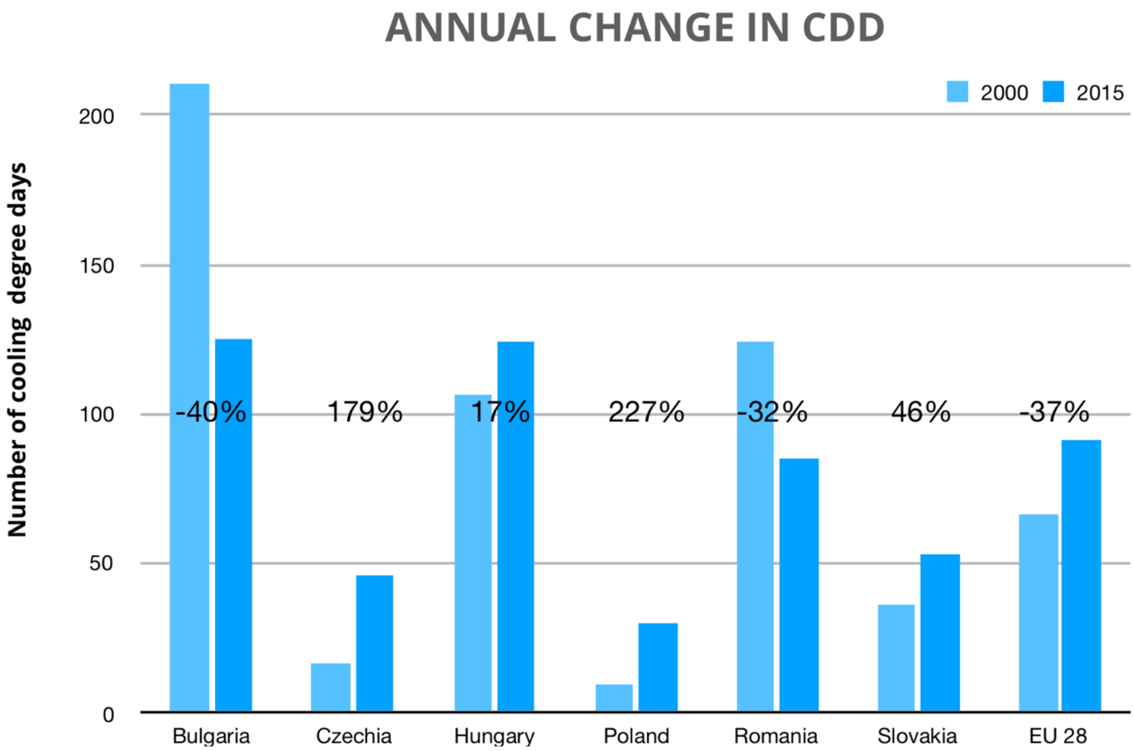

Figure 19: Average change in cooling degree days between 2000-2005 and 2010-2015 in the six selected countries. Own calculations based on (Eurostat, 2020b).

The impact of the increasing cooled space has been limited by a decrease in energy intensity reflected in a decrease in the amount of energy per square meter. In absolute terms, the most energy per square meter of cooled space was used in Romania – 7.6 kWh – which was almost three times as much as in Poland – 2.8 kWh (Figure 18). This difference could be explained by weather conditions, but also better efficiency of mostly recent bought air conditioners: whereas in Romania the ratio of thermal to final energy was 2.6, and in Poland it exceeded 2.8. The highest efficiency of air conditioning equipment could be recorded in Slovakia, with one unit of final energy generating 3.5 units of useful energy.

4.3. Water heating

On average 16% of final energy used in residential building sector is used for water heating. This means an increase both in the share – by around 2.7%-points – and in absolute terms: by 22%. Water heating was also the source of around 16% of direct emissions from the residential sector. However, in this case the share increased faster than in the case of final energy consumption: by 3.2%-points, which indicates slower decarbonisation of this source of emissions.

The increase was the slowest in Poland with the highest energy consumption for water heating in 2000. As a result, in 2015 it was overtaken by Czechia. Despite the fastest increase, Romania remained the country with the smallest amount of energy for water heating per capita (See Figure 17). But the difference between the weighted average for all countries and Romania decreased: in 2000 an average Romanian used 65% of the average energy consumption for all countries. By 2015 it was already 74%.

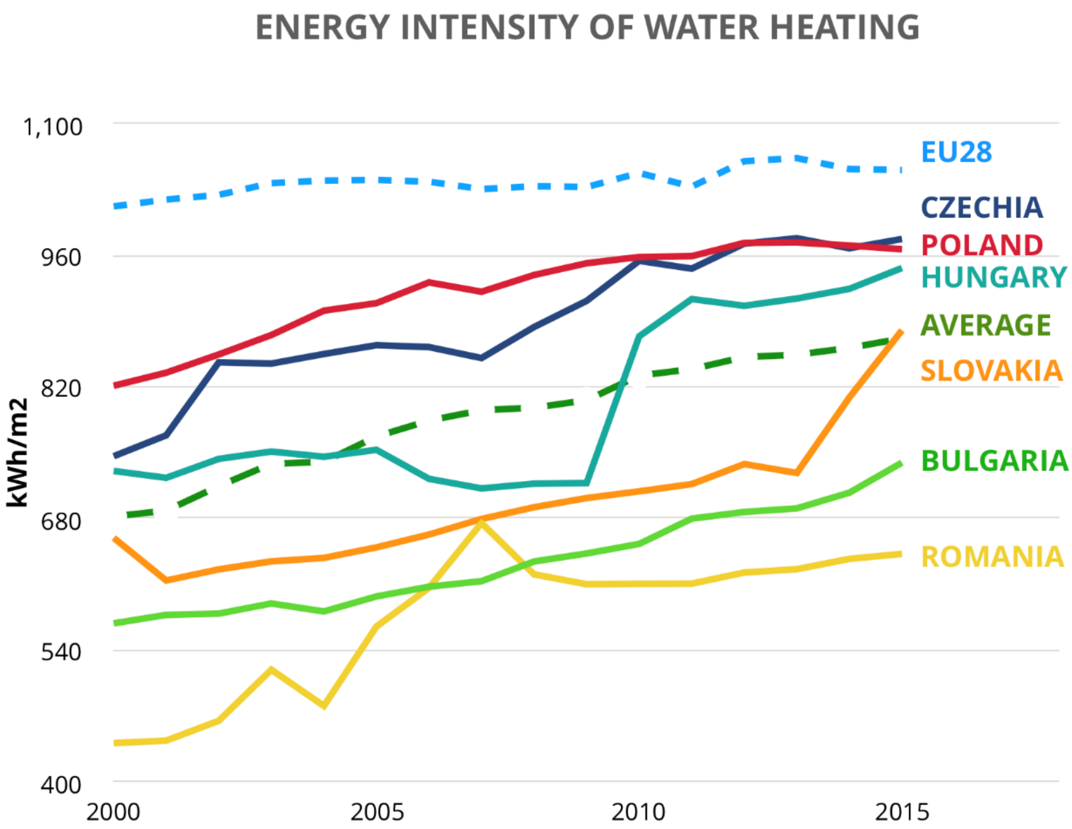

Figure 20: Energy used for water heating per capita in the selected countries. Own calculation based on (EU Science Hub, 2019).

Emissions intensity of the energy used for water heating decreased in half of the countries and increased in the other half. The highest increase could be noted in Poland – by 1.1% annually. As a result, with the emissions intensity of the energy used for water heating at 170gCO_2/kWh, Poland ended up with by far the highest emissions intensity. It was followed some way behind by Slovakia with 122 gCO_2/kWh. Bulgaria was the country with the cleanest energy for water heating – with only 18 gCO_2/kWh (See Figure 20). Due to Poland's size and thus impact on the weighted average, the average emissions intensity for all countries increased by 7.6% between 2000 and 2015, or around 0.5% annually (See Figure 21).

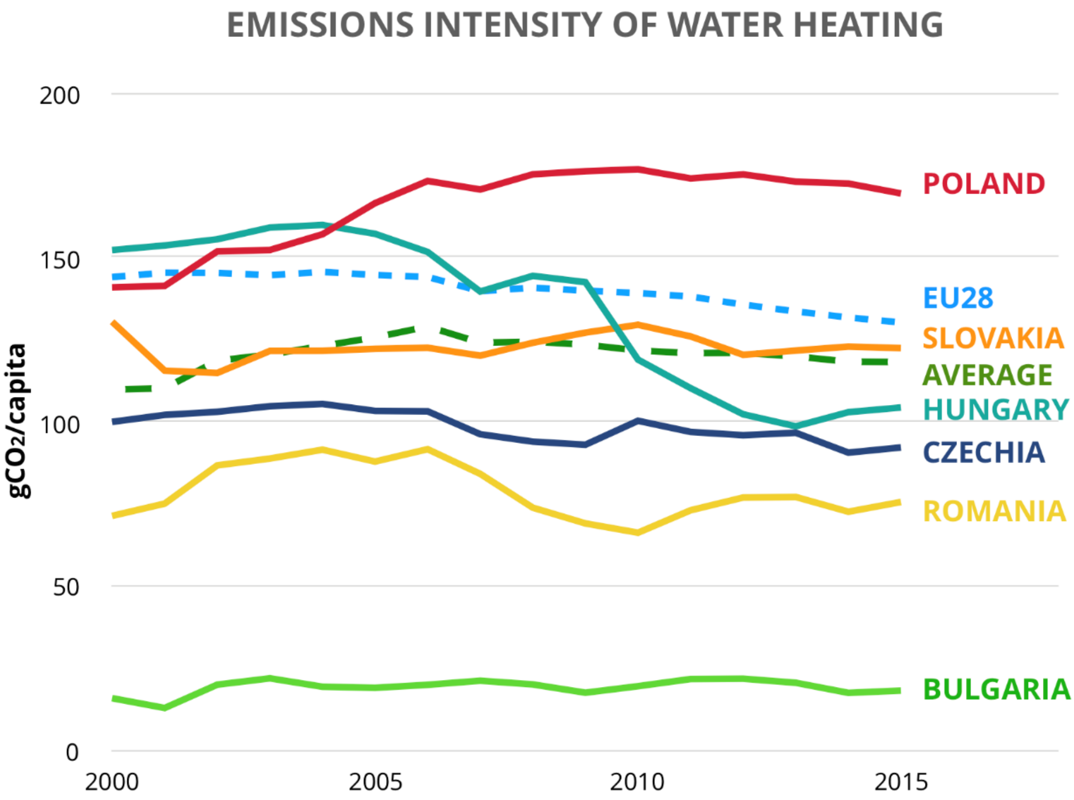

Figure 21: Emissions intensity of energy used for water heating. Own calculation based on (EU Science Hub, 2019).

This significant difference in the emissions intensity between Poland and Bulgaria was driven mainly by the high – and increasing – share of coal for water heating. This simultaneous increase in the role of coal for space and water heating in Poland results from often common central heating installation, which in summer is temporary replaced by electric water heating. In Bulgaria a large portion of the electric and district heating has been replaced by biomass – similarly to space heating. In all selected countries the role of solar energy increased between 2000 and 2015 but was still relatively small – up to 2.1% of all final energy used for water heating in Bulgaria (See Figure 22).

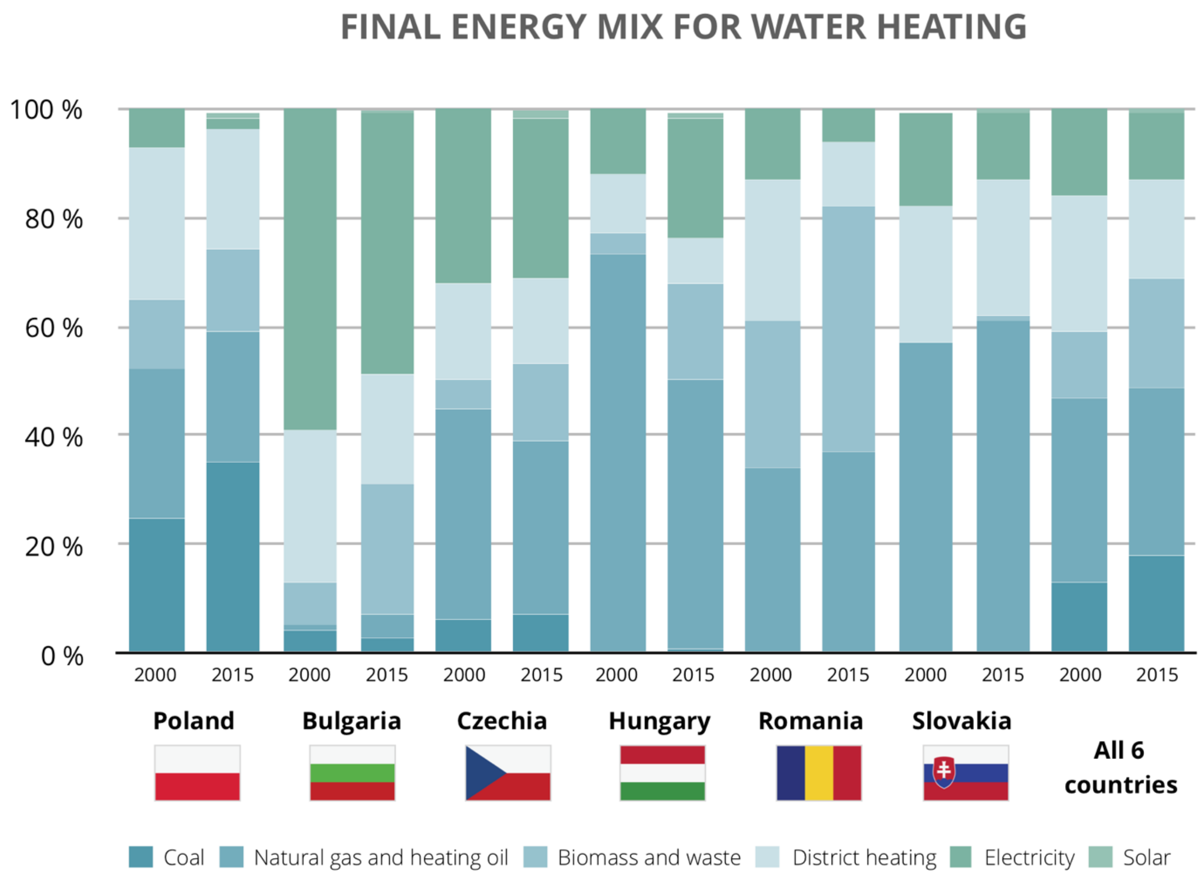

Figure 22: Final energy mix used for water heating. Own calculation based on (EU Science Hub, 2019).

4.4. Cooking

In all selected countries final per capita energy consumption for cooking increased, both in absolute and in relative terms. On average almost 9% of energy used in residential building sector was used for this purpose in 2015 – an increase in the share by 2.1%-points, or 33% in comparison to 2000. The highest share was recorded in Bulgaria and Romania – almost 12 and 10%, respectively. However, this was much more driven by lower energy consumption in the other subsectors, rather than lower absolute energy consumption. In that respect Hungary was well ahead of other countries, with 610 kWh/per capita used for cooking in 2015.

The 2.2% average annual increase in final energy consumption was driven mainly by Poland (+3% annual increase) and Romania (+2.6%). In Czechia and Slovakia the increase was much slower: at 0.7% and 1.1% annually. The much lower starting point for the latter – 386 kWh/capita – combined with the second slowest rate of increase in energy consumption, resulted in the lowest per capita energy consumption for cooking among the selected countries (See Figure 23).

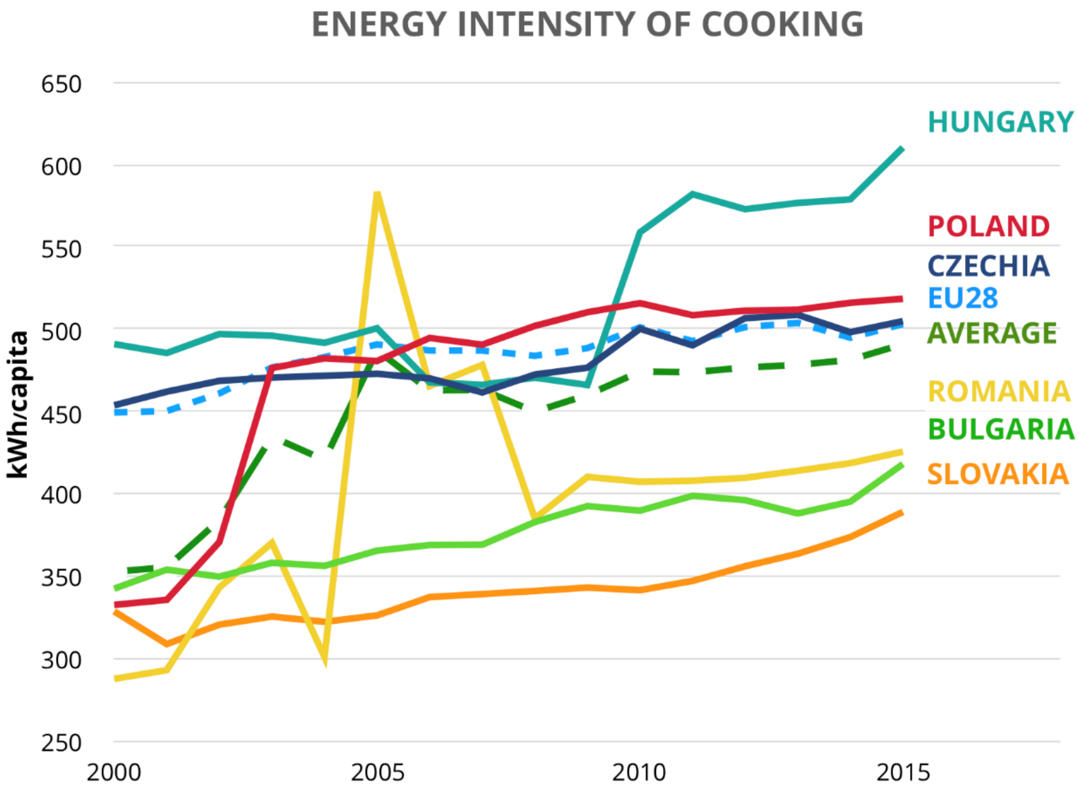

Figure 23: Energy used for cooking per capita in the selected countries. Own calculation based on (EU Science Hub, 2019).

The impact of cooking on the overall emissions has also increased. On average, in 2015 almost 15% of emissions from residential building came from this activity, an increase by 3.4%-points, or 31% in comparison to 2000. This is the highest increase out of the three subsectors that contribute to direct emissions, and considerably above the 4% increase in overall emissions.

This trend was driven by Poland and was the result of the aforementioned increase in energy consumption, combined with only modest decrease in emissions intensity of the energy used for cooking – on average 0.4% annually. As a result Poland remained the country with more than twice as high emissions intensity in comparison to the 2nd country in this regard, Romania. Bulgaria was the only country in which emissions intensity increased – by 2.4% annually – but remained by far the lowest among the selected countries (See Figure 24).

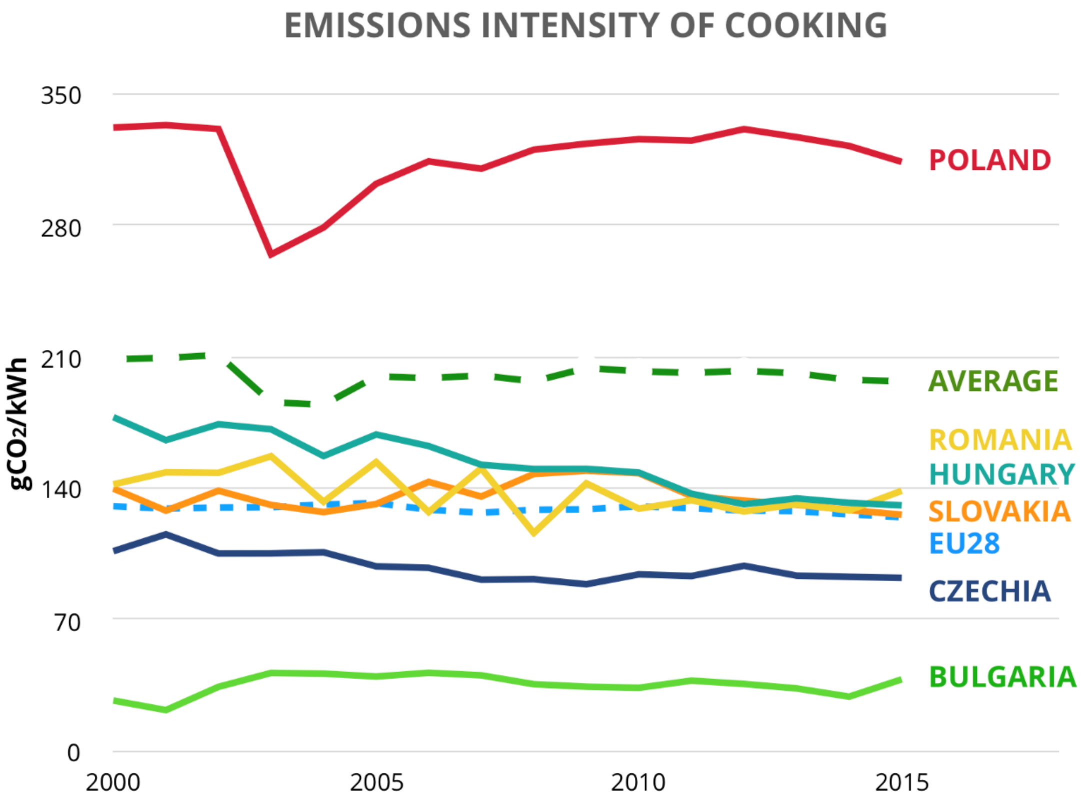

Figure 24: Emissions intensity of energy used for cooking. Own calculation based on (EU Science Hub, 2019).

Poland's high emissions were caused by far the highest – and increasing – role of coal for cooking. With 21% of final energy used for cooking coming from this source of energy in 2015, it was the only country using this fuel on such a scale. In Bulgaria, where coal generated 7% of energy used for cooking in 2000, this share of coal decreased in 2015 to 2%, whereas in Hungary it halved and amounted to 0.1% (See Figure 25).

All countries, except for Bulgaria, registered an increase in the role of electricity for cooking. This could be explained on one hand by increasing utilisation of the existing appliances, while on the other by "healthy eating" lifestyle which drove the increases of appliances such as light fryers, slow cookers, electric grills and cookers (Euromonitor International, 2020b, 2020a).

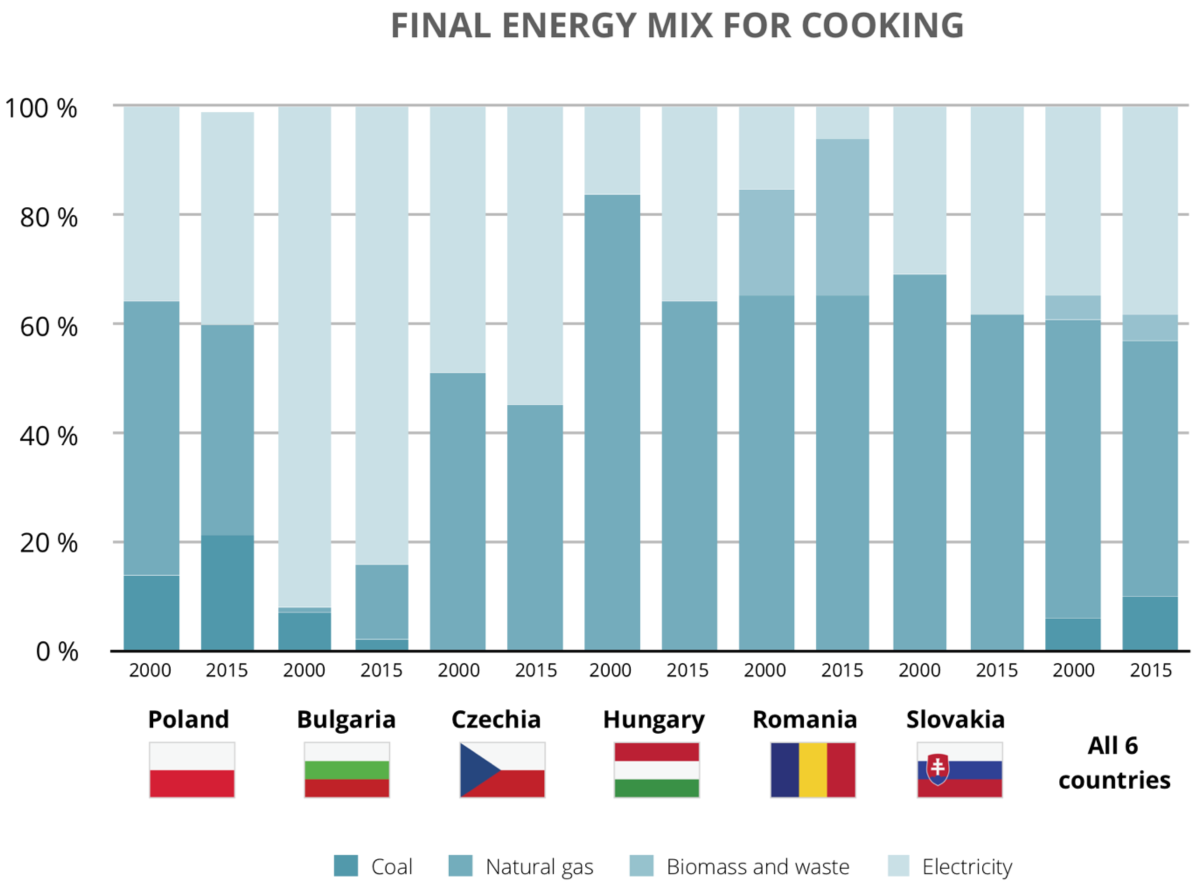

Figure 25: Final energy mix used for cooking. Own calculation based on (EU Science Hub, 2019).

4.5. Appliances

Final energy consumption by appliances increased in all selected countries, both in terms of share and absolute energy consumption. On average, in 2015 appliances used as much final energy as cooking – around 9% - but recorded slightly faster increase: by 2.3%-points, or 39% in absolute terms. However, the trend of this increase in final energy consumption was different than for cooking: after a steady increase until 2012, all countries registered stabilization or even a decrease for Czechia and Poland (See Figure 26). At the same time the number of appliances continued increasing – even faster for Bulgaria (See Figure 27).

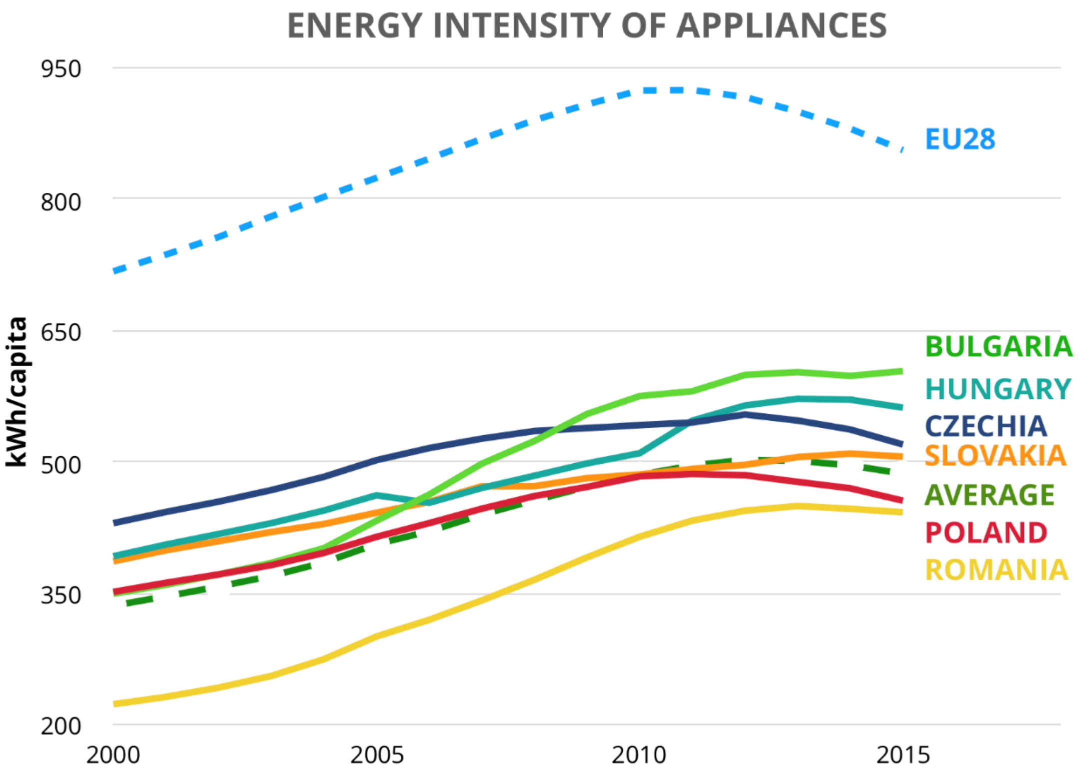

Figure 26: Energy used for appliances per capita in the selected countries and the EU28. Own calculation based on (EU Science Hub, 2019).

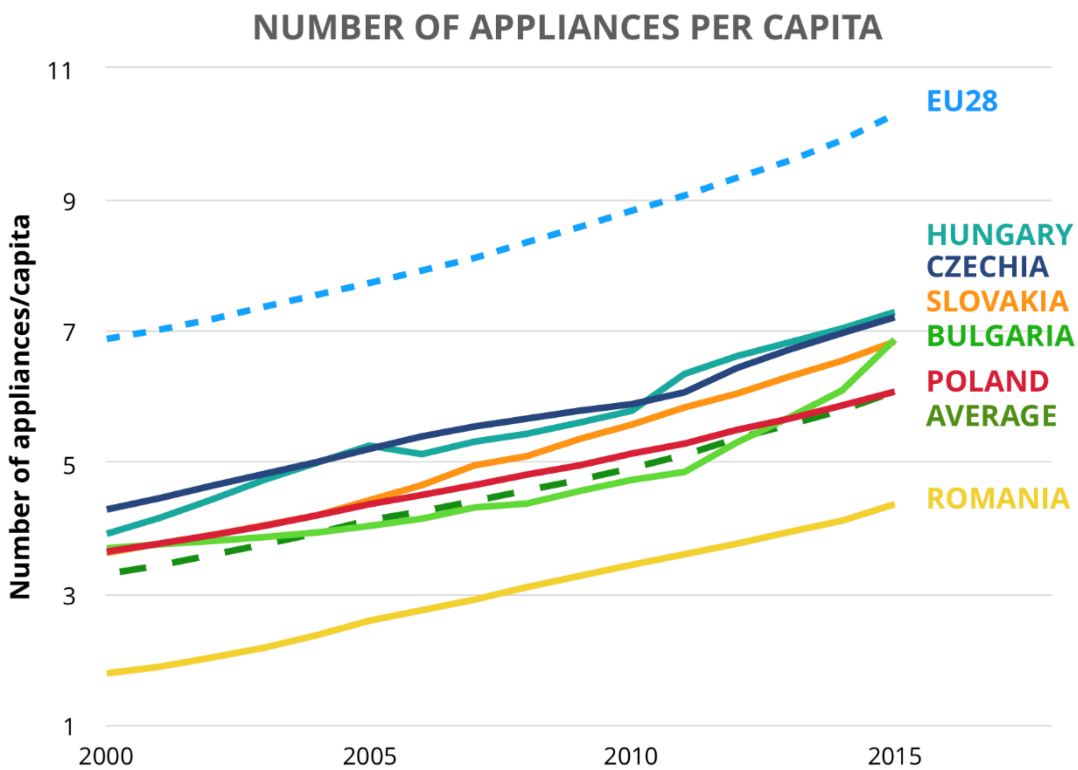

Figure 27: Number of appliances per capita in the selected countries. Own calculation based on (EU Science Hub, 2019).

This discrepancy between slowing energy consumption and an increasing number of appliances per capita can be explained by an increase in the variety of appliances driven by their increasing affordability and increasing income in the selected countries. After 2012 this trend was counterbalanced by market saturation and increasing efficiency of the appliances, resulting from technological development and EU eco-design legislation. The early peaking of energy consumption for appliances in Romania, despite increasing income per capita, could indicate that most of the appliances usually used for a longer time, e.g. refrigerators and washing machines, were newer, thus the market saturation could be achieved at a lower level of energy consumption.

It must be noted, however, that despite the continued increase in the number of appliances as a result of which there were between 4.4 and 7.3 appliances per capita (weighted average at 6.1) all countries were significantly below the EU28 average at 10.3 per capita.

5. RBP Scenario until 2030

The continuation of existing national trends for all factors that influence emissions described above (BAU Scenario), would result in combined residential emissions for the selected countries increasing by almost 5% between 2015 and 2030. The highest increase in Poland (+26%) would be counterbalanced by a significant decrease –27% in Slovakia, 24% in Bulgaria, and 23% in Hungary. According to BAU Scenario, emissions in Czechia would decrease by 10% and increase by around the average rate in Romania (see Figure 28).

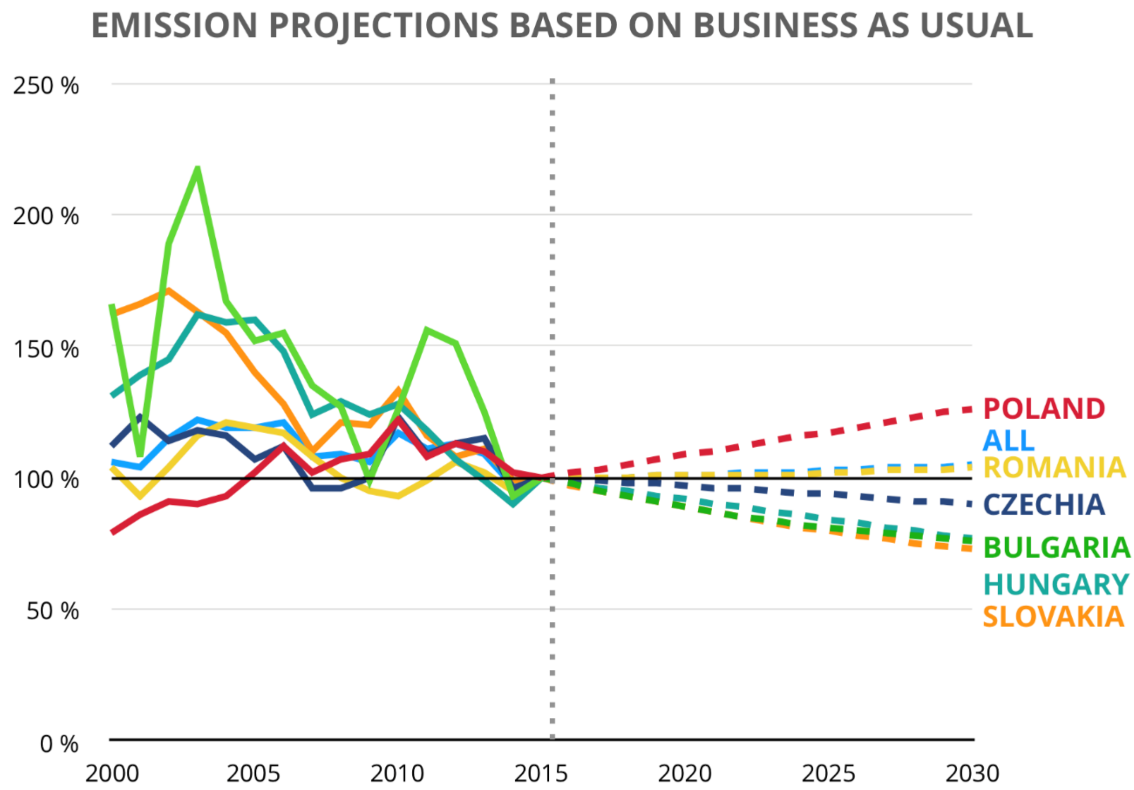

Figure 28: Emissions in the BAU Scenario based on trend between 2000 and 2015. Own calculation based on historic data from (EU Science Hub, 2019).

Energy consumption would increase on average by 7.3%. This is driven by an increase in energy consumption in five out of the six selected countries – the fastest in Poland by 11%. Only in Slovakia would energy consumption decrease by 10.5%. This faster increase in energy consumption in comparison to emissions could be explained by two trends. Firstly, decreasing emissions intensity of energy used for space heating (-6.4%), water heating (-1.0%), and cooking

(-7.6%). Secondly, a significant increase in energy consumption by space cooling and to a lesser degree appliances sectors, for which no direct emissions are recorded. For space cooling energy demand would increase 8-fold between 2015 and 2030. The continuation of past trends would result in cooled space per capita reaching the levels of heated space by the late 2020s in Czechia, Slovakia, and Hungary.[8] Energy consumption for appliances would increase by 42% on average for all selected countries.

The application of the Regional Best Practice (RBP) trends would result in average emissions reduction of almost 57% between 2015 and 2030. While there is some variety between different countries, the range of the emissions reduction is relatively small: the largest reduction in emissions would take place in Bulgaria (-61%), and smallest in Slovakia (-53%) (See Figure 29).

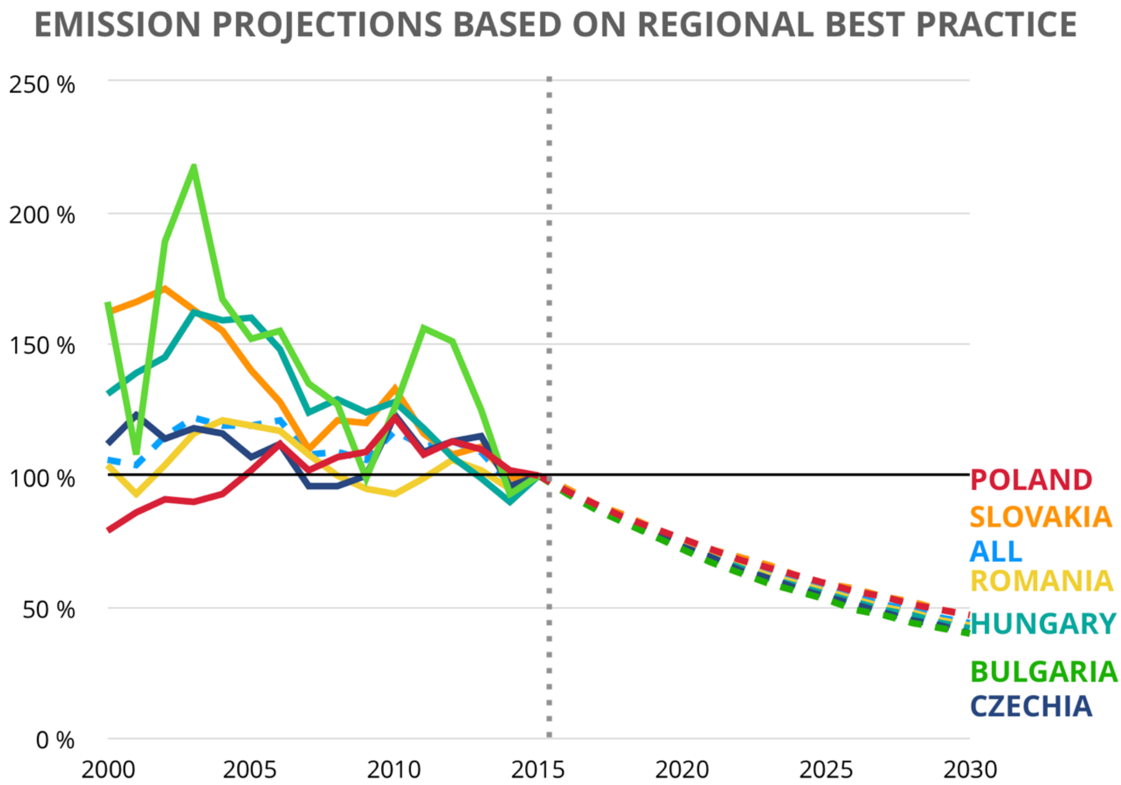

Figure 29: Emissions in the RBP Scenario. Own calculation based on (EU Science Hub, 2019).

Out of the 10 RBP, only Romania did not contribute any. Three RBPs are found in Hungary – decreasing emissions intensity for water heating and cooking, and the slowest increase in heated space per capita. Czechia, Bulgaria, and Slovakia contributed each two RBPs. Slovakia's RBPs dealt with decreased energy intensity for heating and cooling, both of which could result from better home insulation. Bulgaria registered the slowest increase in cooling space, which to a large degree results from higher starting base, as well as decreasing emissions intensity of energy for space heating – despite already one of the lowest emissions intensity in 2000. Czechia's RBPs dealt with the slowest increase in energy consumption for cooking and appliances. The sole RBP from Poland dealt with the slowest increase in water heating (See Figure 30).

[8] The BAU rate of growth for cooled space per capita was adapted to cooled space not exceeding heated space for those countries.

Poland, which was the source of only one RBP, would register the largest decrease in emissions in comparison to BAU in 2030 (by 63%). The significant decrease in emissions for Bulgaria – already the country with the lowest emissions intensity from the residential buildings sector in 2015 – results from complementarity of the "imported" RBP with the areas in which it is the source of RBP. This concerns especially the RBPs concerning slowdown in an increase in space heated space and acceleration in an improvement in *energy intensity* for space heating, which complemented a decrease in *emissions intensity* of energy used for space heating. Whereas the latter may not be socially desirable, the former would result in energy consumption at around 40 kWh/m2 on average for the housing sector.

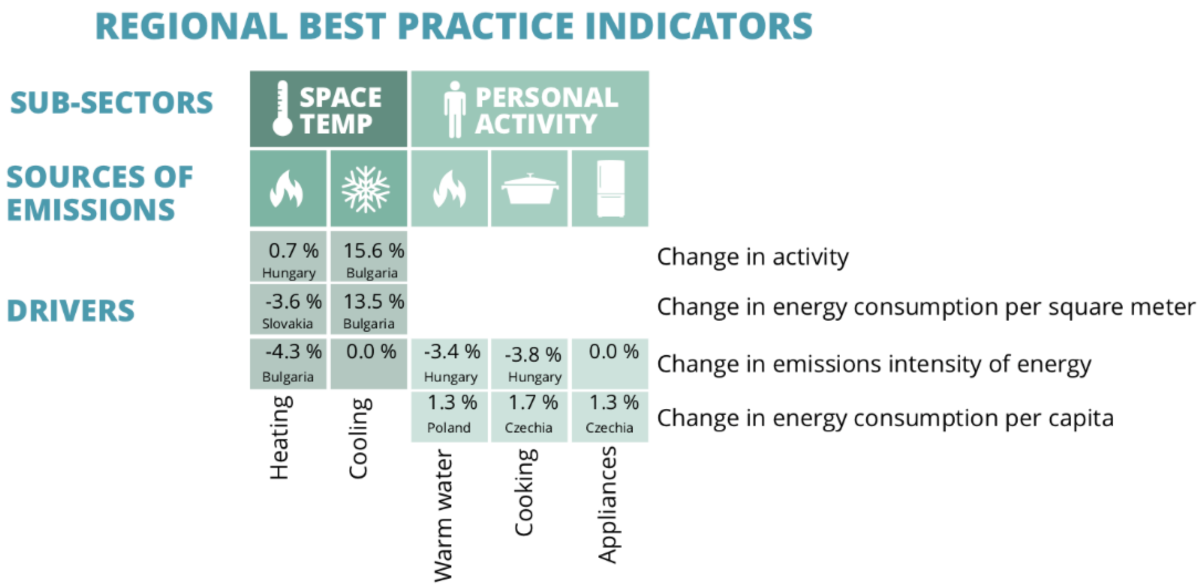

Figure 30: Regional Best Practice in residential buildings sector.

The most impactful were the RBPs dealing with space heating. Reducing an increase in space to 0.7% annually, combined with accelerating the decrease in energy intensity to 4.7% annually and emissions intensity to 5.7% annually, would result in reducing emissions from the residential sector by 30.2 $MtCO_2$ in 2030 – or 75% of the impact of RBP (See Figure 31). However, the impact of slowing down an increase in space per capita is relatively small and corresponds to around 2.2 $MtCO_2$ emissions reduction. Should countries increase heated space at the same speed as between 2000 and 2015, but implement the optimal trends in terms of energy and emissions intensity in space heating, emissions from this subsector in 2030 would decrease by 37%.

Application of RBP indicators dealing with water heating – slowing down an increase in energy consumption to 1.1% and improving energy efficiency by 2.5% annually – would reduce emissions from this subsector by 40% in comparison to BAU Scenario in 2030 or by 21% in comparison to 2015. The impact of reduced emissions intensity is playing a dominant role: even with energy consumption increasing at the same speed as in the past, decreasing emissions intensity would reduce emissions from water heating by 37% in comparison to BAU Scenario, or 17% in comparison to 2015 emissions levels.

While to a lesser degree, this observation also applies to cooking, where the impact of emissions intensity of the energy used is larger than the decrease in energy consumption per capita for this purpose. Replacing national BAU trends (weighted average at -0.4%) with the best practice of decreasing emissions intensity by 2% annually would result in emissions from cooking decreasing by 25% in comparison to BAU in 2015. If the consumption of energy for cooking increases at the RBP speed of 0.7% instead of the 2.2%, which is the weighted average for selected countries, emissions from this subsector would decrease by 20% in comparison to 2015 or 41% compared to BAU in 2030.

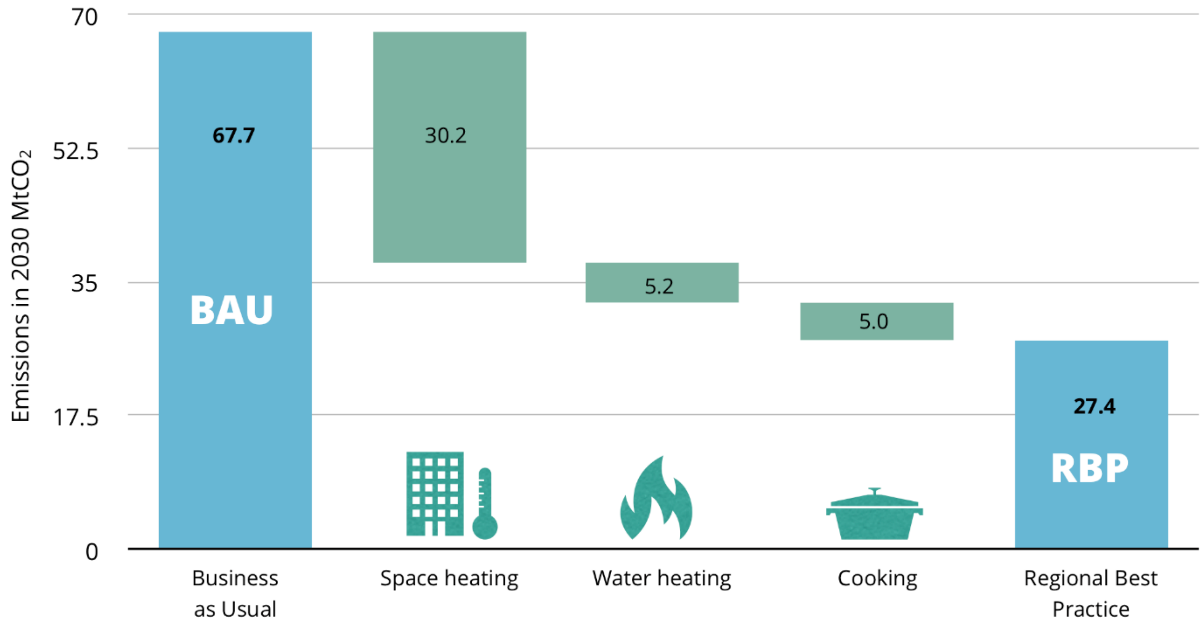

Figure 31: Impact of different subsectors on emissions - combined for all countries. Own calculation.

Application for RBP would reduce the overall energy demand in residential sector by 32% in comparison to BAU in 2030 or by 27% in comparison to 2015. This decrease would mainly result from an increase in energy efficiency for space heating. As a result, final energy consumption for space heating would decrease by 45% in comparison to BAU in 2015, or 48% in comparison to 2015 (See Figure 32).

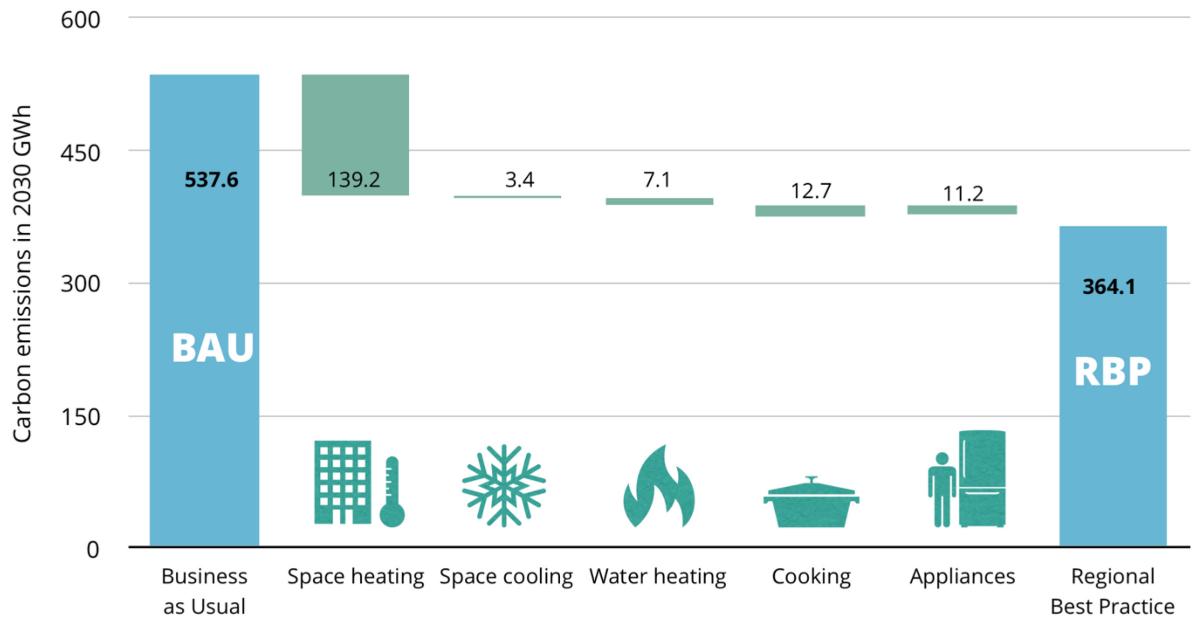

Figure 32: Impact of different subsectors on final energy consumption - combined for all countries. Own calculation.

In comparative terms, space cooling would also be the most impacted by the application of the RBP: in comparison to BAU Scenario, energy consumption in from this activity would decrease by 62%. However, it would still increase significantly in comparison to 2015: by 242%. While at much lower pace, energy consumption would also increase in comparison to 2015 for water heating, cooking, and appliances (See Table 1).

Change in energy consumption		
	RBP versus BAU in 2030	RBP versus 2015
Space heating	-45%	-48%
Space cooling	-62%	242%
Water heating	-7%	14%
Cooking	-21%	8%
Appliances	-18%	17%
Space heating	-45%	-48%

Table 1: Change in energy consumption in comparison to BAU Scenario in 2030 and energy consumption in 2015

The emissions mitigation potential offered by space heating would result in a decrease in its role as contributor to emissions and energy consumption. Application of RBP trends would decrease the share of emissions from this subsector to 46% and final energy consumption to 47% – a decrease from 69% and 66%, respectively in 2015. In terms of emissions, this share would be taken up by water heating (increase by 12%-points) and cooking (increase by 11.5%-points). In terms of energy consumption, the highest increase would be for water heating, which in RBP Scenario would consume a quarter of all final energy used in residential buildings, and appliances, which in RBP scenario would consume 14% of all final energy, over 5%-points more than in 2015.

6. Compatibility with the Paris Agreement

The universal implementation of the Regional Best Practices across the selected countries would allow Czechia, Hungary, Romania, and Slovakia to reduce emissions from residential building sector below the levels that could be considered as the highest possible that could be considered as compatible with the Paris Agreement. That level has been calculated by scaling down the results of the Beyond 2°C scenario (B2DS) using the SIAMESE model (see Methodology Section for more details). For Slovakia, even the continuation of the past trends would allow it to reduce its emissions below the Paris Agreement compatible levels.

Poland and Bulgaria would need to go beyond the implementation of the best trends from the selected countries to cover the 22%-points and 24%-points gap between Paris Agreement compatibility and emissions according to the RBP Scenario in 2030. However, Poland is also the country in which the implementation of the RBP creates the biggest impact – instead of increasing by 26%, emissions would decrease by 53%, a difference of 79%-points. Combined emissions in a scenario assuming universal implementation of the regional best trends in 2030 would reduce emissions by 55% – only 6% above the levels compatible with the Paris Agreement temperature goal in the residential buildings sector.

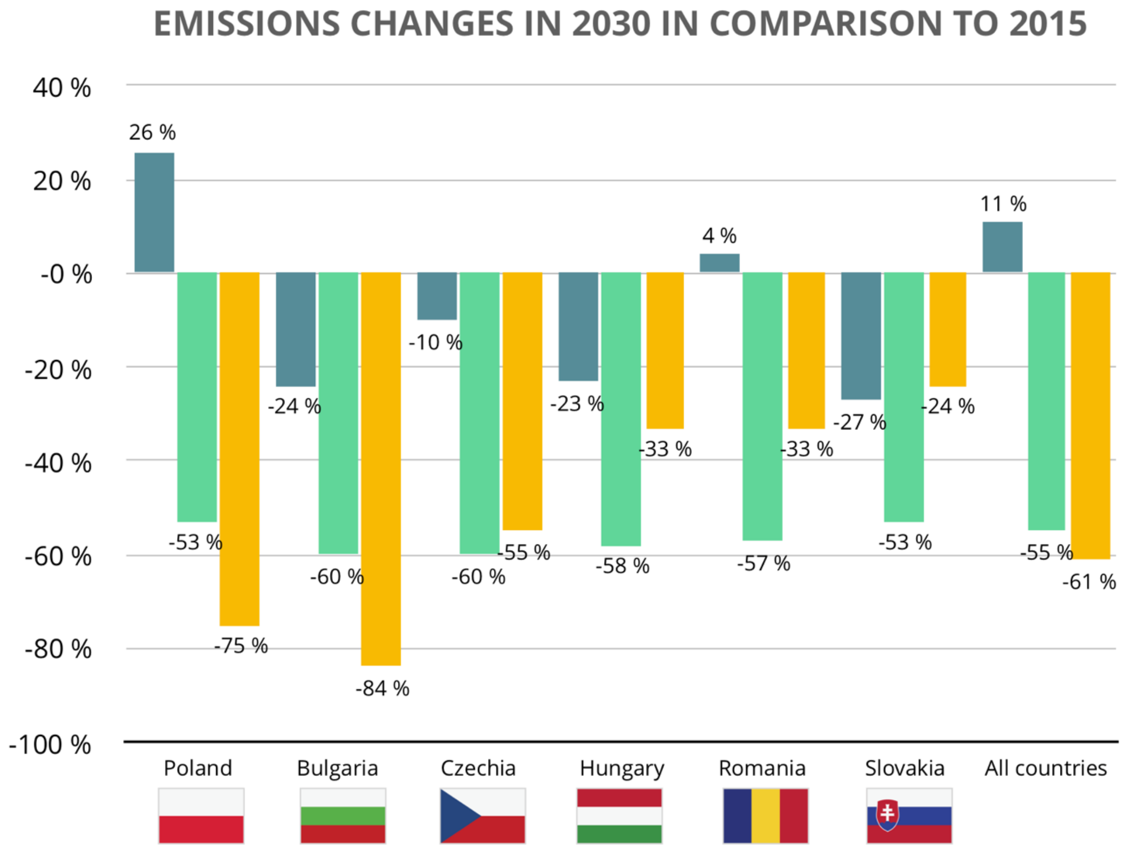

Figure 33: Change in emissions in the residential buildings sector in 2030 according to different scenarios. Own calculation.

The RBP concerning slowing down an increase in heated space per capita belongs to the indicators, which can be politically the most challenging to implement and in many cases run contrary to the economic and social policies. This concerns especially Romania and Bulgaria, which are among the most affected by overcrowding in the EU. Should this trend be ignored and each country continue an increase in heated space per capita at the speed observed between 2000 and 2015 (See Figure 33), the overall emissions would still decrease by 52%, or 3%-points less than in the RBP Scenario. An acceleration in the annual decrease of energy intensity and emissions intensity by 0.5% would make up for this increase in emissions.

7. Conclusions

Increasing income in the selected countries resulted in two countervailing trends from emissions perspective: on one hand construction of new homes and higher expenditures on heating the often under heated dwellings resulted in higher emissions. On the other, it allowed some home owners to invest in energy efficiency and thus reduce energy poverty and emissions.

The results of the assessment of the trends show that despite numerous similarities, countries in the region went in different directions, with important long-term repercussions from an energy and climate perspective. A case in point is the Slovak retrofit support program with 0% interest loans for refurbishment and insulation which resulted in a significant decrease in emissions from space heating and also – possibly less obvious but increasingly important – slowing down an increase in energy demand for space cooling (WiseEuropa, Climate Analytics, Climate Strategies, & Expert Forum, 2019). Where such programs were missing or were less effective, increasing income resulted in higher emissions from badly insulated dwellings.

While space heating constitutes the largest share of emissions, its role is slowly decreasing, both as the source of emissions, and as the source of energy consumption. There is no doubt that reducing energy consumption for space heating at least at the speed observed in Slovakia, and decreasing the emissions intensity of the energy at least as fast as in Bulgaria, is essential to significantly reduce overall emissions from the residential buildings sector. For both, adequate policies driving home insulation and replacing fossil fuels by renewables and electricity, already exist.

However, water heating and cooking will gain on importance as the sources of emissions even if the best observed trends are copied by the other countries. Increasing the role of renewable sources of energy, especially water heating and electrification, could drive a reduction of direct emissions from these two sectors.

But without decarbonization of the electricity sector, electrification would only result in shifting emissions and not their reduction. The need to decarbonize the electricity sector is made even more urgent by the increasing role of appliances and space cooling, which in 2030 will be responsible for 13% and 15% of final energy consumed in BAU and RBP Scenarios respectively. This also applies to district heating, which needs to switch from coal and natural gas to low carbon sources of energy to contribute to indirect emissions reduction from space heating and water heating.

Combined for all selected countries, the application of the Regional Best Practices would close 91% of the gap between emissions resulting from continuation of the past trends and what's needed to achieve compatibility with the Paris Agreement in the residential buildings sector. While some of these trends are optimal from a climate perspective, they may not be considered optimal from a social and economic point of view. This is especially true of the aforementioned slowdown in increasing space per capita. However, these trends can be replaced by going slightly beyond RBP trends for energy consumption and emissions intensity – both of which would result in reduced energy bills and cleaner air, in addition to reduction in emissions.

Taking a disaggregated perspective on the main contributors to emissions and energy consumption aims not to prescribe solutions, but to make clear where there is potential and where there is a need for more effective policy action. Which of these drivers will be addressed and how effective the measures will be is to be decided by the policymakers.

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