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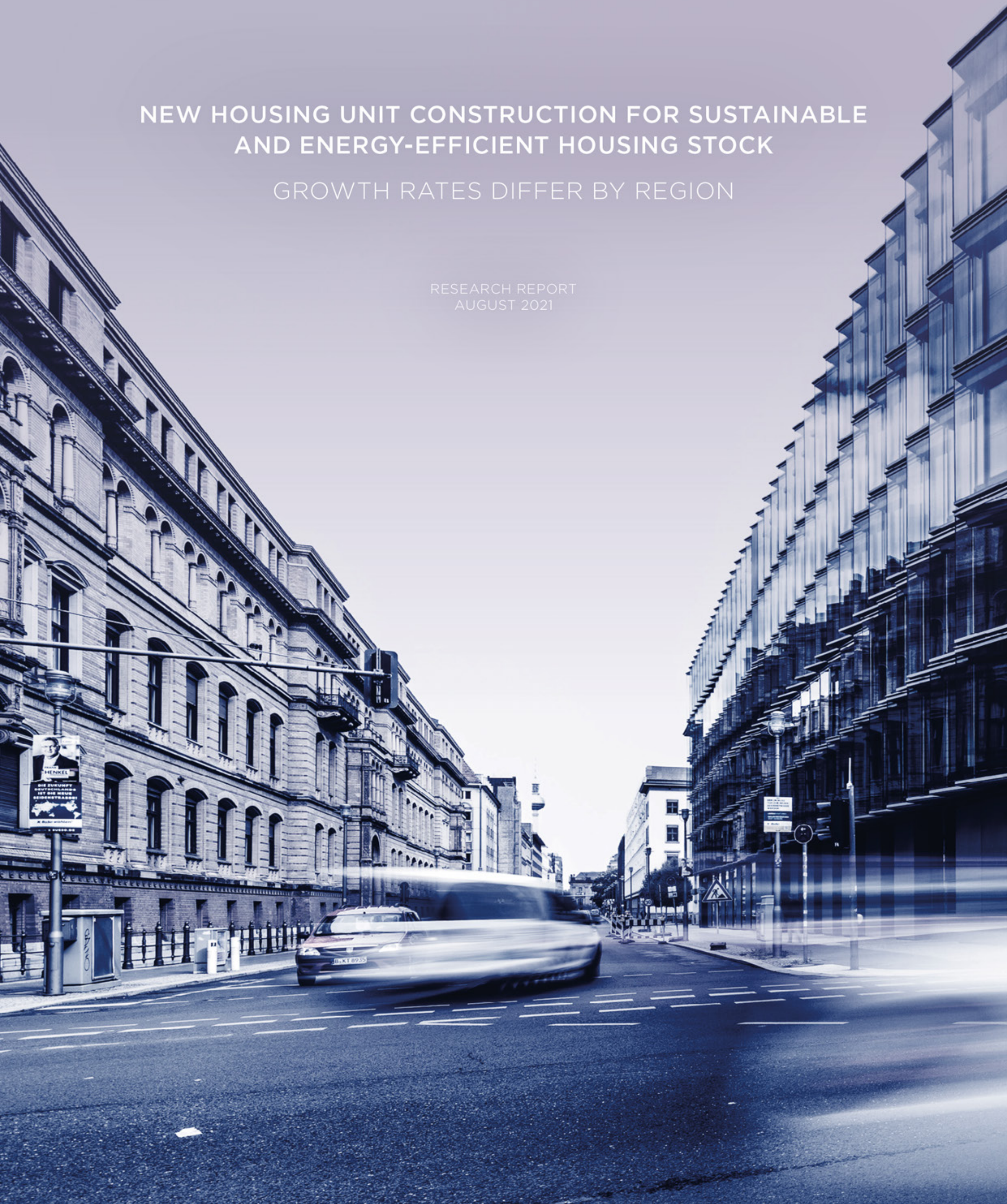
NEW HOUSING UNIT CONSTRUCTION FOR SUSTAINABLE AND ENERGY-EFFICIENT HOUSING STOCK

GROWTH RATES DIFFER BY REGION

RESEARCH REPORT
AUGUST 2021



REAL EXPERTS.
REAL VALUES.

New Housing Unit Construction for Sustainable and Energy-Efficient Housing Stock

Growth rates differ by region

The environmental sustainability of housing stock depends on various specific factors such as energy and other resource conservation, thermal insulation, cutting carbon emissions, and durability. These sustainability criteria are translated into ESG guidelines by real estate investors, project developers, and industry associations as well as their stakeholders. Above all, focusing on building a targeted and steady supply of new homes serves to optimize the respective portfolios and the stock of housing in general. However, the pace of growth varies greatly by country and region. Looking forward, this differentiation is becoming increasingly important for assessing locations and allocating investments with a view to more strongly weighting sustainability criteria. This study quantifies the various developments, drivers, and possibilities for ensuring sustainable and energy-efficient housing stock.

REAL EXPERTS.
REAL VALUES.

Contents

1. Sustainable demand for housing based on trends in population and household numbers

The amount of residential space used in an economy, region, or city implies a corresponding demand for energy for heating, air conditioning, lighting, and operating numerous other technical systems. In addition to ongoing consumption, the energy and resources required for building, modernizing, and later demolishing dwellings must be taken into account to suitably evaluate the topic of housing in the overall context of societal debates about sustainability, ESG issues, and carbon emissions.

The total built and used residential space (in total square meters) can be viewed as a key quantitative parameter, and therefore statistically speaking, as the main driver of resource consumption related to housing. In contrast, relative resource and/or energy consumption per square meter can be reduced by implementing higher standards. The resulting cumulative effect from an overall increase in living space would have to be determined.

In this context, the fundamental question remaining is the quantity of residential space required or in demand. Socio-demographic factors such as the number of inhabitants and households are significant in this regard, and ultimately determine the need for a particular number of dwelling units. Units in residential facilities or extended-stay suites may be possible substitutes to help meet demand but will not be considered here in detail due to their comparative lack of significance.

Socio-demographic developments in Germany

The demand for housing in Germany does not necessarily correlate with population growth. For Germany, this factor can even be seen as relatively insignificant overall. The change in population since the turn of the millennium indicates stationarity in the number of inhabitants (Fig 1). The single decline that occurred around ten years ago is caused mainly by statistical factors (correction due to the 2011 census). In contrast, the annual increases since 2014 constitute a real change triggered by intensive foreign migration. Over the covered period, an overall increase happened from 82.26 million inhabitants in 2000 to 83.17 million in 2019, with a temporary decline to only 81.75 million inhabitants in 2010. This corresponds to an increase in population of 0.91 million residents, or 1.1 %, over a period of around 20 years.

A sharper increase in the number of households is evident from 2000 to 2018. During that period, the number of households rose from 37.71 million (2000) to 41.38 million (2018). This equals an increase of 3.67 million households, or 9.73 %, in about 20 years.

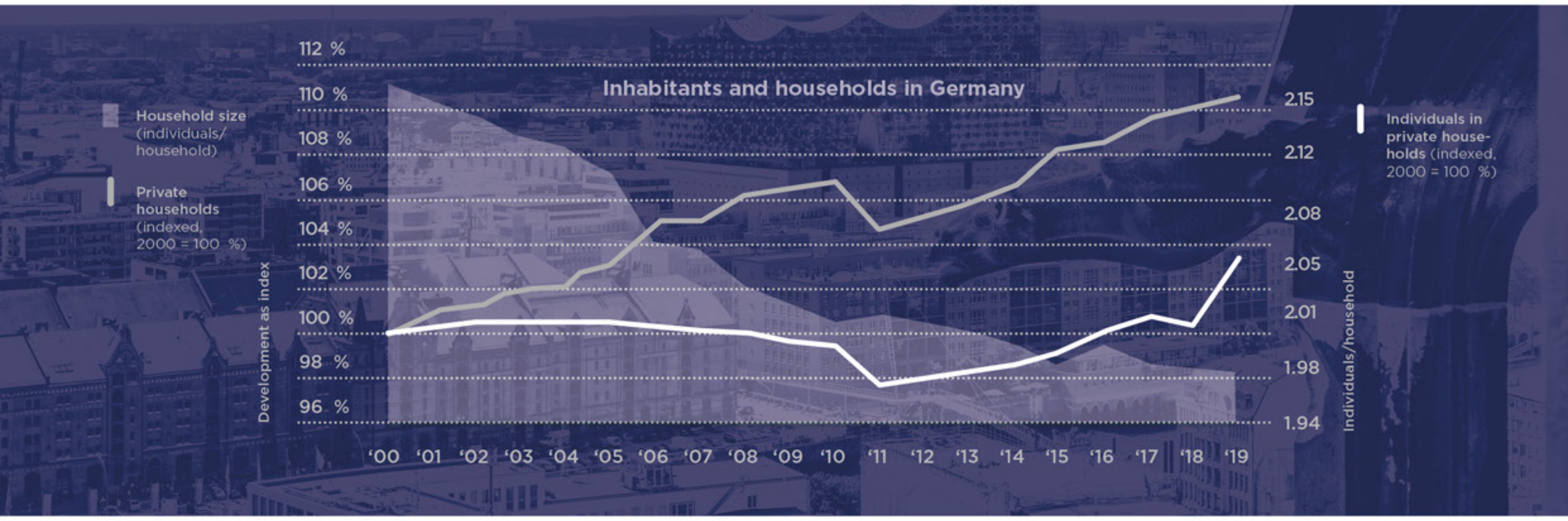


Fig. 1: Residents, households (left-hand scale indexed, 2000 = 100 %), and household size (right-hand scale) in Germany; source: Federal Statistical Office; own calculation and illustration.

A more important factor in quantifying the demand for residential space than the number of inhabitants is the number of households. This value is mainly driven by a declining household size. Factors such as cultural and value shifts as well as increasing prosperity can trigger or accelerate this trend. Furthermore, numerous newly established households consisting of individuals who are temporary single (e.g., young people moving out of their parents' homes, people moving from other regions or abroad) can reduce average household size. Average household size in Germany is currently below two individuals per household. Due to certain basic requirements for all dwellings (e.g., kitchen, bathroom), this tends to increase the use of space and resources. At the same time, there is a basic requirement for energy irrespective of the use of residential or living space by a certain number of individuals.

An average household size below two implies a certain number of single-person households in the sample. These households are generally expected in particularly young population groups (apprentices, university students, career starters) or older seniors (widow(er)s). Due to this, analyses and forecasts of statistics regarding residential space in demand also require information on the age structure and development of the population.

In the long run (index with base 100 in 1970), the population group older than 68 is growing faster than average . In contrast, the overall number and the median age group remain almost constant in the long run; only Germany's reunification caused a sharp increase, but this was a non-persistent effect. The number of young inhabitants under 25 is declining over time, with the figure in the former West German states even lower than in 1970, despite the growth precipitated by reunification.

This indicates that Germany's medium- to long-term demand for residential space is not primarily driven by population growth. At least, this figure does not explain any additional demand, and at most, it only explains the replacement demand for continuing to ensure the current quality of housing. However, looking at Germany as a whole, the occupancy structure changes depending on the respective age cohort (Fig. 2).

Older age cohorts constitute a growing group of people seeking housing. During this stage of life, a typical scenario would be people who maintain their current housing style while at the same time seeing their household size remain the same or in some cases decrease (children moving out). Conversely, the number of younger people is declining. The effect of combining households due to marriage or starting a family is also declining in relevance within the market as a whole. Even assuming constant population numbers, this structural shift in housing demand gives rise to additional demand for living space based on the number of dwelling units and also the living area required. The previously presented household numbers and household sizes support this hypothesis.

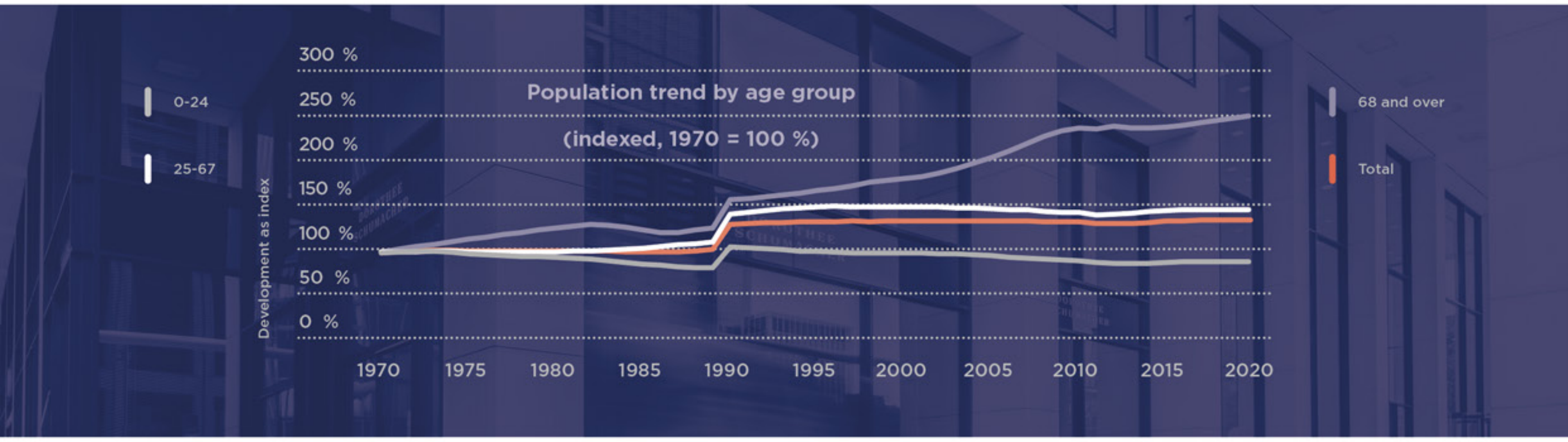


Fig. 2: Demographic developments by age group;
source: Federal Statistical Office; own calculation and illustration (Prior to 1990: territory of former West Germany, sharp increase caused by Germany's reunification)

Regional differences

The change in the number of inhabitants and households over time differs by region and depends on factors such as urbanization, economic development, and social and cultural influences. In each residential housing market, the effects can therefore diverge greatly. This is evident in the trends in Germany (regional differentiation) and in other European countries (international comparison) described below.

Looking back, regional differentiation by individual German states reveals significant differences. A population decline occurred especially in the former East German states and Saarland, whereas the population has increased in Bavaria and Baden-Württemberg. This is explained in particular by domestic migration to economically stronger regions with more job opportunities and in the city-states of Hamburg and Berlin by their many various cultural offerings, numerous colleges and universities with available places for students, as well as the high quality of live people seek there (general trend toward urbanization). According to forecasts by the federal government and the states, this trend in the aforementioned cities will continue, whereas it is not expected overall for the non-city-states. The states already affected by declining populations are likely to see the number of inhabitants decrease further.

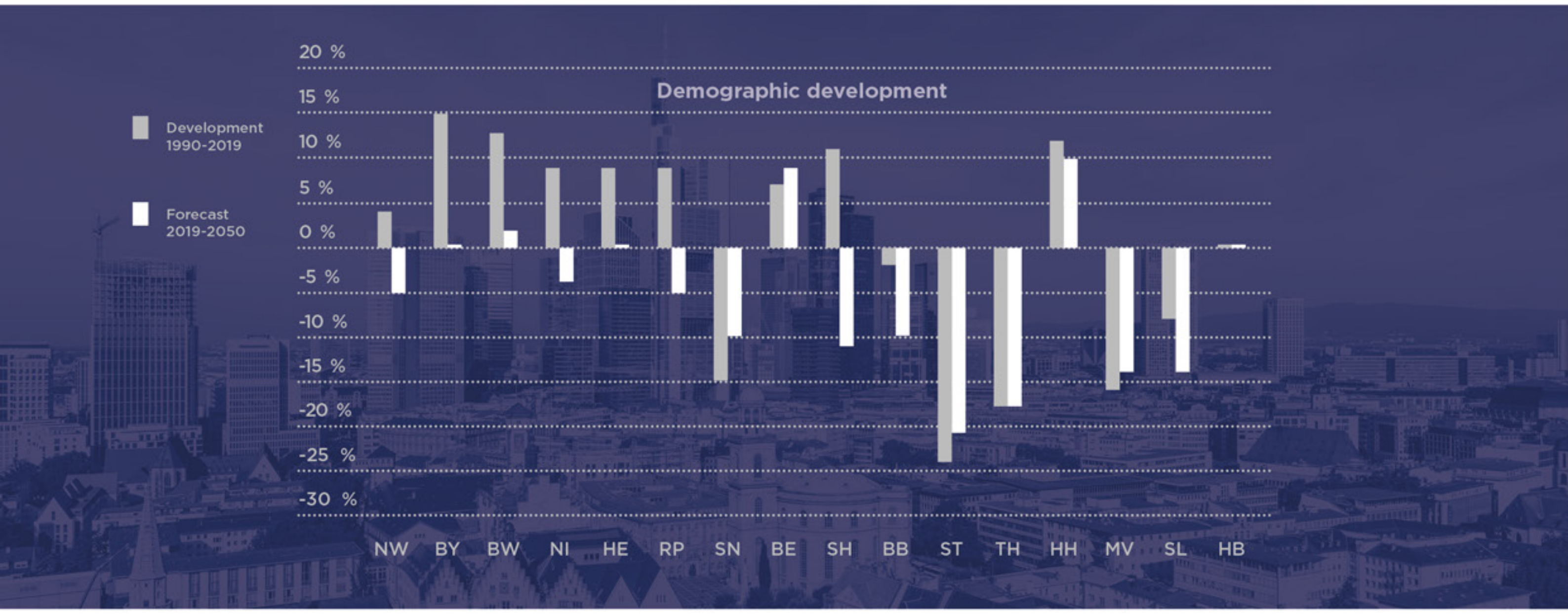


Fig. 3: Demographic developments and forecast; source: Federal and State Statistical Offices; own calculation and illustration.

In particular, the comparison of city-states and non-city-states highlights the smaller average household size typical in cities. In 2019, for instance, Berlin had the smallest average household size (1.79 individuals per household (I/HH)), followed by the Hanseatic cities of Hamburg (1.83 I/HH) and Bremen (1.86 I/HH). The more densely populated non-city-states fall on the other side of the distribution. Baden-Württemberg, for instance, currently has the largest average households (2.09 I/HH). The top third also includes Rhineland-Palatinate, Bavaria, Hesse, and North Rhine-Westphalia.

The trend that household size has decreased in all federal states over the past 30 years (Fig. 4) seems to be unbroken. City-states are exceptions, in which the numbers were already very low ten years ago: no further decline in household size has been observed there, rather a small increase in some cases. Growth in cities is often faster than in the non-city-states in the same region, for example, Berlin in comparison with the surrounding state of Brandenburg, as indicated by state statistics. Interestingly, there is a certain level of convergence in household sizes despite varying growth rates. The noticeable approximation of Brandenburg's household size to that of Berlin suggests that the family home typical in the surrounding region for quite some time and the equally typical one-person apartment in the city center are no longer as critical as they once were to shaping these locations. Instead, smaller housing units will increasingly also have to be made available in the non-city-states, especially for older populations, two-person households, etc.

On the whole, household sizes and the associated number of households in most regions constitute a significant factor in the real estate market and therefore also for energy demand.

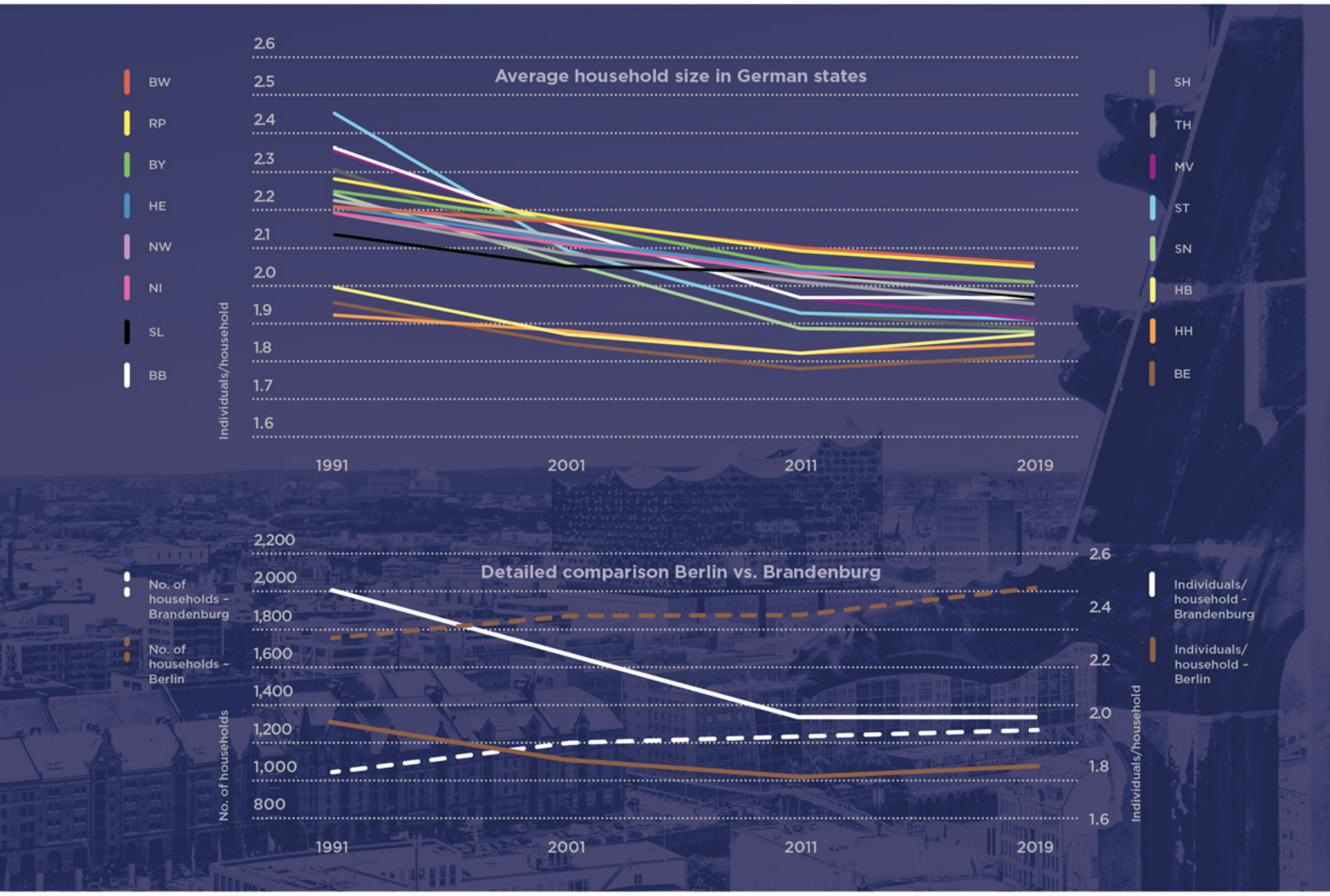


Fig. 4: Household size in German states; source: Federal Institute for Population Research (BiB); own calculation and illustration

Germany in a European comparison

Compared with the rest of Europe, Germany has ranked toward the bottom in terms of population growth for a long time. In the period from 1990 to 2010, only a few countries such as Poland and the Czech Republic reported lower growth rates. Immigration rates in recent years caused a sharp temporary increase in Germany but did not cause the country to catch up with the population trend in high-growth countries such as Switzerland, Norway, or the UK.

Another outlier by European standards is the change in the population of Italy, where numbers stagnated after a multiyear growth phase. Since 2014, the population has even declined slightly. In the last 30 years, almost no population growth has been measured not only in Germany or Italy, but in Poland or the Czech Republic either. In contrast, Switzerland and Norway rank most highly in terms of the number of inhabitants.

Most countries exhibit the same trend in household size as Germany: Household size is declining and is approaching the average of two individuals per household. Only in Poland is this number still much higher at around

2.8 individuals per household. In recent years, no downward trend has been discernible here either, unlike the one that took hold recently in the Czech Republic and Italy – countries with a higher starting level. Besides Poland, Belgium and the UK are two countries where this statistic also remains constant.

Declining household size therefore appears to be a phenomenon identifiable across Europe. This results in a trend toward increased demand for housing in conjunction with rising (or at least steady) population numbers, which also has an impact on energy consumption in the construction and use of residential space in an economy (assuming that technical innovations do not counteract this effect).

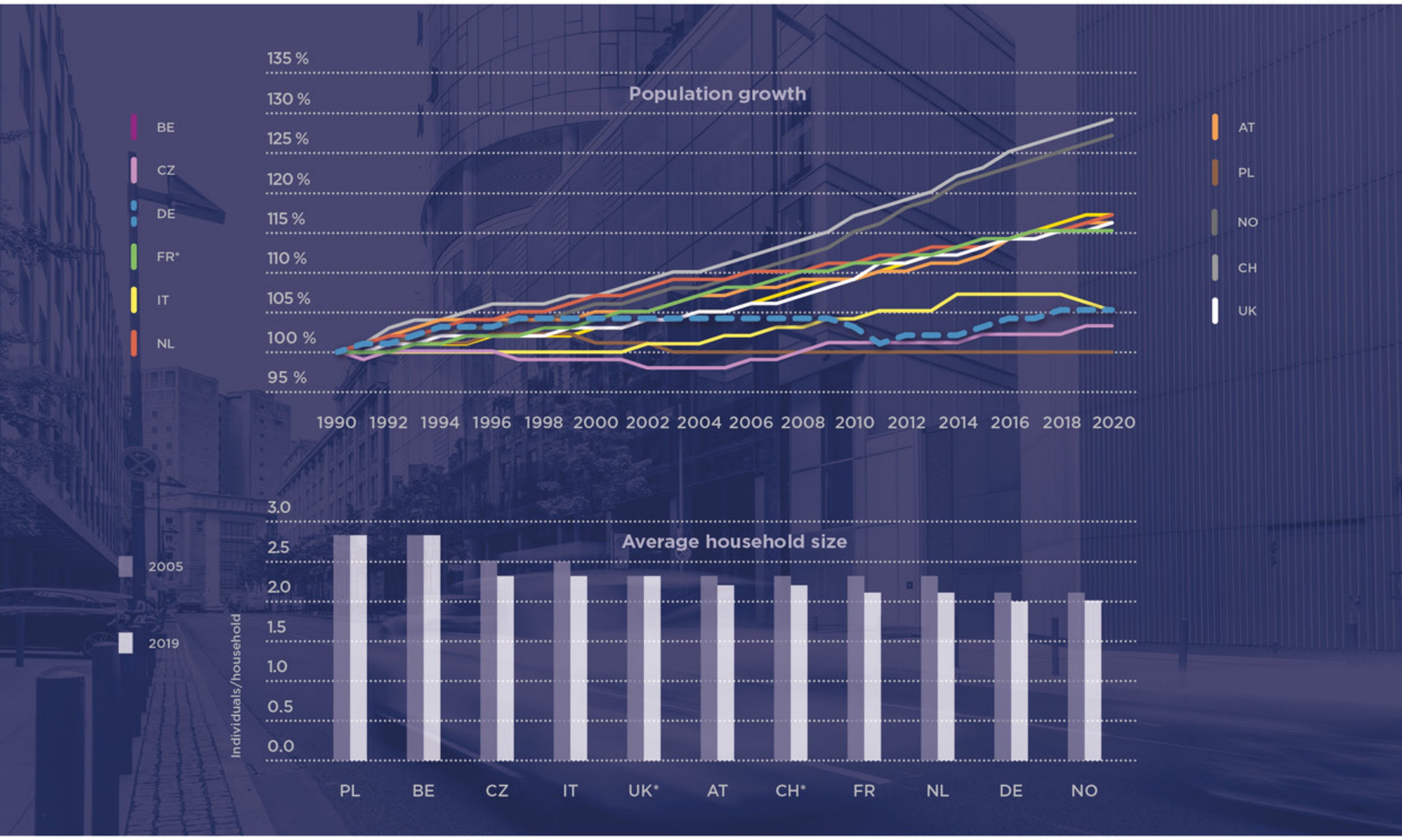


Fig. 5: Population growth and average household size in selected European countries; source: Eurostat; own calculation and illustration. (left: France starting in 1991 instead; right: Switzerland* 2007/2019 instead; UK* 2005/2018 instead).*

2. Sustainable demand for housing based on individually used living space

While numbers of inhabitants and households determine the required number of dwelling units, the area required for residential space – to be planned, built, and used – depends on many other factors. Changes in attitudes toward individual lifestyles, new requirements for the use of space, such as home offices, and, not least, growing purchasing power led to an increased use of space for residential purposes in general. This applies both in absolute figures for the country as a whole as well as in relative terms per inhabitant. This per capita usage may be seen in qualitative terms as a positive contribution to greater prosperity and a higher quality of life, but at the same time, it represents the additional use of resources for residential purposes.

Growing use of residential space in Germany

An analysis of the last three decades shows that the statistical average per capita use of living space has risen steadily. This applies to Germany as a whole and even more so to the former East German states, which started out at a low level in 1990 and had considerable room to catch up to the Western half of the country. Currently (according to 2019 data), the living area per inhabitant in the former West German states amounts to around 48 m², while in the former Eastern German states it is slightly smaller at approximately 44 m². The trend toward greater living space usage per person appears to be continuing unabated.

Of course, the explanation could lie in the aforementioned decline in household sizes. A certain amount of area per dwelling unit taken up by the bathroom, kitchen, and hallways, for instance, results in a trend toward the use of a larger amount of space per person in smaller households. Because small households with one or two individuals do not necessarily require a third or fourth room, a reduction in dwelling unit size would be expected at the same time. Surprisingly, the statistical average size of dwelling units is also increasing over time. Whereas the average was still around 87 m² in the former West German states in 1990, the size there has now risen to around 96 m². The average for Germany as a whole is roughly 92 m². At an average dwelling unit size of approximately 79 m², the former East German states trail behind, although this figure has risen substantially from the 1990 level of 64 m² per dwelling unit.

As a result, more and larger housing units are being used in Germany. Per capita living space as well as unit size are both growing. This is mainly due to the increasing number of single-person households and the increase in living space as the population ages. Changes in lifestyle and in the use of residential space also have an indirect impact on the relevant energy consumption and CO2 emissions.

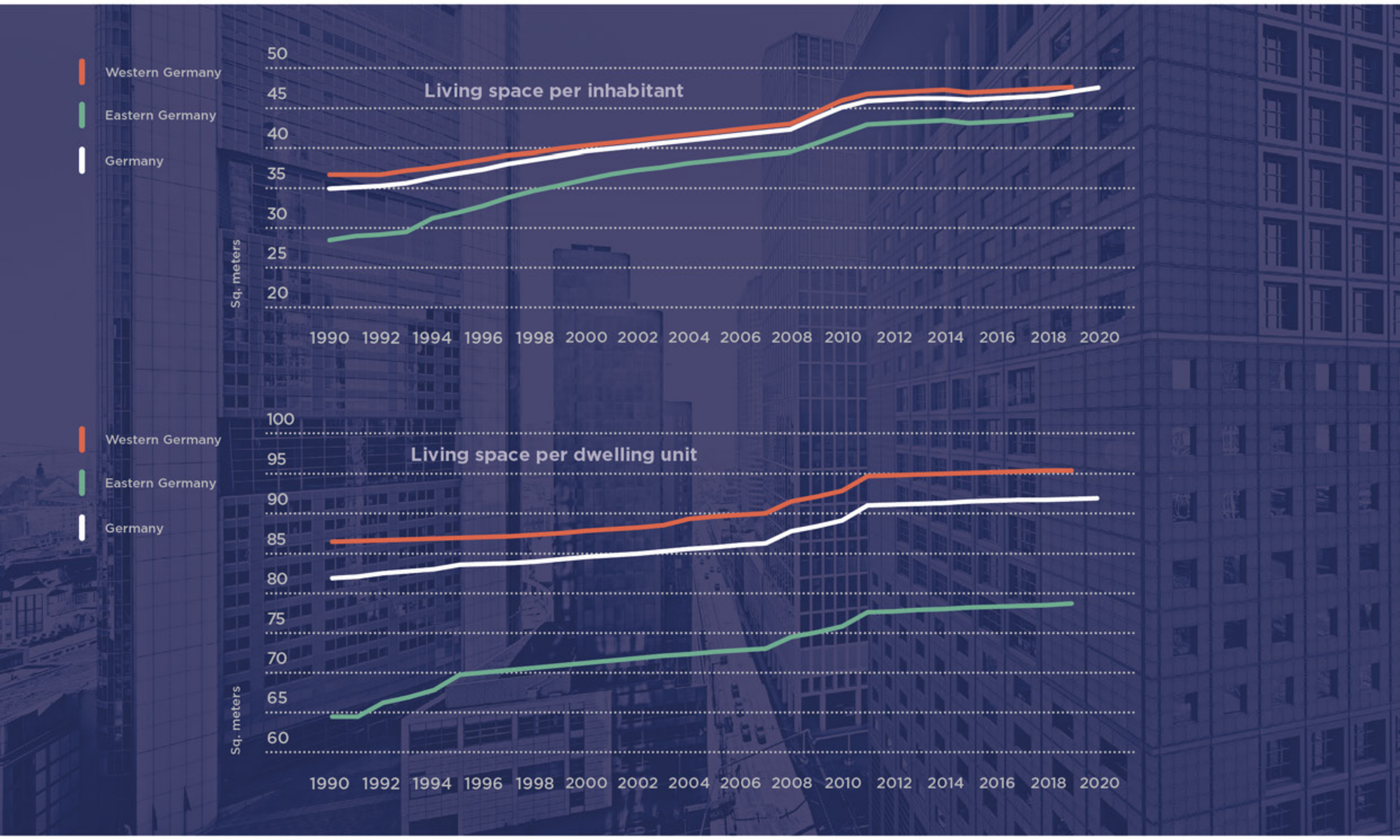


Fig. 6: Per capita use of residential space in Germany; source: Federal Statistical Office; own calculation and illustration (In some cases, statistical methods were used to smooth the time series data.)

Regional differences

The average floor space per dwelling unit and per person differs widely by region. In the city-states of Berlin and Hamburg, these figures are below average. Whereas the average per capita floor space in Germany amounts to 45 m², Berlin's inhabitants enjoy only 39 m², and Hamburg's residents only have 40 m² available. The situation is similar with average dwelling unit size, which measures 76 m² in Hamburg and 74 m² in Berlin in contrast to an average of 94 m² in Germany as a whole.
The living space average in Germany is notably increased by the less densely populated Western non-city-states such as Saarland (54 m² per capita / 109 m² per dwelling unit), Rhineland-Palatinate (50 m² per capita / 107 m² per dwelling unit), and Lower Saxony (49 m² per capita / 103 m² per dwelling unit). In the case of regional variations in the use of residential space, the greater or lesser availability of housing units and the associated prices per square meter should therefore play an important role. Market models (e.g., the well-known DiPasquale-Wheaton Four Quadrant model) regularly use a given budget for a household (or the aggregated overall market) as the starting point. Differences in the availability, or lack thereof, of residential space and the associated divergence of prices per square meter result in demand for more or

less residential space in regional markets. The conclusion drawn here is that higher budgets (resulting from changes in income, tax rates, other costs of living) are used to obtain more living space, at least in part. Conversely, budget restrictions (e.g., due to higher taxes or unemployment) lead to a reduction in the demand for space and therefore the use of space, at least in the medium term.

The use of residential space is therefore not necessarily a result only of absolute demand, which may be defined objectively, but instead also derives from individual lifestyles. To differentiate in terms of demand, a distinction would be conceivable between necessary living space on the one hand (basic need, to some extent independent of income or market price, technically speaking: inelastic demand) and additive living space on the other hand, defined as additional space in demand depending on income, individual lifestyle, and market price. Questions about housing affordability and, in some cases, desirable market interventions should take into account this proportionate effect of improvements in quantity, and presumably also of the quality, of housing. For this reason, the minimum requirements (per capita or per housing unit) cannot be determined alone on account of regional differences and the general upward trend. Further research is required for this purpose that will need to include various other disciplines.

Nevertheless, these figures can be used to explain energy consumption for residential purposes. Due to the increasing use of living space per person and household, no energy saving effects arise from the parameter „used living space". Optimization in other areas must therefore overcompensate these effects in order to meet the targets for conserving energy and cutting carbon emissions in the residential real estate segment.

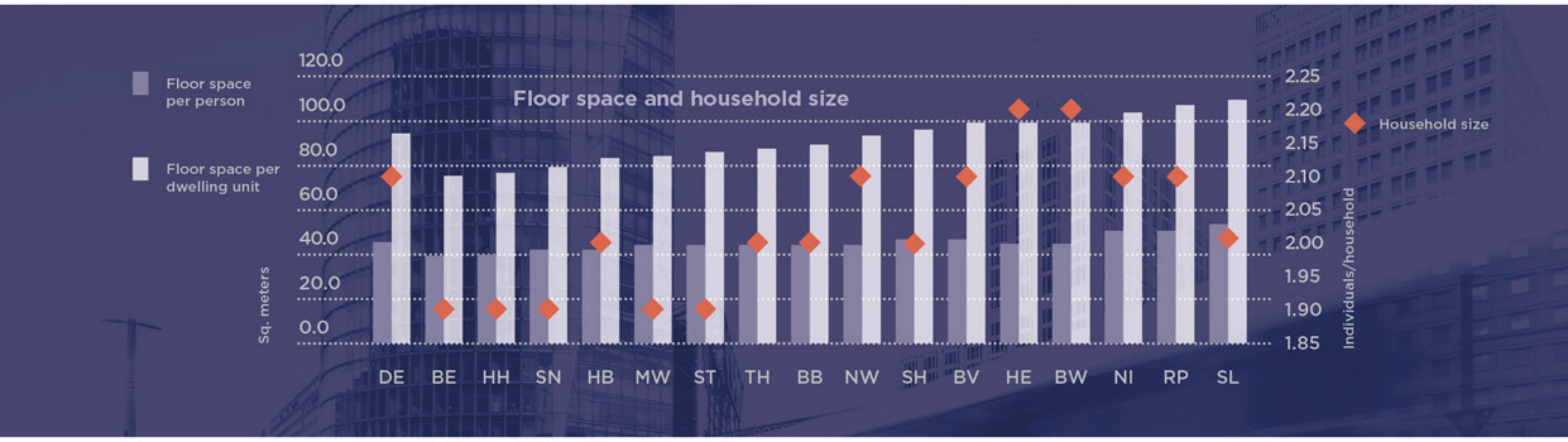


Fig. 7: Household size and floor space per person and dwelling unit in Germany and individual states, 2018; source: Federal and State Statistical Offices; own calculation and illustration.

Germany in a European comparison

The correlation between income and population density on the one hand and use of living space on the other is also evident in a European comparison. In relative terms, the lower-income Eastern European countries Poland and the Czech Republic rank much lower in per capita living space than countries such as Switzerland and Norway. Two-person households in the Czech Republic and Poland also occupy somewhat smaller dwelling units than the average household in these countries. In other countries, two-person households instead use more living space.

An additional effect in Norway may be attributable to its relatively low population density and the resulting greater availability of inexpensive land for construction. The rate of home ownership there is also relatively high at around 80 %.

Generally speaking, the pattern in Europe is that more living space is used in the Northern countries than in the Southern countries (as hypothesis: dependence on population density?) and that the use of space increases from East to West (hypothesis: dependence on GDP per capita?). Undoubtedly, this is not a linear relationship, and there are outliers within the general trend (e.g., Switzerland and Belgium with much higher use of space per inhabitant than in their respective neighboring countries, which is also due to the countervailing effect of high purchasing power). Germany falls somewhere in the middle of the pack of European countries reviewed.

The following finding is important in terms of assessing the use of energy, particularly in the larger context of Europe: The differences in population trends, household size, and per capita living space in the European countries are not necessarily factors that shape sustainability, carbon emissions, or energy consumption. Other factors such as climate, features and amenities, and the condition of properties as well as the duration of use are critical parameters. In some regions with favorable climates, older and larger buildings can also be sustainable. However, the connection between utilization period and efficiency is not generally applicable, as the further analyses will show.

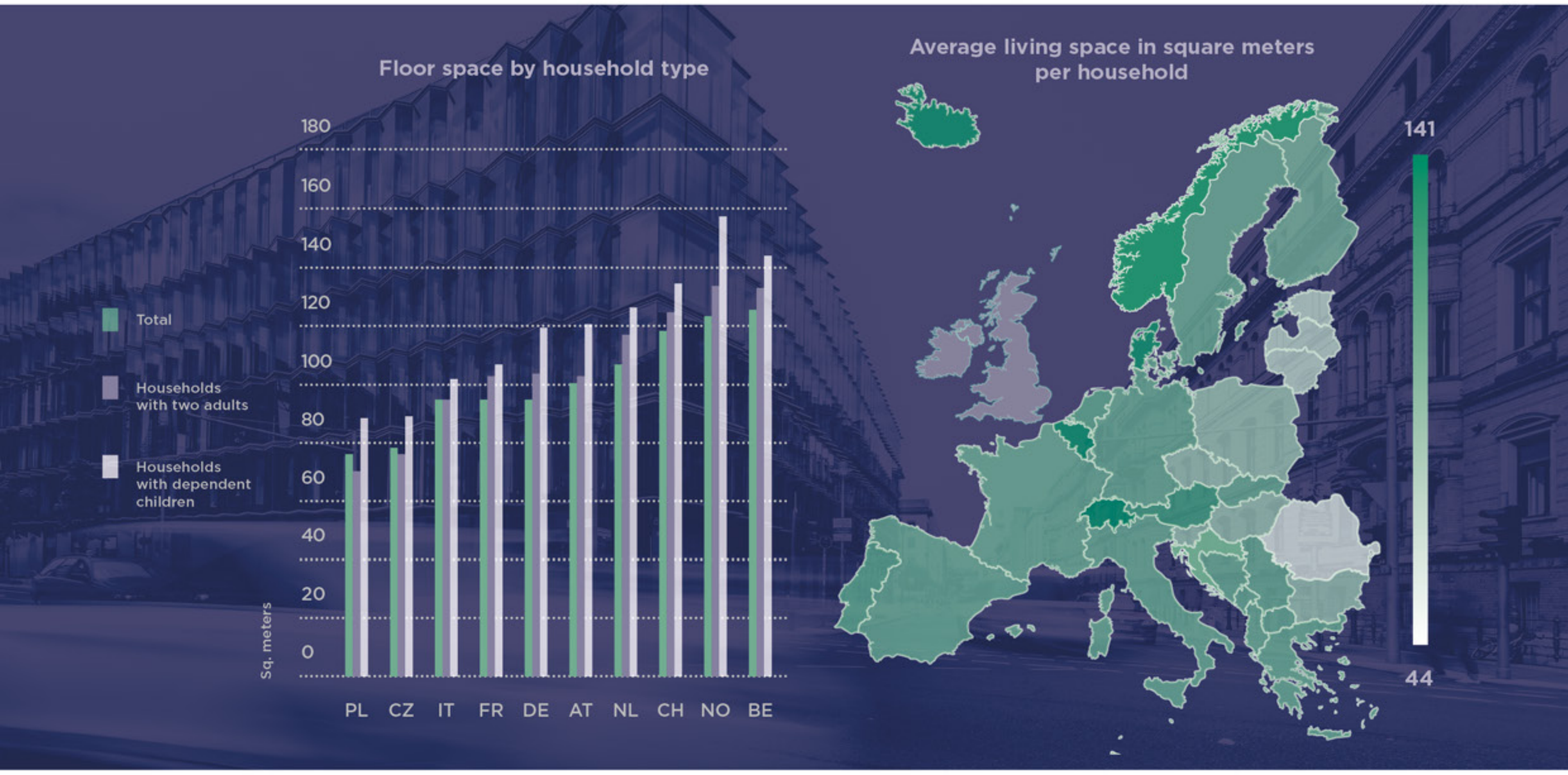


Fig. 8: Average floor space per household 2012; source: Eurostat; own calculation and illustration.

3. Energy consumption resulting from residential uses

The social goal of a sustainable, resource-efficient economy stands in contrast to high demand for goods, materials and energy for the basic need of housing. Growing population and household numbers – and particularly the increasing use of space – generally boost demand. This effect can be partly offset by innovative solutions and new technologies, such as demonstrated by energy consumption in private households.

Energy consumption by private households in Germany

Private households use energy in many ways for residential purposes. In 2018, this figure was around 644 terawatt hours (TWh), which is the equivalent of some 2,320 petajoules (PJ) or one-fourth of total final energy consumption. This energy is used for purposes such as lighting, operating elevators and electric appliances, heating water, and indirectly also for other services like administration, property management, and maintenance. However, by far the largest share - around 73 % - is accounted by space heating (Fig. 9).

In the medium term, the trend in total energy consumption by private households for residential purposes has been almost constant (minimal decline of around 1.0 % from 2000 to 2018, and by 2.6 % since 1990, despite increasing living space). The shares attributable to various uses have shifted. Particularly notable is energy consumption for hot water, which increased by 32 % in the period under review. In contrast, the energy used for space heating decreased by 8 %. The minimum was reached in 2013 with a decline of 19 % compared with 2000.

In other words, there was a downward trend in space heating until around 2013, but since then, consumption has been increasing again. This cannot be explained entirely by individual colder years. According to weather records, 2001, 2003, 2010, and even 2013 were colder years, whereas 2014 and 2018 had warmer winters. Perhaps other factors play a greater role, e.g., other sources of heat in the household such as lighting or kitchen appliances, which are now increasingly energy efficient. However, this is merely a supposition supported in part by the changes over time in energy consumption for lighting.

Another surprising fact is that despite the continuous market launch of increasingly energy-efficient appliances, the attributable energy consumption has risen by 9 % overall. This could be the result of a greater number of features and/or changes in usage.

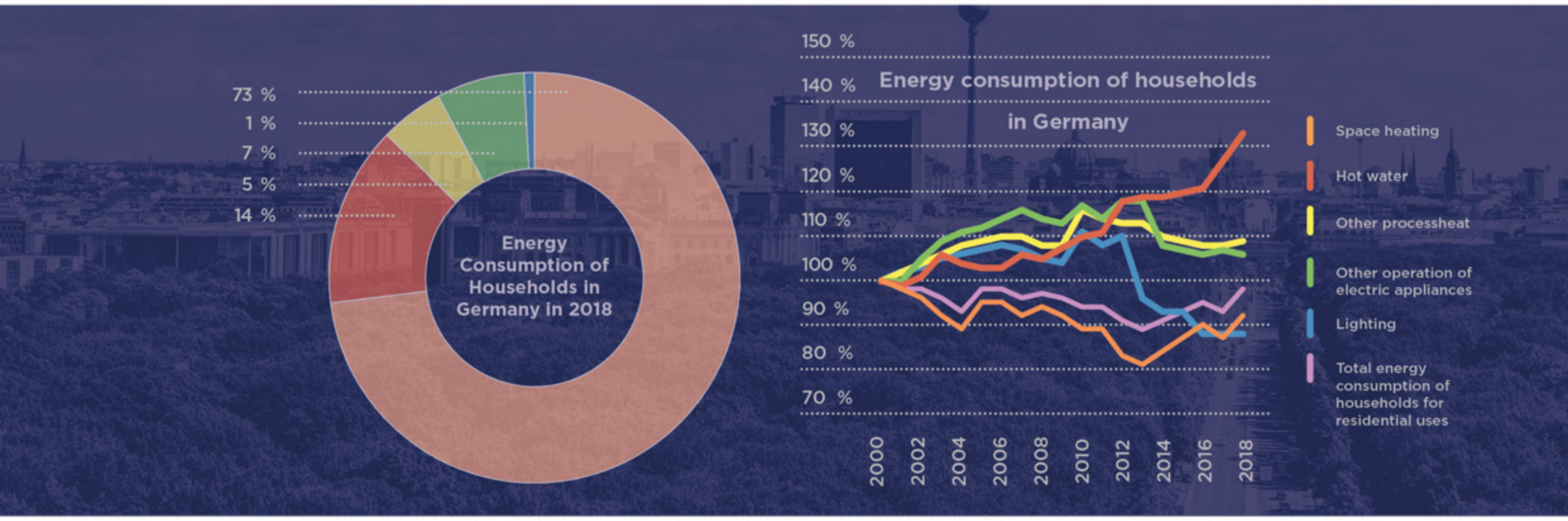


Fig. 9: Energy consumption of private households in Germany for residential uses by purpose; source: Federal and State Statistical Offices; own calculation and illustration

In this respect, when discussing potential energy savings in the area of private households, it must be anticipated that the area of space heating and hot water generation will be strongly dominant. However, only if technical, qualitative, or usage-related measures result in savings will the entirety of private households be able to contribute substantially to meeting the corresponding sustainability targets.

In estimating the potential, the relatively long history of regulations in this field must be taken into account, ranging from the Thermal Insulation Regulations (WärmeschutzV 1977, 1984, 1995) and the Heating System Regulations (HeizanlV 1978, 1982, 1989, 1994, 1998) to the more recent Energy Conservation Regulations (EnEV 2002, 2004, 2007, 2009, 2014). In 2020, the new Building Energy Act (Gebäudeenergiegesetz – GEG 2020) entered into effect, now integrating the previous Renewable Energy Heating Act (Erneuerbare-Energien-Wärmegesetz – EEWärmeG). The numerous, increasingly narrow regulations comprise a legal framework for energy conservation in buildings. They regulate the energy efficiency of buildings, the issuance and use of energy certificates, and the use of renewable energies in buildings.

With regard to primary energy sources, it can be seen that the use of coal for heat generation in residential buildings can be considered to have almost ceased, the consumption of heating oil in private households is falling, and greater use of natural gas is partially compensating for the energy sources that are now lacking. In addition, there is a persistent trend toward using renewable energies. The share of renewable energies of total heating has to increase and/or buildings must be significantly more energy efficient in order to meet the target issued by the federal government of ensuring that Germany's housing stock is nearly climate-neutral by 2050.

Regional differences

Statistics on state level can be used to differentiate the energy consumption of private households by region. The annual final energy consumption figure for private households presented in Fig. 10 (measured in gigajoules per inhabitant (GJ/IH) differs significantly between the federal states. Brandenburg's maximum value of approximately 35 GJ/IH is nearly twice as high as Berlin's figure of around 20 GJ/IH. The figures in other non-city-states such as Saarland, Schleswig-Holstein, and Bavaria are also higher than the German average, whereas consumption in the city-state of Hamburg is as low as in Berlin. The reason could be the greater efficiency of urban structures, particularly the larger percentage of multi-family residential buildings. Certain resources are used communally, and services such as building lighting and garden maintenance are outsourced so that individual households do not individually bear the full burden. These structural components will be outlined in greater detail in Section 4. Because most states fall relatively close to the German average, meaningful findings would be expected particularly from the analysis of the few outliers (Brandenburg and Saarland on the one hand and Berlin and Hamburg on the other hand).

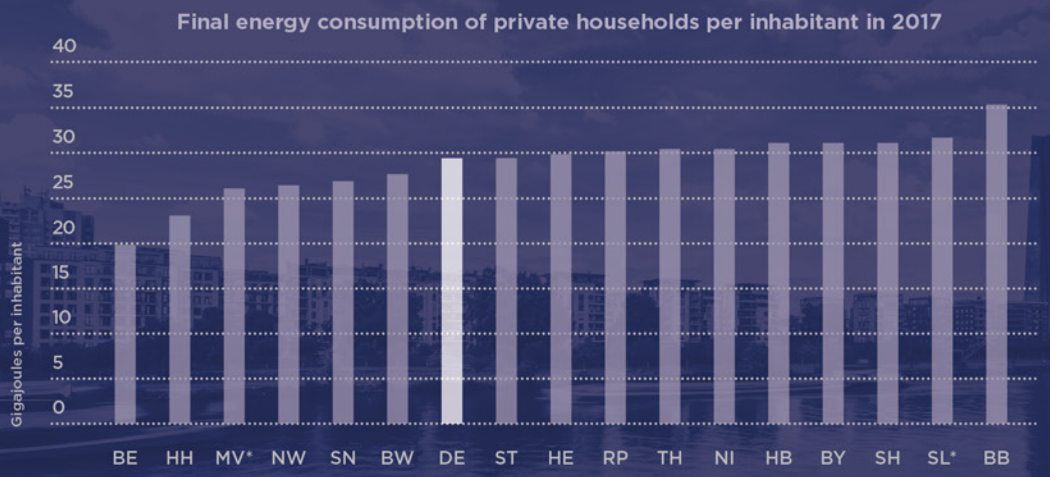


Fig. 10: Energy consumption of private households in gigajoules per inhabitant; source: Federal and State Statistical Offices; own calculation and illustration (MV and SL* 2016 instead.)*

Germany in a European comparison

The high share of energy costs attributable to generating heating by private households in Germany indicates that internationally there is also a strong correlation between housing-related energy consumption and the climatic conditions within a region. For this analysis, the heating degree days over a period of 18 years (2000 to 2017) were calculated for 27 countries and compared with the respective per capita energy consumption of households. This resulted in 486 observations to analyze.

The heating degree days used for this purpose are calculated by Eurostat or the Joint Research Centre (JRC) for the regional (NUTS 2), national, and European levels. The heating degree days determined in this way express the extent of the heating requirements during a certain period, considering both outdoor temperatures and room temperature. These comprehensive calculations are conducted on a daily basis. Heating degree days generally occur at average outdoor temperatures below 15°C. The long-term average for the EU-27 produced an average of around 3,081 heating degree days.

However, the number varies considerably among the member states. By far the highest number of heating degree days are experienced by Finland, followed by Sweden and Estonia. The lowest number is reported by Malta, followed by Cyprus and Portugal. Therefore, the climate and outdoor temperature have a significant impact on energy consumption for space heating in households. In order to enable a more highly aggregated presentation, the observed values and countries were assigned to the Troll-Paffen climate zones prevalent there:

CLIMATE ZONES	COUNTRIES
COLD-TEMPERATE ZONE	
Continental boreal climates	Sweden, Finland
COOL-TEMPERATE ZONE	
Oceanic climates	Netherlands, Belgium, France, Ireland, Luxembourg
Sub-oceanic climates	Poland, Czech Republic, Slovakia, Hungary, Romania, Bulgaria, Austria, Slovenia, Germany, Denmark
Sub-continental climates	Lithuania, Latvia, Estonia
WARM-TEMPERATE SUB-TROPICAL ZONE	
Mediterranean climates	Portugal, Italy, Spain, Cyprus, Malta, Greece, Croatia

Fig. 11: Classification of countries by seasonal climates according to Troll and Paffen; own breakdown of countries.

Undoubtedly, there are significant differences in climate even within countries (e.g., Sweden). This was not further broken down for the purposes of this analysis; instead, the country was assigned to a single climate zone. The resulting correlations between heating degree days, household energy consumption, and climate zones is presented in Fig. 12 below. In addition to the general statistical correlation (shown as a regression line), typical cluster properties can also be identified here by means of purely optical evaluation.

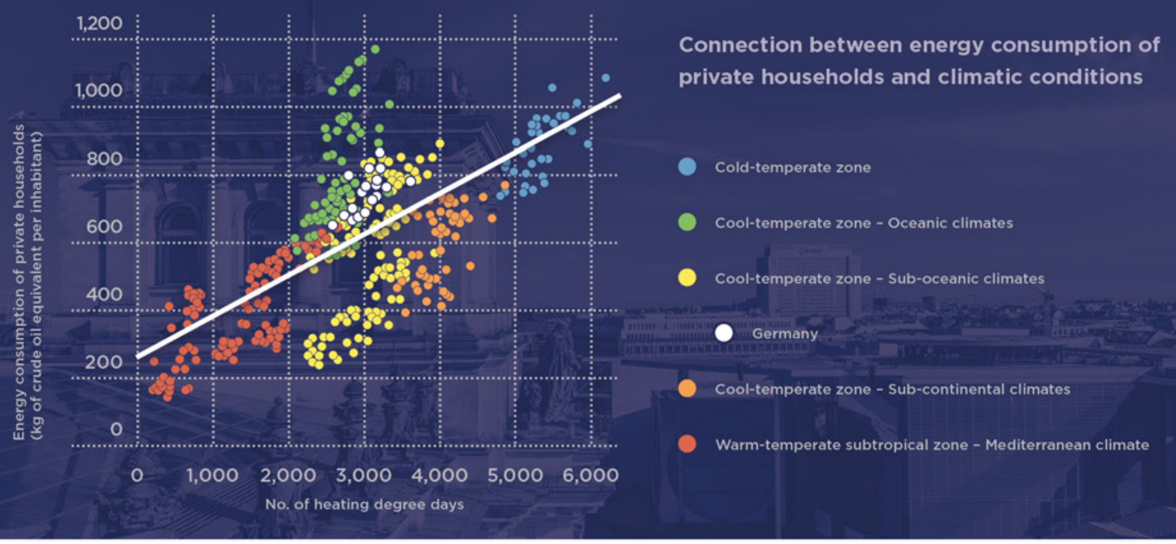


Fig. 12: Final energy consumption of private households by inhabitant and number of heating degree days in Europe (2000–2017); source: Eurostat; own calculation and illustration.

A further statistical analysis indicates that energy consumption by various countries and variations among them can be at least partly explained by the heating degree days (coefficient of determination $R^2 = 0.42$). In the yearly analysis for an individual country, R^2 is lower at 0.19, which is due to other factors playing a certain role, such as warmer or colder years. It is possible, for example, that there are reserves of fuel in private households not large enough to register statistically but that increase and are additionally used.

In the period and countries under review, an increase in heating degree days by 1 (one additional degree on a given day) results in an average increase in energy consumption by 0.12 kg crude oil equivalent per capita. The scope of this metric is perhaps better understood since the average consumption for the EU-27 from 2000 to 2019 was 586 kg of crude oil equivalent per capita per day. Conversely, in this study framework, a warmer climate can be expected to result in corresponding energy savings in the residential sector. Regardless of heating degree days, the regression function for the period under review indicates that the countries have a baseline requirement of 257 kg of crude oil equivalent per capita (at heating degree days = 0, starting point of the line at left).

Countries in oceanic climates such as the Netherlands or Ireland tend to consume more energy during the same heating degree days as countries in the sub-oceanic zone. Additional climate factors such as wind, precipitation, or humidity may play a role, but this is not a subject of this study.

Also, there may be some range within a climate zone. For example, in Germany, energy consumption is higher than in countries in the same category. Luxembourg's consumption figure was relatively high at 1,072 kg crude oil equivalent per capita in 2000, although later this figure dropped considerably to 896 kg of crude oil equivalent per capita in 2017. In Finland, very cold winters are an important factor that resulted in a maximum of 1,084 kg of crude oil equivalent per capita in 2017, for instance. Sweden's average energy consumption is regularly better than Finland's in a direct comparison, because the country measures more than 1,500 km from north to south, and a greater share of the population lives in somewhat warmer regions.

In general, therefore, the energy consumption of private households varies greatly across Europe. A correlation with the respective climatic conditions cannot be rejected out of hand. Particularly in the central and northern

European countries, higher building standards and, in particular, efficient methods of space heating and thermal insulation used across the board can lead to significant energy savings in private households.

4. Types of residential buildings as a key driver of heating energy consumption

The energy consumption of private households determined above is dominated by heating in Germany and other countries with similar climates. Typically, the building type, construction year, fittings, and renovation status influence relative energy consumption by user or unit area. The structure of the housing stock is a key determinant of energy consumption. A large bandwidth can be assumed both for building features as well as the resulting energy consumption. The respective building types and housing options are analyzed and compared below.

Structure of residential housing stock in Germany – by building type

Germany's residential housing stock comprises approximately 21.9 % multi-family buildings and 78.1 % single-family homes or duplexes (information collected in the 2011 Census and 2014 Microcensus). Nonetheless, a greater number of existing housing units are located in multi-family buildings. In total, Germany has somewhat more than 19 million residential buildings with 41.1 million housing units and living space measuring approximately 3,783 million m².

For a long time, new housing construction was dominated by the number of units in single-family homes and duplexes, but since 2015, more dwelling units in multi-family buildings have been completed. In 2019, only 40 % of the total of around 256,000 housing units completed were built as single-family homes or duplexes. At an average of 145 m², the space they provide was nearly twice (exact factor of 1.86) that of dwelling units in multi-family buildings at 78 m². It should be noted with regard to planning efficiency and the construction of new residential units that the smaller buildings accounted for a total of nearly 93,500 projects, whereas new multi-family buildings totaled only approximately 14,400 buildings.

The data concerning existing buildings and new construction are essential for the evaluation of sustainability metrics in the areas of energy and resources. Typically, the heating requirements for smaller single-family homes and duplexes are somewhat higher per unit area than in the case of multi-family buildings. The difference averages around 15.4 kWh per m² and year (Fig. 13). The reasons for this lie in the way these structures are built, e.g., they have a larger proportion of roof and facade per built living space. Heating systems in larger properties are also somewhat more efficient to operate.

Electricity consumption is proportionally less significant than heating energy: The statistical difference is around 1,740.4 kWh per household and year in this case. This higher household consumption is likely attributable to different building features (separate lighted outside spaces, entryways, etc. for the use of a single dwelling unit) and the generally larger living space provided by single-family homes and duplexes. Heating systems possibly constitute an increasingly important factor here, since they use proportionately more electricity (e.g., heat pumps). Although these systems are increasingly in demand for reasons of heating cost savings in the owner-occupied housing sector and are often also financially subsidized, they nevertheless lead

to a relative increase in demand per dwelling (proportionately higher technical and operating expenditure per dwelling or unit of area compared with larger houses).
Overall, multi-family buildings are the more efficient building type from an energy conservation perspective – purely according to the metrics. However, this should by no means be seen here as the sole or dominant decision variable in the sustainability discussion. Of course, qualitative, social, safety-related and socio-economic aspects continue to support other building types and forms of housing.

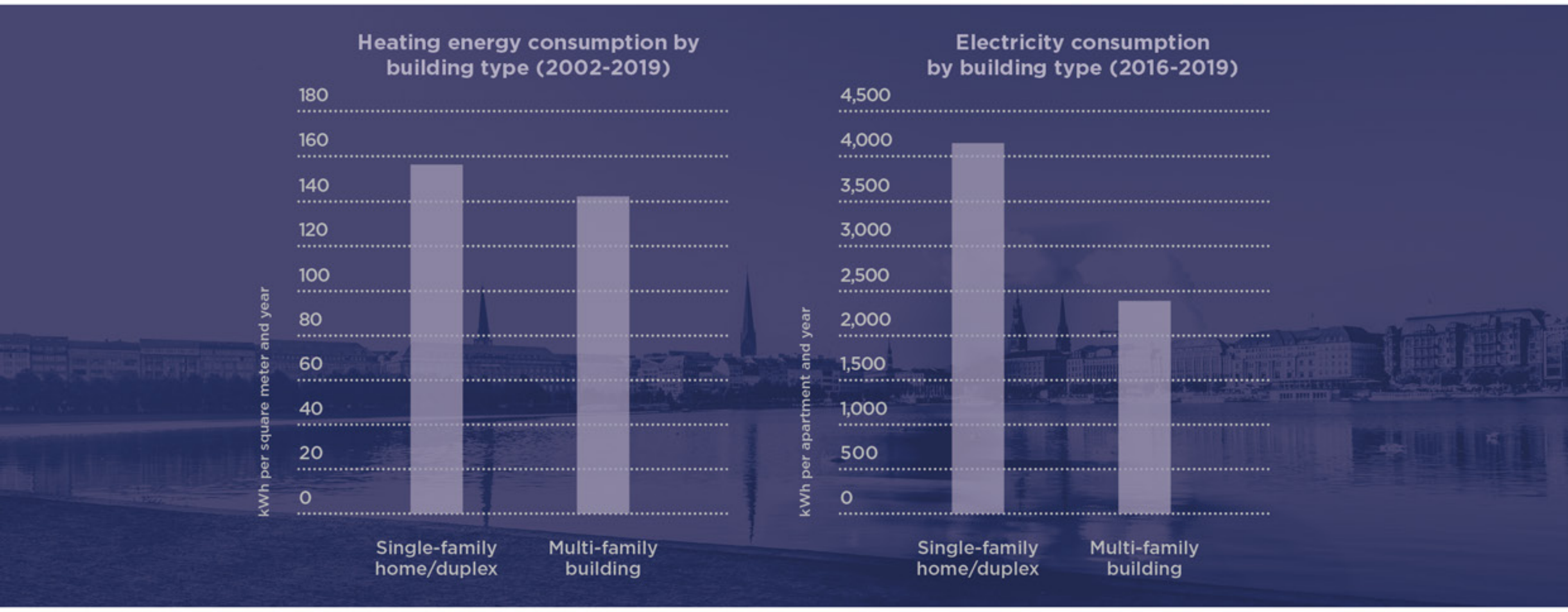


Fig. 13: Energy consumption by building type in Germany averaged over the survey period; Source: co2online; own calculation and presentation.

Regional differences

Building types differ greatly by region in Germany. Larger-scale apartment buildings containing many rental apartments make up the greatest percentage of the housing stock in the city-states of Berlin and Hamburg. Only somewhat more than 40 % of residential buildings in Berlin fall under the category of single-family homes and duplexes, while in Hamburg this figure is at least 60 %. Nearly 82 % of Berlin's residents and more than 75 % of Hamburg's residents live in rental apartments. The opposite side is made up of non-city-states in Germany such as Schleswig-Holstein, Rhineland-Palatinate, Saarland, Lower Saxony, and Brandenburg, where more than 80 % of the housing stock comprises conventional single-family homes.

The reasons behind these structural differences by region are undoubtedly many and various. For one, the land available for construction in major cities, and therefore in the aforementioned city-states, is very limited. In order to build as many housing units as possible on the designated parcels of land, only typically highly dense developments such as multi-family buildings and perimeter block developments are possible in city centers. Another factor is that real estate prices are generally much higher in cities than in rural areas, which is another point in favor of constructing taller buildings for maximum efficiency. Prices would in any case exceed the budget normally available for building a single-family home. Additional factors simply include structural differences resulting from the historical growth of cities, rural areas, and regions.

In view of the considerable regional differences in building structures and types, as well as the differences in energy consumption described above, the optimization of the overall stock requires suitable, individually adapted solutions in each case. From this point of view, a uniform nationwide concept for optimizing the energy performance of existing buildings does not seem plausible and is not very precise.

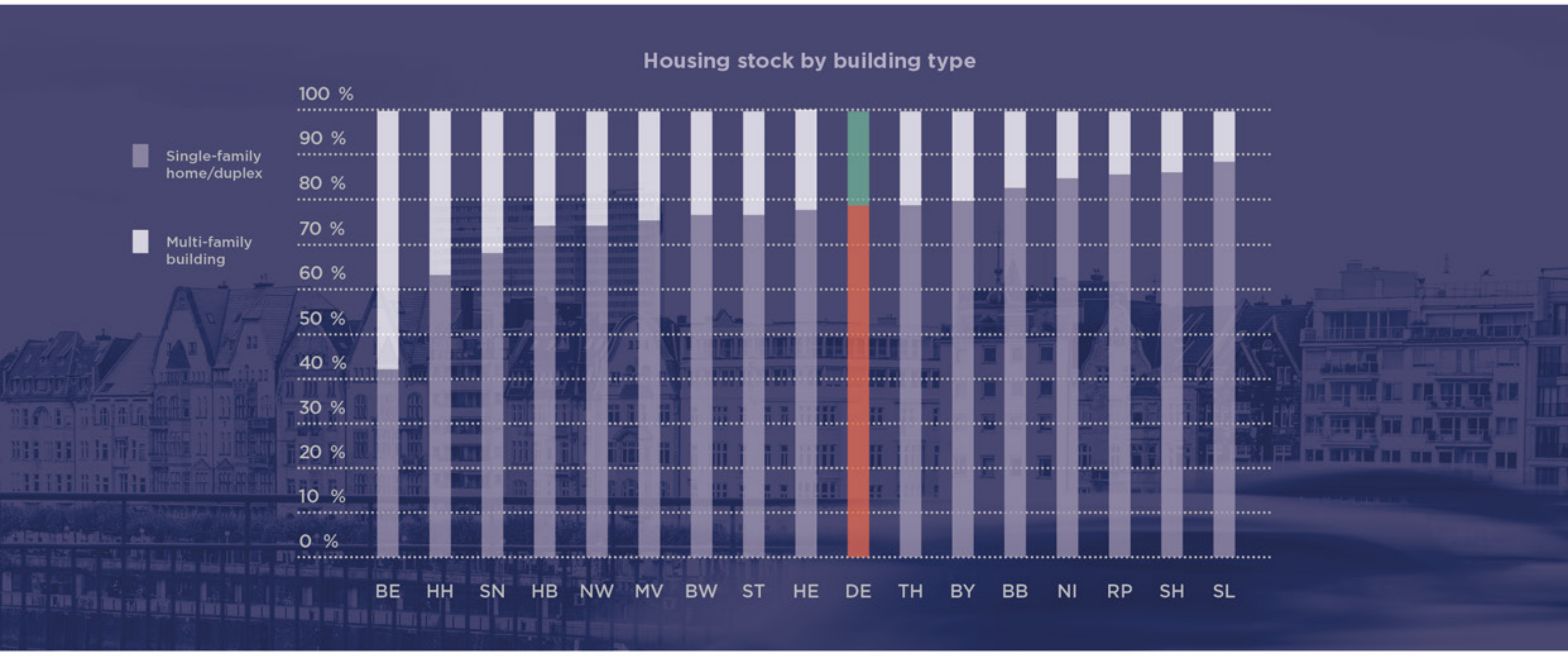


Fig. 14: Building type by state (2011 and 2014); source: co2online; own calculation and illustration.

European comparison

Comparing housing stock in various countries across Europe reveals a level of diversity like that found in various regions within Germany (Fig. 15). The share of the population residing in single-family homes and duplexes in Switzerland, Germany, and – surprisingly – also Italy and the Czech Republic is relatively low. The share of these housing types sometimes falls well below 50 %, with Switzerland exhibiting the lowest rate in Europe at around 35 %. In contrast, the UK, Norway, Belgium, and the Netherlands have high shares in the range of approximately 80 %.

In most countries, the percentage of housing accounted for by these types has also decreased in recent years. A minor upward trend is evident only in the Czech Republic, while the shares in France and the UK have remained almost constant in this respect. This is mainly due to rising prices and low availability as well as possibly a general trend toward urban living and away from the increasingly less prevalent cultural emphasis on owning a single-family home with a yard.

The extent to which the structures and trends indicated here support or are detrimental to the aims of energy conservation and reducing carbon emissions cannot be stated in general terms. On the one hand, housing stock mainly dominated by multi-family buildings is a positive factor and generally indicates professional and efficient structures in planning, construction, and in the management of housing units. On the other hand, a single-family home lived in for generations, always maintained, and passed on to family can also constitute a sustainable way to use residential space. Once again, this requires further analysis and - if there is any need at all - optimization approaches.

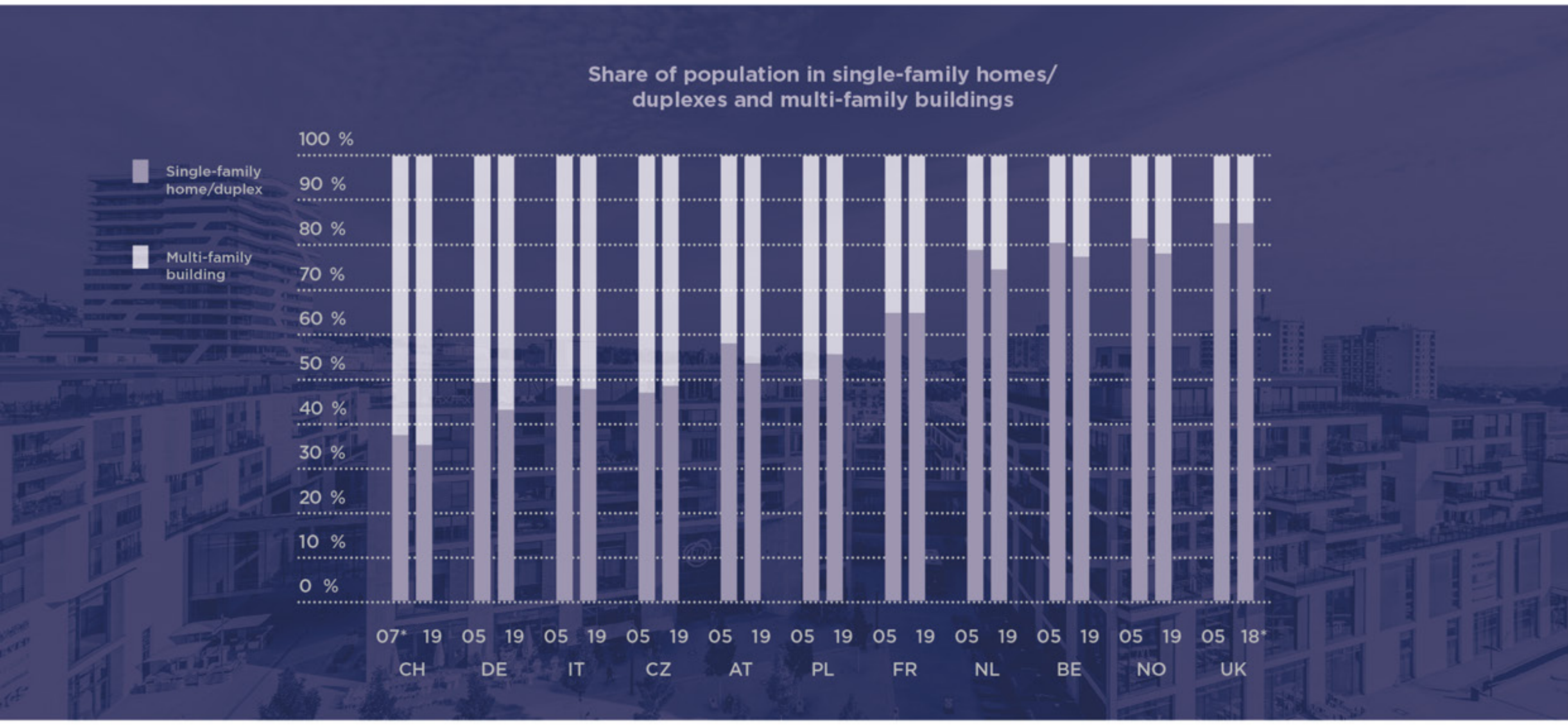


Fig. 15: Share of the population living in single-family homes/duplexes and multi-family buildings (2005 and 2019); source: Eurostat; own calculation and illustration (Switzerland 2007 instead; UK 2018 instead).*

5. Age and condition of residential buildings as a key driver of energy consumption

In addition to the building type, which would have to be represented by other architectural, constructional and material-related features in addition to the brief discussion of single-family, two-family and multi-family houses, the aspects of age and condition also play a major role in the extended structural consideration of residential buildings. These will be examined below as parameters of energy consumption.

Structure of residential housing stock in Germany – by condition

Building age, maintenance condition, and renovation requirements are key drivers of residential energy consumption. This is particularly true for heating and hot water. The best reference example here is the usage metrics of unrenovated existing properties. According to co2online and the Institute for Ecological Economy Research (IÖW), such older properties without significant modernization efforts to improve energy efficiency historically comprise a share of 36 % of Germany's housing stock. The consumption of heating energy for space heating and hot water amounts to 151 kWh per m² and year in this case, adjusted for severe weather conditions.

At 143 kWh/m², partially renovated buildings making up 50 % of Germany's housing stock use only 5 % less. Buildings are classified as "partially renovated" if at least one and no more than three projects have been completed to make them more energy efficient. These projects can include installing roof insulation, installing facade insulation, or replacing windows, and completed individually, only save a minimal amount of energy.

Fully renovated properties in which at least four projects leading to energy savings were completed are substantially more energy efficient. This reduces heating energy consumption to 115 kWh/m², which corresponds to savings of 24 % compared with an unrenovated building.

The greatest efficiency improvement was exhibited by new buildings constructed according to current technical standards. This category includes properties built starting in 2002. The average heating energy consumption of these properties was 89 kWh/m², or only 59 % compared to an unrenovated reference property.

New and fully refurbished buildings can thus contribute significantly to energy savings, as their demand for heating energy is much lower. However, both categories currently comprise only 13.8 % of Germany's housing stock. The energy conservation and CO2 reduction effects achievable with new standards have therefore not taken full effect throughout Germany's stock of housing. The extent to which this differs by region is explained below in detail.

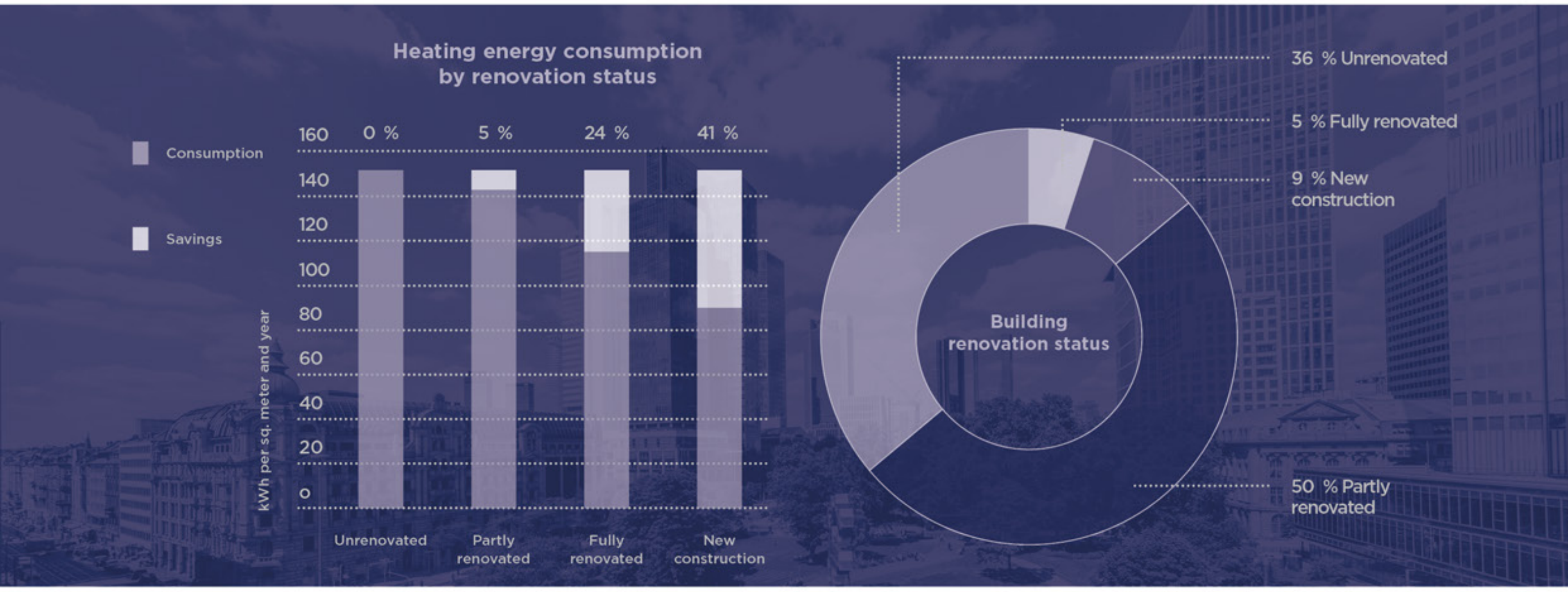


Fig. 16: Building renovation status and heating energy consumption by renovation status in Germany (1995 to 2019); source: co2online; own calculation and illustration.

Regional differences

In a regional view of building classes in the various German states, the differences in the structure in the former West German states on the one hand and the former East German states on the other hand is particularly notable. Due to considerable public and private investment after reunification bolstered by large tax incentives provided by the German Regional Development Act (Fördergebietsgesetz), the percentage of buildings newly built and fully renovated since 1990 is considerably higher in regions formerly comprising East Germany than in those formerly making up West Germany. Tens of thousands of buildings, often already heavily damaged, with outdated fittings – some dating to before World War II – were equipped with modern heating and electrical systems during comprehensive renovations. They were also equipped with significantly better insulation, typically including new windows, elimination of thermal bridges, often also facade insulation).

Modernization projects to install energy-efficient technical systems have been undertaken broadly across the whole of Germany. In regional terms, however, there are differences, for example in building shells and heating technology. A sharp north-south divide exists especially in the use of solar heating. An average of approximately 7.0 % of buildings in Germany have been equipped with various types of solar heating installations. Such systems have already been installed in 11.2 % of the buildings in Bavaria, and this figure is 9.1 % in Baden-Württemberg and 8.1 % in Saarland. Trailing are the city-states of Bremen at 3.6 %, Berlin at 2.8 %, and Hamburg at 2.4 %. Presumably, these systems are often installed in single-family homes, the prevalence of which is already much lower in cities, as previously mentioned.

Based on regional differences in building structures (age, modernization, fittings), many factors on the whole point in favor of a differentiated, state-specific approach to renovating buildings and improving energy efficiency. Programs applied uniformly across Germany can instead quickly lead to unfavorable misallocation and financial knock-on effects and should therefore be considered less efficient.

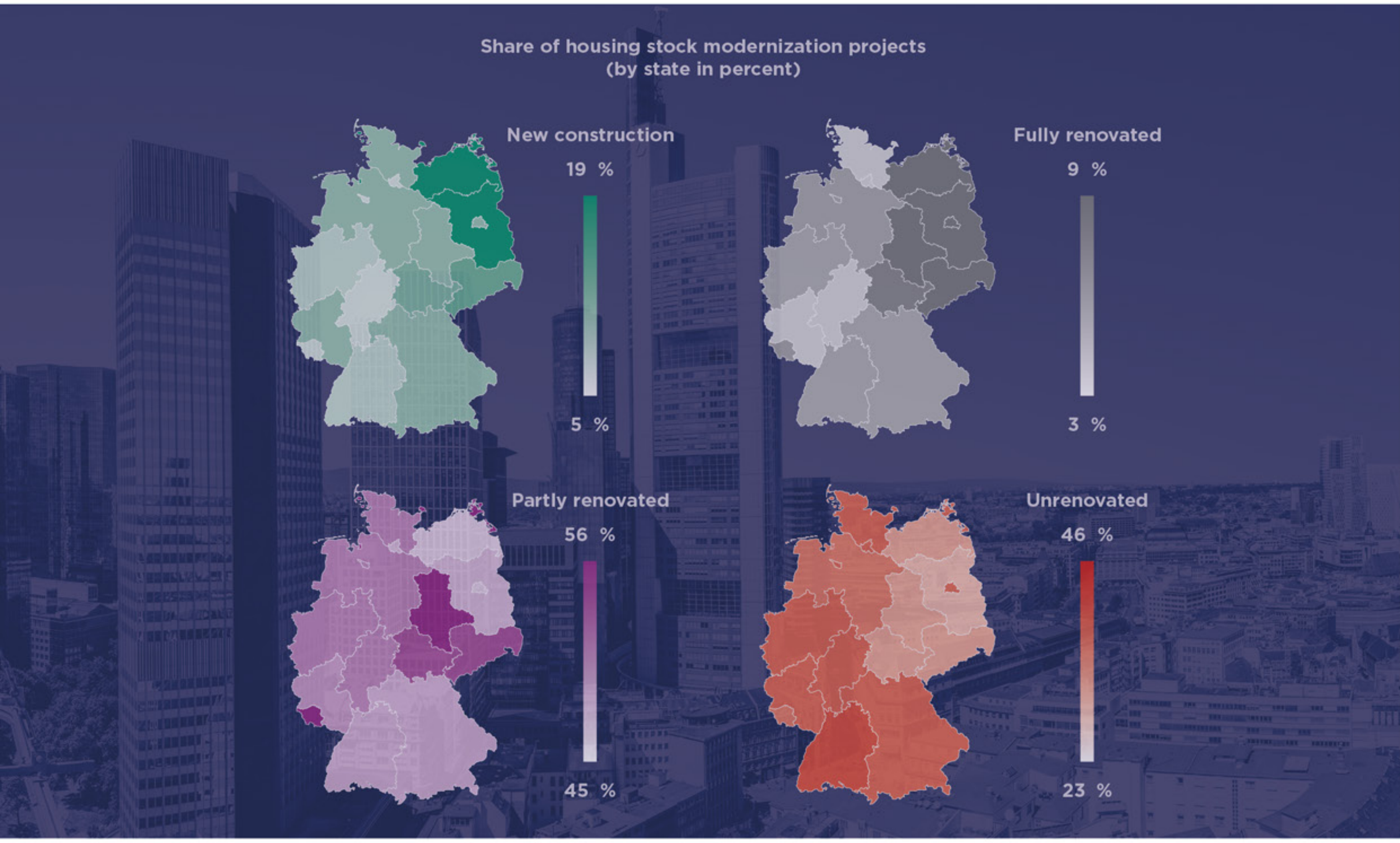


Fig. 17: Building renovation status in Germany (1995 to 2019); source: co2online; own calculation and illustration.

Germany in a European comparison

The European statistics allow an analysis at least by construction age categories. Due to a lack of comparable standards across countries, it is unfortunately impossible to differentiate by individual types of fittings or condition. However, due to the difference in requirements by country (e.g., based on the climate zones), this would likely be beyond the scope of this study in any case.

The following table (Fig. 18) distinguishes four different periods for classifying buildings by year of construction. Classic older buildings fall in the category of those built up to 1945. At 25 % of the country's housing stock, Germany comes close to the European average of 23 %. Countries like Finland (12 %), Poland (19 %), and the Netherlands (19 %) have substantially fewer older buildings, but they occur disproportionately often in the UK, where they account for 37 %.

Due to the buildings lost during World War II which had to be replaced, Germany has many post-war structures falling in the category of buildings constructed up to 1979. This category amounts to 49 % of the housing stock and features poor energy efficiency and a high degree of potential for optimization because of the usually fast and inexpensive construction methods used to build these buildings. Specific energy-efficiency standards were first issued toward the end of this period in the form of the (first) Thermal Insulation Regulation, which entered into force in 1977. However, this housing stock has already been modified and renovated in the meanwhile in some cases.

In contrast, Germany has relatively few new buildings constructed after 2000, with the most modern buildings accounting for only 7 %. The European average (for the EU-28, including the UK) is 13 %. The highest percentage can be found in France, where 17 % of its housing stock is newer.

The construction year categories typical in Germany indicate that the overall need for renovation may be higher than is apparently the case for the European average.

	<1945	1945-1979	1980-1999	>2000
Germany	25 %	49 %	19 %	7 %
United Kingdom	37 %	39 %	15 %	10 %
Italy	20 %	49 %	20 %	11 %
Czech Republic	22 %	40 %	26 %	12 %
Belgium	34 %	37 %	17 %	12 %
EU-28	23 %	42 %	22 %	13 %
Poland	19 %	39 %	28 %	14 %
Netherlands	19 %	40 %	26 %	14 %
Finland	12 %	42 %	30 %	16 %
France	27 %	34 %	22 %	17 %

Fig. 18: Residential housing stock by construction year (2014); source: Eurostat; own calculation and illustration.

6. Investments in new construction for sustainable, energy-efficient housing stock

Creating additional residential space by building new housing is counteracting surplus demand, particularly in metropolitan areas. Beyond just the social aspects, the analyses above have shown that newly constructed and (with some reservations) also fully renovated properties result in a significant reduction in relative energy consumption per unit area or dwelling unit. This gives rise to a corresponding increase in efficiency across the entire stock of housing – not just in the major cities otherwise the primary focus. New construction therefore enables energy conservation and cuts carbon emissions, assuming that buildings are not constructed in an overly complicated manner and are used for as long as possible.

Momentum in new residential housing construction in Germany

As shown with the construction age categories above, relatively few new buildings have been constructed in Germany in recent years, at least compared to other countries in Europe. The relevant project developers and building contractors must be addressed with this aim in mind to find approaches for more quickly renovating and therefore modernizing Germany's housing stock. There is considerable diversity here as well as different weightings of goals, motives, experiences, and services in their real estate industry activities. Private sector building contractors are by far the top category in terms of the number of new construction projects completed. They are responsible for most new construction. However, professional commercial real estate companies produce the most residential space by area. The shift in shares between the two charts on numbers of projects and area (Fig. 19) can easily be explained by the fact that the companies construct far larger properties, generally multi-family buildings. The corresponding effect was already explained in Section 4. In the interest of meeting energy, CO2, residential space, and residential quality aims, an approach that should be considered in this context is to first turn to companies active in this market. They are in the position to operate efficiently while also conserving resources and, due to their repeated activities, possess considerably greater experience and expertise than private sector building contractors who build one-time projects. Lastly, the amount of space provided rose while at the same time the number of projects stagnated, which points to a corresponding growth in average project size.

For further classifying the groups to be approached about optimization projects, it is also interesting that the public sector defined narrowly (e.g., public corporations) is responsible for an almost insignificant share of housing construction. The newly built area and housing construction projects completed by the public sector hardly make a blip in the overall view of housing construction. It is interesting that the public sector's activities are very stable only in specialized segments of the housing market (e.g., low-income housing, construction companies involved). During the financial crisis, the public sector's amount of space made available and project numbers were almost unchanged, unlike for other housing market players. Private sector building contractors are very sensitive in this regard.

The statistics additionally include real estate funds and non-profit organizations such as churches, NGOs, and foundations. These are only included in the chart for the sake of completeness, but their contribution to housing construction is very minor. For instance, with regard to approaching these groups, addressing them with funding programs directly would likely not further the aims, but including them in discussions with private sector building contractors would make sense (e.g., in defining groups entitled to apply for or receive subsidies).

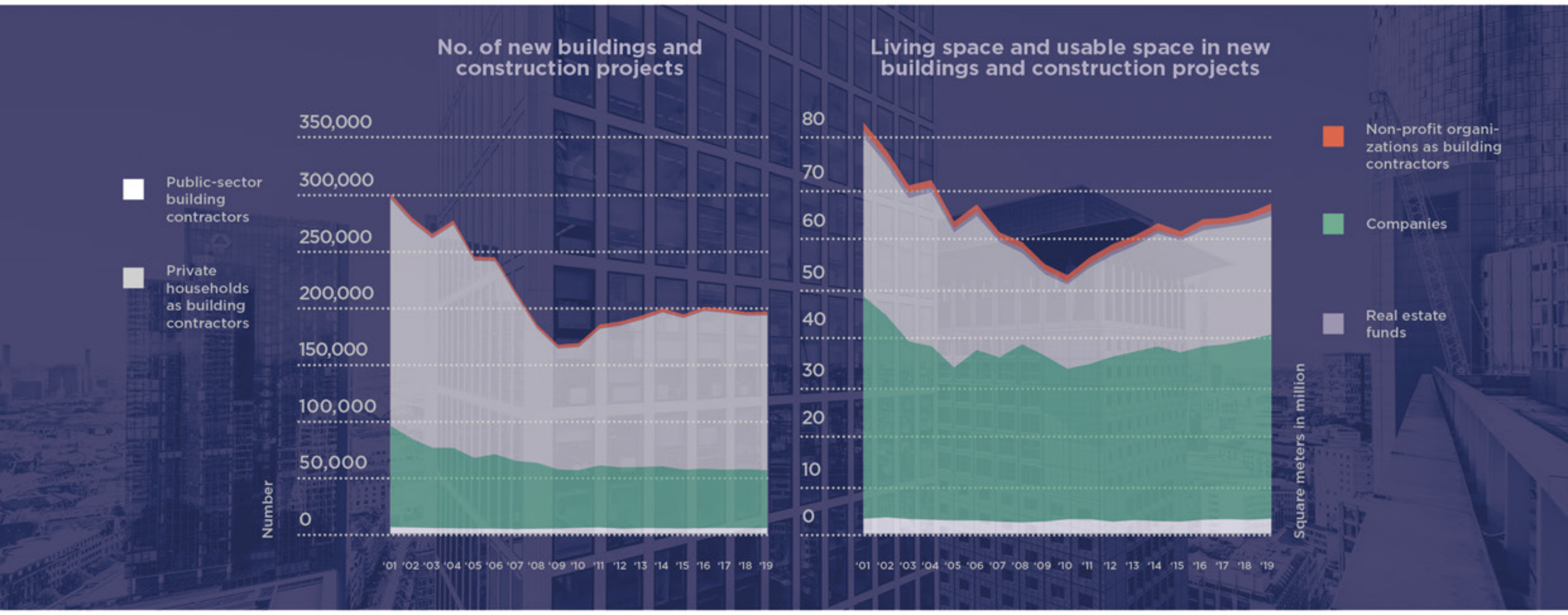


Fig. 19: New building completions and construction projects in Germany; source: Federal Statistical Office; own calculation and illustration

Regional differences

The large non-city-states are by far the leaders in new housing construction of all the regions in Germany. In 2019, over 21,000 housing construction projects were completed in Baden-Württemberg alone (the total including non-residential buildings is more than 26,000). Bavaria accounted for around 34,000 housing construction projects. At 58,000, Bavaria is also the clear leader in the number of new housing units, in contrast to Mecklenburg-Western Pomerania, where only slightly more than 5,000 dwelling units were built in all of 2019. All these figures illustrate construction activity in the conventional housing construction market. There is additional potential in what are known as non-residential buildings as well. This refers to properties such as retail or office buildings which feature a certain number of dwelling units, especially on the upper floors, sometimes comprising a minimum share of the building due to building regulations.

The share of various states' construction activity accounted for by housing construction differs significantly as well. Based on 2019 figures, Berlin ranks highly with housing construction accounting for around two-thirds of total newly constructed space. In other states such as Bremen, Bavaria, Saarland, and Baden-Württemberg, housing construction only makes up some 40 % of newly constructed space.

STATE	NEW HOUSING CONSTRUCTION IN RESIDENTIAL BUILDINGS			NEW HOUSING CONSTRUCTION IN NON-RESIDENTIAL BUILDINGS		SHARE OF HOUSING CONSTRUCTION
	Projects	Dwelling units	Area	Dwelling units	Area	Residential space to total space
	Number	Number	1,000 m²	Number	1,000 m²	Ratio
Baden-Württemberg	21,240	37,347	4,019	1,478	131	39.3 %
Bavaria	34,143	58,263	6,337	1,516	102	42.9 %
Berlin	3,065	18,870	1,363	129	8	66.0 %
Brandenburg	7,068	10,770	1,130	125	8	63.2 %
Bremen	695	2,145	186	45	2	37.2 %
Hamburg	2,535	9,666	798	139	21	60.5 %
Hesse	9,631	20,175	2,113	184	18	48.2 %
Mecklenburg-Western Pomerania	2,926	5,243	538	29	3	54.4 %
Lower Saxony	18,108	28,057	3,181	299	17	46.4 %
North Rhine-Westphalia	26,340	47,387	4,985	1,260	84	46,5 %
Rhineland-Palatinate	8,774	13,730	1,625	373	25	48.5 %
Saarland	1,741	2,409	280	122	7	41.7 %
Saxony	7,083	10,128	1,170	78	8	47.6 %
Saxony-Anhalt	3,345	4,367	502	59	3	52.4 %
Schleswig-Holstein	7,847	13,314	1,266	354	23	49.5 %
Thuringia	3,250	4,843	621	98	9	52.8 %

Fig. 20: Construction completions in the states in 2019;
source: Federal and State Statistical Offices; own calculation and illustration

Housing is being constructed primarily in the in-demand major cities. In Frankfurt/Main, around 8 % of the housing stock was newly built in the period from 2011 to 2019 alone. Munich's rate is equally high at almost 8 %, while Hamburg added more than 6 % to its housing stock. Cologne, Stuttgart, Berlin, and Düsseldorf each have new construction rates of between 4 % and 5 %. This in turn also indicates the great significance of major cities for providing housing, improving quality, and ensuring sustainability of the housing stock.

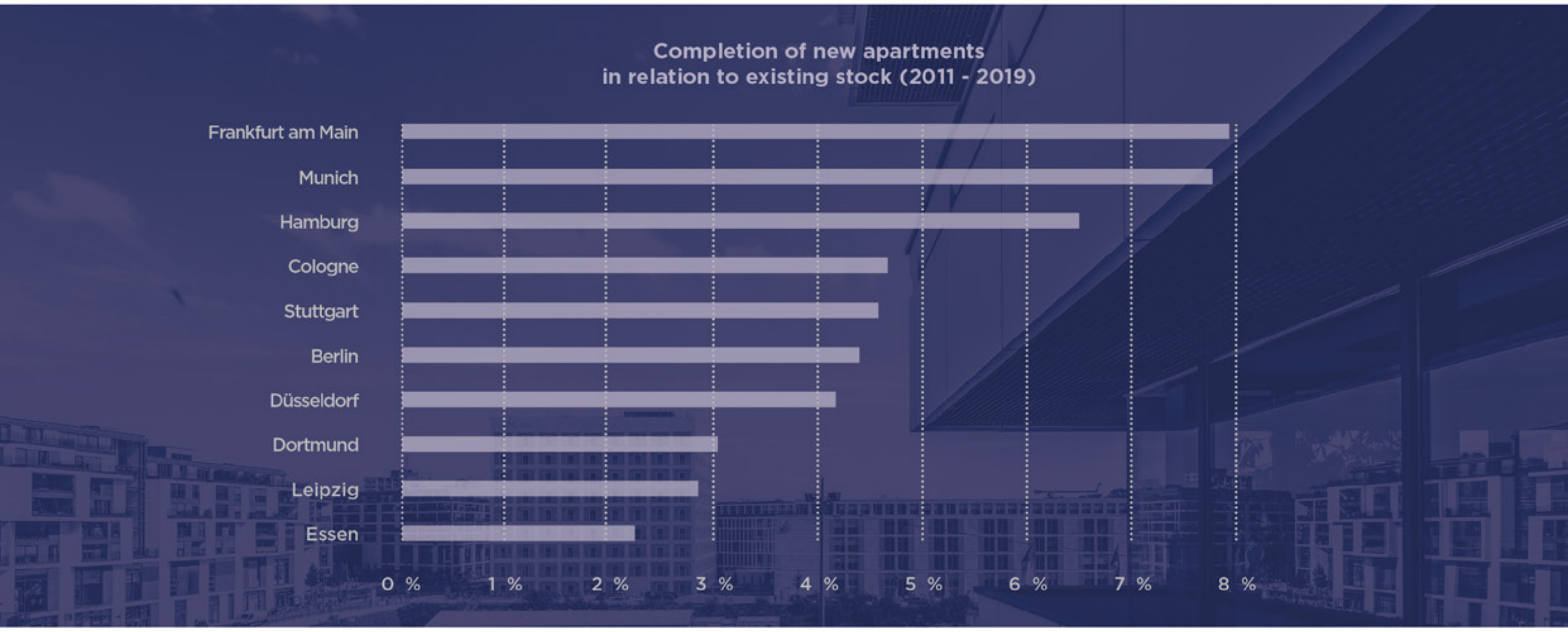


Fig. 21: Completion of new housing units measured against total housing stock; source: Federal and State Statistical Offices; own calculation and illustration

Germany in a European comparison

As already demonstrated in the statistics on existing housing (Section 5), relatively little housing is being built in Germany versus the rest of Europe. Housing construction numbers in countries such as Austria, Belgium, and France were significantly higher, especially in recent years.

In relation to the population, for instance, Austria built much more housing than Germany (6.48 dwelling units per 1,000 inhabitants in 2016 alone) in the past few years. Belgium, France, and Poland also built more housing units, and the Netherlands is comparable to Germany in construction activity. The Czech Republic and Italy (1.35 dwelling units per 1,000 inhabitants in 2016) come in at the end of the list. Metrics for 2018 are available for only a few countries. Germany's figure for 2018 is 3.47.

Over the long-term observation period starting in 1980, the high figure was 10.4 new units per 1,000 inhabitants in Austria in 1980, and the low figure was 1.23 in the Czech Republic in 1995. In Germany, the fewest housing units were built shortly after the 2009/2010 crisis (1.94/1.95), whereas the most were constructed in 1995/1997 (7.39/7.05). As discussed previously in the regional view, this was mainly due to the new construction subsidized in Germany's new states.

Construction completions across Europe are below the largely higher numbers in the 1990s as shown in Fig. 22. Adjusting for high and low outliers, the number of completions in the housing market have remained relatively constant recently. The average for the period from 2010 to 2018 totals an annual 3.67 new housing units per 1,000 inhabitants.

Based on the figures, it can be assumed that the housing stock in countries like Austria and France is relatively modern. Of course, this requires similar framework conditions: from the energy perspective, particularly equally high standards for construction and fittings.

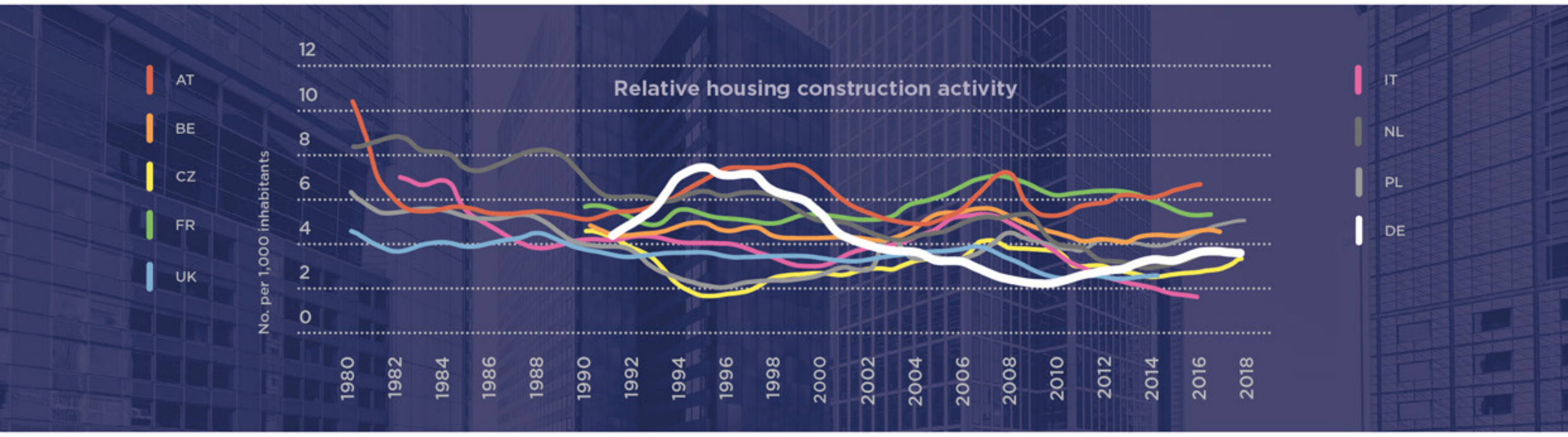


Fig. 22: Construction completions in selected European countries; source: ECB; own calculation and illustration

7. Conclusion

The use of buildings for living space plays a considerable part in energy consumption and carbon emissions both in Germany and in Europe as a whole. For this reason, the housing, real estate, and construction industries are key players in meeting the European Union's aim of near-climate neutrality by 2050.

A quantitative reduction in the use of residential space should not be expected: In past decades, per capita living space has increased continuously in nearly all countries and regions, while household size has tended to decline. Fundamentally, this implies a growing need for energy and therefore rising carbon emissions, assuming the energy mix and energy efficiency remain the same.

A significant decrease in energy consumption and CO2 emissions can therefore only be achieved through qualitative improvements, primarily in generating heating, which is responsible for 87 % of energy consumption (space heating plus hot water).

The analyses indicate that new residential construction has substantially greater potential for conserving energy and cutting emissions than renovating existing buildings to improve their energy efficiency. As a result, an intensive level of new residential construction is essential for meeting these ambitious climate goals. Germany continues to trail its own expectations – including compared to other European countries. If Germany is to catch up, it must tap the considerable potential especially of commercial real estate companies equipped with extensive private capital. These will continue to play by far the most important role in creating living space in Germany in the future.

A regional and European comparison additionally shows that there are some marked differences in energy consumption, partly for climatic reasons, but also partly explained by variations in settlement patterns and age categories of existing housing stock. Therefore, uniform pan-German or even pan-European standards and measures should be questioned as to their effectiveness for meeting climate policy targets. Energy usage per housing unit in multi-family buildings tends to be lower than that of single-family homes or duplexes – without consideration of political implications.

The most effective course for allowing residential real estate to contribute to climate policy goals would be to offer commercial residential project developers an attractive environment for creating new energy-efficient housing.

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