

The typology of the residential building stock in Serbia and modelling its low-carbon transformation

Serbia

Support for Low-Emission Development in South Eastern Europe (SLED)

REGIONAL ENVIRONMENTAL CENTER

WITH FUNDING FROM
AUSTRIAN DEVELOPMENT COOPERATION

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The REC is implementing the project "Support for Low-Emission Development in South Eastern Europe" (SLED) to help policy makers in the project countries (Albania, the former Yugoslav Republic of Macedonia, Montenegro and Serbia) to establish realistic but ambitious decarbonisation pathways for their electricity and building sectors by 2030.
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MODELLING THE TRANSFORMATION TO A LOW-CARBON RESIDENTIAL BUILDING STOCK

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Executive summary

Energy demand in the building sector represents a big challenge for Serbia. In 2013, the sector was responsible for 35 percent of national final energy consumption and 53 percent of national electricity consumption. The quality of energy services delivered to residential buildings is poor. Most notably, typically only half the floor area of dwellings is heated for a limited number of hours per day. The continued use of outdated wood stoves results in numerous environmental and health problems.

As a contracting party to the Energy Community Treaty, Serbia is obliged to introduce EU energy efficiency legislation. However, meeting the related targets requires more ambitious policy efforts and bigger investments in demand-side energy efficiency than are being made at present.

The present publication aims to provide the necessary information to assist in the design of energy efficiency and climate mitigation policies for the residential building sector in Serbia. We identified 18 representative categories of residential buildings, calculated their thermal energy performance, designed standardised retrofitting packages, and calculated the possible energy savings and required investments by building type. We identified the current and future level and structure of final energy consumption by building age category, building type, and energy end use. We suggest two policy packages additional to the present policies, aimed at transforming the residential building stock to zero energy and zero carbon by 2050 and 2070. We estimate the level of effort required to achieve these goals in terms of the floor area affected and the investments required by actor and by policy tool. Finally, we evaluate energy savings, saved energy costs, avoided CO_2 emissions, and the cost-effectiveness of the packages.

In order to carry out the analysis at sector level, we designed and applied a bottom-up simulation model. The model is applicable to the period up until 2030. We assessed only thermal energy services delivered to residential buildings — that is, space heating, space cooling and water heating. We did not include energy use for electrical appliances, lighting and cooking. We considered both direct and indirect CO_2 emissions in our analysis.

The model itself, with all the underlying input data, is provided to national policy makers and experts to use and modify according to their needs. It is also available on request to other experts, subject to proper referencing and acknowledgement.

WHAT ARE THE CURRENT LEVELS AND FUTURE TRENDS OF FINAL ENERGY CONSUMPTION AND CO_2 EMISSIONS IN THE RESIDENTIAL BUILDING SECTOR?

According to our estimates, in 2015 final energy consumption in the residential sector for thermal energy services was 42 billion kWh, of which 61 percent was in the form of wood, 16 percent electricity, 9 percent district heating, 7 percent coal, 6 percent natural gas and 2 percent liquefied petroleum gas (LPG). The sector was responsible for 9.8 million tonnes of CO_2 emissions, the biggest share being associated with electricity consumption. Final energy consumption calculated on the basis of the geometrical and thermal characteristics of buildings, as well as the characteristics of the installed energy systems, differed significantly from the estimated energy balance. Final energy consumption was therefore calibrated to the balance, correcting for the current level of thermal comfort — that is, partial floor area heated and cooled and the duration of space heating and cooling.

In the business-as-usual reference scenario, final energy consumption for thermal services will decrease by around 5 percent between 2015 and 2030 to reach 40 billion kWh in 2030. In 2030, emissions of CO_2 will be 89 percent of the 2015 level. Changes in the structure of consumed energy sources will not be significant. Energy demand in existing buildings is expected to decline in spite of the increase in thermal comfort due to business-as-usual improvements. Business-as-usual improvements occur once during a building's lifetime — that is, once every 45 years.

WHAT ARE THE PRIORITY SECTOR SEGMENTS FOR POLICY MAKING?

From a long-term perspective, it is important to ensure that buildings built between 1971 and 1990 are retrofitted. While these buildings will represent 34 percent of building floor area in 2030, they will be responsible for 46 percent of total final energy consumption and are therefore a clear priority for policy intervention. Another important category comprises buildings constructed between 1961 and 1970, which will represent 16 percent of building floor area and be responsible for 17 percent of final energy consumption.

New buildings will be responsible for 9 percent of final energy consumption in 2030, even though their floor area represents 22 percent of the total sector floor area. This estimate assumes that new buildings comply with the building code introduced in 2011, which is why policies that ensure the compliance of new buildings with the building code are also important.

Small buildings are a clear priority for policy making because, in 2030, single-family houses will be responsible for 85 percent of final energy consumption for thermal energy uses. Small buildings constructed in 1971–1980, 1981–1990 and 1961–1970 will be responsible for more than 15 percent of final energy consumption by 2030. Single-family houses built after 2016 will also be responsible for a large share of final energy consumption (8 percent). Almost all final energy savings will be attributable to space heating.

WHAT POLICY PACKAGES ARE POSSIBLE?

The SLED moderate scenario supposes that by 2070 the performance of all new and existing buildings corresponds to the performance after standard improvement 1 defined in the present publication. The measures of standard improvement 1 comply with the requirements envisioned by the building code introduced in 2011. Improvement implies not only lower energy consumption, but also higher thermal comfort than in the business-as-usual improvement.

To ensure that all existing buildings that remain in 2070 are retrofitted by this time, we assume that Serbia will introduce financial incentives for investors in the residential sector. These include the introduction of low-interest loans for 90 percent of households in detached and semi-detached houses, and the introduction of grants for the remaining 10 percent of such households. They also include, starting from 2016, the introduction of loans for 10 percent of households in row (terraced) and multi-dwelling apartment buildings, and this share is assumed to reach 90 percent by 2070. The remaining households in row and multi-dwelling apartment buildings would obtain grants.

Due to high upfront investment costs, we recommend coupling thermal efficiency improvements in existing buildings with their business-as-usual renovation wherever possible in order to take advantage of costs that are anyway incurred. The retrofitting rate in the SLED moderate scenario is lower than the retrofitting rate in the reference scenario, and we make maximum use of business-as-usual investments. We assume that financial incentives will be provided to cover the share of eligible investment costs for better buildings, which are approximately equal to the share of incremental investment costs in improvement 1 as compared to the business-as-usual improvement.

The SLED ambitious scenario implies that by 2050 the performance of the majority of new and existing buildings will correspond to performance following ambitious improvement 2 defined in the present book. Improvement 2 implies even greater thermal comfort than improvement 1.

According to the scenario, in addition to the 2011 building code, Serbia would also introduce a more stringent building code in 2022, with requirements no lower than those of the measures in improvement 2. In order to prepare the market, from 2016 Serbia would introduce low-interest loans for the construction of new buildings that comply with the 2022 building code. Similar to the SLED moderate scenario, the SLED ambitious scenario assumes the retrofitting, by 2050, of all existing buildings that would remain at this time. The retrofitting would be carried out according to improvement 1 by 2022, and according to improvement 2 from 2023 up to 2050.

To ensure that retrofitting is carried out, Serbia would introduce financial incentives for investors in the residential building sector. Up to 2022, financial incentives would be provided in order to achieve a level of performance according to improvement 1. Between 2023 and 2050, incentives would be provided in order to achieve a level of performance according to improvement 2.

The retrofitting rate in the SLED ambitious scenario is higher than in the reference scenario, which is why the incremental costs of the SLED ambitious scenario include the incremental investment costs of thermal efficiency retrofitting for a part of the retrofitted building stock and the total investment costs of thermal efficiency retrofitting for the rest of the retrofitted building stock. The structure of the financial incentives and the definition of eligible costs are the same in the SLED moderate and ambitious scenarios.

HOW BIG ARE THE ASSOCIATED FINAL ENERGY SAVINGS AND CO_2 EMISSIONS REDUCTIONS?

According to the SLED moderate scenario, final energy consumption for thermal energy services would decrease to 33 billion kWh in 2030, or 17 percent lower than the business-as-usual level. The associated CO_2 emissions would be 27 percent lower than the business-as-usual level. The scenario would lead to a 15 percent reduction in business-as-usual wood consumption and a 33 percent reduction in business-as-usual electricity consumption, as well as to a 26 percent increase in business-as-usual natural gas consumption. More than 60 percent of final energy savings would originate from single-family houses built between 1961 and 1990. The biggest energy savings would be associated with space heating.

According to the SLED ambitious scenario, final energy consumption for thermal energy services would decrease to 29 billion kWh in 2030, or 27 percent lower than the business-as-usual level. The associated CO_2 emissions would be 16 percent lower than the business-as-usual level in 2030. The scenario would allow a 34 percent reduction in business-as-usual wood consumption, a 13 percent reduction in business-as-usual electricity consumption, and a 43 percent reduction in lignite consumption. Almost 67 percent of final energy savings would originate from single-family houses built between 1961 and 1990, and after 2016. The largest energy savings would be associated with space heating.

HOW MUCH WOULD SUCH EFFORTS COST THE GOVERNMENT AND OTHER ACTORS?

In the SLED moderate scenario, 6.6 million m^2, or 2 percent of the total building floor area, would be retrofitted per year between 2015 and 2030. This transformation requires significant investments, which should be distributed among different actors.

The total investment costs are EUR 12.3 billion between 2015 and 2030, or EUR 822 million per year. The biggest investments are required in buildings constructed in the periods 1971–1980, 1961–1970 and 1981–1990. When the costs of the reference scenario are deducted from the costs of the SLED moderate scenario, the incremental costs of the SLED moderate scenario are EUR 4.9 billion over 2015–2030, or EUR 329 million per year.

Assuming a discount rate of 4 percent, the annualised incremental costs of the SLED moderate scenario for 2015–2030 are EUR 2.9/m^2. Saved energy costs are EUR 3.8 per m^2 of new or retrofitted floor area on average over this period. This means that investments in the SLED moderate scenario are profitable. It is important to note that the saved energy costs are higher than the annualised investment costs for the scenario as a whole at country level, but not for all building categories. For a few building categories, saved energy costs are lower than the annualised incremental investment costs, thus in their case the incremental investments do not pay back. Raising the discount rate higher than 6.5 percent would make the SLED moderate scenario unattractive if saved energy costs alone were counted as scenario benefits. The analysis is carried out assuming a likely increase in energy prices.

Eligible investments in building retrofits that investors would borrow are EUR 5 billion over 2015–2030, or EUR 313 million per year. Assuming a market loan interest rate of 10 percent, a subsidised interest rate of 0 percent, and a loan term of 10 years, the government would provide EUR 2.2 billion to commercial banks as compensation for lowering the interest rate. The cost of grants to the government is EUR 1 billion over 2015–2030, or EUR 67 million per year.

In the SLED ambitious scenario, 7 million m^2, or 2.1 percent of the total building floor area, are retrofitted per year between 2015 and 2030. In addition, all new floor area — that is, 5.2 billion m^2 per year — is included. Total investment costs are EUR 16 billion over 2015–2030, or EUR 1.1 billion per year. The incremental investment costs of building retrofits in the SLED ambitious scenario are EUR 8.7 billion over 2015–2030, or EUR 583 million per year. The incremental investment cost in new, more efficient buildings in the SLED ambitious scenario is EUR 4.2 billion over 2015–2030, or EUR 264 million per year.

Assuming the same discount rate, the annualised incremental cost of the SLED ambitious scenario over 2015–2030 is EUR 4.2/m^2. Saved energy costs are EUR 2.7/m^2 of new or retrofitted floor area over this period. This means that investments in the SLED ambitious scenario will not pay back if only saved energy costs are counted as scenario benefits.

Eligible investments in building retrofits that investors should borrow are EUR 8.5 billion over 2015–2030, or EUR 564 million per year. Eligible investments into more efficient construction that should be borrowed are EUR 1.7 billion over 2016–2022, or EUR 116 million per year. Given the same assumptions as in the SLED moderate scenario, the government would provide commercial banks with EUR 3.6 billion as compensation for lowering the interest rate for building retrofits, and EUR 1.5 billion for lowering the interest rate for building construction. Grants cost the government EUR 1.5 billion over 2015–2030, or EUR 117 million per year. In addition, investors would have to bear EUR 842 million in incremental investment costs per year as compared to the business-as-usual practice in order to comply with the building code due to be adopted in 2022.

I. Introduction

Background

Following a steep decline in the 1990s, Serbia experienced economic growth reaching an annual 5.9 percent in 2007 (World Bank online). In the years following the global financial crisis, the economy went into recession. In order to recover and maintain high rates of economic growth, Serbia needs, on the one hand, access to a long-term, secure, affordable and sustainable energy supply. On the other hand, the country needs to use its domestic energy resources or purchased energy in the most efficient and rational way.

Energy demand in the residential building sector represents a particular challenge. In 2010, final energy consumption in this sector was 35 percent of the national total (SORS 2014a). Furthermore, the sector consumed around 53 percent of the electricity available for final consumption (*ibid*.). The quality of energy services delivered to residential buildings is far lower than the EU average. Most notably, Serbian dwellings are heated partially, and only for a few hours a day. The continuing use of outdated wood stoves results in high levels of indoor air pollution and therefore high rates of respiratory disease (Legro, Novikova and Olshanskaya 2014).

Serbia is a contracting party to the Energy Community Treaty and is thus obliged to introduce EU energy efficiency legislation. As of April 2015, the country had transposed the following EU energy efficiency directives into its national legislation: Directive 2006/32/EC on Energy End-Use Efficiency and Energy Services (ESD); Directive 2010/31/EU on the Energy Performance of Buildings (EPBD); and the Energy Labelling Directive (2010/30/EU). The Energy Efficiency Directive (EED) (2012/27/EU) is still to be adopted. In accordance with the ESD, the country must meet an energy-saving target equal to 9 percent of total energy sales in 2018 as compared to 2010. Achieving this target requires more ambitious policy efforts and bigger investments in demand-side energy efficiency than are being made at present.

Alignment with EU energy efficiency legislation also supports the measures required under the United Nations Framework Convention on Climate Change (UNFCCC). Examples include nationally appropriate mitigation actions (NAMAs), where developing countries are invited to contribute voluntary actions that help create low-carbon development strategies with the aim of promoting mitigation efforts; and intended nationally determined contributions (INDCs). Such measures require the introduction of a wide range of energy efficiency and low-carbon policies.

Even though there are many opportunities for energy efficiency improvements in the residential building sector, the policy mix in Serbia to address these opportunities could be significantly improved. However, designing an intelligent policy package is made more difficult by the fact that energy efficiency potential is spread among different types of buildings and fragmented among end users. There is a lack of understanding of how to structure the building sector for policy making; and also of the potential for energy saving and CO_2 emissions reductions, where this potential is located, and how much it would cost to realise.

Aims and structure of the present publication

This publication aims to address the gap in knowledge outlined above and, by providing the necessary information, to assist in the evidence-based design of energy efficiency and climate mitigation policies in Serbia that target the residential building sector.

The book comprises two parts. The first part offers answers to the following questions:

- How can the existing residential buildings in Serbia be classified according to their age and type? What are the representative building types in the Serbian residential building stock? How many buildings are there, and how many dwellings within them, according to such a building typology?
- What are the energy demand, the delivered energy by energy source, the primary energy consumption and CO_2 emissions of space heating, water heating and space cooling for each representative building type?
- What are the possible retrofitting options and packages of options by representative building type? What are the investment costs per retrofitting measure and per building by representative building type?

The second part focuses on the following questions:

- What are the future trends in energy consumption and CO_2 emissions in the residential building sector in Serbia? What are the key influencing factors? What are the priority sector segments for policy making?

- What policy packages are possible, and what level of policy efforts are required to make residential buildings low energy and low carbon in the medium- and long-term future? How big are the associated energy savings and CO_2 emissions reductions? How much might such efforts cost the government and other actors?

PART 1

The typology of residential buildings, possible retrofitting packages and associated investment costs

II. Building typology of existing buildings

This work is based on the building typology developed by the Serbian expert team (Milica Jovanović Popović, Dušan Ignjatović and Bojana Stankovic) prior to the SLED project.

The original typology is described in Jovanović Popović et al. 2013. During the project, further country-specific data were provided by the same team in terms of statistics, methodology, energy prices and investment costs.

Antecedents

The national typology of residential buildings in Serbia was created during a three-year research project by a group of professors and associates at the Faculty of Architecture of the University of Belgrade, which was dedicated to the creation of an unprecedented, comprehensive classification of single- and multi-family residential buildings. The results were published in the book *National typology of residential buildings in Serbia* (Jovanović Popović et al. 2013).

The typology was based on premises defined in earlier research projects carried out by the same group, as well as on the methodology adopted in the Intelligent Energy Europe (IEE) project TABULA-EPISCOPE (IEE TABULA-EPISCOPE online), the idea of which — to create a uniformly structured typology of residential buildings — had attracted support in 20 EU countries (European Commission 2012). The adopted method was recommended as one of two that were officially accepted. The extensive field survey and the work on creating the typology of residential buildings in Serbia were carried out with the support of Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.

Since official statistics obtained in the course of regular census procedures do not cover those features of buildings that can contribute to an evaluation of their quality in terms of energy performance, extensive field research had to be carried out. In 2011, approximately 6,000 family houses were surveyed, followed by a census of about 13,000 multi-family buildings in 2012. To date, this is the largest study of the energy performance of buildings ever carried out in Serbia. The procedure for defining the methodology and carrying out the field research in both censuses is described in detail in two monographs by Jovanović Popović et al. (2012 and 2013).

Simplification of the typology matrix

The original building type matrix consisted of 39 building types, and even though these were later reduced to 32, such a large number of types was not necessary for the purposes of the SLED project, thus possibilities were investigated for merging types. Building types with less significance in terms of family housing and the total floor area in multi-family housing were merged with other types with similar architectural and technical characteristics. As a result, the SLED matrix consists of 18 building types.

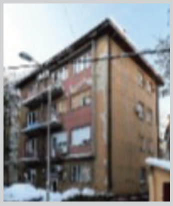
The main considerations behind the typology are outlined below.

- Size of building. Statistical data based on censuses were available for the number of dwellings in a building, as follows: buildings with one or two dwellings; row or terraced houses with a minimum of three dwellings; buildings with three to nine dwellings; and buildings with 10 or more dwellings.
- Building type. Taking census data into account in the typology, the following categories were defined: single-family houses (SFH); terraced houses (TH); multi-family houses (MF); and apartment blocks (AB).
- Construction period. Buildings were classified into five construction periods: those built before 1945; between 1946 and 1960; between 1961 and 1970; between 1971 and 1990; between 1991 and 2000; and between 2001 and 2011.

Further aspects were also analysed, but as statistical data were not available per building type, these aspects were not incorporated directly into the matrix:

- Climate zone. Heating degree days were available for several cities and towns.
- Construction materials. Limited data were available.

Table 1 Serbian residential building typology applied in the SLED project

		Family housing		Multi-family housing	
		Single-family houses	Terraced houses	Multi-family houses	Apartment blocks
		1	2	3	4
A	<1945				
B	1945–1960				
C	1961–1970				
D	1971–1980				
E	1981–1990				
F	1991–2011				

III. Statistical data on the building stock

The total number of residential buildings in Serbia was 2,246,320 in 2011 (Jovanović Popović et al. 2013). On January 1, 2015, the estimated population of the country was 7,114,393 (SORS online). The number of occupied dwellings was 2,423,208, of which 1,489,982 were located in urban settlements. The number of unoccupied dwellings was 808,723 (SORS 2011).

As explained above, we classified the building stock into 18 building types. Figures 1 and 2 show the number of buildings and dwellings in each building type. Detached houses built between 1971 and 1990 (type D1) represent the largest group, with 475,529 buildings (or 14.7 percent). Alongside the dominant small buildings, large multi-apartment buildings (types E3 and F3) built between 1981 and 1990, and after 1911, are also significant in terms of the number of dwellings they contain.

Occupied and unoccupied buildings are not separated, because such statistics are not available on the basis of building type. Only estimates are possible, based on average figures for the country.

Residential buildings by building type

As shown in Figures 3 and 4, detached houses represent the biggest share in the building stock, at 95 percent of all buildings. Apartment buildings represent only 0.6 percent of the stock, although these multistorey buildings include a large number of dwellings, representing about 8.6 percent of all dwellings. Multifamily houses (excluding apartment blocks) have a share of 2 percent in terms of the number of buildings (and 23.9 percent in terms of the number of dwellings), while the share of row/terraced houses is less significant.

Residential buildings by construction period

Approximately 15 percent of the existing building stock was built before 1945. Between 1971 and 1990, there was an upswing in the construction sector in terms of both small and large houses, including apartment blocks built with industrialised technology. Around 41 percent of buildings and 44 percent of dwellings were constructed between 1971 and 1990. In the next two decades (1991–2011) we can observe a decline in the construction sector, particularly with respect to detached houses (Figures 6 and 7). All figures are related to the total stock, including unoccupied dwellings (SORS 2011).

SMALL HOUSES (DETACHED AND TERRACED)

Most detached and terraced houses were constructed after 1945, with a peak between 1961 and 1990 when about 59 percent of the existing detached and terraced houses were constructed (Figures 8 and 9). After this period, the construction rate decreased significantly (12 percent of these houses were built after 1990) (SORS 2011).

MULTI-APARTMENT BUILDINGS, EXCLUDING APARTMENT BLOCKS

Only 9 percent of multi-apartment buildings (excluding apartment blocks) were built before 1945. The boom started after 1960, and a large number of buildings were built in the communist era. The construction of apartment buildings slowed down after 1990, but not as significantly as in the case of small houses (SORS 2011) (see Figures 10 and 11).

LARGE APARTMENT BLOCKS

The construction of apartment block buildings started after 1960, when prefabrication was introduced during the communist era. The construction of apartment blocks slowed down after 1990, but not as significantly as in the case of small houses (SORS 2011) (see Figures 12 and 13).

Figure 1 **Total number of (occupied and unoccupied) residential buildings and dwellings by building type and age** (SORS 2011)

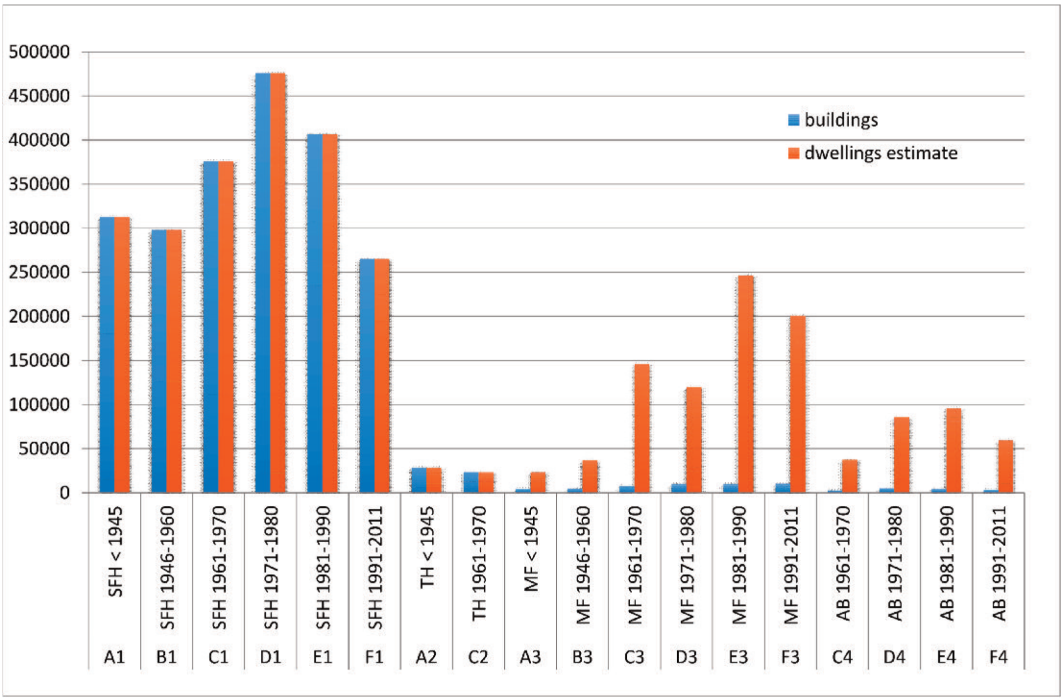
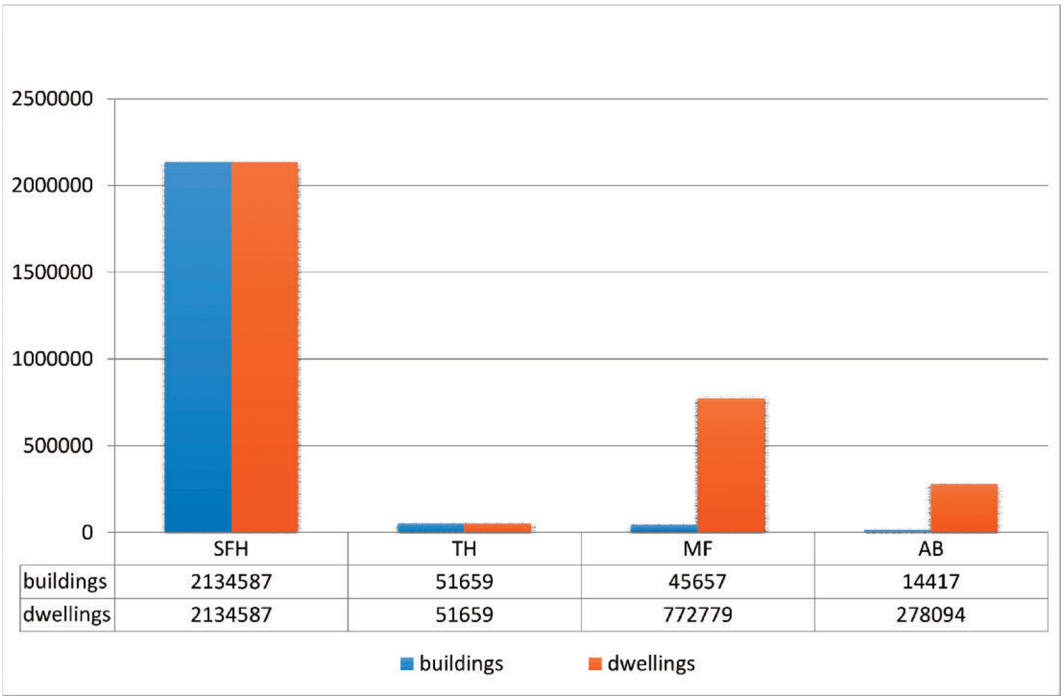


Figure 2 **Number of residential buildings and dwellings by building type** (SFH: single-family houses; TH: terraced houses; MF: multi-family houses; AB: apartment blocks) (SORS 2011)



	SFH	TH	MF	AB
buildings	2134587	51659	45657	14417
dwellings	2134587	51659	772779	278094

Figure 3 Share of residential buildings by building type (SORS 2011)

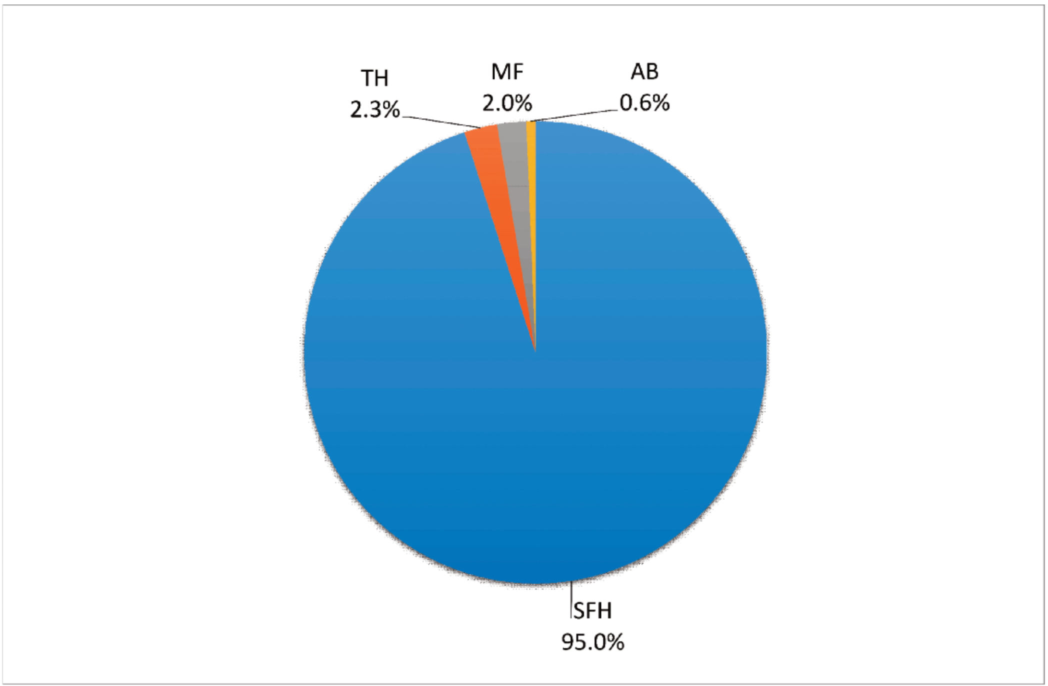


Figure 4 Share of dwellings in residential buildings by building type (SORS 2011)

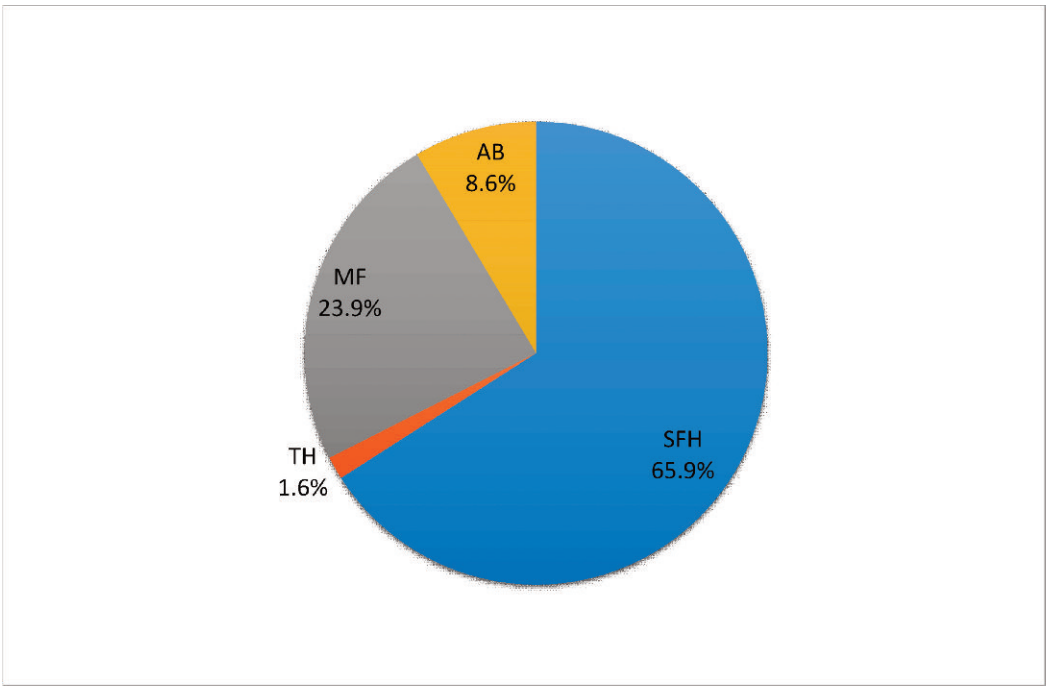


Figure 5 Number of residential buildings by construction period (SORS 2011)

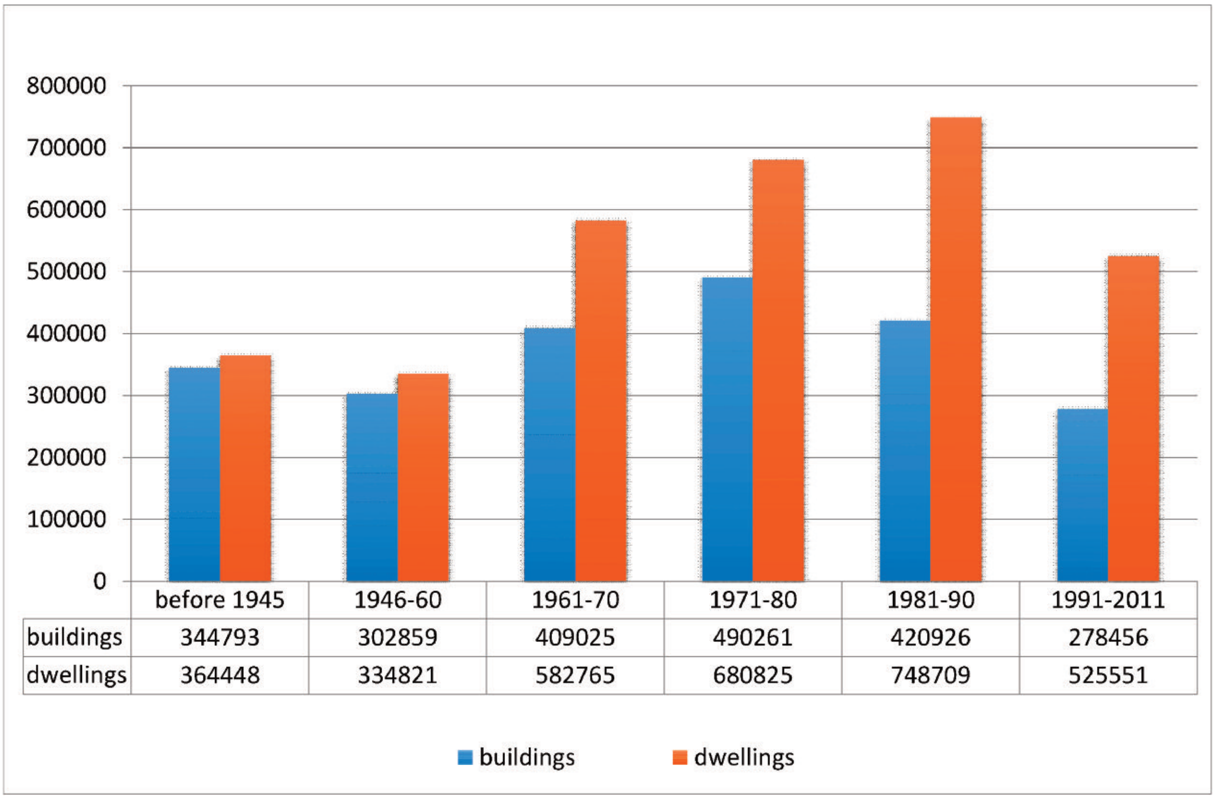


Figure 6 Share of residential buildings by construction period (SORS 2011)

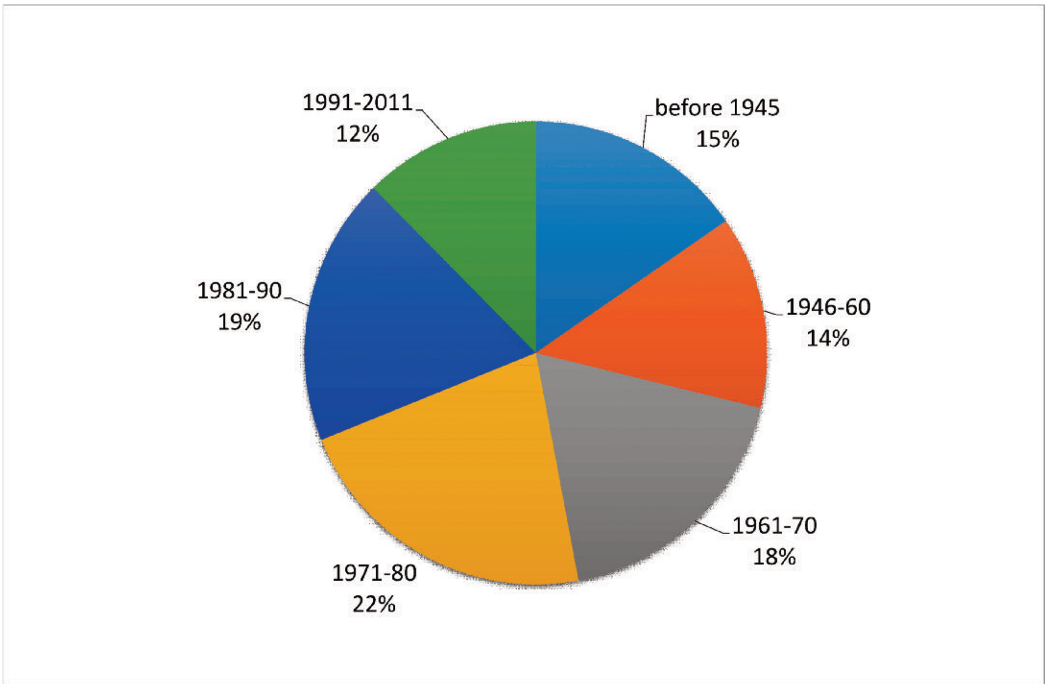


Figure 7 Dwellings in residential buildings by construction period (SORS 2011)

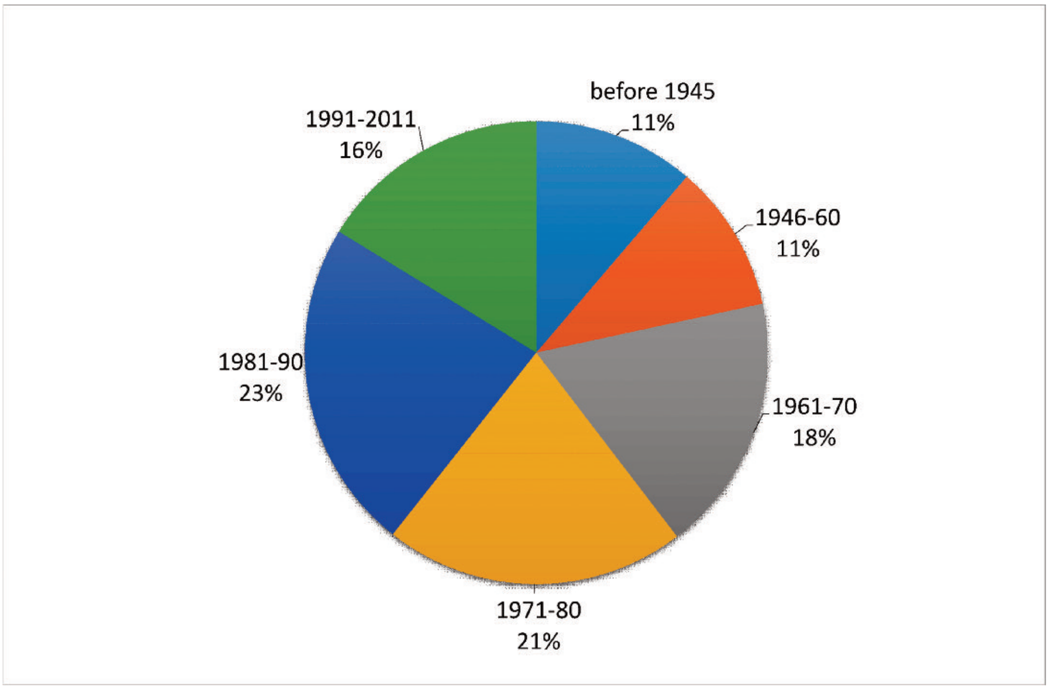


Figure 8 Number of small (detached and terraced) houses by construction period (SORS 2011)

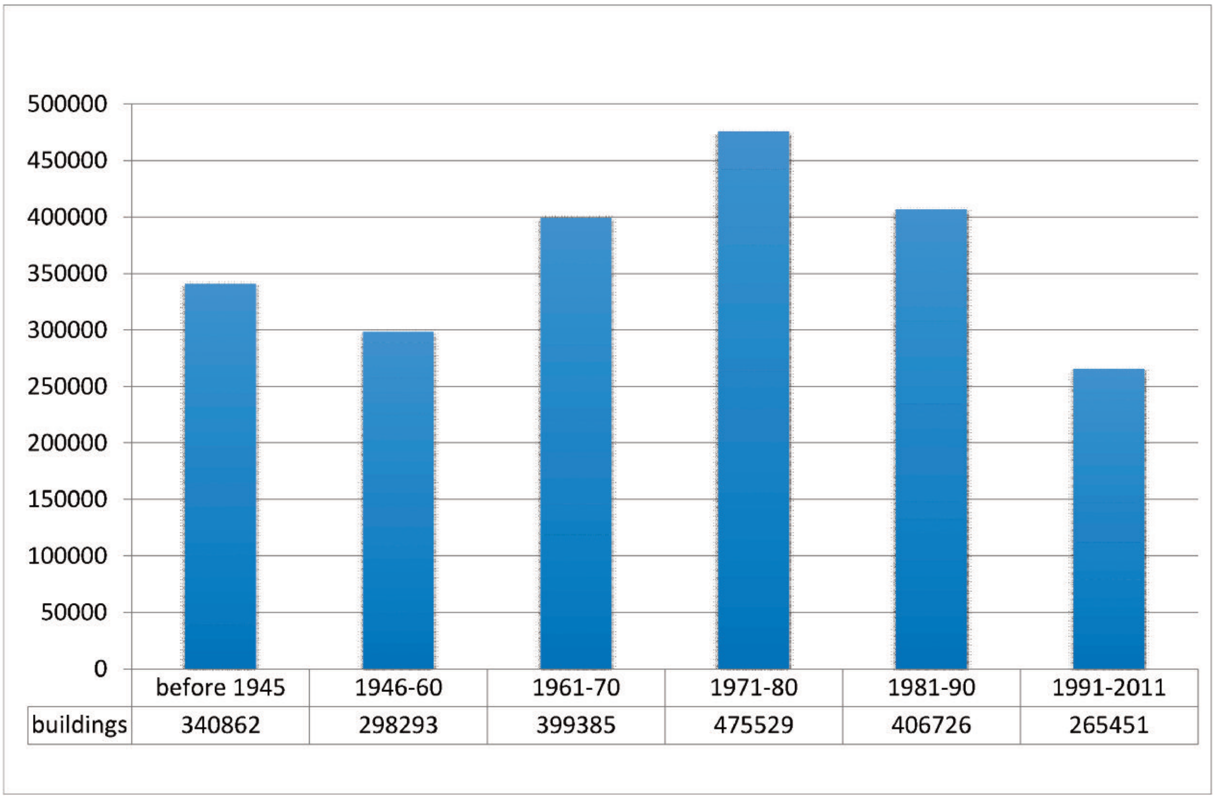


Figure 9 Share of small (detached and terraced) houses by construction period (SORS 2011)

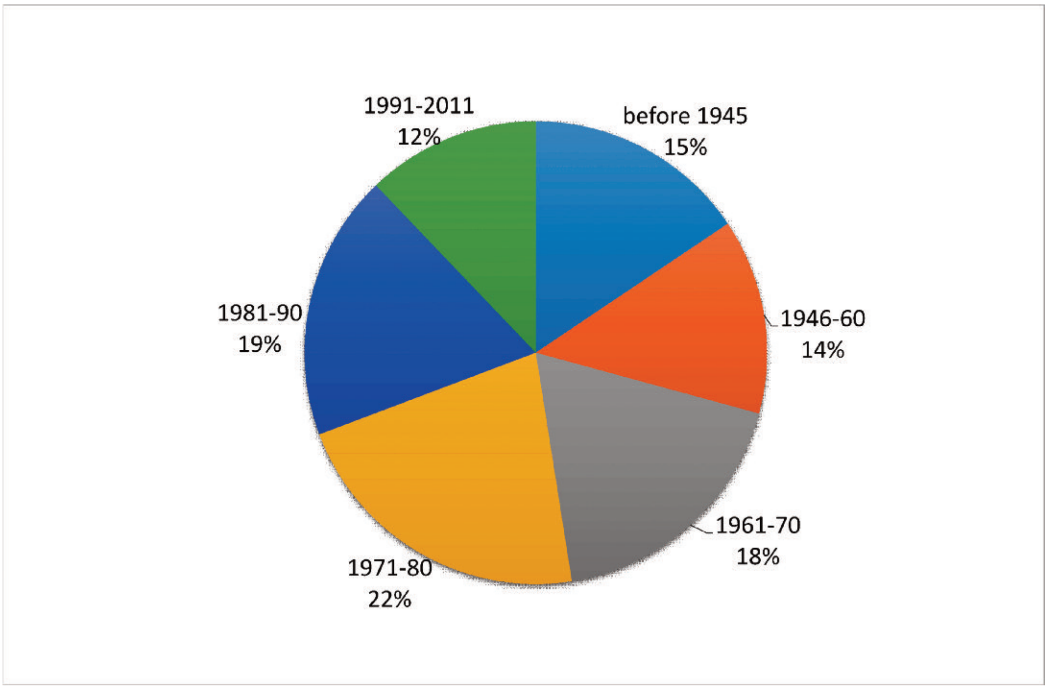


Figure 10 Number of multi-apartment buildings (excluding apartment blocks) by construction period (SORS 2011)

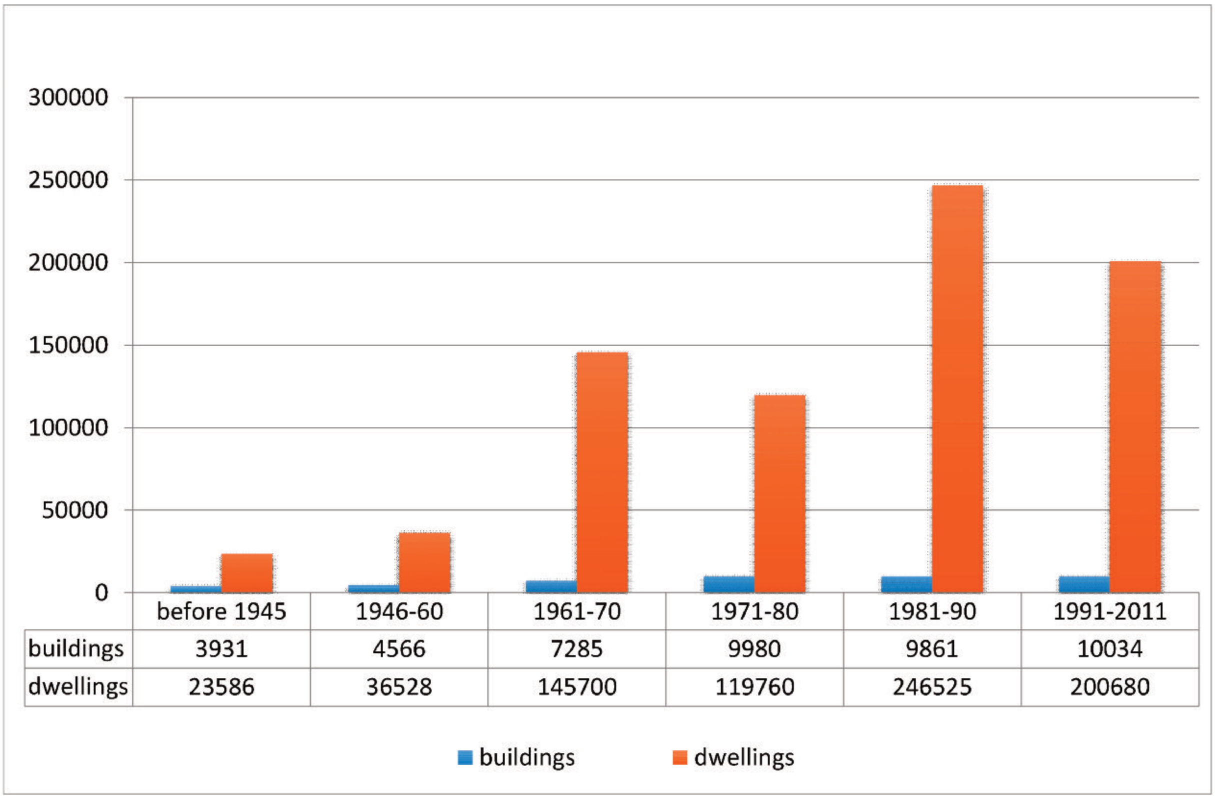


Figure 11 Share of multi-apartment buildings (excluding apartment blocks) by construction period (SORS 2011)

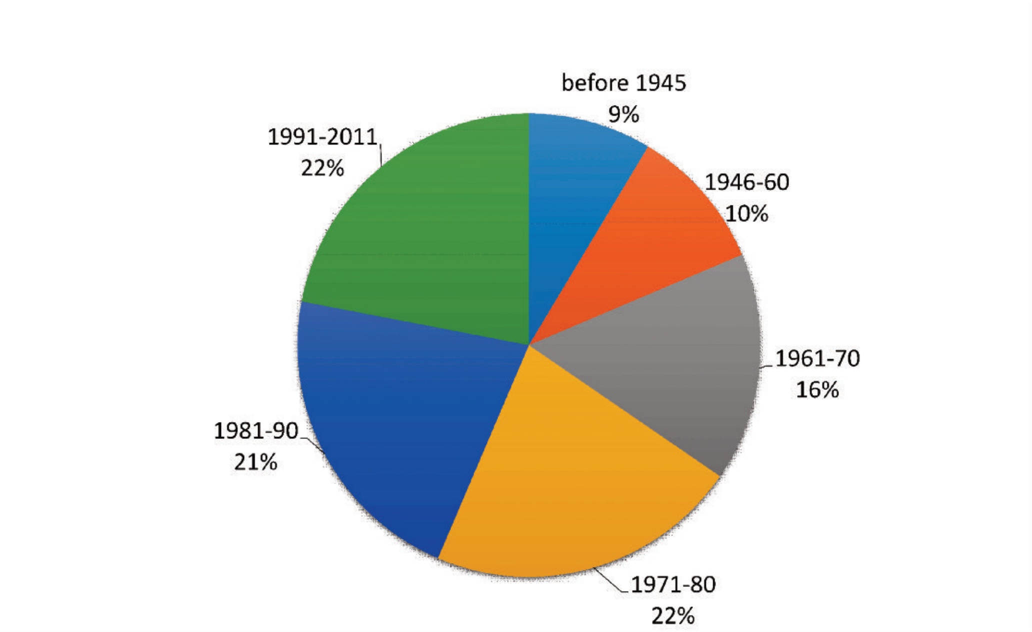
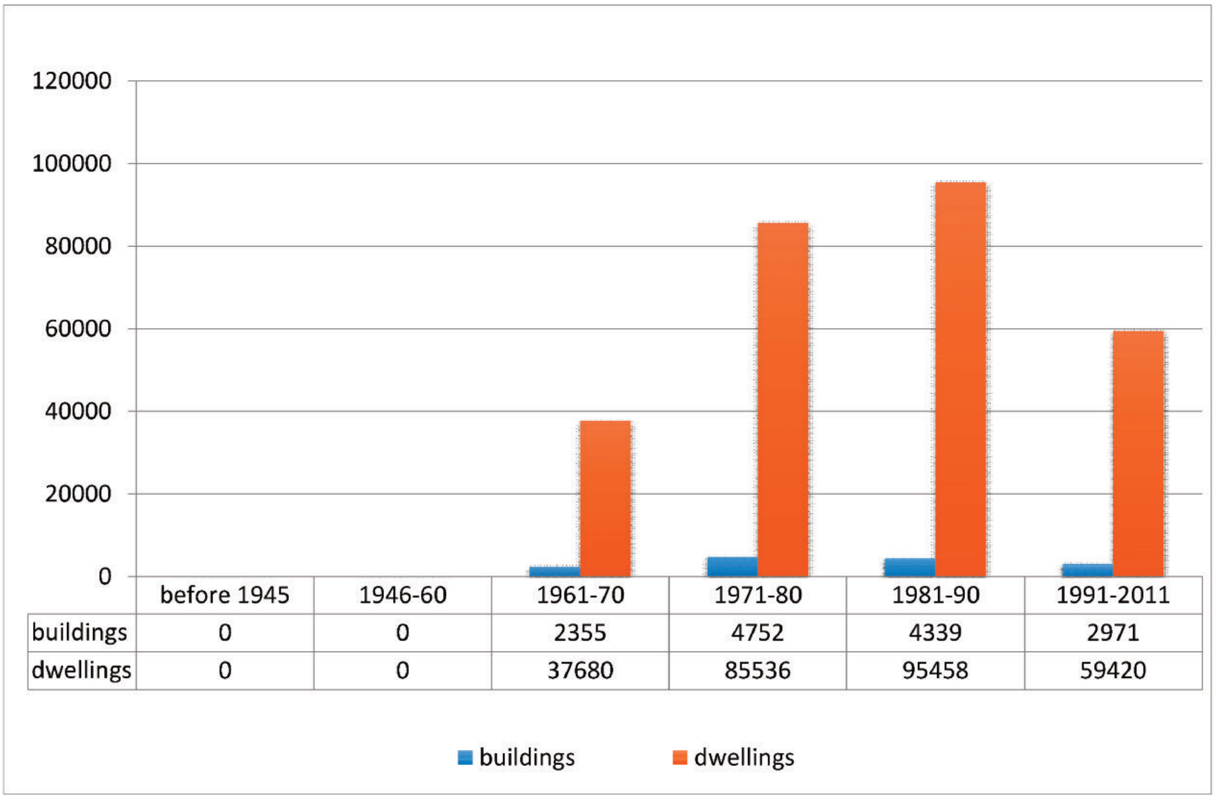
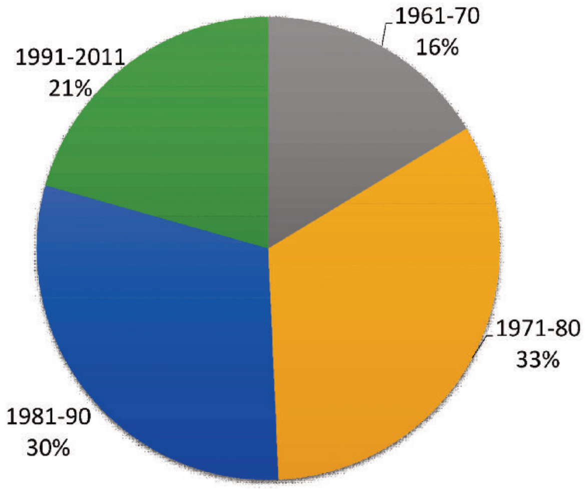


Figure 12 Number of apartment block buildings and dwellings in these buildings by construction period (SORS 2011)



	before 1945	1946-60	1961-70	1971-80	1981-90	1991-2011
buildings	0	0	2355	4752	4339	2971
dwellings	0	0	37680	85536	95458	59420

Figure 13 **Share of apartment block buildings by construction period** (SORS 2011)



Climate zones

In Serbia no climate zones are defined. The impact of local climate characteristics is taken into account on the basis of heating degree days (HDD) from the nearest weather station. Heating degree days are defined by the Rulebook on Energy Efficiency (Republic of Serbia 2013), as shown in Table 2. There are no statistical data about the distribution of building types per area corresponding to the weather stations, therefore a country average for HDD was determined, taking into account dwelling statistics per area.

The country average HDD values were determined in two ways: they were weighted firstly by the total number of dwellings; and secondly by the number of occupied dwellings only (Table 3). The results are very close to each other, the difference being just 0.1 percent. In the model, a value of 2,658 degree days was applied. All calculations were carried out using this value.

Non-inhabited buildings and dwellings

There are no statistical data concerning the number of inhabited buildings, only the number of inhabited dwellings (Figure 14, Table 4). Many of the non-inhabited dwellings are probably located in inhabited buildings. However, this fact could not be taken into account in our calculations.

The high number of non-inhabited dwellings is remarkable. Around 25 percent of dwellings are temporarily vacant or uninhabited. This includes dwellings for vacation and recreational purposes (5.5 percent).

Table 2 Heating degree days defined by the Rulebook on Energy Efficiency (HD: number of heated days, θH,min: average outdoor temperature in the heating season) (Republic of Serbia 2013)

Location	HDD	HD	ΘH,min	Location	HDD	HD	ΘH,min
Aleksinac	2,517	176	5.7	Leskovac	2,625	181	5.5
Beograd	2,520	175	5.6	Požarevac	2,588	181	5.7
Bečej	2,797	184	4.8	Negotin	2,818	183	4.6
Bor	3,100	200	4.5	Niš	2,613	179	5.4
Valjevo	2,784	192	5.5	Novi Sad	2,679	181	5.2
Vranje	2,675	182	5.3	Pančevo	2,712	182	5.1
Vršac	2,556	180	5.8	Pirot	2,610	180	5.5
Gornji Milanovac	3,078	208	5.2	Prokuplje	2,604	186	6.0
Divčibare	3,839	243	4.2	Senta	2,824	187	4.9
Zaječar	2,880	192	5.0	Smederevo	2,610	180	5.5
Zlatibor	3,728	239	4.4	Sombor	2,850	190	5.0
Zrenjanin	2,748	182	4.9	Sremski Karlovci	2,496	177	5.9
Jagodina	2,599	178	5.4	Sremska Mitrovica	2,738	185	5.2
Kikinda	2,763	183	4.9	Užice	3,015	201	5.0
Kopaonik	5,349	311	2.8	Čačak	2,755	190	5.5
Kragujevac	2,610	180	5.5	Ćuprija	2,380	163	5.4
Kraljevo	2,628	180	5.4	Šabac	2,588	181	5.7
Kruševac	2,654	183	5.5	Šid	2,686	184	5.4

Trends

The total number of residential buildings in Serbia was 2,246,320 in 2011. On January 1, 2015, the estimated population of the country was 7,114,393. The number of occupied dwellings was 2,423,208, of which 1,489,982 dwellings were located in urban settlements. The number of unoccupied dwellings was 808,723.

Since 2001, an annual 10,000 to 20,000 new dwellings have been built (Figures 15 to 17). The trend increased until 2008, since when it has been decreasing. The average floor area of a dwelling is almost continuously decreasing (78 to 64 m^2) (SORS online).

Energy sources and building service systems

Data on the main type of energy sources are not available for heating and hot water production per building type. The most recent statistical data from 2013 (SORS 2014a) concerning overall household consumption indicate that the most common energy source is electricity (41.5 percent), although a large share does not relate to heating and hot water production, but to other household consumption (appliances, cooling), in both multi-family and family housing types. For heating, biomass is the most widely used option (27.7 percent), followed by district heating (12.8 percent). Coal, natural gas and LPG are also notable. Solar, geothermal and other energy sources are negligible (Figure 18).

Based on the national balance the following energy distribution was assumed in our model for heating in most cases (see Table 5). For certain building types (A3, B3, C3), electric heating was assumed.

Table 3 **Number of dwellings by areas corresponding to different weather stations** (Republic of Serbia 2013; SORS online)

Area		Number of dwellings	
	HDD	total	occupied
Beograd – Belgrade	2,520	734,909	586,337
Zapadnobačka oblast – HDD Sombor	2,850	80,497	66,890
Južnobanatska oblast – HDD Vršac	2,556	126,360	99,197
Južnobačka oblast – HDD Novi Sad	2,679	273,323	217,967
Severnobanatska oblast – HDD Kikinda	2,763	67,648	55,218
Severnobačka oblast – HDD Sombor	2,850	84,383	69,789
Srednjobanatska oblast – HDD Zrenjanin	2,748	83,447	66,601
Sremska oblast – HDD Sremska Mitrovica	2,738	132,406	101,897
Zlatiborska oblast – HDD Užice	3,015	133,278	93,056
Kolubarska oblast – HDD Valjevo	2,784	85,072	58,013
Mačvanska oblast – HDD Šabac	2,588	134,697	97,635
Moravička oblast – HDD Čačak	2,755	97,657	71,596
Pomoravska oblast – HDD Jagodina	2,599	101,236	69,946
Rasinska oblast – HDD Kruševac	2,654	100,322	75,226
Raška oblast – HDD Kraljevo	2,628	118,890	88,319
Šumadijska oblast – HDD Kragujevac	2,610	131,987	94,562
Borska oblast – HDD Bor	3,100	68,664	44,979
Braničevska oblast – HDD Pozarevac	2,588	90,414	58,820
Zaječarska oblast – HDD Zaječar	2,880	64,302	41,409
Jablanička oblast – HDD Leskovac	2,625	89,188	65,055
Nišavska oblast – HDD Niš	2,613	176,335	125,460
Pirotska oblast – HDD Pirot	2,610	53,526	33,189
Podunavska oblast – HDD Smederevo	2,610	84,672	63,088
Pčinjska oblast – HDD Vranje	2,675	70,495	48,375
Toplička oblast – HDD Prokuplje	2,604	48,223	30,566
Average HDD		2,661	2,658

The share of dwellings equipped with mechanical cooling systems is also unknown. In the Garrigues 2011 study, it is assumed that 27 percent of households use air-conditioning systems, although there are no solid statistics behind this assumption. In consultation with local experts, we assumed that at least 20 percent of households have space-cooling systems.

Statistics on heating and hot water systems are very limited and contradictory. Our assumptions related to system types are based on the educated guesses of local experts.

Figure 14 Occupancy according to the number of dwellings (SORS 2011)

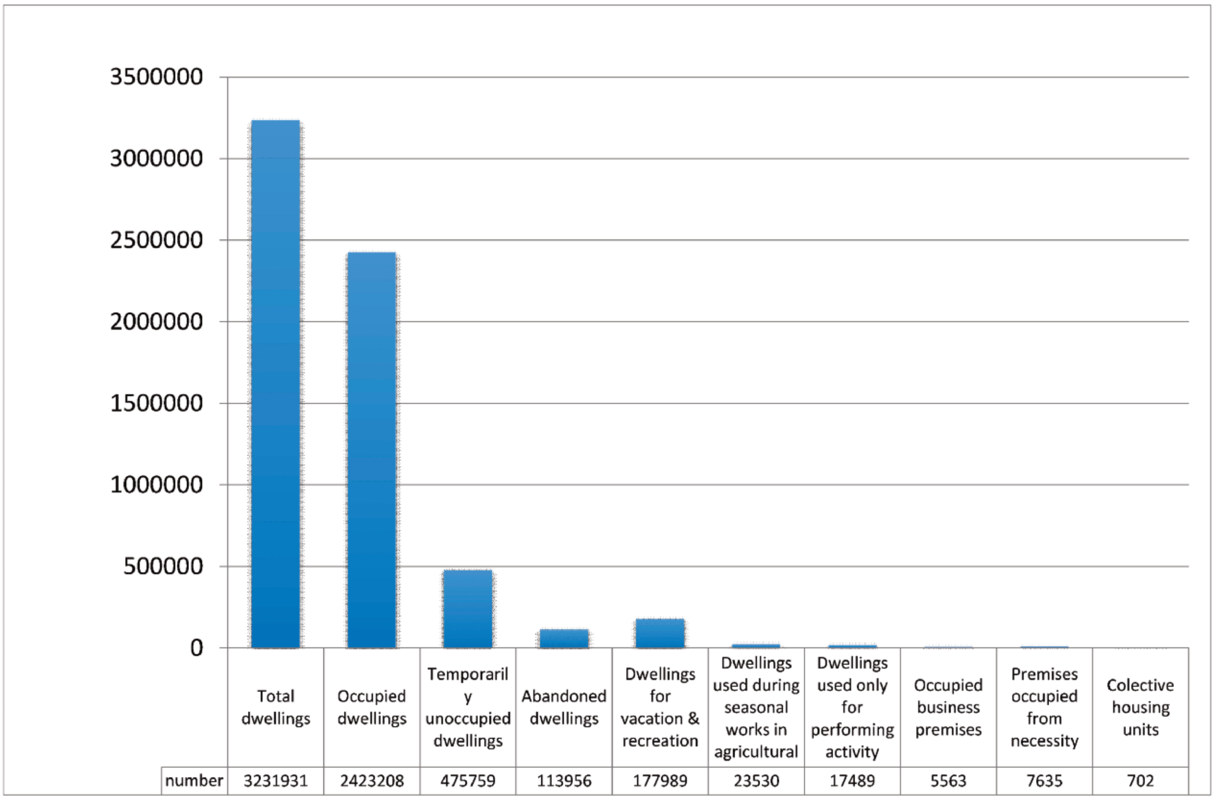


Table 4 Number and useful floor area of dwellings according to occupancy (SORS 2011)

	number	floor space (m²)
Total dwellings	3,231,931	230,518,414
Occupied dwellings	2,423,208	179,703,282
Temporarily unoccupied dwellings	475,759	31,741,687
Abandoned dwellings	113,956	6,404,089
Dwellings for vacation and recreation	177,989	10,379,218
Dwellings used during seasonal agricultural work	23,530	1,102,303
Dwellings used only for performing activities	17,489	1,187,835
Occupied business premises	5,563	297,419
Premises occupied from necessity	7,635	134,458
Collective housing units	702	0

Figure 15 **New constructions: Number of finished dwellings** (SORS online)

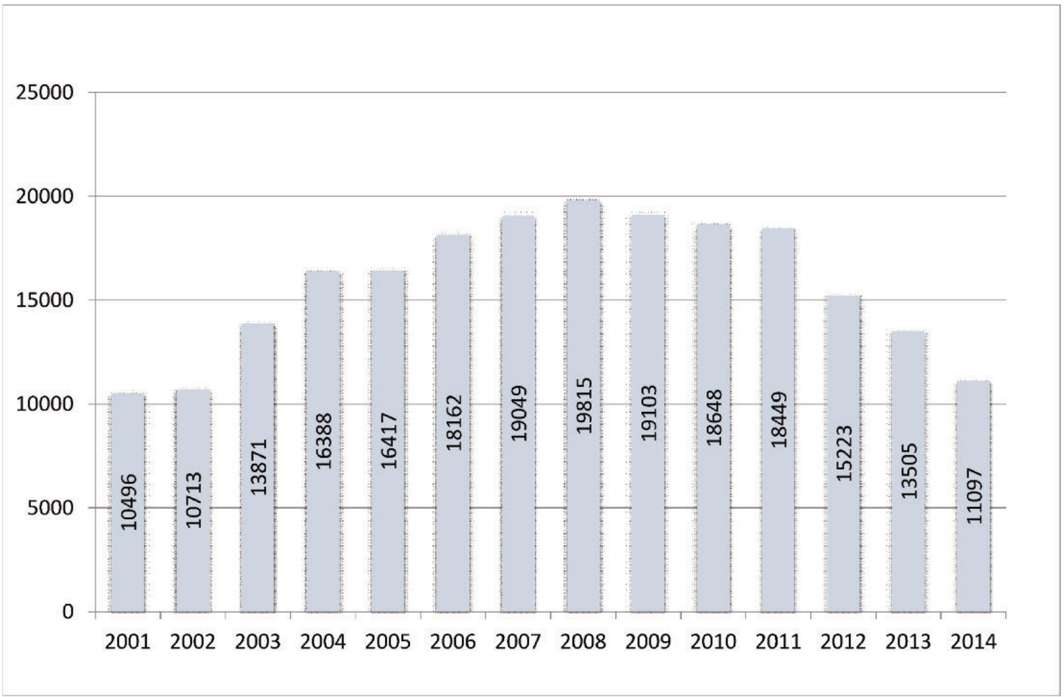


Figure 16 **New constructions: Total floor area of finished dwellings (m^2/year)** (SORS online)

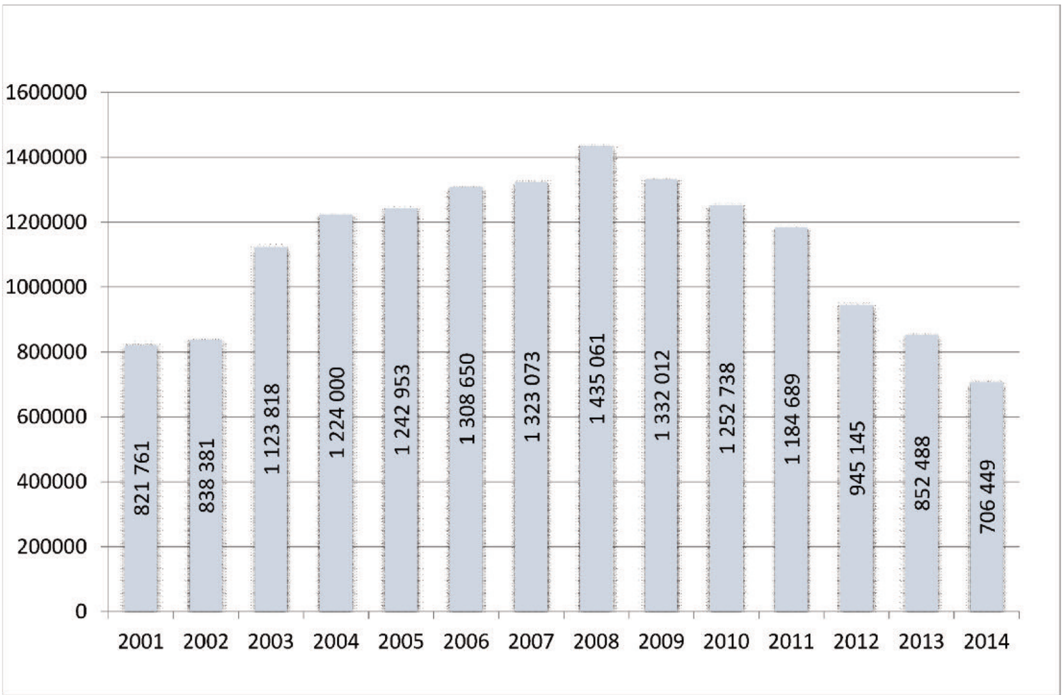


Figure 17 New constructions: Average floor area of finished dwellings (m²) (SORS online)

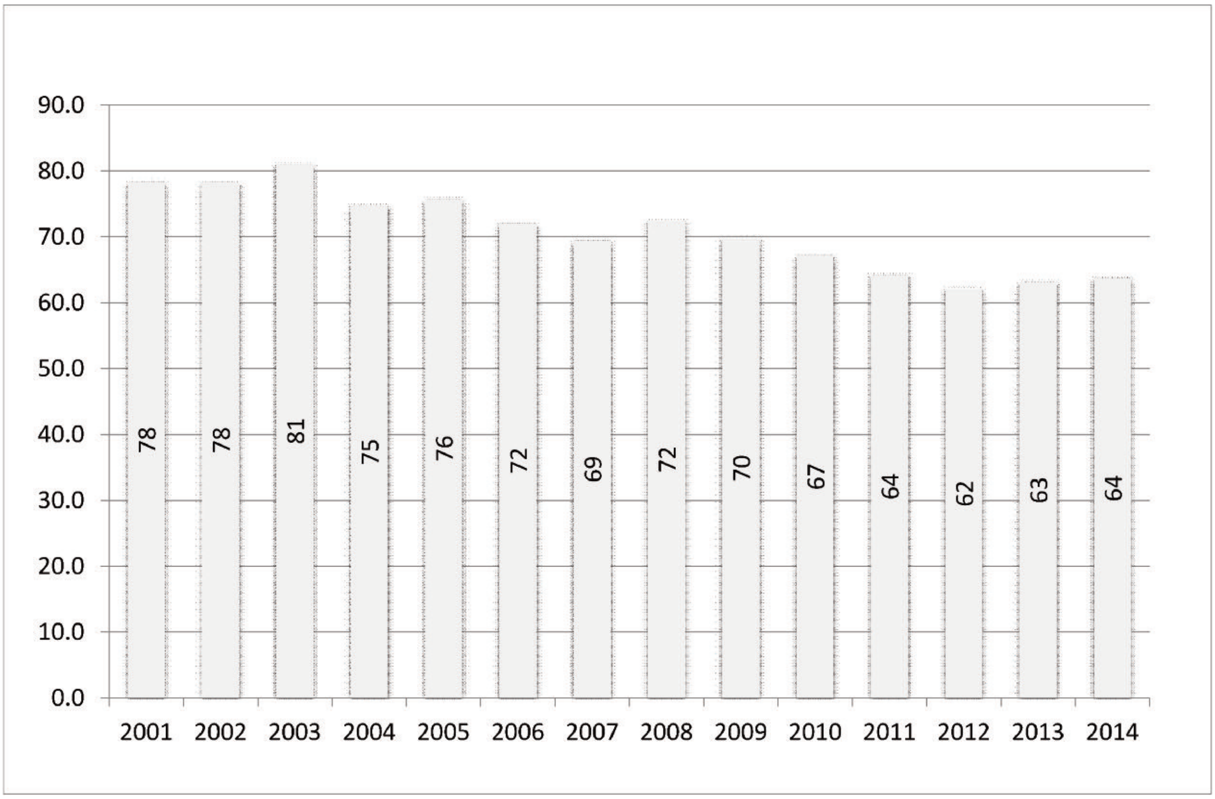


Figure 18 Energy sources used by households (TJ/year) (SORS 2014a)

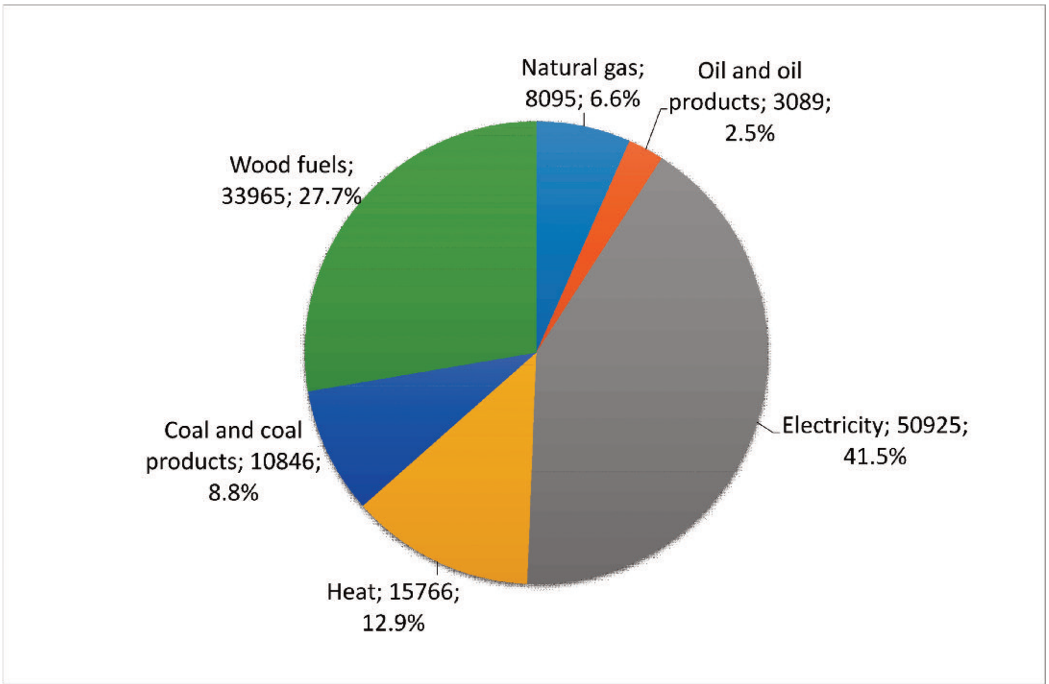


Table 5 Assumed energy source mix for heating in the model

	Natural gas	Electricity	Coal	Oil	Wood	District heating
	%	%	%	%	%	%
General case	9	17	7.5	3	63.5	0
Buildings with district heating	0	0	0	0	13	83

IV. Calculation method and main assumptions

Energy calculations

As already explained in Section II, the building type matrix is based on an already existing building typology. The energy calculation models and results are described in the work *National Typology of Residential Buildings in Serbia*, prepared in cooperation with the TABULA project (Jovanović Popović et al. 2013). However, the original typology was simplified, building types were merged, and finally 18 building types were applied in our model. The energy calculations were carried out according to the national Rulebook for Energy Efficiency (Republic of Serbia 2013).

Definition of existing state and retrofitting options

In the models, three renovation scenarios were developed for all building types, two of them representing a complex renovation package. The complex packages consist of measures for upgrading the building envelope and the heating, cooling and domestic hot water (DHW) systems. For the building envelope, the same measures were applied as defined and explained in detail in Jovanović Popović et al. (2013).

The existing state of the building stock was modelled taking into account the following factors:

- The different energy sources, meaning that several system options were taken into account for several building types weighted with the importance of the energy sources.
- For older detached and terraced houses, individual heating wood stoves and electric stoves were considered.
- For new detached houses, efficient central wood boilers with hot water heating systems were selected.
- For multi-apartment buildings, district heating or individual electric stoves were applied.
- In Serbia most DHW systems include individual electrical storage and, occasionally, non-storage water heaters.

The "business-as-usual" (BAU) improvement represents partial renovations such as changing windows or improving the heating system controls. In this case, a simplified estimate of 20 percent energy savings was taken into account for all building types.

The "standard" improvement was defined in accordance with the current regulations as improving building energy performance by at least one energy efficiency class. It therefore includes:

- Replacing existing windows with new ones that comply with the current regulations or are close to the given values. Despite their poorer performance, the installation of wooden windows was suggested in order to preserve the visual identity of the buildings.
- Improving the thermal properties of walls and floor constructions by adding layers of insulation, usually 10 cm thick, where applicable. Walls are typically refurbished using a contact façade system, since this method of energy renovation is common in practice as the most economical and least technically demanding. An exception was buildings with façade brick cladding, which is technically difficult to reapply; in this case, it is possible to use special market-ready systems in which ceramic cladding, as the final façade layer, has integrated thermal insulation.
- Adding layers of insulation to floor constructions, horizontal and oblique, either in subsequent interventions or integrated into the existing structure (Jovanović Popović et al. 2013).
- For heat supply systems, the "standard" improvement involves the following (Jovanović Popović et al. 2013):
  - A change of fuel source (where applicable) or the modernisation of the heating system.
  - For systems with stoves using wood, coal or electric power, either as single units or as part of the central (or, alternatively, independent per floor) radiator heating system, the improvement includes a shift to central heating with a low-temperature gas boiler (in most cases) or a biomass boiler fired by pellets or logs (in some cases).
  - In fossil-fuel district heating systems, the "standard" refurbishment measure involves improving the control and efficiency of the existing system by installing thermostatic valves on radiators and upgrading the substation and heat supply control based on external air temperature. In accordance with the current legislation on energy efficiency (Republic of Serbia 2013), it is necessary to install equipment for heat supply metering in order to adopt consumption-based billing.

- The domestic hot water improvement measures involve central combined domestic hot water and heat supply connected either by the boiler itself or by the heat exchanger in the substation storage tank in the case of district heating systems.

The "ambitious" improvement goes beyond the building regulations regarding the building envelope:

- It includes specific measures to raise the building energy efficiency class to the maximum. The full scope of rehabilitation depends on the building characteristics, such as the shape factor, window to wall ratio, relationship with adjacent buildings etc.
- Not typically used, these measures include the installation of top-quality windows available on the market and thick insulation layers in the thermal envelope.
- Even further improvement of the energy rating can be achieved only in certain cases, using very complex constructions and elements that are not available on the local market (Jovanović Popović et al. 2013). After introducing the nearly zero-energy requirements, the availability of these products will significantly improve.
- For heat supply systems, the "ambitious" improvement involves the following (Jovanović Popović et al. 2013):
  - A change of fuel source (where applicable) or the modernisation of the heating system.
  - The use of the latest technology available on the market in each particular case, depending on the availability of the fuel source.
  - Central heating with a condensing gas boiler (or, alternatively, a biomass boiler fired by pellets or logs) or central heating with an air/water heat pump.
  - In fossil-fuel district heating systems, the "ambitious" refurbishment measure involves improving the control and efficiency of the existing system by installing thermostatic valves on radiators and upgrading the substation and heat supply control based on external air temperature. In accordance with the current legislation on energy efficiency (Republic of Serbia 2013), it is necessary to install equipment for heat supply metering in order to adopt consumption-based billing. In addition to these measures, the installation of variable flow pumps with power and heat metering is considered.
  - The domestic hot water improvement measures involve central combined domestic hot water and heat supply connected either by the boiler itself or by the heat exchanger in the substation storage tank in the case of district heating systems. In addition, the "ambitious" improvement includes the use of an auxiliary solar hot water system.

Cooling systems

Regarding cooling, there are no significant differences between single- and multi-family housing types. It is usual that cooling is regulated with single wall-mounted air-conditioning units, and their number depends on the size of the living area (the most common is one per household, since the average household occupies about 60 m^2). It can be said that, based on dwelling size, in the case of dwellings of between 60 and 150 m^2 two units are installed, and above 150 m^2 three units. There are no official data concerning the percentage of occupied dwellings that have an air-conditioning system installed, but it is not insignificant. In most flats with a cooling system, only part of the dwelling is cooled in peak hours (Zivkovic 2015).

In the model, we assumed — for the existing and BAU state — cooling devices with the lowest efficiency that have an energy efficiency value (EER) of <2.0. For the retrofitting options, non-reversible systems with an EER of 3 were considered.

In some building types, reversible split systems were considered for heating as a retrofitting option. In such cases we assumed that cooling is available without extra measures. In other cases, cooling can be installed only at extra cost.

Domestic hot water demand

Net heat demand for DHW is calculated based on the national Rulebook on Energy Efficiency (Republic of Serbia 2013). It is 10 kWh/m^2 per year for single-family houses and 20 kWh/m^2 per year for multi-family houses (on the basis of heated floor area). This means that hot water demand was not calculated on the basis of the number of persons and personal demand, but on statistical average consumption related to floor area.

Partial heating and cooling

In Serbia, typically only a part of the dwelling (one or two rooms) is heated in order to save energy and costs, with the exception of those connected to a district heating system. There are no statistics on the percentage of heated spaces and daily heating hours, although according to the experts' educated estimates, the heated floor area is approximately 75 percent and the heating period is six months at 14 hours daily. However, when all family members are working (outside their home), the heating system operates for fewer hours (Zivkovic 2015).

In our model, it turned out that the significance of partial heating is even greater, therefore lower figures were finally applied. As already discussed, in Serbia cooling is also applied in only part of a dwelling, and in an intermittent manner.

The concrete correction factors for partial heating and cooling and daily heated hours applied in the modelled options are detailed in the calculation Excel sheets. However, it should be highlighted that the estimated figures need to be handled with caution, as no statistics are available on partial heating and cooling. It is recommended to carry out statistical surveys to obtain a more precise picture of this issue.

System efficiencies

Delivered energy is calculated from the net heating energy demand (Q_{ND}) per energy source:

$$Q_{delivered} = \frac{Q_{ND}}{\eta_t}$$

The system efficiency (η_t) of the energy supply system is calculated as follows:

$\eta_t = \eta_b \cdot \eta_p \cdot \eta_c$ where:

η_b = boiler (source) efficiency;

η_p = piping (distribution) efficiency; and

η_c = control (regulation) efficiency.

The concrete efficiency figures applied in the modelled options can be found in the Excel sheet Serbia_types_energy.xls, which is available at www.sled.rec.org.

Primary energy and CO_2 emission factors

Primary energy consumption ($Q_{primary}$) is calculated as the sum of the delivered energy ($Q_{delivered}$) multiplied by the primary energy factors (fp,source) of the energywares (Republic of Serbia 2013):

$$Q_{primary} = \sum Q_{delivered} \cdot f_{p,source\ i} \quad \left[{kWh}/{year}\right]$$

Annual CO_2 emissions from space heating and DHW supply are determined as follows (Republic of Serbia 2013):

$$m_{CO2} = \sum Q_{delivered} \cdot f_{CO2,source\ i} \quad \left[{kg}/{year}\right]$$

where

$f_{CO_2,source\ i}$ = the CO_2 emission factor of the energyware used by heat generator i.

It should be noted that, in most other countries, CO_2 emissions are calculated from the delivered energy, not the primary energy.

The conversion factors for determining annual primary energy and specific CO_2 emissions per energy carrier are shown in Tables 6 and 7.

As part of the SLED project the electricity sector was also modelled (based on IPCC), and for electricity significantly different figures were calculated — that is, 2.84 kWh/kWh; and 1.036 kg/kWh. In our calculations, these figures were used for electricity (Szabó et al. 2015).

In the IPCC guidelines, the tier 1 factors are as follows (IPCC NGGIP online):

- lignite: 0.364 kg/kWh;
- LPG: 0.227 kg/kWh; and
- natural gas: 0.202 kg/kWh.

In our model, these figures were taken into account. For wood 0.0 kg/kWh and for district heating 0.53 kg/kWh were applied.

Table 6 Conversion factors for determination of annual primary energy consumption per energy carrier (Republic of Serbia 2013)

Energy carrier	Conversion factor (kWh/kWh)
Heating oil	1.2
Gas	1.1
Coal	1.3
Wood biomass	0.1
Electrical energy	2.5
District heating system using fossil fuels	1.8
District heating system using cogeneration	1.0
Solar energy	0.0

Table 7 Conversion factors for determination of annual specific CO_2 emissions per energy carrier (Republic of Serbia 2013)

Energy carrier	Per fuel unit	Per energy unit (kg/kWh)
Natural gas	1.9 kg/m^3	0.20
Liquid oil gas	2.9 kg/kg	0.215
Extra light heating oil	2.6 kg/l	0.265
Light heating oil	3.2 kg/kg	0.28
District heat	0.33 kg/kWh	0.33
Electrical energy	0.53 kg/kWh	0.53
Brown coal (domestic)	1.5 kg/kg	0.32
Brown coal (imported)	1.88 kg/kg	0.40
Lignite coal (domestic)	1.0 kg/kg	0.33
Solar energy	0.0 kg/kWh	0.00

V. Calculation results

The detailed energy calculation results by building type are provided in the Excel file (Serbia_types_energy.xls, available at www.sled.rec.org). This file contains the most relevant input data and the results for heating, cooling and hot-water energy demand in each building type. As mentioned above, the building models (net heating energy demand calculations) are based on the energy calculations in Jovanović Popović et al. (2013) and on the considerations detailed in the sections above.

Net energy demand and primary energy consumption in the existing building stock

Summary diagrams of the results are presented in Figures 19 and 20, which are based on the permanent heating of the entire building.

The change in net heating demand shows that the thermal characteristics of the building stock have somewhat improved over time, but that significant improvement is remarkable only in the last decade. It should be noted that although the thermal properties of detached houses are worse than those of larger buildings due to the unfavourable surface-to-volume ratio, the primary energy results are more balanced. This can be explained by the heating sources considered: the primary energy factor of wood (which has a significant share in the heating of detached houses) was assumed to be 0.1, while for district heating, which was assumed in most of the larger buildings, the primary energy factor is 1.8.

The share of primary energy consumption for DHW is relatively large, due to the fact that electric water heaters were taken into account, which have a high primary energy factor. The demand is also high compared to other countries (31.9 kWh/m^2 per year).

In all building types heating is dominant in terms of total energy demand.

The values for cooling must be considered with caution. The building typology was created in order to model heating, because heating is the most important area of energy use in Serbian households. This typology is not appropriate to model cooling, as the most important factors that determine cooling demand — that is, the ratio of glazed surfaces, orientation and shading devices, and neighbouring environment — were not considered as classification criteria (due to a lack of statistical data). However, as cooling has a far smaller significance in the national energy balance than heating, and as there are no appropriate statistical data for developing a building typology to model the building stock for cooling, we decided to apply the same typology for cooling and heating. The figures for net cooling demand are therefore educated guesses by experts based on the calculation results of other countries (Albania and Hungary). For the more appropriate modelling of cooling demand, another type of typology should be developed, although before this, statistical data must be collected on the building characteristics that determine cooling.

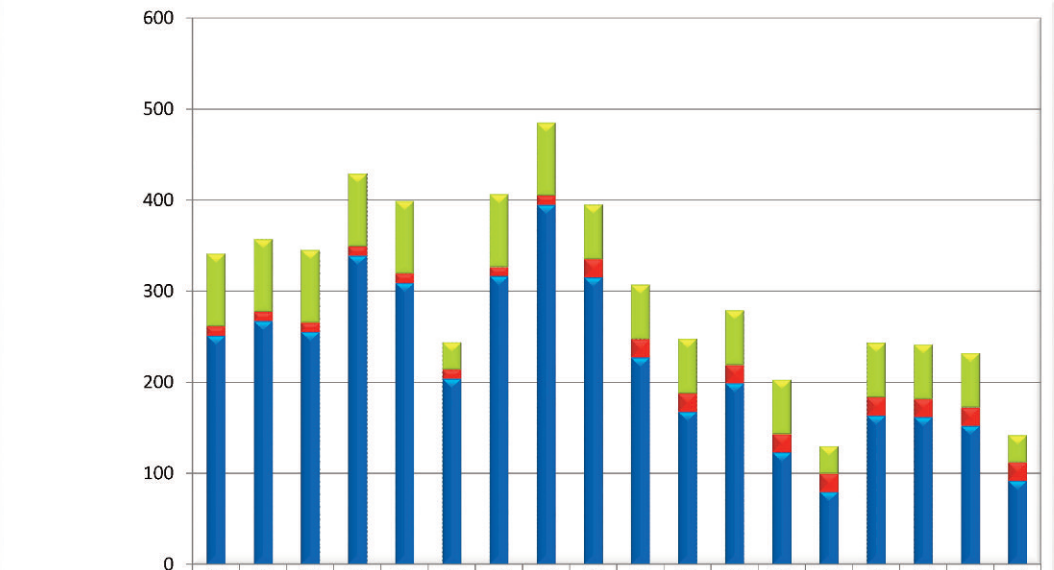
It should be highlighted once again that the presented diagrams correspond to full heating, although an average household usually applies partial and intermittent heating and cooling. The full results can be found in the file Serbia_types_energy.xls, available at www.sled.rec.org.

Net energy demand and primary energy consumption in the retrofitting options

The two complex retrofitting options lead to very significant energy savings in both net energy demand (mean savings: 59 percent and 71 percent) and primary energy consumption (mean savings: 74 percent and 79 percent) (see Figures 21 and 22). In detached houses, improvement 1 is mainly based on wood heating, exclusively in efficient wood gasification or pellet boilers; but in improvement 2 efficient heat pumps are applied based on electricity. This leads to close results in primary energy for the two options. In multi-family and apartment buildings, mostly district heating is retained in all renovation options.

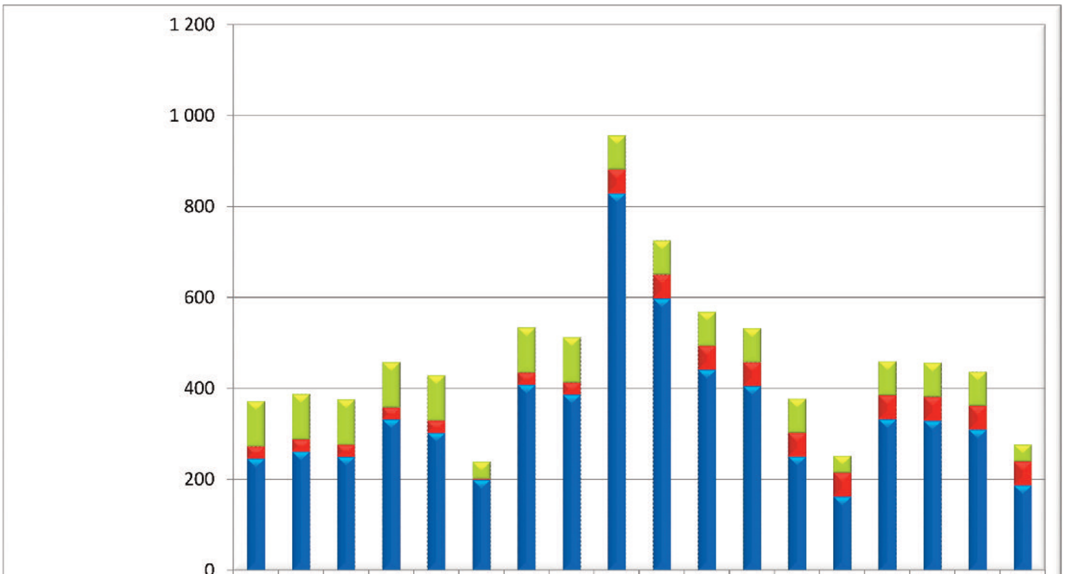
The figures for the present state and BAU option correspond to full heating, which leads to an overestimation, since an average household usually applies partial and intermittent heating and cooling, although this cannot be supported by statistical data. All the results can be found in the Excel file Serbia_types_energy.xls, which is available at www.sled.rec.org.

Figure 19 Net energy demand by building type (present state, full heating)



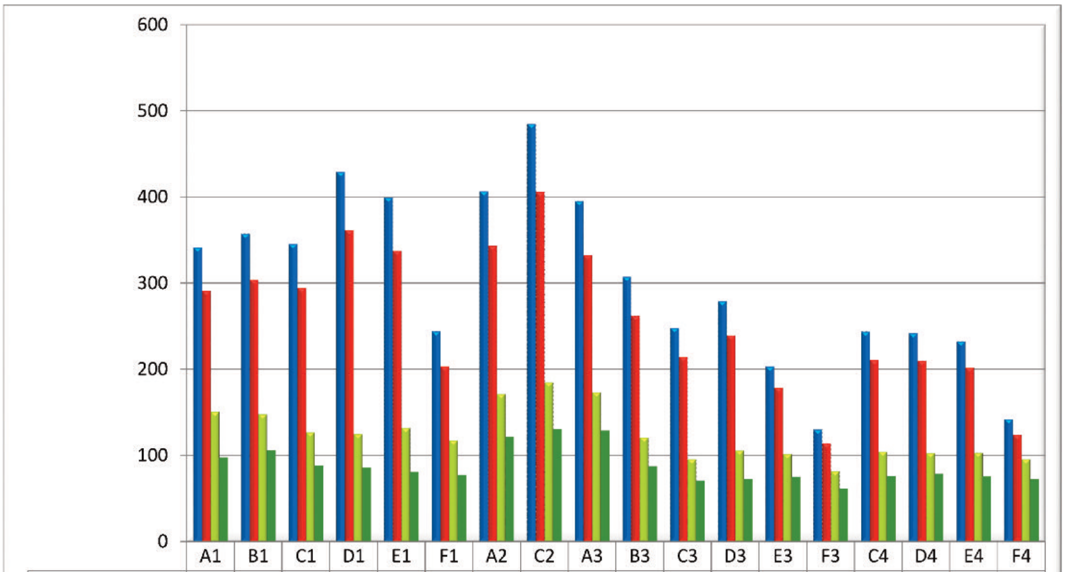
	A1	B1	C1	D1	E1	F1	A2	C2	A3	B3	C3	D3	E3	F3	C4	D4	E4	F4
Cooling [kWh/m2a]	80	80	80	80	80	30	80	80	60	60	60	60	60	30	60	60	60	30
DHW [kWh/m2a]	10	10	10	10	10	10	10	10	20	20	20	20	20	20	20	20	20	20
Heating [kWh/m2a]	251	267	255	339	309	204	317	395	315	227	168	199	123	80	163	162	152	92

Figure 20 Primary energy consumption by building type (present state, full heating)



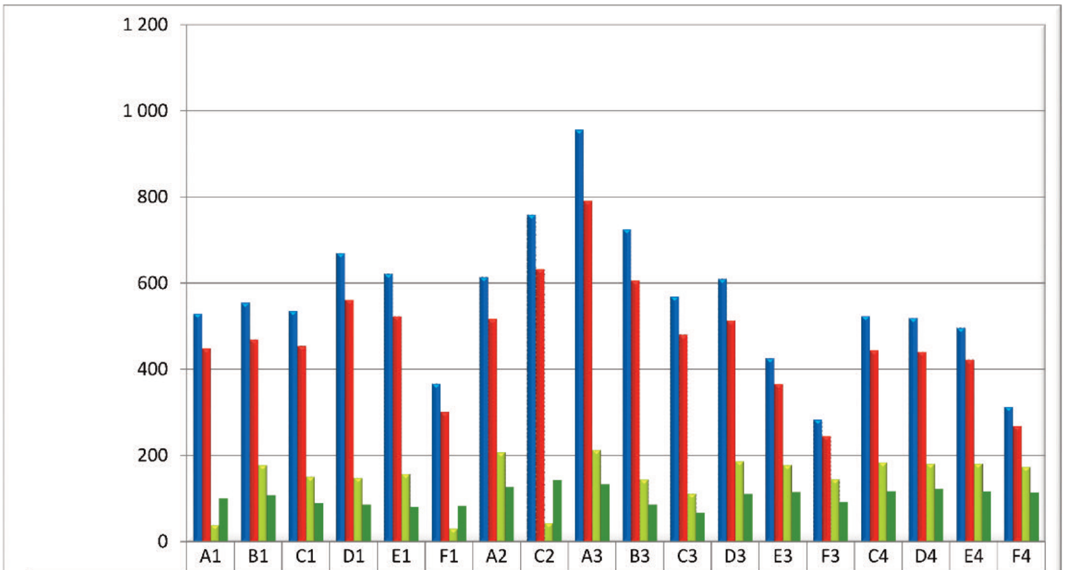
	A1	B1	C1	D1	E1	F1	A2	C2	A3	B3	C3	D3	E3	F3	C4	D4	E4	F4
Cooling [kWh/m2a]	100	100	100	100	100	38	100	100	75	75	75	75	75	38	75	75	75	38
DHW [kWh/m2a]	26	26	26	26	26	2	26	26	52	52	52	52	52	52	52	52	52	52
Heating (Z1) [kWh/m2a]	246	262	250	332	303	200	409	387	829	598	441	406	251	163	333	329	310	187

Figure 21 Net energy demand by building type (present state and retrofitted states, full heating)



	A1	B1	C1	D1	E1	F1	A2	C2	A3	B3	C3	D3	E3	F3	C4	D4	E4	F4
present state	341	357	345	429	399	244	407	485	395	307	248	279	203	130	243	242	232	142
improvement BAU	291	304	294	361	337	203	343	406	332	262	214	239	178	114	211	209	202	124
improvement 1	151	148	127	125	132	117	171	185	173	121	95	106	101	82	104	103	103	96
improvement 2	98	106	88	86	81	77	122	130	129	88	71	73	75	61	76	78	75	72

Figure 22 Primary energy consumption by building type (present state and retrofitted states, full heating



	A1	B1	C1	D1	E1	F1	A2	C2	A3	B3	C3	D3	E3	F3	C4	D4	E4	F4
present state	529	554	536	670	622	366	614	759	956	725	569	609	425	283	523	519	496	312
improvement BAU	448	469	454	561	523	301	516	632	790	606	480	513	366	245	444	441	422	268
improvement 1	39	177	150	148	157	30	207	43	213	144	111	186	178	144	184	180	181	173
improvement 2	100	108	89	86	80	83	126	143	133	86	67	110	115	92	117	122	116	114

Delivered energy consumption per energy source

For the sectoral analysis it is important to know the delivered energy consumption per energy source. For the present and BAU state we used the estimated proportion of energy sources adjusted to the national balance.

In the retrofitted cases, the most probable options were taken into account, depending on building type. All results can be found in the Excel file Serbia_types_energy.xls, which is available at www.sled.rec.org.

CO_2 emissions

In some cases, the CO_2 emissions savings are relatively higher than the primary energy savings in the case of "standard" renovation. This is because these renovations are based on wood, which has a CO_2 emission factor of 0.1, which is multiplied by the primary energy factor of 0.1, resulting in a very low figure. In the "ambitious" renovation, the savings are less significant because heat pumps are supplied by electricity with good efficiency but high emission factors. In other building types the "ambitious" renovation gives better results.

All results can be found in the Excel file Serbia_types_energy.xls, available at www.sled.rec.org.

VI. Investment costs and energy prices

Costs per measure and floor area: Building envelope

Investment costs are provided per building type and measure (see Tables 8 and 9). The prices are averages, which means that there is no differentiation between smaller and larger buildings. Prices include all system elements, although, depending on the current state of the building, there could be some additional work to remove old installations. The prices include labour costs but not VAT.

For the sectoral modelling it was more appropriate to provide the investment costs per heated floor area rather than per unit area, thus we calculated it per building type. The results are summarised in Tables 10 and 11.

Costs per floor area: Building service systems

The building service system prices were provided per building type and measure. The prices were later differentiated, taking into account that for larger buildings price discounts are applied (see Tables 12, 13 and 14). Prices include all system elements, although, depending on the present state of the building, there could be some additional work to remove the old installations. The prices include labour costs but not VAT.

In some cases heating is supplied by reversible heat pumps that also serve cooling purposes without additional costs. In most cases cooling can be provided only by additional split systems (smaller, less-efficient heat pumps).

Specific system costs per heated floor area were calculated as well. The results are summarised in Tables 10 and 11.

Energy prices

The Energy Agency of the Republic of Serbia, based on the Energy Law, has defined methodologies for the determination of energy prices (Republic of Serbia 2004). Regulated prices are the price of:

- access to the electricity transmission system;
- access to the electricity distribution system;
- access to the natural gas transportation system;
- access to the natural gas distribution system;
- access to the natural gas storage facility;
- access to the system for oil transport via oil pipelines;
- access to the system for oil derivatives transportation via oil derivatives pipeline;
- natural gas for public supply; and
- ancillary services — primary regulation, voltage regulation, voltage-free starting and remote site operation.

In addition, the following prices may also be regulated:

- price of electricity for guaranteed supply; and
- price of power reserve lease for system services of secondary and tertiary regulation.

The methodology may determine different prices (i.e. tariffs, depending on the quality of the received energy or energy-generating products and takeover conditions); power (i.e. capacity); the annual, seasonal, monthly and daily dynamics of delivery; the category and group of customers (i.e. system users); the point of takeover; the manner of consumption; the method of measurement; and other characteristics.

An overview of energy source prices that are freely set or regulated by the state (Energy Agency) is given in Table 15. All energy sources are subject to VAT, while in the case of liquid fuels (oil derivatives) excise duty is also applicable (Table 16).

OIL

Wholesale oil prices, including excise duty and VAT, are presented in Table 17.

NATURAL GAS

The prices of natural gas for public supply are determined by 33 public suppliers with the approval of the Energy Agency of the Republic of Serbia.

Natural gas may be supplied to end customers by an energy entity holding a licence for performing supply activities. The public supplier is designated by the government, in the manner and according to the procedure set out in the Energy Law. Households and small customers whose facilities are connected to the natural gas distribution system are entitled to public supply unless they select another supplier. End customers of natural gas have been entitled to freely select their supplier on the market since January 1, 2015.

Table 8 Investment costs per measure unit area: Standard improvement

	External wall	Ground floor	Floor construction in unheated attic	Floor construction in unheated area (basement)	Pitched roof (renovation)	Flat roof (renovation)	Window
A–F1, A2, C2	22–30	45	14–30	18–28	-	-	150
A–F3	25	-	14	18–45	35	55	150
C–F4	25	-	14	18	35	55	150

Table 9 Investment costs per measure unit area: Ambitious improvement

	External wall	Ground floor	Floor construction in unheated attic	Floor construction in unheated area (basement)	Pitched roof (renovation)	Flat roof (renovation)	Window
A–F1, A2, C2	28–40	28–50	24–35	23–28	-	-	160
A–F3	31	42	24	28–55	45	65	160
C–F4	31	-	24	28	45	65	160

Each supplier has their own prices, which are approved by the Energy Agency. Table 18 shows the price range (without VAT) for all suppliers and categories of consumers, valid from March 2, 2015. The natural gas monthly bill consists of three parts: measured consumption (Sm^3 gas), lump sum (flat value) per customer, and measured maximum daily quantity of gas during the year (Sm^3/day). The third part does not apply to households and small consumers.

The categories of users are:

- Users of the system for the distribution of natural gas from the connection point to the distribution system of natural gas with operating pressure less than 6 bar (Category 1).
- Users of the system for the distribution of natural gas from the connection point to the distribution system of natural gas with operating pressure equal to or greater than 6 bar, and less than 16 bar (Category 2).

The elements of the bill for natural gas can be further clarified as follows:

- Energy source (paid in EUR/Sm^3). In accordance with the tariff system, energy spent in cubic metres during the accounting period (m^3 of natural gas of lower calorific value than 33,338.35 kJ/m^3 at a temperature of 288.15 K [15°C] and a pressure of 1.01325 bar).
- Capacity (paid in EUR/(Sm^3/day) per year). Capacity is given for the buyer's disposal, whenever needed. This figure is obtained in such a way that, for every consumer, the day of the year with the highest consumption (Sm^3) is determined, then increased by 20 percent and rounded to the nearest integer, and paid for each month. Consumers belonging to the "households" user group do not pay for capacity.
- Fee per delivery place (paid in EUR/delivery place/year). The fee includes all costs incurred in dealing with customers that are recognised and approved by the Energy Agency of the Government of the Republic of Serbia. The fee is also payable in months when the customer does not consume any natural gas.

The detailed natural gas prices of each supplier can be found in AERS 2015.

Table 10 Investment costs per heated floor area: Standard improvement

	A1	B1	C1	D1	E1	F1	A2	C2
	EUR/m²	EUR/m²	EUR/m²	EUR/m²	EUR/m²	EUR/m²	EUR/m²	EUR/m²
Walls (and arcade ceilings)	48.20	28.80	29.30	32.90	24.80	4.50	36.70	25.70
Windows	33.80	34.70	31.90	36.80	32.50	23.40	37.70	36.50
Floor construction in attic	25.00	30.90	11.50	9.00	8.10	9.00	23.60	16.10
Floor construction in unheated area beneath (basement)	0.00	0.00	0.00	11.60	1.60	2.60	34.80	5.20
Flat roof	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pitched roof	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Floor construction on ground	0.00	0.00	0.00	0.00	0.00	22.10	0.00	0.00
Total (envelope)	**107.00**	**94.40**	**72.70**	**90.30**	**67.10**	**59.00**	**132.90**	**83.60**
Heating system	49.00	32.60	27.60	28.90	28.10	8.20	31.10	44.80
Hot water system	24.00	7.60	2.60	3.90	3.10	8.20	6.10	19.80
Total (systems)	**72.90**	**40.30**	**30.30**	**32.80**	**31.20**	**16.40**	**37.20**	**64.60**
Total (envelope + systems)	**179.90**	**134.70**	**103.00**	**123.10**	**98.30**	**75.40**	**170.10**	**148.20**
Cooling (optional)	**6.40**	**6.80**	**7.00**	**6.90**	**5.50**	**6.60**	**5.40**	**5.30**

	A3	B3	C3	D3	E3	F3	C4	D4	E4	F4
	EUR/m²	EUR/m²	EUR/m²	EUR/m²	EUR/m²	EUR/m²	EUR/m²	EUR/m²	EUR/m²	EUR/m²
Walls (and arcade ceilings)	58.90	36.40	20.60	22.60	16.40	20.00	19.40	22.60	20.50	20.40
Windows	49.00	46.20	30.50	31.90	38.80	24.50	30.80	37.10	34.20	26.70
Floor construction in attic	6.70	3.40	2.30	3.30	2.70	2.80	0.00	1.40	1.80	2.30
Floor construction in unheated area beneath	21.40	4.40	2.90	4.30	2.90	3.60	2.60	2.70	2.30	4.00
Flat roof	0.00	0.00	0.00	0.00	0.00	0.50	9.20	3.30	0.00	0.30
Pitched roof	0.00	0.00	0.00	0.00	0.00	0.60	0.00	0.00	1.60	2.20
Floor construction on ground	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total (envelope)	**143.10**	**95.20**	**62.50**	**65.30**	**64.00**	**53.20**	**62.00**	**70.90**	**65.30**	**59.50**
Heating system	27.70	26.60	26.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Hot water system	2.70	1.60	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total (systems)	**30.40**	**28.20**	**27.10**	**4.00**	**4.00**	**4.00**	**4.00**	**4.00**	**4.00**	**4.00**
Total (envelope + systems)	**173.60**	**123.40**	**89.60**	**69.30**	**68.00**	**57.20**	**66.10**	**74.90**	**69.40**	**63.50**
Cooling (optional)	**14.50**	**8.50**	**6.60**	**6.40**	**5.50**	**5.90**	**6.00**	**8.40**	**7.60**	**5.60**

Table 11 Investment costs per heated floor area: Ambitious improvement

	A1	B1	C1	D1	E1	F1	A2	C2
	EUR/m²	EUR/m²	EUR/m²	EUR/m²	EUR/m²	EUR/m²	EUR/m²	EUR/m²
Walls (and arcade ceilings)	64.20	36.60	37.40	41.90	33.60	28.10	44.70	37.80
Windows	33.80	36.30	33.40	39.00	34.00	24.80	39.30	39.00
Floor construction in attic	37.50	38.60	16.80	15.50	17.30	15.30	29.90	27.60
Floor construction in unheated area beneath (basement)	0.00	0.00	0.00	14.80	2.10	4.10	34.80	6.70
Flat roof	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pitched roof	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Floor construction on ground	62.50	48.90	0.00	0.00	20.40	24.60	0.00	0.00
Total (envelope)	**198.10**	**160.50**	**87.60**	**111.10**	**107.40**	**92.90**	**148.80**	**111.10**
Heating system	60.90	37.70	29.40	31.50	30.20	12.30	35.10	34.90
Hot water system	35.90	46.60	16.10	23.80	19.00	12.30	37.20	36.30
Total (systems)	**96.90**	**84.30**	**45.40**	**55.30**	**49.10**	**24.60**	**72.30**	**71.20**
Total (envelope + systems)	**295.00**	**244.90**	**133.00**	**166.40**	**156.50**	**117.50**	**221.10**	**182.30**
Cooling (optional)	**incl.in heating**	**6.80**	**7.00**	**6.90**	**5.50**	**incl. in heating**	**5.40**	**5.30**

	A3	B3	C3	D3	E3	F3	C4	D4	E4	F4
	EUR/m²	EUR/m²	EUR/m²	EUR/m²	EUR/m²	EUR/m²	EUR/m²	EUR/m²	EUR/m²	EUR/m²
Walls (and arcade ceilings)	74.40	45.80	25.90	28.30	20.80	25.30	24.90	29.00	26.30	25.90
Windows	51.30	48.70	32.10	33.60	40.90	25.70	32.50	38.90	36.10	28.10
Floor construction in attic	11.40	5.90	3.90	5.70	4.60	4.70	0.00	2.40	3.10	3.90
Floor construction in unheated area beneath (basement)	26.10	6.80	3.70	6.70	4.50	5.60	4.00	4.20	3.50	6.20
Flat roof	0.00	0.00	0.00	0.00	0.00	0.60	10.90	3.90	0.00	0.30
Pitched roof	0.00	0.00	0.00	0.00	0.00	0.80	0.00	0.00	2.00	2.90
Floor construction on ground	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
Total (envelope)	**171.70**	**112.80**	**72.90**	**78.10**	**75.50**	**64.10**	**72.30**	**82.90**	**76.70**	**71.60**
Heating system	29.50	27.00	26.40	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Hot water system	19.60	27.40	19.50	16.00	16.60	16.20	18.70	18.60	17.30	17.50
Total (systems)	**49.20**	**54.40**	**45.90**	**20.10**	**20.60**	**20.20**	**22.70**	**22.60**	**21.30**	**21.50**
Total (envelope + systems)	**220.90**	**167.20**	**118.80**	**98.20**	**96.20**	**84.30**	**95.00**	**105.50**	**98.00**	**93.10**
Cooling (optional)	**14.50**	**8.50**	**6.60**	**6.40**	**5.50**	**5.90**	**6.00**	**8.40**	**7.60**	**5.60**

Table 12 Investment costs for building installations in detached and terraced houses

Types A–F1, A2, C2, A3, B3	EUR
Biomass boiler for pellets or logs, wood gasification boiler with a buffer tank	3,000
HP air-water	4,500
Low-temperature gas boiler	900–1,200
Condensing gas boiler	1,500
DHW auxiliary system (solar thermal)	2,000–2,500
Piping installation	25/m^2
Air-conditioning (split) system	400/dwelling

Table 13 Investment costs for building installations in multi-family buildings excluding types with district heating

Types A–C3	EUR
Low-temperature gas boiler	900–2,500
Condensing gas boiler	1,500–3,500
DHW auxiliary system (solar thermal)	2,500–22,000
Piping installation	25/m^2
Air-conditioning (split) system	400/dwelling

Table 14 Investment costs for building installations in buildings with district heating

Types E3–F4	EUR
Realisation of controllable heating system	50/m^2
DHW auxiliary system (solar thermal)	12,000–30,000
Air-conditioning (split) system	400/dwelling

Table 15 Regulated and freely set prices for energy sources

Energy source/fuel	Price setting
Oil	Free setting of prices
Natural gas	Regulated prices (Energy Agency)
Coal	Free setting of prices
Wood	Free setting of prices
Electricity	Regulated prices (Energy Agency)
Heat	Regulated prices (local authority/municipality)

COAL

Coal used in residential buildings, as well as public sector and industrial premises, is sold through the stocks of public companies and private stocks, although part is sold directly from the mine (through an intermediary). Net calorific values and average prices, with and without VAT, for the most commonly used types of coal in Serbia are given in Table 19.

WOOD

A small part of firewood is sold through the stocks of public companies and private stocks. A large part comes from private forests and is cut and sold on the black market (directly from trucks at certain locations in cities, or even directly ordered). No VAT is charged. The prices of wood fuels are given in Table 20.

ELECTRICITY

The prices of electricity for public supply are set by the director of the company that supplies electricity to final consumers (EPS Supply d.o.o. Belgrade), with the approval of the Energy Agency of the Republic of Serbia and applied throughout the territory of the Republic of Serbia. The current price list has been valid since March 1, 2013 (AERS 2013b).

The prices for access to and use of the system for the transmission of electricity are set by the Elektromreža Serbia Management Board, with the approval of the Energy Agency of the Republic of Serbia, and applied throughout the territory of the Republic of Serbia. The current price list has been valid since March 1, 2013 (AERS 2013a)

The prices for access to and use of electricity distribution are set by the directors of commercial companies for electricity distribution by region (Vojvodina, Belgrade, Kraljevo, Nis and Kragujevac) with the approval of the Energy Agency of the Republic of Serbia. The price lists contain prices for medium-voltage consumption, low-voltage consumption, consumption by public consumers and consumption for public lighting. All current price lists have been valid since August 2013.

Electricity prices without VAT (20 percent), valid since August 1, 2013, for households are shown in Table 21. An example of a household's monthly electricity bill is given in Table 22.

DISTRICT HEATING

For decades, the district heating of residential buildings in Serbia has been paid according to the apart-

Table 16 Excise duty and VAT for energy sources

Energy source/fuel	Excise duty	VAT (%)
Oil	EUR 0.02/litre	20
Natural gas	-	10
Coal	-	20
Wood	-	10
Electricity	-	20
Heat	-	10

Table 17 Heating oil prices

Fuel	Unit	Price
Extra light heating oil (EL)	EUR/litre	1.1
Heavy heating oil	EUR/kg	0.47
Low-sulphur heavy heating oil	EUR/kg	0.49

ment's floor area. According to a new legal regulation, from 2015 the payment is to be based on actually consumed heat (Republic of Serbia 2004; Republic of Serbia 2013). The process of transition to billing by energy consumption is ongoing.

There are 59 cities and municipalities in Serbia with remote heating system, but billing is based on actual heat consumption in the case of only seven heating plants (Radio-Televizija Srbije 2014).

Prices for heating from the district heating system vary from city to city, depending on factors such as the type of fuel applied, the system size, the condition of the heating plant, and subsidies from the city/municipality.

In Belgrade, where approximately 40 percent of the total installed capacity of heating plants in Serbia operates, prices for heating are determined by the founder of the public company: the Belgrade City Assembly. The billing system for heat and DHW is determined by the status of the user.

Thermal energy for households that do not have heat meters is charged at a flat rate per square metre of living space. Households that have heat meters installed pay for a measured amount of heat. The accounts of these users consist of a fixed and a variable component, which are proportional to the installed capacity and the measured heat consumption in kWh (Table 23). For dwelling area, thermal energy is paid for every month throughout the year, while for garages it is only paid for during the heating season, which runs from October 15 to April 15.

Households pay their heating bills through one of the following models:

- If there is no heat metering: columns 3 + 8 (if there is DHW).
- If there is heat metering: columns 5 + 7 + 8 (if there is DHW) or columns 6 + 7 + 8 (if there is DHW).

Table 18 **Range of natural gas prices without VAT** (AERS 2015)

Consumer		Natural gas (cEUR/Sm³)	Capacity (cEUR/(Sm³/day)/year)	Lump sum (EUR/user)
Households and small users		0.40–0.50	-	5.87 –22.21
Category 1	Off-peak consumption	0.39–0.44	0.53–1.52	8.53 –19.97
	Uniform consumption	0.39–0.44	0.60–1.85	5.87–20.70
	Non-uniform consumption	0.39–0.47	0.70–2.50	5.87–22.21
Category 2	Off-peak consumption	0.40–0.42	0.55–0.99	87.01–168.23
	Uniform consumption	0.38–0.42	0.43–1.20	87.01–199.70
	Non-uniform consumption	0.38–0.42	0.51–1.95	87.01–199.70

Table 19 **Price of coal in Serbia**

Coal type and name of mine	Net calorific value (kJ/kg)	Price without VAT (EUR/t)	Price with VAT (20%) (EUR/t)
Lignite (Kolubara, Kostolac, Kovin)	7,000–10,000	49.30–55.60	59.20–66.70
Lignite (Stanari, Kreka)	10,500–14,000	62.50–79.80	75.00–95.80
Dried lignite (Kolubara Vreoci)	17,000	86.80–90.30	104.20–108.30
Brown coal (Soko, Banovici, Stavalj, Miljevina, Mezgraja)	<20,000	79.80–93.80	95.80–112.50
Brown coal (Breza, Zenica, Djurdjevik)	>20,000	100.70–111.10	120.80–133.30
Hard coal (from Russia)	-	125.00–145.80	150.00–175.00
Anthracite	-	150.00	180.00
Coke	-	450.00	540.00

Table 20 Price of wood-based fuels in Serbia

Wood type	Unit	Price without VAT	Price with VAT (20%)
Firewood (beech, oak, I class)	EUR/m^3	36.40–45.50	40.00–50.00
Briquettes	EUR/t	90.90–127.30	100.00–140.00
Pellets	EUR/t	109.00–181.80	120.00–200.00
Wood chips	EUR/t	36.40–54.50	40.00–60.00

Table 21 Electricity prices for households (without 20% VAT) from August 1, 2013 (AERS 2013b)

Tariffs		Unit	cEUR
	Cost of public supply		101.08
	Capacity charge		**35.70**
	Active energy:		
One-tariff system	Green zone (<350 kWh)	kWh	3.95
	Blue zone (351–1,600 kWh)	kWh	5.92
	Red zone (>1,600 kWh)	kWh	11.84
Two-tariff system	Higher daily tariff – green zone	kWh	4.51
	Lower daily tariff – green zone	kWh	1.13
	Higher daily tariff – blue zone	kWh	6.77
	Lower daily tariff – blue zone	kWh	1.69
	Higher daily tariff – red zone	kWh	13.55
	Lower daily tariff – red zone	kWh	3.38
Remote tariff control	Higher daily tariff – green zone	kWh	4.51
	Lower daily tariff – green zone	kWh	1.13
	Higher daily tariff – blue zone	kWh	5.75
	Lower daily tariff – blue zone	kWh	1.44
	Higher daily tariff – red zone	kWh	11.50
	Lower daily tariff – red zone	kWh	2.88
Remote tariff control (DUT) by electricity supplier – Separate measuring group	Lower daily tariff – green zone	kWh	1.13
	Lower daily tariff – blue zone	kWh	1.69
	Lower daily tariff – red zone	kWh	3.38

Table 22 Example of a household's monthly electricity bill (December 2014)

No	Item	Tariff	Quantity	Unit price (cEUR/kW)	Price (EUR)
1.	Capacity charge		11.04 kW	0.357	3.94
2.	Cost of public supply		Lump sum		1.01
3.	Electricity		419 kWh		
	Green zone	High tariff	311	4.51	14.03
		Low tariff	51	1.13	0.58
	Blue zone	High tariff	49	6.77	3.31
		Low tariff	8	1.69	0.14
4.	Price for electricity (1+2+3)				23.01
5.	Charge for privileged producers of electricity from RES		419 kWh	0.0675	0.28
6.	VAT base (4+5)				23.29
7.	VAT base (20%)				4.66
8.	Bill for December (6+7)				27.95

Table 23 Heat price in the district heating system in Belgrade (Radio-Televizija Srbije 2014)

Space heating							
No	Category of user	According to heated area	According to installed heat capacity for t_{design} = -12.1°C	According to measured heat consumption			Domestic hot water (DHW)
				Installed heat capacity for t_{design} = -12.1°C		Delivered heat	
		EUR/m² year	EUR/kW year	EUR/kW year	EUR/m² year	EUR/kWh	EUR/m³
1.	2.	3.	4.	5.	6.	7.	8.
1.	Residential	10.85	-	32.54	3.89	0.0541	1.434
1.1	VAT (10%)	1.09	-	3.25	0.39	0.0054	0.143
1.2	Price	11.94	-	35.79	4.28	0.0595	1.577
2.	Other users	-	110.80	32.54	-	0.0662	2.524
2.1	VAT (10%)	-	11.08	3.25	-	0.0066	0.252
2.2	Price	-	121.88	35.79	-	0.0728	2.776

PART 2

Modelling the transformation to a low-carbon residential building stock

VII. Methodology

Modelling approach

In order to assist in the development of energy efficiency and climate mitigation policies for the residential building sector in Serbia, we designed and applied a bottom-up simulation model. The model aggregated information on energy consumption by end use at the level of representative buildings to a sector balance at country level. The model also calculated the costs of consumed energy. Assuming the retrofitting costs of the representative buildings, we calculated the retrofitting costs required at country level. The model also made it possible to run scenarios with different levels of policy effort, assuming the transformation of the building stock to a low-energy and low-carbon level by a particular target year or at a particular rate.

Building age

We classified the whole residential building stock into seven age categories and four type categories. This classification followed the building typology prepared in Part 1 of the present book, with some differences. The first difference is that the age category 2001–2011 was extended to 2015. The second difference is that we added a category of buildings constructed after 2016. The geometrical characteristics of the buildings correspond to those of the buildings constructed in 2001–2011.

The building age categories are based on construction dates:

- before 1945;
- 1946–1960;
- 1961–1970;
- 1971–1980;
- 1981–1990;
- 1991–2015; and
- after 2016.

The building type categories are:

- single-family houses;
- terraced houses;
- multi-dwelling houses; and
- apartment blocks.

Altogether we considered 21 representative buildings. Not each of the building age categories contains all four building types. For more details on the building typology for Serbia, see Part 1 of the present book.

Modelling scope and boundaries

Our model assessed only thermal energy services delivered to residential buildings in Serbia — namely space heating, space cooling and water heating. We did not cover energy use for electrical appliances, lighting and cooking. The latter three energy services consume a large share of the residential sector balance, thus it is important to keep in mind that our calculated levels of energy consumption and CO_2 emissions are far lower than the total sector levels.

The retrofitting options include both the improvement of the thermal envelope and the changing of technical systems, which often imply a fuel switch. The improvement of the thermal envelope means retrofitting walls, roofs, floors and windows. Better technical systems are more efficient systems for water heating, space heating and space cooling. Depending on the technical and economic feasibility, households may switch to solar, biomass, natural gas or electricity as energy sources. All households in multi-dwelling houses and apartment blocks that previously had district heating as their energy source for space heating retain it as a source. We do not consider the impact of climate change on space heating and cooling patterns (see Part 1 for details).

The model includes the illegal building stock. It does not cover buildings used for temporary purposes (vacation houses) or abandoned buildings. The model includes the non-inhabited building stock (see Section VIII, page 65, for details of their treatment).

The base year for our model is 2014, and it is calibrated to the energy balance of 2013. The model is only applicable up to 2030. We estimated the building stock turnover up to 2070, although this only served to obtain an understanding of the number of existing buildings that remain by this time, and the number of new buildings.

In terms of environmental impacts, we calculated only CO_2 emissions but considered both direct and indirect emissions in our analysis. Direct emissions are those originating from fuel combustion that takes place in buildings. Section IV, page 39, of the present publication contains information on the emission factors of fuels used in residential buildings. Indirect emissions are those produced in the transformation sector and accounted on the supply side according to the IPCC guidelines (IPCC NGGIP online), but which are associated with energy commodities consumed in energy-using sectors. In our case, indirect emissions include emissions from electricity use and district heating.

Modelling steps

Figure 23 illustrates the stepwise procedure of our modelling. Our team of national and international architects prepared the country's building typology, calculated building energy performance by end use, and assessed the possible building retrofitting packages and associated costs at the level of individual representative buildings. This information is documented in detail in Part 1.

Part 2 of the present book focuses on how we aggregated this information to the sector level and built scenarios for the sector's energy consumption and CO_2 emissions in the future for different levels of policy effort. First we developed a building stock model to estimate the building floor area and its structure by representative building and climate zone up to 2070. We then married the data from the building stock model with energy consumption by representative building in order to calculate the energy balance at sector level. The results obtained were compared and calibrated to the sector energy balances available from national public statistics.

Next, based on assumptions about likely technological, market and policy developments, we calculated the sector's energy consumption and associated CO_2 emissions in the business-as-usual reference scenario. Together with policy makers we then formulated policy packages aimed at ensuring that buildings become low energy and low carbon in the long-term future. Finally, we calculated energy savings, CO_2 emissions avoided, saved energy costs and investments required in the realisation of the packages.

Involvement of sectoral stakeholders

In order to ensure that the project results are useful for policy making in Serbia, we communicated our progress to national policy makers and experts and incorporated their feedback into our work. We conducted interviews on adopted, forthcoming and other potentially useful policies and included this information into the business-as-usual and low-energy/low-carbon scenarios. We also presented the modelling results, which provided an opportunity to receive additional data, comments and requests for the model.

The model itself, with the underlying input data, was provided to national policy makers and experts to use and modify according to their needs. It is also available on request for use by other experts, subject to appropriate referencing and acknowledgement.

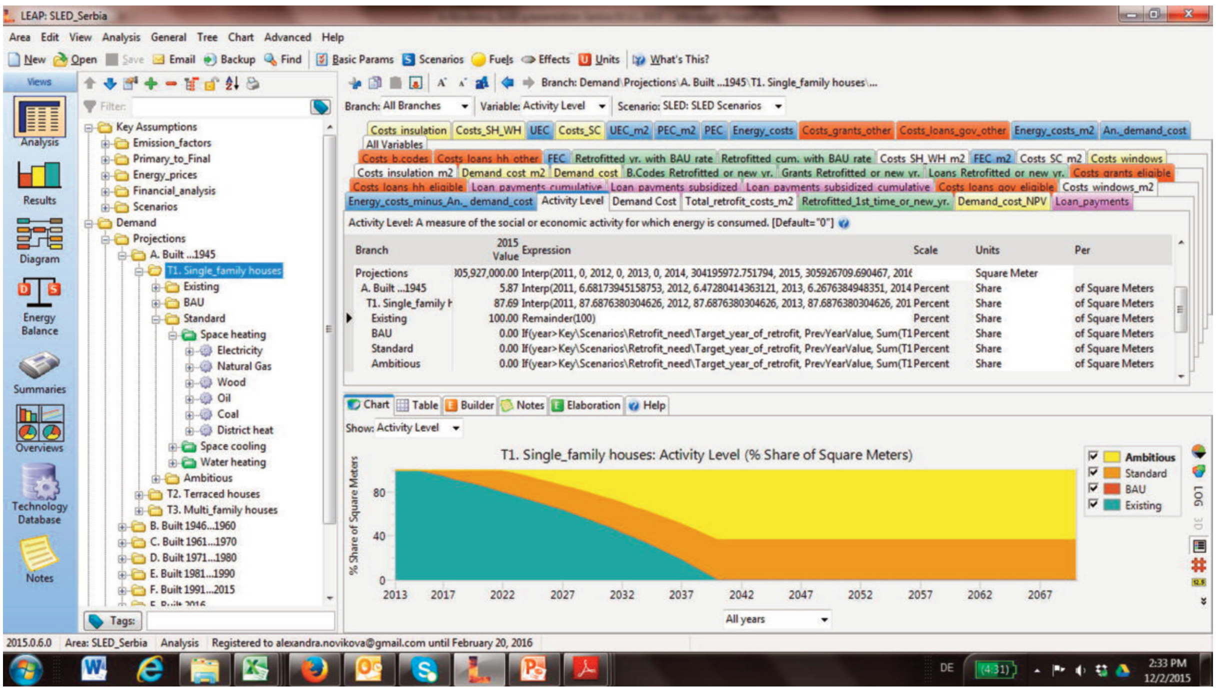
Modelling tool

As a modelling tool we used the Long-range Energy Alternatives Planning System (LEAP) software, developed by the Stockholm Environment Institute, which is widely used for energy policy analysis and climate change mitigation assessment. Figure 24 shows the Serbian model in this software.

Figure 23 Modelling steps

Part 1	Part 2
Step 1: Development of the building typology	Step 5: Construction of the building stock model
Step 2: Calculation of building energy perform-ance at present	Step 6: Construction and calibration of the sector energy balance in the base year
Step 3: Calculation of possible retrofitting packages (business-as-usual, standard and ambitious options)	Step 7: Calculation of baseline energy consumption and CO_2 emissions until 2030
Step 4: Calculation of the cost of the retrofitting packages	Step 8: Formulation of policy packages and evaluation of their impacts and associated costs

Figure 24 The Serbian model in the LEAP software



VIII. Building stock model

Household trends

The evolution of the building stock is driven, above all, by the country's demographic situation. For this reason we first calculated the number of households and their demand for dwellings over the modelling period.

In order to calculate the number of households, we relied on population data up to 2011, provided by the Statistical Office of Serbia (SORS online). We assumed a population growth until 2041 according to the medium variant of the population projections for Serbia in 2011–2041 (SORS 2014b). For 2042–2070, we assumed the continuation of past population trends. Based on these assumptions, the population will decline to 6.8 million in 2030, but will grow to 6.9 million in 2050 and to 7.1 million in 2070.

We assumed that, in line with the overall European trends, the average number of persons per household in Serbia would decrease. This change is due to factors such as population ageing, fewer children per family, and a higher share of mono-parental households (European Commission 2011b). According to the Serbian censuses (SORS 2011; Economic Commission for Europe 2006), the average number of persons per household was 3.0 in 2002 and 2.9 in 2011. If such a trend continues, this indicator will reach 2.6 persons per household in 2030; 2.3 in 2050; and 2.0 in 2070. The 2070 value is equal to the average number of persons per household in Europe by 2050 (European Commission 2011b). According to the latest census (SORS 2011), 1.03 households lived in each dwelling, and this number is assumed to remain constant.

Based on the expected trends in population growth and persons per household, we were able to estimate the total number of households. According to our calculations, the number of Serbian households will grow from 2.5 million in 2015 to 2.6 million in 2030; 3.0 million in 2050; and 3.5 million in 2070.

Figure 25 shows the indices for population, persons per household and number of households until 2070. In 2070, the population of Serbia will be almost the same as in 2015, the number of persons per household will reach 71 percent of the 2015 level, and the number of households will be 41 percent higher than in 2015.

Remaining stock of existing buildings and dwellings

Two Serbian censuses, in 2002 and 2011 (SORS 2011; Economic Commission for Europe 2006) provide data on the number of buildings and dwellings by building age in a similar format. The demolition rate of residential buildings could therefore be calculated based on a comparison of these censuses. Figure 26 shows the number of dwellings by construction period calculated using the 2002 and 2011 census data. The figure illustrates that, during this time, the building demolition rate depended on the construction period and is not therefore linear. For this reason, rather than a linear approach, we used a more precise approach to estimate the demolition rate of the building stock.

The mortality trends of many technologies tend to follow a so-called Weibull curve, even though the useful lifetimes of these technologies differ (Weibull 1951; Welch and Rogers 2010). The curve presents the fraction of remaining units and is described by the following equation:

$$Fraction\ of\ units\ remaining\ (t) = e^{-(\frac{t-c}{a})^b}$$

where:

t = year;

a = scale factor;

b = shape factor; and

c = location parameter.

The mean lifetime of units can be estimated as:

$$Mean\ lifetime = a \times \gamma(1 + \frac{1}{b})$$

where:

γ = the value of the Gamma function

Figure 27 illustrates the Weibull curves for different shape factors, assuming the location parameter 0. As we did not have sufficient data to estimate all the parameters of the Weibull curve for the Serbian building stock, we assumed a shape parameter of 2.5 and a location parameter of 0.

Using the Weibull curve, we calculated the average lifetime of the existing residential buildings in Serbia. In the case of buildings constructed before 1945, the estimated building lifetime is 75 years. For buildings constructed in 1946–1980, 1961–1970, 1971–1980 and 1981–1990, the estimated lifetime is 80, 65, 75 and 65 years respectively. This is rather short, given the life-

Figure 25 Key demographic indicators (2015=1.0)

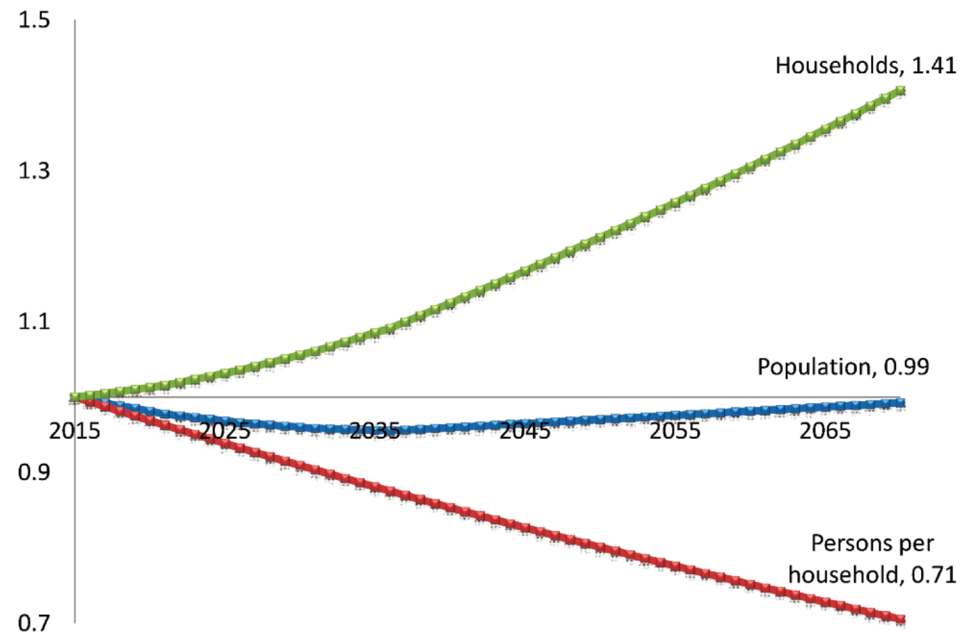


Figure 26 Number of dwellings by construction period according to the 2002 and 2011 censuses

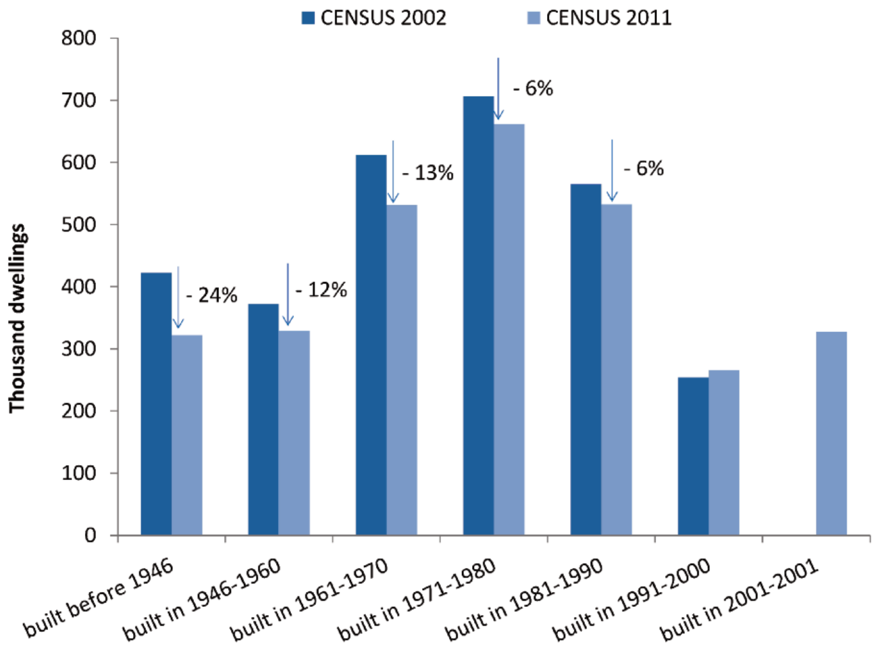
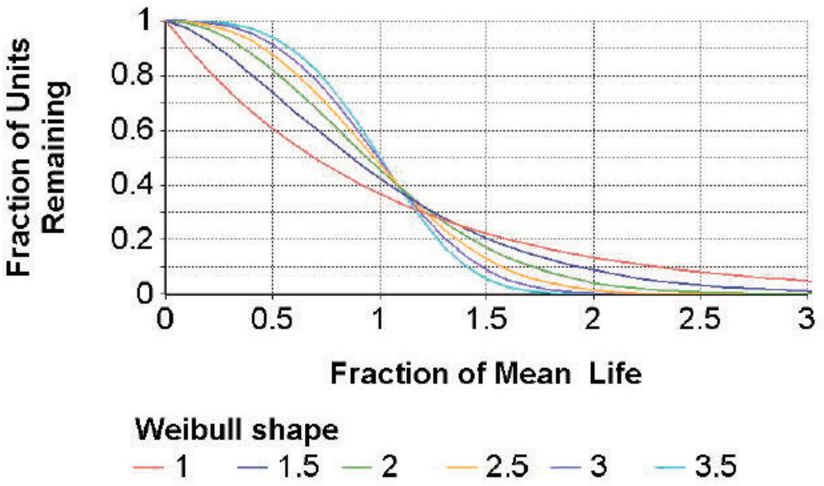


Figure 27 **The Weibull curve** (Welch and Rogers 2010)



time of similar buildings in neighbouring countries, and is probably due to the impact of political and economic migration. For the future, we therefore somewhat increased the building lifetime to 100 years for buildings constructed before 1960 and after 1991, and to 80 years for buildings constructed in 1961–1990.

Using the Weibull curve and these assumptions, we calculated the number of remaining dwellings by each age category until 2070. Applying assumptions about the number of dwellings per building, made using data from the 2011 census (SORS 2011), we also calculated the number of remaining buildings by each age category until 2070.

Building stock habitation

In 2011, 20 percent of dwellings in Serbia were not inhabited. Of this number, 4 percent were abandoned and 16 percent were temporarily vacant. This proportion of temporarily vacant dwellings is fairly common in Southern European countries, and we assume that it does not grow in the future. We excluded abandoned dwellings from our model because they do not make an impact on the sector's energy consumption. In order to avoid overestimating energy consumption for buildings with temporary non-inhabited dwellings, we introduced correction factors.

The distribution of temporarily vacant dwellings among buildings by type and age category is not clear from the statistics. It is equally possible that a proportion of single-family houses or some apartments in multi-dwelling buildings are temporarily vacant. When we calculated the energy consumption in different segments of the building sector, we therefore applied the same factor of 0.84 in order to correct for habitation. This is an approximation, because the share of energy consumption of a partially inhabited multi-dwelling building is not the same as the share of the inhabited dwellings in it. However, no better approximation was possible due to the unclear picture of the distribution of vacant dwellings.

Construction of new buildings and dwellings

We estimated the construction rate of dwellings as the gap between the demand for dwellings, represented by the number of households, and the remaining stock of existing dwellings. We assumed that the new dwellings have the same structure by building type as those built during the last 15 years.

In order to calculate the building floor area in 2015–2070, we multiplied the remaining dwelling stock by the dwelling floor area by building age and type, as suggested by the building typology. We assumed for the new dwellings the same floor area as for dwellings built during the last 15 years.

The annual calculated construction rate is 1.0–1.4 percent of the residential building floor area between 2015 and 2030; 1.4–1.7 percent between 2030 and 2050; and 1.6–1.7 percent between 2050 and 2070.

Building floor structure in the future

We estimated that the building floor area in 2015 was 316 million m² and that it will reach 357 million m² in 2030; 449 million m² in 2050; and 555 million m² in 2070. The structure of the building floor area will change due to the demolition of old buildings and the construction of new buildings.

As Figure 28 shows, the share of new building floor area will reach 22 percent of the total in 2030; 51 percent in 2050; and 72 percent in 2070. It is therefore important to ensure that new buildings comply with the existing building code. It is also important to tighten this code as soon as possible in order to avoid locking high energy consumption patterns into the long-term future. We can also conclude from the figure that a significant share of the building stock constructed in 1961–1990 (if calculated by decade) will remain in the medium-term future. Ensuring that these buildings have a high energy performance after their retrofitting is therefore essential.

The structure of the building floor area by building type is also expected to change in the future. As Figure 29 illustrates, the floor area of single-family houses is currently, and will continue to be over the modelling period, the highest share out of the total floor area. While small buildings tend to consume more thermal energy per square metre than large buildings, their retrofitting is easier to stimulate due to lower organisational barriers than in large buildings. The options for retrofitting small buildings to low-carbon levels are therefore more flexible than for large buildings.

Figure 30 presents the structure of the building floor area by building type and age — that is, the shares of 21 representative buildings in the building floor area over the modelling period. The representative buildings with a share of more than 5 percent in the total area are named. The biggest categories are all categories of single-family houses built after 1961.

Figure 28 Building floor area by building age category, 2015–2070

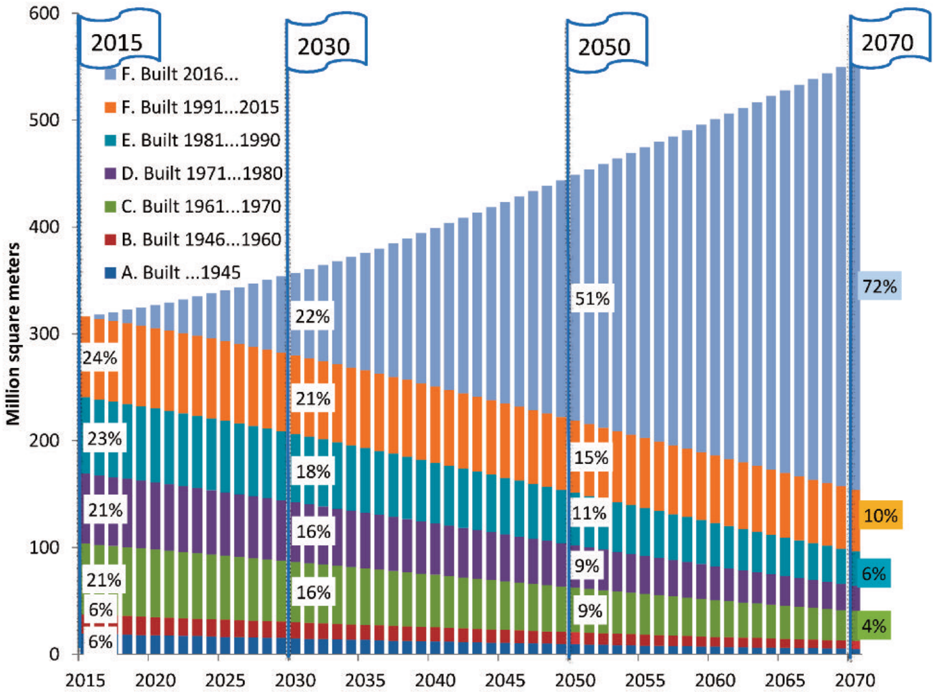


Figure 29 Structure of the building floor area by building type, 2015–2070

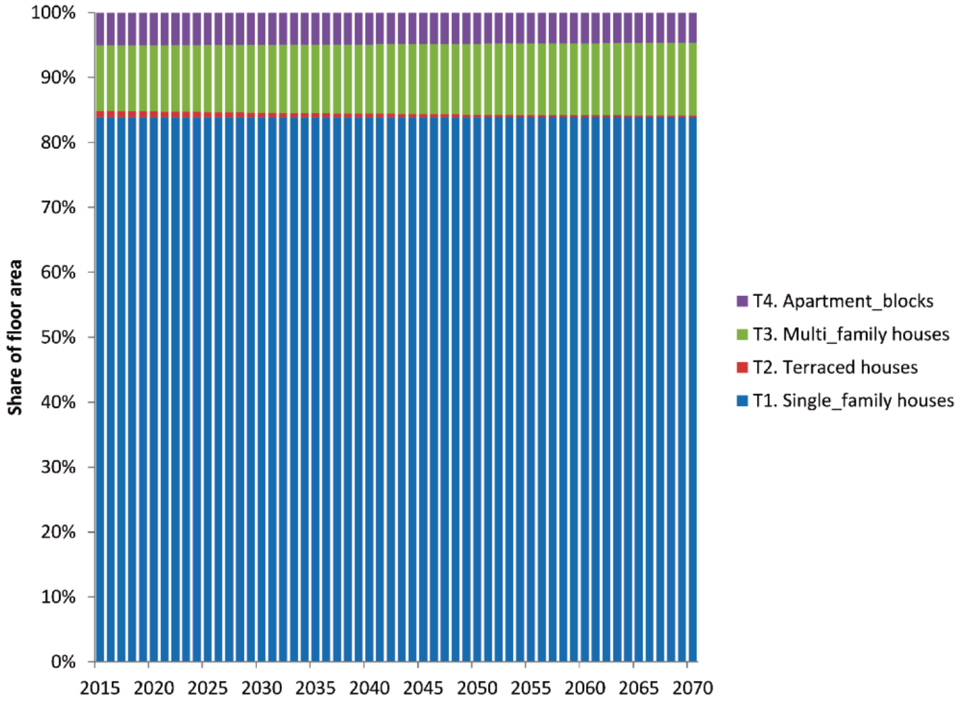
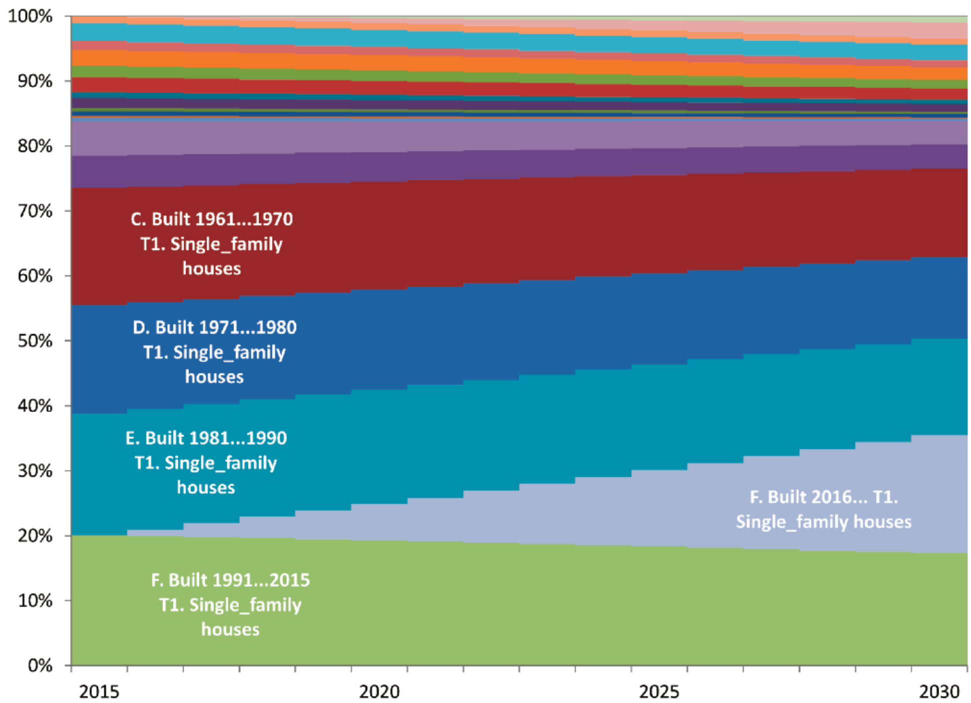


Figure 30 Structure of building floor area by building age and type, 2015–2030



IX. Construction and calibration of the sector energy balance

In the next step, we calculated final energy consumption at sector level in the base year. Final energy consumption (delivered energy) at building level is defined in Section V (page 45). Final energy consumption in each representative building was estimated as the sum of its final energy consumption for space heating, water heating and space cooling. We then multiplied the number of representative buildings by their final energy consumption and added the results across all building types and building age categories.

By way of a check, we compared the calculated final energy consumption with the sector energy balance available at the macro level. The latest (2013) energy balance of Serbia was published by the Serbian Statistical Office (SORS 2014a). In order to estimate only the share of the energy balance that is associated with thermal energy uses, we deducted from the electricity consumption of the sector as a whole electricity consumption for cooking, appliances and lighting. This was assumed as 25 percent of the sector's final energy consumption, in line with other countries in South Eastern Europe: Bulgaria (23 percent), Greece (25 percent), Slovenia (20 percent), Croatia (29 percent) (EEA 2012). We refer to the energy balance that is associated with thermal energy uses as an estimated energy balance for our model, or simply as an estimated energy balance.

The calculated final energy consumption appeared significantly different from the estimated energy balance. Based on consultation with experts, we identified three factors causing such a difference. First, households in Serbia heat and cool their dwellings only partially; second, dwellings are not heated and cooled for the whole of the day; and third, households are likely to use more wood than reported in the official balance.

With respect to the first and second factors, there are no official data that lead to any assumptions. Our assumptions were therefore based on our experience in running similar models in Albania and Montenegro (Novikova, Szalay et al. 2015; Novikova, Csoknyai et al. 2015). In summary, to correct the calculated final energy consumption for heating we assumed that 50 percent of the dwelling area is heated for 12 hours a day in all single-family and terraced houses as well as in multi-dwelling buildings built before 1960. In multi-dwelling buildings built in 1961–1970, we assumed that 80 percent of the dwelling area is heated for 14 hours. Finally, in multi-dwelling houses built after 1990, and in all apartment blocks, we assumed that the whole of the floor area is heated for 14 hours. We corrected the final energy consumption for cooling assuming that 30 percent of the dwelling floor area is cooled for around 12 hours a day, regardless of building type and age.

Initially, we conducted our calculations using the breakdown of households by energy source for space heating and water heating, assumed on the basis of the energy balance of Serbia (SORS 2014a). After correcting the final energy consumption for thermal comfort, as discussed in the paragraph above, it was clear that the shares of energy sources must be different. District heating, LPG, natural gas, coal and electricity are traded commodities, and are thus well counted. The statistics for the number of dwellings using district heating and their consumption can be regarded as particularly accurate, because dwellings connected to the district heating network usually use only this source for space heating, and because district heating is not consumed for any purposes other than space heating. Since biomass can be easily obtained by means other than trade, its consumption is less certain. In order to better fit our calculated energy consumption to the estimated energy balance, we focused in particular on those energy commodities where consumption is more certain. When the calculated energy consumption of a more certain commodity was higher than in the energy balance (e.g. natural gas), we reallocated a share of that energy source to wood.

Table 24 compares the estimated energy balance of Serbia in 2013 and the calculated energy consumption of thermal energy uses, with and without the calibration. The non-calibrated calculated energy consumption was five times higher than the estimated energy balance. The calibrated calculated energy consumption is 1.5 times higher than the estimated energy balance. The difference comes from wood consumption, which, according to our calculation, is around 2.5 times higher than reported in the balance.

Table 24 Sector energy balance and calculated final energy consumption (billion kWh)

Fuels	Energy balance: all energy uses	Energy balance: estimated share of thermal energy uses	Non-calibrated calculated final energy consumption for thermal energy uses	Calculated calibrated final energy consumption for thermal energy uses
Electricity	14.1	5.6	29.2	6.6
Natural gas	2.2	2.2	25.0	2.3
LPG	0.9	0.9	5.6	0.9
Coal (lignite)	3.0	3.0	16.2	3.1
Wood	9.4	9.4	44.5	25.1
Heat	4.4	4.4	7.3	3.6
Total	**34.1**	**25.6**	**127.7**	**41.5**

X. Formulation of the reference and low-energy/low-carbon scenarios

In order to formulate the business-as-usual and low-energy/low-carbon-emission scenarios, we reviewed the barriers to energy efficiency penetration in the residential building sector in Serbia, as well as existing, planned and other relevant policies aimed at overcoming these barriers. The review presented is dated as of April 2015.

National policies prior to Serbia signing the Energy Community Treaty

The Energy Law, adopted in 2004 (Republic of Serbia 2004), defined the key objectives of energy policy and the implementation instruments. The law explicitly states the importance of providing conditions for the promotion of energy efficiency when carrying out energy activities and in energy consumption.

In 2005, Serbia adopted the Energy Sector Development Strategy until 2015 (Republic of Serbia, Ministry of Mining and Energy 2005), which was implemented by the Energy Sector Development Strategy Implementation Programme 2007–2012 (Republic of Serbia 2007). The strategy recognised the rational use of energy and energy efficiency as the second directed priority. In 2012, Serbia issued a draft of the Energy Strategy until 2030.

Commitments under the Energy Community Treaty

Becoming a contracting party to the Energy Community Treaty prompted the adoption of many energy efficiency policies in Serbia. In accordance with the treaty, the country has made a commitment to adopt the EU energy acquis, including energy efficiency legislation. The commitment implies the transposition of the following directives:

- The Energy Performance of Buildings Directive (EPBD) 2010/31/EC by September 30, 2012 (European Commission 2010b)
- The Directive on the Indication by Labelling and Standard Product Information of the Consumption of Energy and Other Resources by Energy-Related Products (Energy Labelling Directive) 2010/30/EU, as well as a set of implementing directives/delegated acts, by December 31, 2011 (European Commission 2010a)
- Directive 2006/32/EC on Energy End-Use Efficiency and Energy Services (Energy Services Directive, or ESD) by December 31, 2011 (European Commission 2006)
- The Energy Efficiency Directive (EED) 2012/27/EU by September 30, 2016 (European Commission 2012)

Even though Directive 2009/125/EC on Eco-design Requirements for Energy-Using Products (Eco-design Directive, European Commission 2009) is also referred to among EU energy efficiency legislation, the Energy Community Treaty does not require its transposition. The EED amended the Labelling and Eco-design directives and replaced the ESD, with the exception of Article 4, which remains in force.

In addition to these pieces of EU legislation directly linked to energy efficiency in buildings, legislation that regulates energy prices for final consumers has an indirect impact on energy efficiency. According to the guidelines of the Energy Community Treaty on the reform of regulated electricity prices in the Energy Community (Energy Community Secretariat 2012), contracting parties had to ensure from July 31, 2013, that regulated electricity prices for all customers, including households, are cost reflective. The reform of other energy markets is expected in future phases.

Implementation of the Energy Services Directive

In 2013, the Law on the Efficient Use of Energy (Republic of Serbia 2013) transposed the main provisions of the ESD. The law set out, among other things, the basis for the introduction of energy-saving targets; the preparation and monitoring of national energy efficiency action plans (NEEAPs); energy auditing; the provision of energy services and contracting; and financial mechanisms for energy efficiency, including the establishment of an energy efficiency fund. The law envisioned the adoption of around 30 secondary pieces of implementing legislation, which are at present in preparation (Republic of Serbia, Ministry of Agriculture and Environmental Protection 2014).

The first and second NEEAPs were prepared in 2010 (Republic of Serbia 2010) and 2013 respectively. The text of the second NEEAP is not yet publicly available. Policies and measures from the first NEEAP that are already being implemented in the residential building sector include:

- the introduction of new rules for building design and construction, minimum energy performance standards, and energy performance certificates in accordance with the EPBD; and
- awareness-raising activities.

According to the report on the implementation of the first NEEAP (Republic of Serbia, Ministry of Energy, Development, and Environmental Protection 2012), the following policies and measures are not yet being implemented in the residential building sector:

- subsidies obtained from credit lines for the improvement or replacement of outside doors and windows and for the thermal insulation of residential buildings;
- the introduction of loans for energy efficiency in households obtained from credit lines (the provision of loans is subject to ex-ante energy audits);
- loans obtained from credit lines and tariff reform for the reduction of electricity use for heating purposes;
- the establishment of an energy efficiency fund;
- billing on the basis of measured energy consumption for consumers connected to district heating systems; and
- minimum standards, information and awareness campaigns and loans to promote the use of energy-efficient household appliances.

Implementation of the Energy Performance of Buildings Directive

The Law on Construction and Planning, adopted in 2009 and amended in 2013 (Republic of Serbia 2009), provided the basis for the introduction of norms and standards on energy efficiency in buildings as well as the certification of buildings according to Directive 2010/31/EU (the EPBD). The implementing bylaws (Solujić 2014) include:

- the Rulebook on Energy Efficiency of Buildings (Official Gazette of RS, No. 61/2011), which contains the national calculation methodology and minimum energy performance requirements for new or reconstructed buildings;
- the Rulebook on the Conditions, Content and Manner of Issuance of Certificates for the Energy Performance of Buildings, which transposes relevant provisions of Directive 2010/31/EU (Official Gazette of RS, No. 69/2012);
- the Rulebook on the Conditions, Programme and Manner of Passing the Professional Exam in the Field of Spatial and Urban Planning, the Production of Technical Documentation and Construction (Official Gazette of RS, No. 4/10, 21/10 и 14/12); and
- the Rulebook on the Conditions and Procedure for Issuing and Revoking Licences for Responsible Urban Planners, Designers, Contractors and Responsible Planners (Official Gazette of RS, No. 116/04 and 69/06).

The Institute for Standardisation has been working on adopting a set of European Committee for Standardisation (CEN) standards on building energy performance (Energy Community Secretariat 2014). The Central Registry of Energy Passports has been active since 2014.

Other provisions of Directive 2010/31/EU, such as the inspection of heating and air-conditioning systems, the training and accreditation of experts, and energy audits will be implemented with the adoption of the following bylaws on the basis of the Law on the Efficient Use of Energy (Republic of Serbia 2013):

- the Rulebook on Regular Inspection of Boilers and Other Combustion Chambers, as well as Heating Systems above 20 kW, currently under preparation (Solujić 2014); and
- the Rulebook on the Regular Inspection of Air-Conditioning Systems above 12 kW, currently under preparation (Solujić 2014).

Implementation of the Energy Efficiency Directive

The transposition of the Energy Efficiency Directive is under consideration.

Implementation of the Energy Labelling Directive

The Law on the Efficient Use of Energy (Republic of Serbia 2013) transposed the key provisions of the Energy Labelling Directive. The secondary bylaws are the Decree on the Labelling of Energy-Related Products, adopted in 2013, and a set of rulebooks on the labelling of energy-related products, adopted in 2014.

Implementation of the Eco-design Directive

Although the transposition of the Eco-design Directive is not required, Serbia is voluntarily working on its transposition. In 2013, the Law on the Efficient Use of Energy (Republic of Serbia 2013) transposed the main provisions of the Eco-design Directive, and in 2014 Serbia investigated the impact of sub-regulations (Banjac 2014).

Implementation of energy pricing reform

At present, households are supplied by the public electricity supplier (EPS Supply) at regulated tariffs (Energy Community Secretariat 2014). The country does not envision a significant increase in energy prices (Singh, Limaye and Hofer 2014).

The law defines vulnerable customers and obliges the government to provide financial support for their protection. Special tariffs for vulnerable customers were regulated by the Energy Regulatory Authority until July 2015 (Energy Community Secretariat 2014). According to the law they are entitled to a reduction in their electricity bill for 120–150 kWh/month, depending on the size of the household. The subsidy comes from the state budget (Energy Community Secretariat 2014).

The price of thermal energy is regulated by the Decree on the Method for Determining the Highest and Lowest Average Price of Thermal Energy (Official Gazette of RS, No. 37/2013). Public and other companies in charge of heat energy distribution are obliged to apply the new tariff system based on consumption billing (Banjac 2014).

Energy efficiency financing

Article 59 of the Law on the Efficient Use of Energy (Republic of Serbia 2013) requires the establishment of a budgetary fund for energy efficiency. The financing of the budget fund is to be provided from the state budget and from grants and loans. According to Article 61, eligibility for financing depends on ex-ante energy audits of existing buildings, or reports on the energy efficiency of new buildings.

In 2013, the Decree on the Establishment of a Budgetary Fund for Energy Efficiency, the Regulation on Conditions for the Distribution and Use of the Fund in January 2014, and a Programme for the Financing of Energy Efficiency Measures for 2014 introduced this financing mechanism. The government allocated to the fund around EUR 2.6 million from the state budget for 2014 (Energy Community Secretariat 2014).

Summary of barriers as well as existing, planned and relevant policies

Table 25 presents a summary of existing barriers to the penetration of energy efficiency in residential buildings in Serbia, as well as policies aimed at overcoming them. Policies labelled “E” are existing policies — that is, policies that have already been elaborated, adopted and implemented. Policies that are currently being planned and adopted according to the requirements of the EU energy acquis are marked with a “P”. Finally, policies required for the transposition and implementation of the EU acquis but not yet planned, as well as additional feasible policies, are labelled “F”.

The summary was prepared based on a review of existing barriers to the penetration of energy efficiency (Singh, Limaye and Hofer 2014; Ryding and Seeliger 2013; Legro, Novikova and Olshanskaya 2014); Serbia’s commitments as a contracting party to the Energy Community Treaty, as discussed above; existing and planned policies in Serbia, also discussed above; and policies recommended in the literature (Lucon et al. 2014; Ürge-Vorsatz et al. 2012; Bürger 2012; Ryding and Seeliger 2013; Singh, Limaye and Hofer 2014).

Assumptions and policy package in the reference scenario

In the reference scenario, we assumed business-as-usual technological, policy and market changes. We assume that existing buildings are retrofitted at least once during their lifetime. Since the lifetime of buildings constructed before 1960 is about 100 years, and the lifetime of the other existing buildings is 80 years, it was assumed that, on average, retrofitting takes place 45 years after the building was constructed.

We estimated that, after this business-as-usual retrofitting, building energy demand decreases by 20 percent. According to the present building code, existing buildings that undergo major renovation also have to

Table 25 Policies in the residential building stock in Serbia tailored to the main barriers (as of April 2014)

Households:	that are not interested in thermal retrofitting		that are interested in thermal retrofitting		that are undergoing thermal retrofitting	
Barriers	Barriers	Policy	Barriers	Policy	Barriers	Policy
All types of dwellings						
Market failures: Imperfect information	Lack of knowledge, attention, interest	Information campaigns (E), energy tariff reform (P) and taxation (E), detailed bills (F), free mini-audits (F), building codes (E), appliance standards (P), obligations to retrofit (F)	Lack of practical knowledge and skills for technical/financial analysis	Detailed bills (F), building codes (E), appliance standards (P), building certification (E), appliances labelling (E, P), desk advice, comprehensive audits (P)	Lack of reliable technical advice	Comprehensive audits (F), desk advice (F)
Behavioural barriers	Ignorance of benefits	Information campaigns (E), energy tariff reform (P) and taxation (E), better collection of energy bills (F), detailed bills (F), free mini-audits (F), building codes (E) and appliance standards (P), obligations to retrofit (F)				
	Energy bill non-payment					
	Culture, tradition					
Financial barriers			High discount rates of households	Concessionary loans (F), grants (F), tax incentives, obligation to retrofit at point of general renovation (F)		
			High up-front costs			
			Lack of access to capital	Concessionary loans (F)		
			High cost of capital from lenders	State guarantees to banks (F)		
			Unwillingness to incur debts	Tax incentives		
			No rise in property sales price and uncertain resale after retrofit	Performance certificates (E), obligation to retrofit at the point of transaction (F)		
	Regulated price of energy, lack of internalisation of external costs			Tariff reform (P), energy taxation (E)		
	Heating tariffs linked to the living floor area			Consumption-based billing for heating (P)		
Hidden costs and benefits	Information search costs	Information campaigns (E), detailed bills (P), free mini-audits (F), building certification (E), appliance labelling (E, P)	Costs of searching the right option	Free mini-audits (F), desk advice (F), subsidised comprehensive audits (F)	Costs of searching installation advice	Free mini-audits (F), desk advice (F), subsidised comprehensive audits (F)
			High transaction costs due to small size	Project bundling by ESCOs		
Market failures: Organisational barriers	Low level of implementation and enforcement of policies			Capacity building (E, F), education and training (E, F), integration with other policies (F)		
			Unstable financing of programmes	Back-up of state programmes with other sources (F), raising finance from commercial banks (F)	Lack of skilled providers	Apprenticeship (E), master training (E), further education (E), accreditation of contractors through branded quality standards (F)
Market failures: Technological risks					Lack or low quality of technologies	Building codes and certification (E), product standards (P) and labelling (E, P)
					Risk of failure, heterogeneous retrofitting outcomes	Quality standards (F), qualified retrofitting plans (F)
Rented dwellings						
Organisational barriers			Landlord–tenant dilemma	Cost and benefit allocation rules between tenants/landlords (F), rent reduction claims of tenants in case retrofitting is not carried out by landlords		
Dwellings in multi-dwelling buildings						
Organisational problems			Collective decision problems	Obligation to retrofit at point of general renovation (F)		
			Access to capital	Requirement for homeowner associations to establish retrofitting funds (F)		
			Low creditworthiness of homeowner associations	State guarantees for commercial banks (F)		
Illegal dwellings						
Behavioural barriers			Disregard for construction rules	Legalisation of dwellings (F)		
Financial barriers			Not eligible for finance	Grants and concessionary loans (F)		
Low-income households						
Financial barriers			Lack of capital	Grants (F), state guarantees for commercial banks (F)		

Notes: E – adopted and implemented policies; P – policies being planned and adopted according to the EU acquis; F – policies required under the EU acquis but not yet planned, as well as other feasible policies

comply with building code requirements. However, the majority of business-as-usual retrofits are not major renovations, which makes it unlikely that the building code will have a significant direct impact on them. The retrofitting of dwellings in the business-as-usual case does not assume the replacement of their heating systems. We assumed that many households that undergo retrofitting start to use space cooling. There have been several estimates of the future penetration rate in Europe, starting from 13 percent in 2030 (Rescue Working Package 2 2013) up to 40 percent in the same year (Ecoheatcool Work Package 2 2006). As we were not able to identify a reliable estimate for Serbia, or an opinion, for those households that do not have a heat pump we accepted the high estimate (i.e. 40 percent), given that Serbia is located in the south of Europe. Households that have heat pumps do not require separate space-cooling systems.

The business-as-usual retrofitting option assumes the improvement of thermal comfort in dwellings. As a result, households in detached and terraced houses, as well as in multi-dwelling houses, built before 1961, increase their share of heated floor area from 50 percent to 60 percent. Households in multi-dwelling buildings built in 1961–1970 increase their share of heated floor area from 80 percent to 85 percent. The duration of heating is assumed to be the same as at present. No increase in the share of cooled floor area was assumed.

New buildings are constructed according to the building code introduced in 2011. The requirements contained in the building code correspond to the characteristics of the measures in standard improvement 1. The thermal comfort delivered is higher in new buildings than it is in existing buildings. We assumed that households in new detached and terraced houses would heat 70 percent of their dwelling area for 12 hours a day; and that households in multi-dwelling buildings and apartment blocks would heat 100 percent of their dwelling floor area for 14 hours a day. We also assumed that around 40 percent of households that heat their dwellings with systems other than heat pumps would also install separate space-cooling systems and would use them for 40 percent of their dwelling area for at least 12 hours a day. Households that have heat pumps automatically have access to space cooling and likewise cool 40 percent of their dwelling area for 12 hours a day. The breakdown of energy sources for space and water heating in new buildings is assumed to be the same as for existing buildings.

It is likely that some buildings will undergo retrofitting more than once during their lifetime. We considered only the first retrofitting, starting from the present moment, over the modelling period.

Assumptions and policy packages in the SLED moderate and ambitious scenarios

Policy tools for energy efficiency improvements are often classified as regulatory tools, fiscal/financial incentives, market-based tools and information (Ürge-Vorsatz et al. 2012). The regulatory group of tools, which includes construction and renovation norms or building codes, has proved to be the most cost-effective (*ibid*.). However, EU experience shows that building codes are not sufficient to reduce energy consumption in existing buildings at the desired rate. A comprehensive package of policy tools, comprising "carrots", "sticks" and "tambourines", should therefore be adopted to tackle this challenge.

Our policy package explicitly models the impact of regulatory policy tools and financial incentives ("sticks" and "carrots"). The impact of "tambourines", or information policies, is difficult to model explicitly using a bottom-up approach. This type of policy is therefore assumed to be included in our policy package as one of its success factors. The designed package does not represent the best or the optimal package, but rather a simulated package that indicates the level of effort required in order to achieve the low-energy and low-carbon transformation of the building sector.

We formulated our policy packages in accordance with EU energy efficiency legislation. The packages are aimed at achieving a transformation to a more efficient building stock in the future, as presented in the EU Energy Roadmap 2050 (European Commission 2011a). We assumed two levels of ambition for such a transformation. According to the first, we assumed that by 2070 all new and existing buildings would achieve at least the level of standard improvement 1, defined in Part 1 of the present book. The second level of ambition assumes that by 2050 the majority of new and existing buildings will achieve the level of ambitious improvement 2 defined in Part 1. We refer to the policy package with the first level of ambition as the SLED moderate scenario; and the policy package with the second level of ambition as the SLED ambitious scenario.

Figure 31 illustrates the SLED moderate scenario, according to which Serbia has no new regulatory policies and financial support schemes for new buildings, except for the building code currently in force.

In order to ensure the retrofitting of the entire existing building stock, we assumed that in the SLED moderate scenario all buildings remaining until 2070 would be retrofitted at least once to the level of improvement 1. This improvement implies not only lower energy consumption, but also a higher level of comfort. As a result, households in detached and terraced houses, as well as in multi-dwelling houses built before 1961, increase the share of heated floor area to 70 percent; while households in multi-dwelling buildings constructed in 1961–1970 increase the share of heated floor area to 90 percent. The cooling floor area will grow to 40 percent, while the duration of cooling will remain at 12 hours a day.

To ensure the implementation of these retrofits, we assume that Serbia introduces financial incentives for investors in the residential sector. Households in single-family and terraced houses face lower organisational and legal barriers to obtaining investment capital than households in multi-family houses and apartment blocks. For this reason, the introduction of low-interest loans is relevant for the majority of households in single-family and terraced houses. For households that live in such buildings and that are considered to be low-income households, we suggest the introduction of grants. We assume that the share of low-income households is 10 percent of total households.

Next, we assumed that at present only 10 percent of households in multi-family houses and apartment blocks are able to overcome the organisational barriers and obtain low-interest loans for building retrofits. We assumed that the remaining households in these buildings are eligible to obtain grants. As the market cumulates experience of providing loans for the retrofitting of multi-family houses and apartment blocks, the share of households that are able to obtain loans will grow to 90 percent by 2050. For the remaining households, which are considered to have a low income, the government will continue to provide grants.

Figure 32 illustrates the SLED ambitious scenario, according to which we assumed that, in addition to the 2011 building code, Serbia would also introduce a more stringent building code in 2022. The requirements envisioned by the building code correspond to the characteristics of the measures of ambitious improvement 2. Up until 2022, the earlier building code is in force.

In order to prepare the market for the new, more ambitious building code, in 2016 Serbia will introduce low-interest loans for new buildings with characteristics corresponding to the measures in improvement 2.

Figure 31 **The policy package in the SLED moderate scenario**

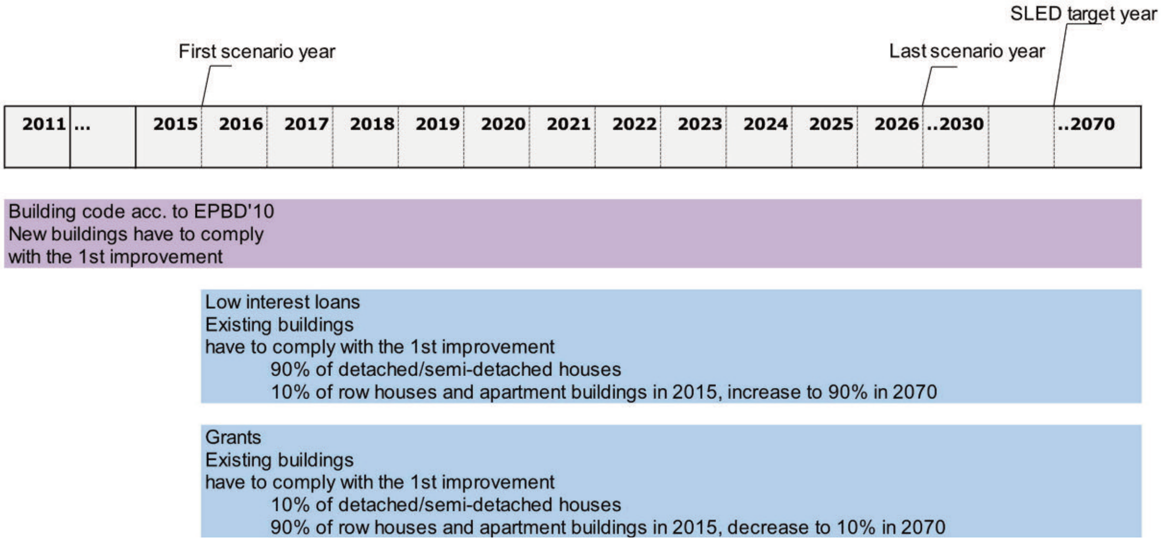
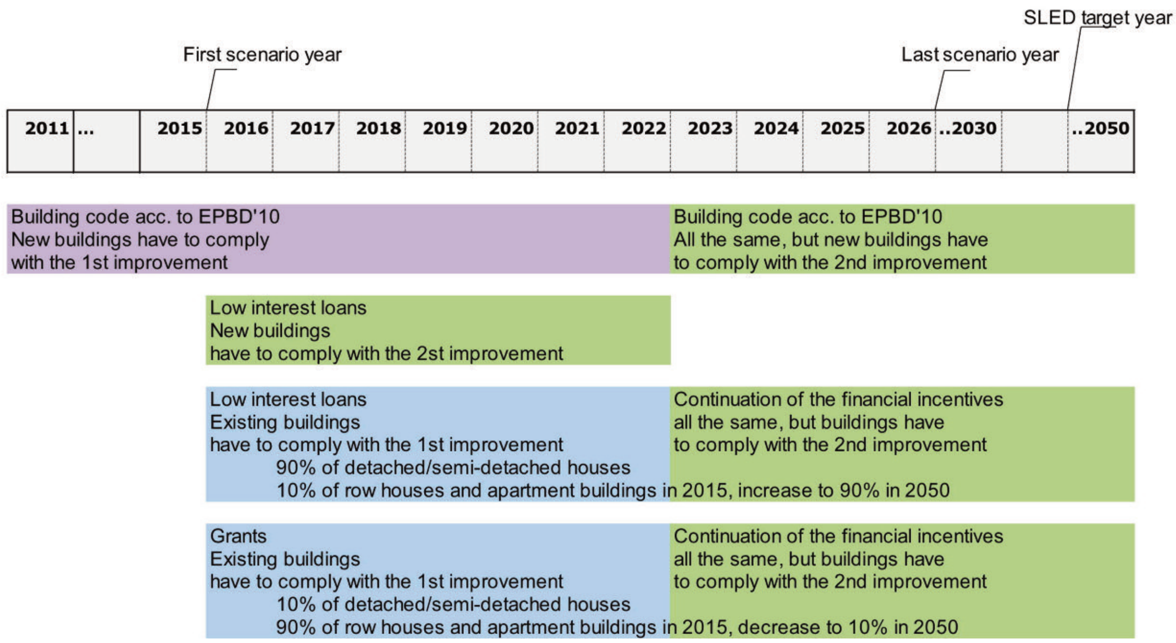


Figure 32 The policy package in the SLED ambitious scenario



Similar to the SLED moderate scenario, in the SLED ambitious scenario we assume that all buildings remaining until 2050 will be retrofitted at least once. The retrofits will be conducted according to improvement 1 up until 2022; and according to improvement 2 from 2023 up until 2050.

Improvement 2 in retrofitted dwellings implies even greater thermal comfort. As a result, households in detached and terraced houses will increase the share of heated floor area to 80 percent, while households in multi-dwelling buildings constructed in 1961–1970 will increase the share of heated floor area to 100 percent. The cooling floor area will increase to 50 percent, while the duration of cooling will increase to 14 hours a day. For new dwellings, the heated and cooled floor area and the duration of heating and cooling are the same as for retrofitted dwellings after improvement 2.

In order to ensure the implementation of these retrofits, we assumed that Serbia would introduce financial incentives for investors in the residential sector. Up until 2022, financial incentives are provided in order to achieve a level of performance according to improvement 1. After 2023 and up to 2050, incentives are provided in order to achieve a level of performance according to improvement 2. The structure of the financial incentives is the same in the SLED moderate and ambitious scenarios.

We assume that all new buildings comply with the requirements of the building codes in both scenarios. This is ensured by the approval of construction plans ex-ante and the issuing of building performance certificates ex-post. Similarly, we assume that low-interest loans for new, efficient buildings, as well as low-interest loans and grants for retrofitting, are provided according to the same conditions.

XI. Reference scenario: Results

Final energy consumption

Figure 33 shows that, in 2015, final energy consumption in the residential sector for thermal energy services was 42 billion kWh. Final energy consumption will decrease by around 5 percent over the modelling period and will reach 40 billion kWh in 2030.

Figure 34 presents final energy consumption by energy source. In 2015, final energy consumption comprised 61 percent wood; 16 percent electricity; 9 percent district heating; 7 percent coal; 6 percent natural gas; and 2 percent LPG. Since we did not assume a fuel switch for new buildings and existing buildings that have undergone retrofitting, there is no change in the structure of energy sources in final energy consumption.

Figure 35 presents final energy consumption by building age category. It shows that final energy consumption in existing buildings is expected to decline, since a share of existing buildings will be demolished by 2030. Although the business-as-usual improvement of existing buildings implies a 20 percent reduction in net energy demand, these savings will be offset by greater thermal comfort.

A comparison of this figure with Figure 28 (page 66), which shows the structure of building floor area by building age category, suggests the priorities for improving energy efficiency in residential buildings. While buildings constructed between 1971 and 1990 occupy 34 percent of the building floor area in 2030, they contribute 46 percent of the total final energy consumption and are therefore a clear priority for policy intervention. Another important category comprises buildings constructed between 1961 and 1970, which will occupy 16 percent of the floor area and be responsible for 17 percent of final energy consumption. New buildings will be responsible for 9 percent of final energy consumption in 2030, even though their floor area will occupy 22 percent of the sector total. This estimate is made assuming that new buildings comply with the building code introduced in 2011. If they do not comply with the code and are built in line with practices typical of the previous 15 years, their share in final energy consumption will be greater. For this reason, policies that ensure that new buildings comply with the building code are also important for policy making. It is far easier to regulate the energy performance of buildings at the point of planning and construction than it is to incentivise the retrofitting of new buildings at a later date.

We found that the breakdown of final energy consumption by building type will remain almost the same over the modelling period. As Figure 36 shows, in 2030 single-family houses will be responsible for around 85 percent of final energy consumption for thermal energy uses. Terraced houses, multi-dwelling houses and apartment blocks will account for 1 percent, 9 percent and 5 percent of the total final energy consumption respectively. This distribution of final energy consumption by building type suggests that single-family houses are a clear priority for policy making.

Figure 37 shows final energy consumption in the residential sector by building age and type over the modelling period. The biggest shares in final energy consumption in 2030 will originate in single-family houses built in 1971–1980, 1981–1990 and 1961–1970 (more than 15 percent in each category, calculated by decade). Single-family houses built after 2016 will also contribute a big share of final energy consumption (8 percent). These categories help to identify the key building categories to which standardised approaches for building efficiency improvements, and the related policies, could be applied.

Figure 38 shows final energy consumption broken down by energy use. Space heating will be responsible for the highest share of final energy consumption in 2030. Water heating and space cooling will be responsible for 9 percent and 1 percent respectively.

CO_2 emissions

Figure 39 presents the trends in CO_2 emissions associated with the residential building stock. Although CO_2 emissions from electricity and district heating are accounted in the transformation sector according to the IPCC guidelines (IPCC NGGIP online), because electricity and district heating are consumed in residential buildings, these emissions originate indirectly from this sector and are thus included in our analysis. The current emission factors are discussed in Section IV (page 39). The emission factor of electricity is assumed to change, as forecast by the SLED decarbonisation model for the electricity sector (Szabó et al. 2015). The emission factor of district heating is assumed to stay the same over the modelling period.

In 2015, the sector was responsible for 9.8 million tonnes of CO_2 emissions. As Figure 39 illustrates, electricity is by far the largest source of CO_2 emissions in the residential building sector, followed by lignite and

Figure 33 Final energy consumption for thermal energy services in the reference scenario, 2015–2030

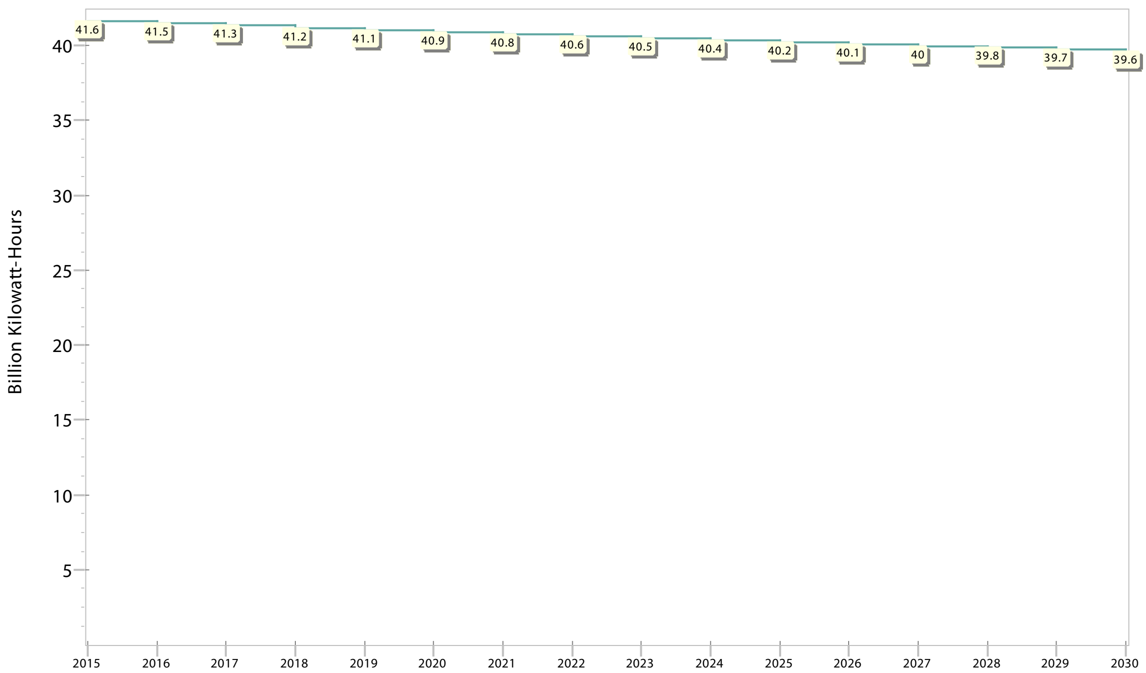


Figure 34 Final energy consumption by energy source in the reference scenario, 2015–2030

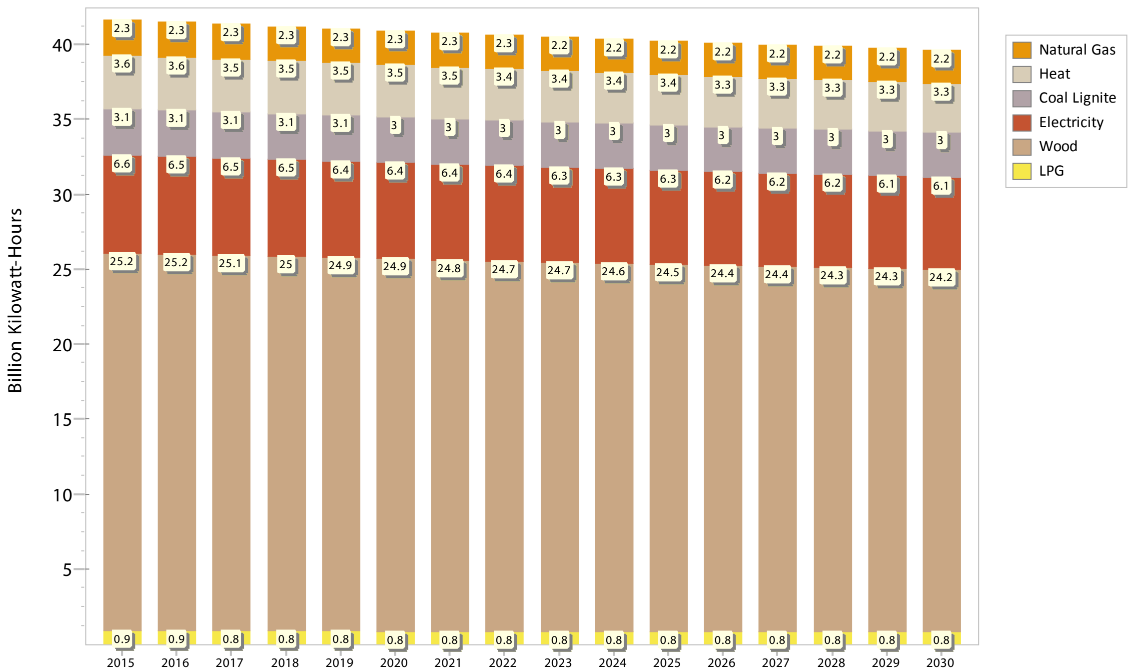


Figure 35 Final energy consumption by building age category in the reference scenario, 2015–2030

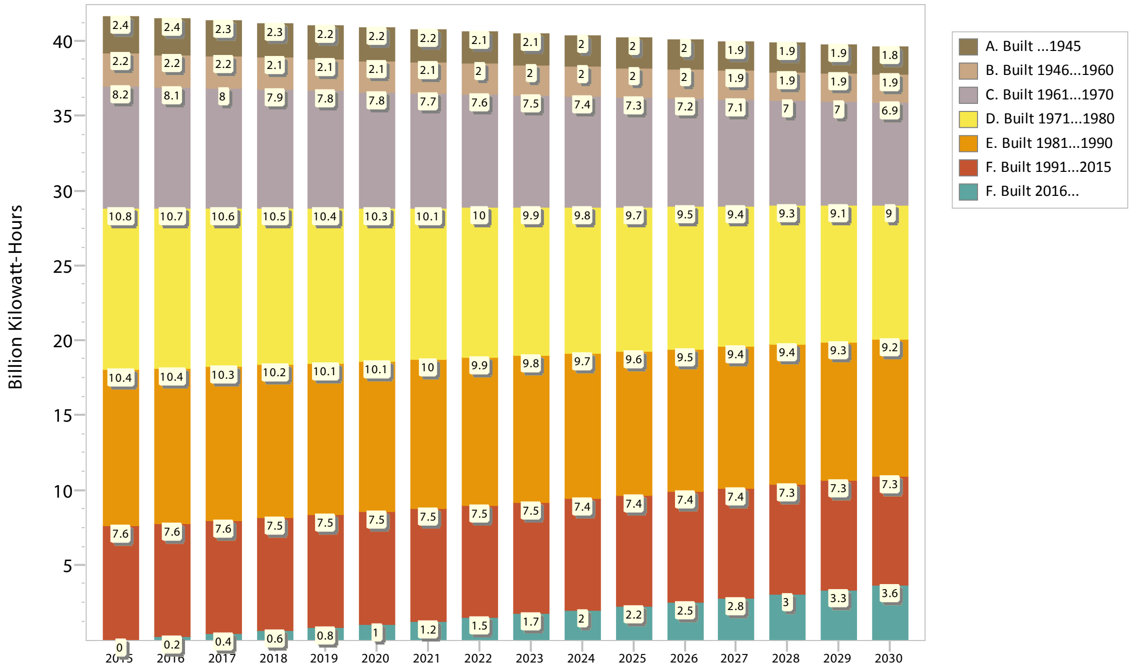


Figure 36 Final energy consumption by building type in the reference scenario, 2015–2030

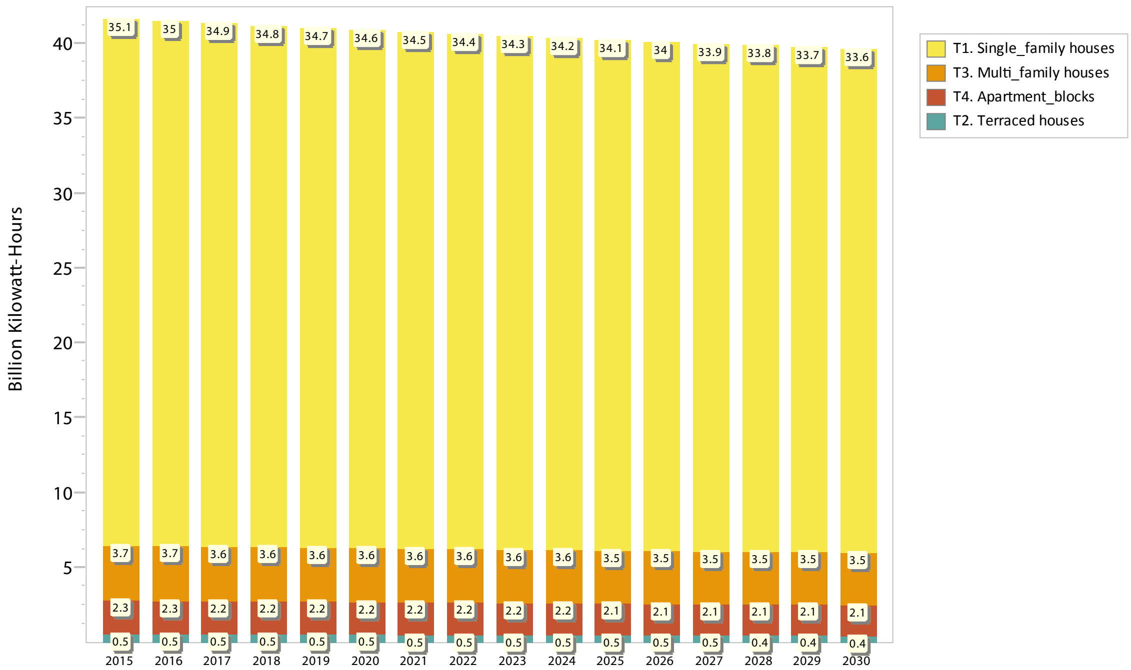


Figure 37 Final energy consumption by building age and type in the reference scenario, 2015–2030

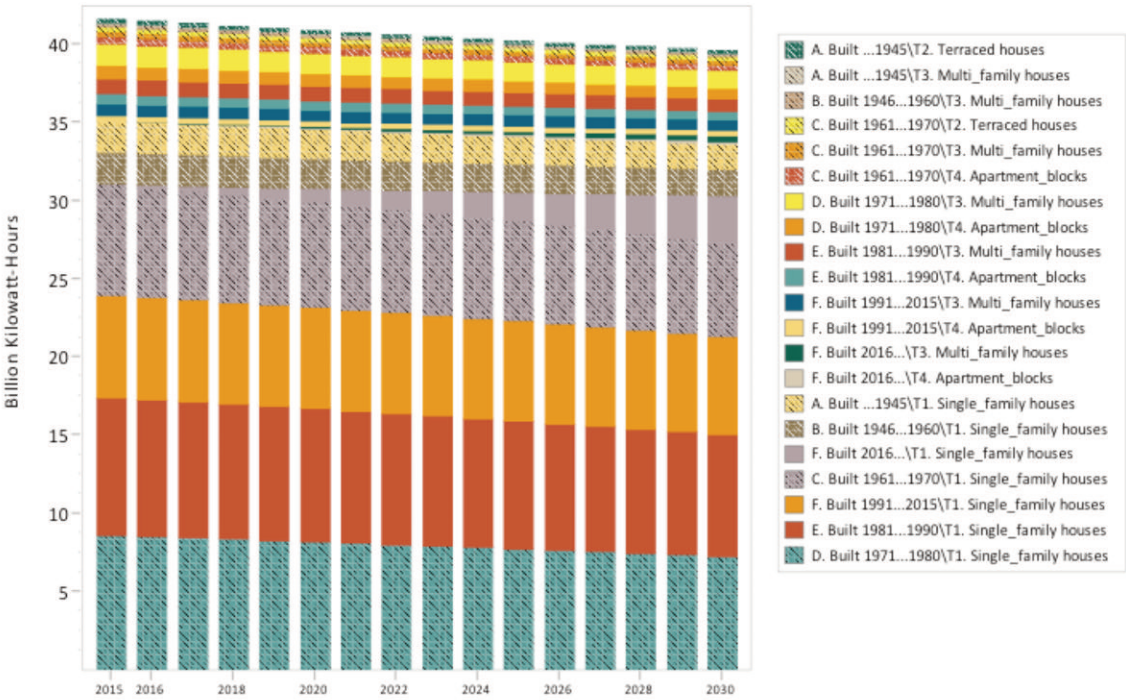
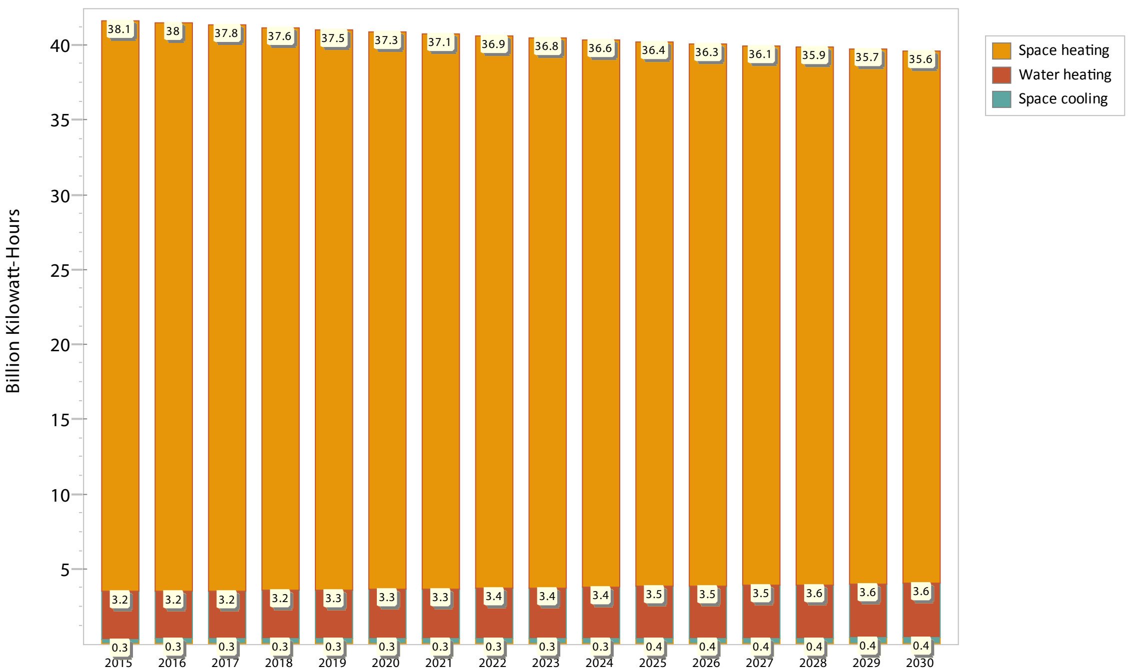


Figure 38 Structure of final energy consumption by end use in the reference scenario, 2030



district heating. The changes in electricity-associated emissions over 2015–2030 are caused by the changing emission factor. In 2030, CO_2 emissions will be 89 percent of their 2015 level.

Energy costs

The current price of electricity for residential users is EUR 0.058/kWh (EUROSTAT), which is almost equal to the electricity wholesale price calculated in the SLED electricity decarbonisation model (Szabó et al. 2015). This means that the current electricity price for households is regulated, something that is unlikely to continue in the future due to the integration of the Serbian electricity market into the EU market. In 2012, on average, taxes and network costs accounted for 58 percent of the electricity price for households in the EU, while energy and supply costs accounted for 42 percent (European Commission 2014). The share of taxes and network costs is continuing to grow. If this tendency is replicated in Serbia, the price of electricity will rise significantly.

We assumed a significant increase in the electricity price in Serbia before and following its accession to the EU. By 2030, the share of taxes and network costs in the electricity price will be around 42 percent of the electricity price — that is, in keeping with the EU average. This represents an increase in the electricity price of 6 percent per year between 2015 and 2030, reaching EUR 0.137/kWh in 2030.

The current price of natural gas for residential users is EUR 13/GJ (EUROSTAT). According to the World Bank forecast for energy commodity prices (World Bank 2015), the real price of natural gas will not change over the modelling period, thus we assumed a constant price.

The current LPG price is EUR 0.45/litre (Global petrol prices online). We assumed that in the future the LPG price would increase in line with the price of oil. The growth in the oil price is estimated at 2.7 percent per year between 2015 and 2030 according to the forecast for energy commodity prices provided by the World Bank (World Bank 2015).

The current lignite price was identified based on a report by our national consultants (see Section VI, page 47) at EUR 96/tonne. A 0.9 percent growth in the price of lignite per year is assumed between 2015 and 2030 according to the forecast for coal prices provided by the World Bank (World Bank 2015).

The current price of district heating is EUR 0.06/kWh, according to a report by our national consultants (see Section VI, page 47). We assumed that this price would change as a weighted average of the fuels in the fuel mix used by district heating plants. The fuel mix is taken as constant over 2015–2030, and the latest fuel mix is taken from International Energy Agency statistics.

Finally, the current price of wood is assumed to be EUR 50/m^3, according to a report by our national consultants. Since wood can be substituted by any of the energy sources listed above, we assumed that its price would change as a weighted average of these energy sources according to their contribution to addressing space-heating needs.

Taking into account these assumptions, in 2030 energy costs for residential consumers in the business-as-usual scenario will reach EUR 2.4 billion (Figure 40).

Figure 41 presents energy costs per square metre of the total building floor area. The figure illustrates that, in the case of the business-as-usual scenario, in 2030 residential consumers will pay around EUR 6.7/m^2 for thermal services in 2030.

Figure 39 CO_2 emissions from electricity consumption in the reference scenario, 2015–2030

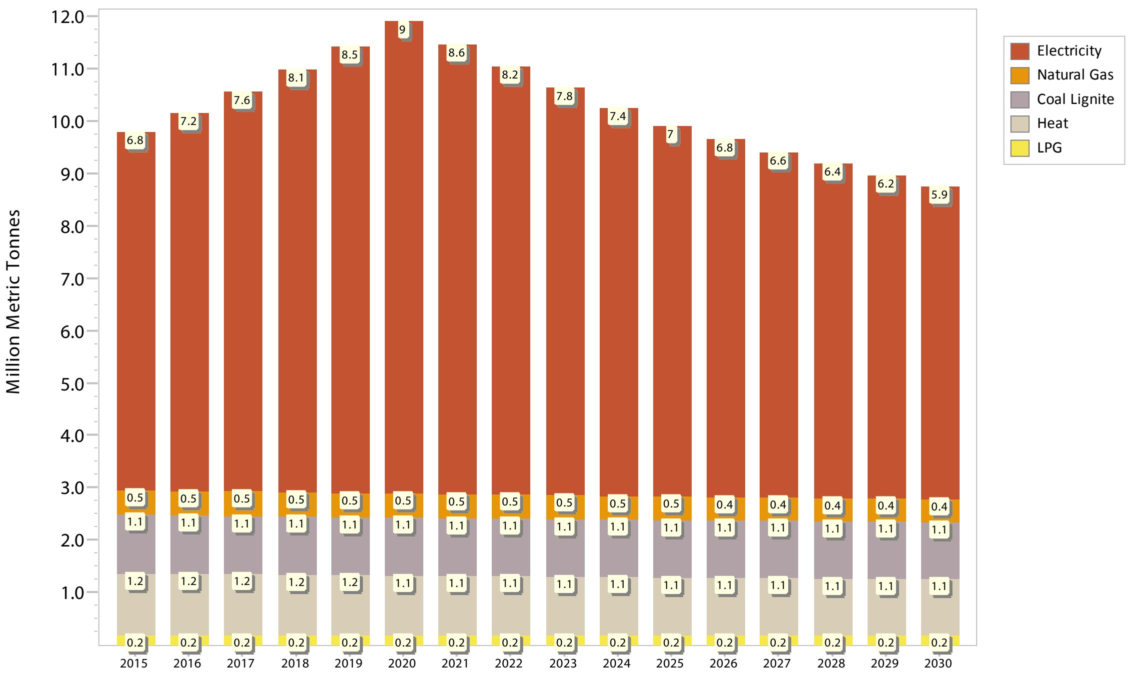


Figure 40 Energy costs in the reference scenario, 2015–2030

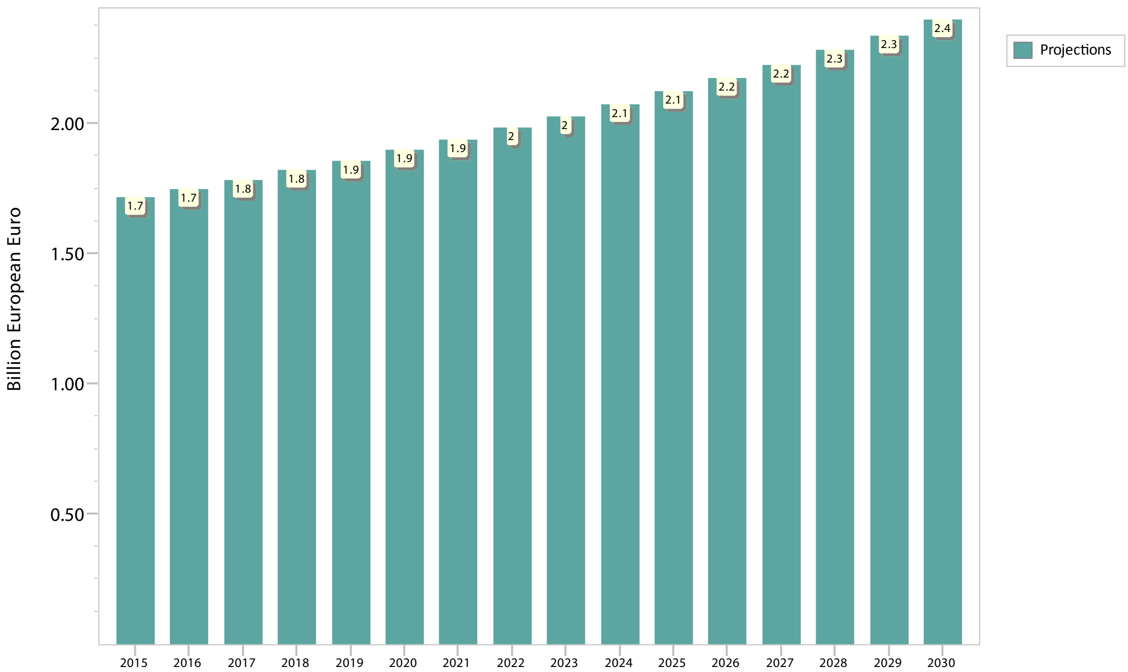
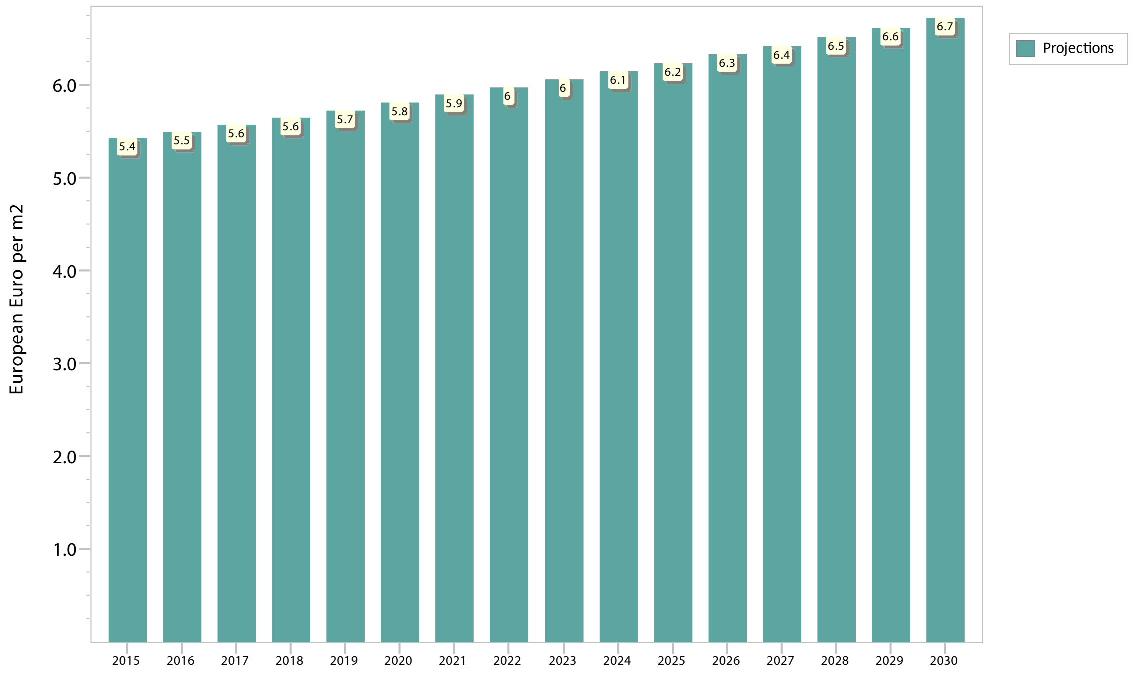


Figure 41 Annual energy costs per m² in the reference scenario, 2015–2030



XII. SLED moderate scenario: Results

Final energy consumption

In 2030, final energy consumption in the SLED moderate scenario, including renewable energy, will be around 33 billion kWh, or 17 percent lower than the business-as-usual level (Figure 42).

The biggest final energy savings in absolute terms are associated with wood and electricity (Figure 43). Avoided wood consumption is around 3.7 billion kWh, or 15 percent of business-as-usual wood consumption in 2030. Avoided electricity consumption is about 2 billion kWh, or 33 percent of business-as-usual electricity consumption in 2030. However, the SLED moderate scenario assumes an increased share of natural gas of 0.6 billion kWh, or an additional 26 percent of the business-as-usual consumption in 2030.

Figure 44 shows the structure of final energy savings by building age category. It shows that the biggest final energy savings are associated with the retrofitting of the thermal envelope of buildings constructed in 1971–1980, 1981–1990 and 1961–1970.

Figure 45 illustrates the structure of final energy savings by building type. The figure shows that the majority of final energy savings originate from single-family houses because of their dominant share in the sector's total floor area, as well as their big potential for energy savings per square metre. Retrofitting single-family houses is a clear priority for policy making in Serbia.

The breakdown of final energy savings by building age and type shows that the key categories for these savings are single-family houses constructed in 1971–1980, 1981–1990 and 1961–1970 (Figure 46). Final energy savings in single-family houses built in 1991–2015 are also significant, but if these savings are recalculated by decade they become smaller.

As Figure 47 shows, the biggest final energy savings are possible in relation to space heating. Final energy consumption for water heating in the SLED moderate scenario is higher than in the reference scenario because of a fuel switch from electric water-heating systems to wood and natural gas systems (combined with space heating), where efficiencies for water heating are lower.

Average final energy consumption per square metre will be 17 percent lower in 2030 as compared to the business-as-usual level, reaching 92 kWh/m^2 (Figure 48).

CO_2 emissions

As Figure 49 illustrates, emissions from the residential sector will be 27 percent lower in 2030 versus their business-as-usual level. The reduction in CO_2 emissions is mostly associated with electricity use.

Saved energy costs

In 2030, energy costs to residential consumers in the SLED moderate scenario will be 20 percent lower than the energy costs in the business-as-usual case. In absolute terms, this difference represents EUR 0.5 billion (Figure 50).

Figure 51 shows saved energy costs per square metre of the total building floor area. The figure illustrates that, in the SLED moderate scenario, in 2030 residential consumers will pay around EUR 1.3/m^2 less for thermal services than in the business-as-usual case.

Investments

The transformation to a more efficient residential building stock in Serbia requires significant investments. It is clear that these investments will not, and cannot, be financed from the public budget alone. The government aims to introduce policy tools and use the available public budget to leverage private investments in the thermally efficient retrofitting and construction of buildings.

Each building undergoes renovation at least once during its lifetime for different reasons, which are not necessarily linked to energy efficiency. The business-as-usual renovation costs often include plastering and painting, floor tiles, new windows and doors of mediocre quality, as well as the changing of space- and water-heating systems. It is therefore very convenient and more cost-effective to integrate thermal efficiency improvements into the business-as-usual retrofitting of buildings in order to take advantage of costs that are incurred anyway, and to pay in addition only the incremental costs of energy efficiency.

Below, we refer to the total investment costs of the scenarios as the total costs of the scenarios without deducting the business-as-usual costs that are incurred in the reference scenario. By the incremental investment costs of the scenarios we understand the

Figure 42 Final energy consumption in the SLED moderate scenario and final energy savings vs. the reference scenario, 2015–2030

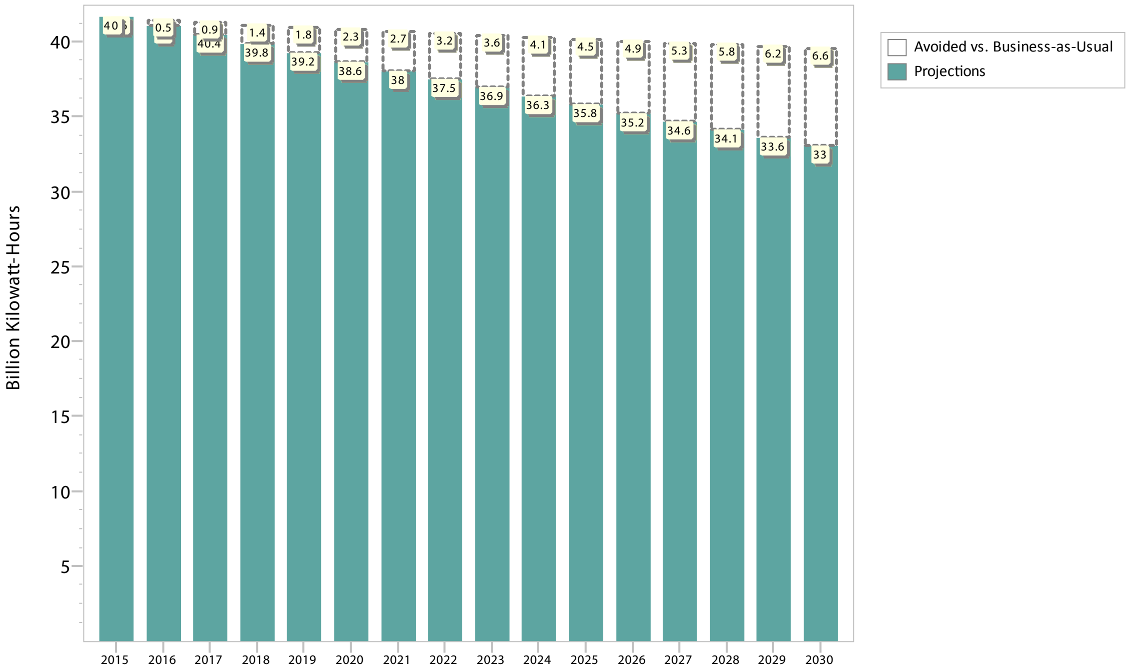


Figure 43 Final energy savings by energy source in the SLED moderate scenario vs. the reference scenario, 2015–2030

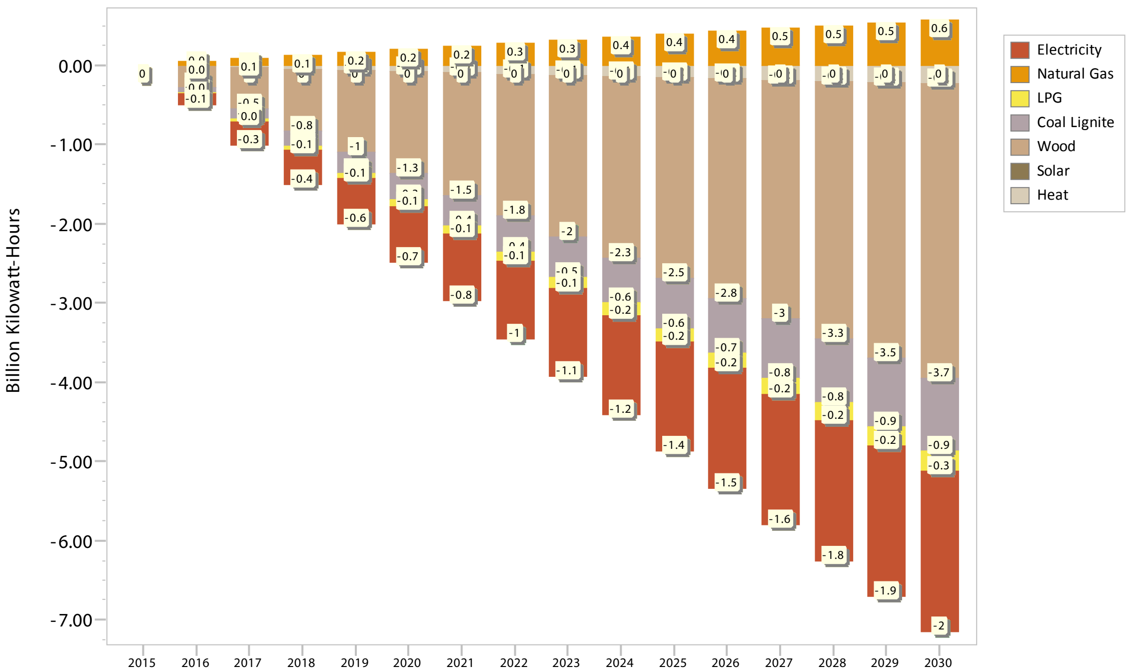


Figure 44 Final energy savings by building age category in the SLED moderate scenario vs. the reference scenario, 2015–2030

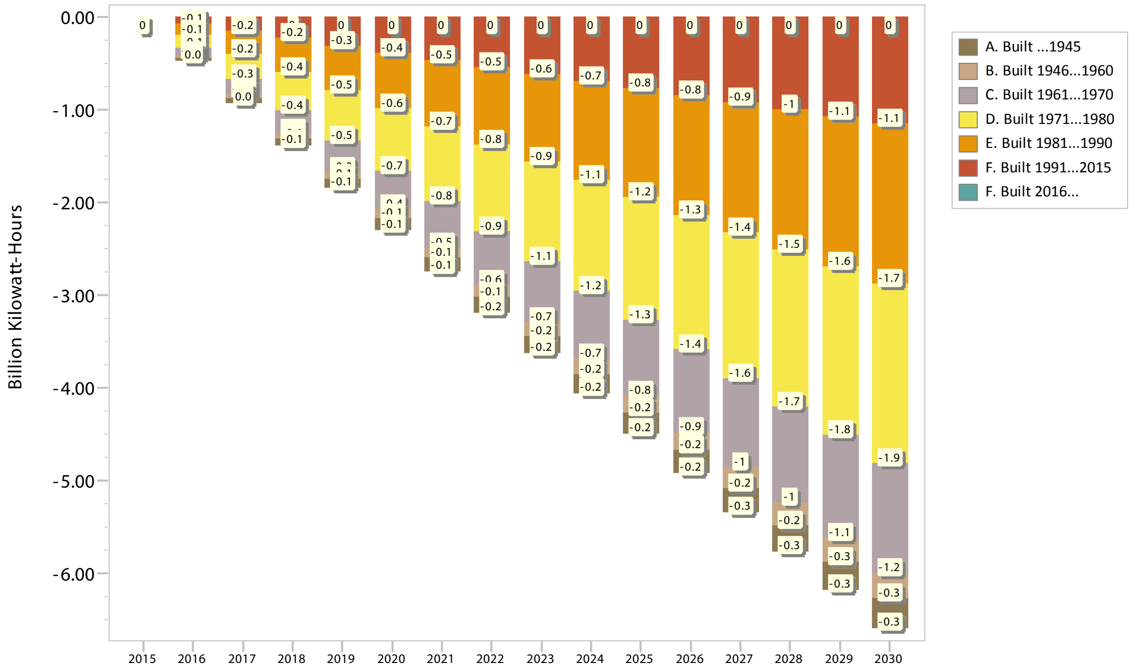


Figure 45 Final energy savings by building type in the SLED moderate scenario vs. the reference scenario, 2015–2030

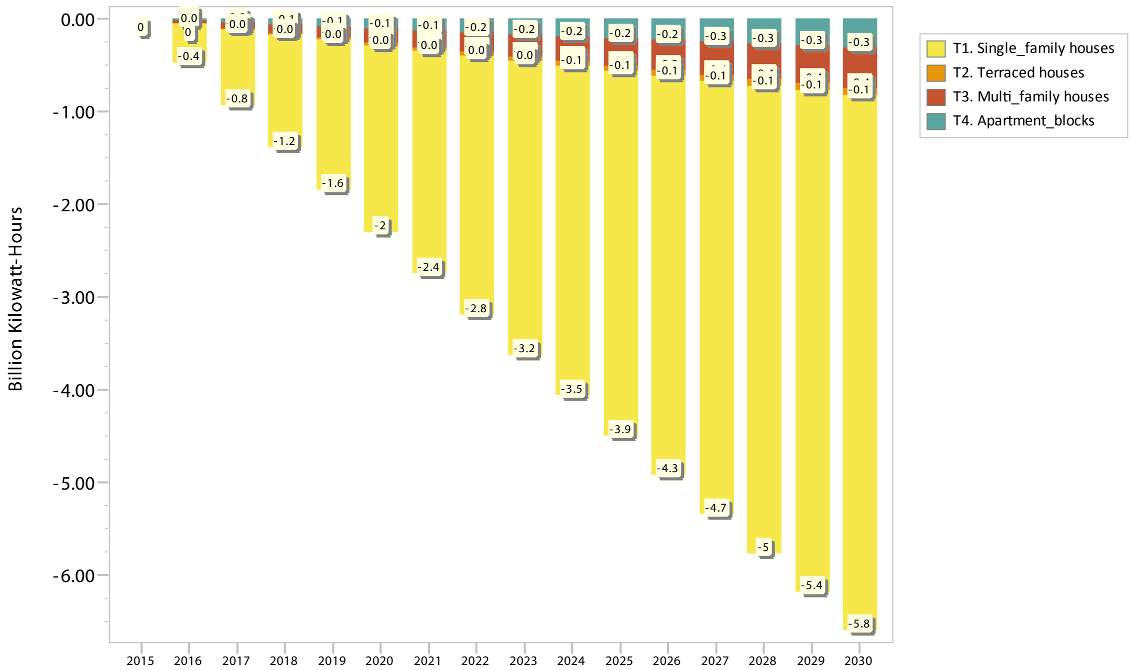


Figure 46 Final energy savings in the SLED moderate scenario by building age and type categories vs. the reference scenario, 2015–2030

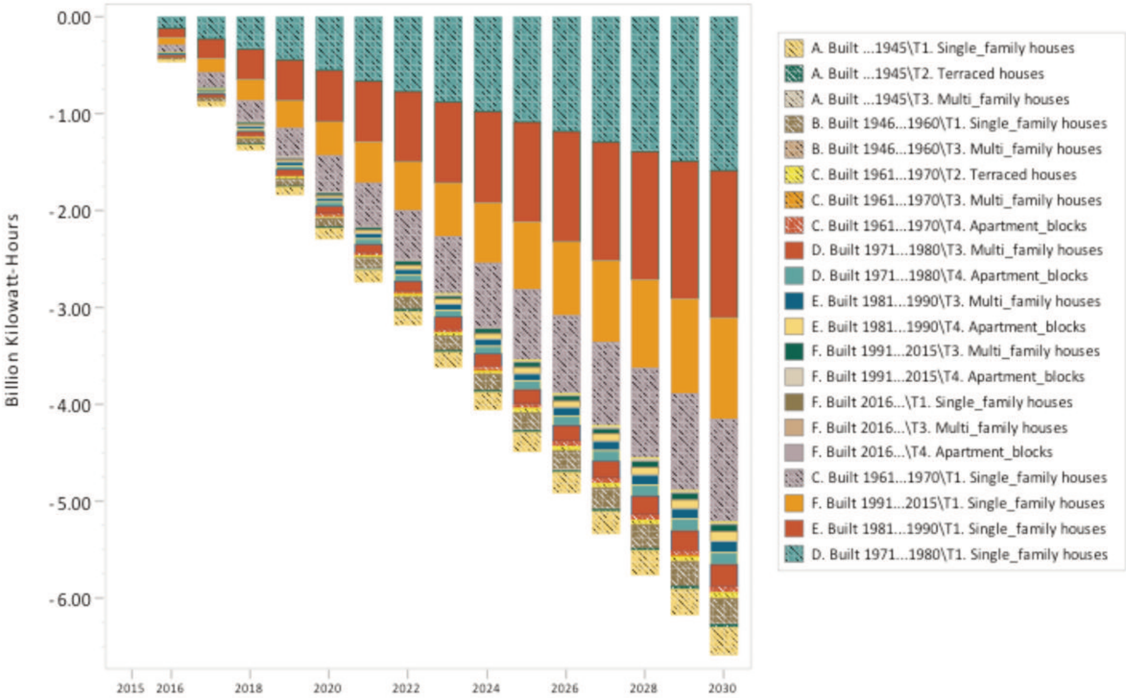


Figure 47 Final energy savings by end use in the SLED moderate scenario vs. the reference scenario, 2015–2030

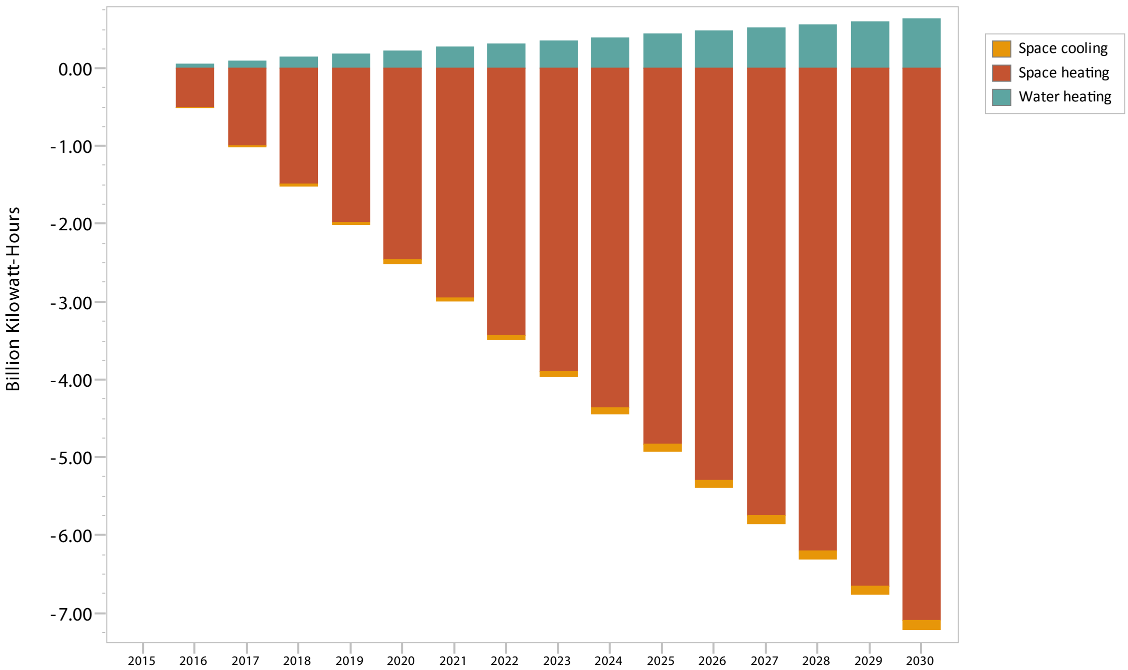


Figure 48 Final energy consumption per m² in the SLED moderate scenario and its reduction vs. the reference scenario, 2015–2030

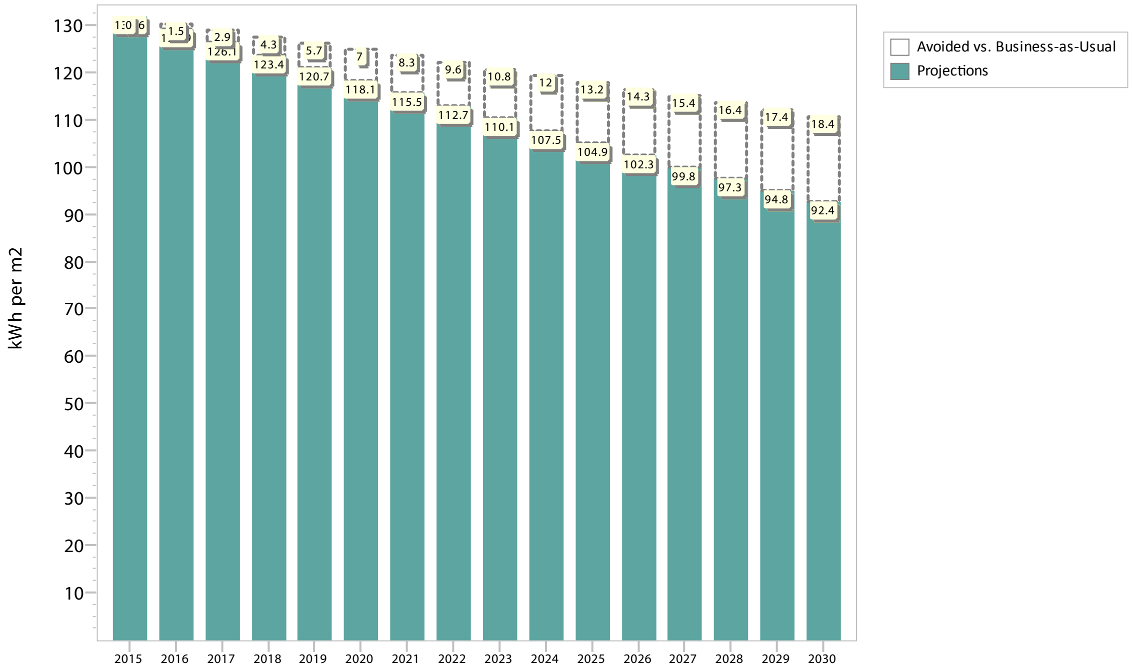


Figure 49 CO_2 emissions in the SLED moderate scenario and CO_2 emissions avoided vs. the reference scenario, 2015–2030

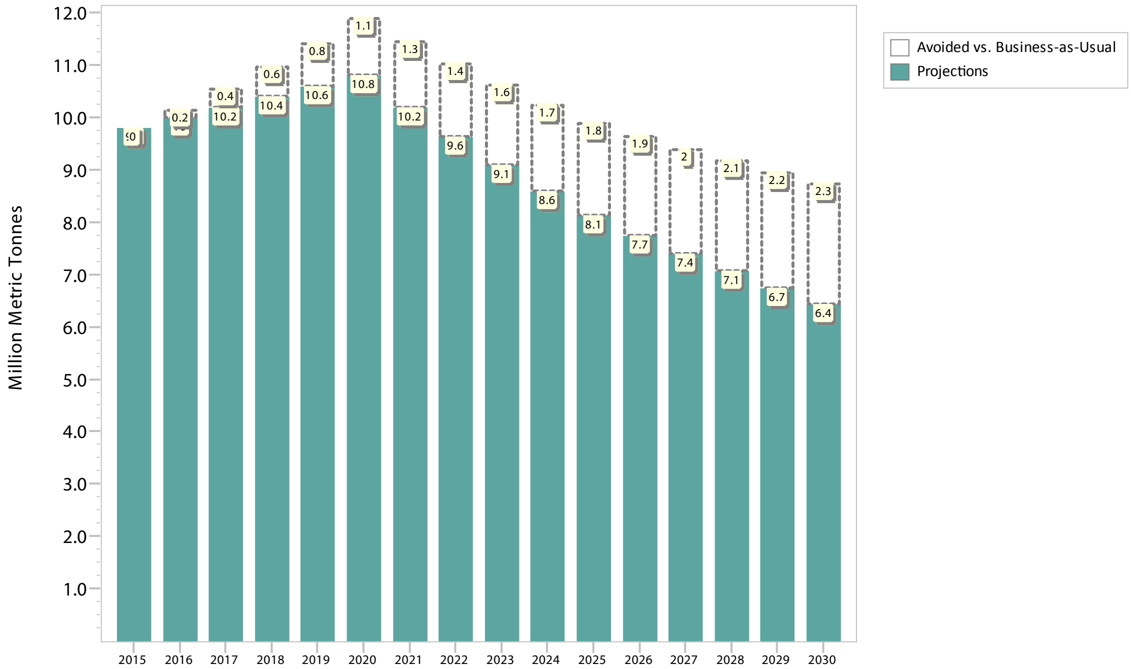


Figure 50 Energy costs in the SLED moderate scenario and saved energy costs vs. the reference scenario, 2015–2030

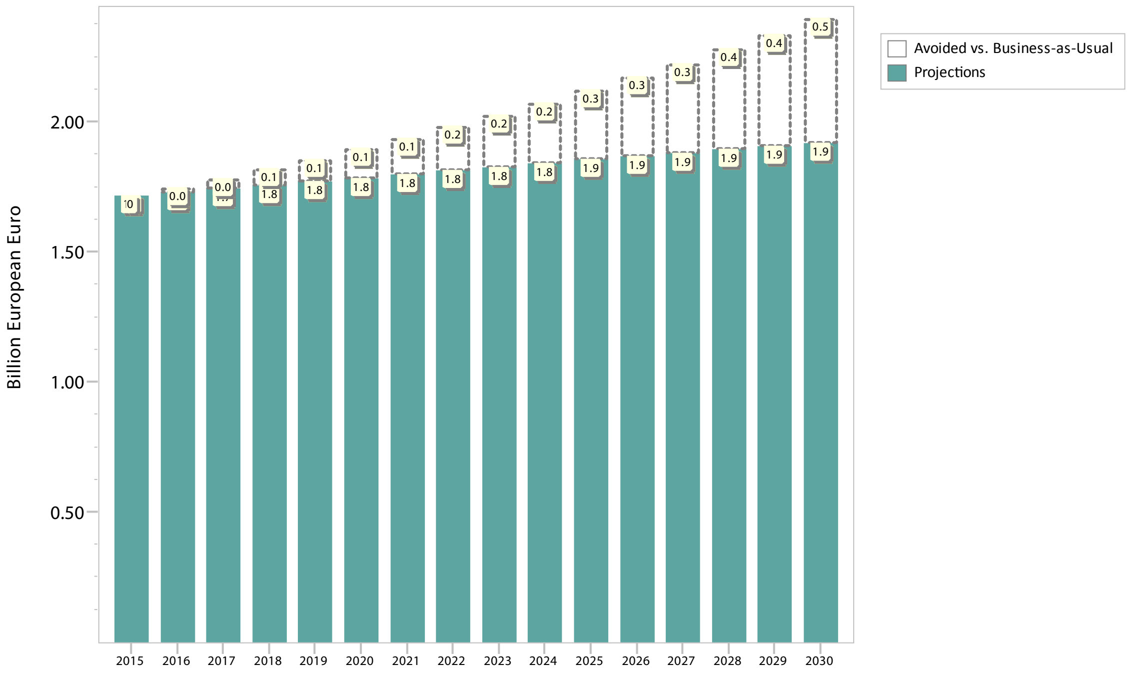
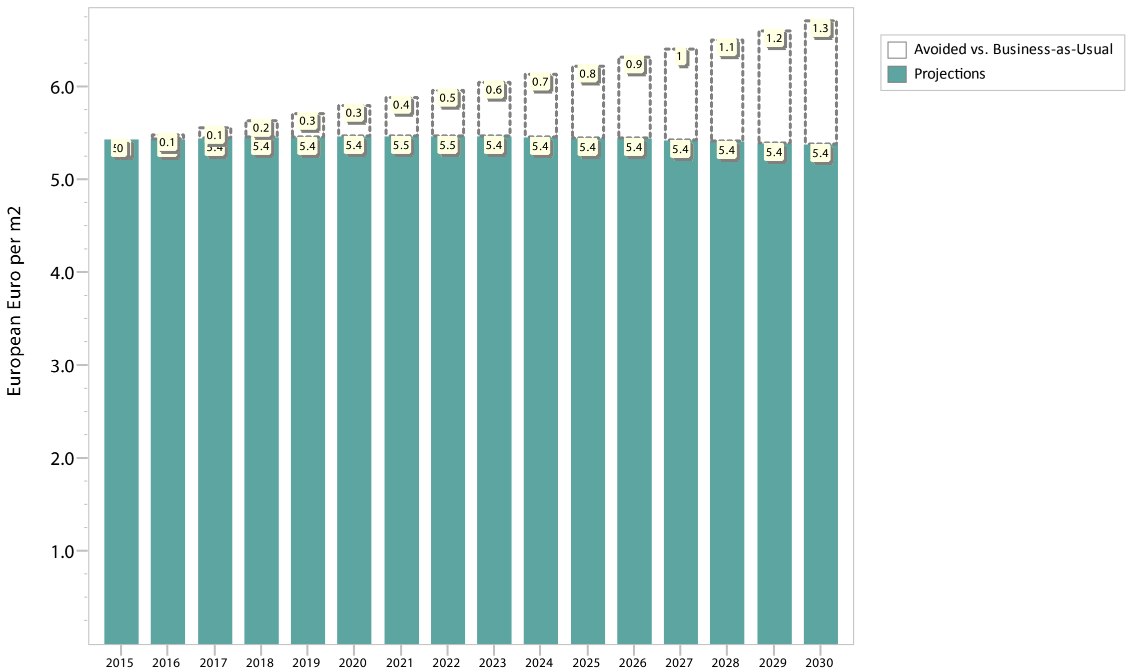


Figure 51 Energy costs per m² in the SLED moderate scenario and saved energy costs per m² vs. the reference scenario, 2015–2030



difference between the total costs of the scenarios and the business-as-usual costs of the reference scenario that are incurred anyway. The retrofitting rate in the reference scenario and scenarios with additional measures may be different, which is why scenarios with additional measures may include not only the incremental costs but also the total investment costs for a part of the building stock that is not affected by business-as-usual renovations.

The retrofitting rate in the SLED moderate scenario is slower than the retrofitting rate in the reference scenario, which is why the incremental costs of the SLED moderate scenario include all the incremental investment costs of the thermal efficiency retrofitting of retrofitted buildings, but not the total investment costs. In the case of newly constructed buildings, it makes sense to consider only the incremental costs of energy efficiency improvements, since the construction costs anyway include the business-as-usual costs of building components and systems.

In order to calculate the retrofitting costs at sector level, we multiplied the cost of building improvements by the floor area affected in the SLED moderate scenario. The costs of building improvement 1 per square metre are documented in Section VI. The cost of the business-as-usual improvement of existing buildings was assumed to be EUR 90/m^2 for single-family and terraced houses, EUR 56/m^2 for multi-family buildings, and EUR 64/m^2 for apartment blocks, based on the business-as-usual costs assumed for retrofitting in Montenegro in a similar SLED study (Novikova, Csoknyai et al. 2015). These costs do not include the installation of separate air conditioning. If separate air conditioners are installed, we add EUR 10/m^2 to the business-as-usual retrofitting costs.

Figure 52 shows the floor area affected by the SLED moderate scenario. On average, 6.6 million m^2, or 2 percent of the total building floor area per year, are retrofitted between 2015 and 2030.

The retrofitting of the existing floor area is supported by low-interest loans and grants over the whole modelling period, as discussed in the assumptions in Section X (page 76). The whole of the new building floor area is regulated by the building code.

For existing buildings, we found that the total investment cost per square metre is in the range of EUR 70 to EUR 219, depending on the building type and age. If the business-as-usual costs are deducted from the total investment costs, the incremental costs of retrofitting existing buildings are around EUR 17 to EUR 155/m^2, depending on the building type and age. Such a big deviation in costs can be explained by the fact that in some cases the space- and water-heating systems were changed, and in some cases were not.

Figure 53 presents the total investment costs in the SLED moderate scenario in the thermal efficiency retrofitting of buildings over the modelling period. We estimated that, on average, these costs are around EUR 822 million per year between 2015 and 2030. The biggest investments are required in buildings constructed in 1971–1980, 1961–1970 and 1981–1990 (if the categories are recalculated by decade). Over the modelling period, the cumulative total investment costs of the SLED moderate scenario are around EUR 12.3 billion.

Figure 54 presents the incremental investment costs in the SLED moderate scenario in the thermal efficiency retrofitting of buildings over the modelling period. The figure shows the clear benefits of coupling thermal efficiency improvements with the business-as-usual retrofitting of existing buildings. We estimated that the scenario incremental investment costs are on average EUR 329 million per year between 2015 and 2030. The cumulative incremental costs over the modelling period are around EUR 4.9 billion.

Assuming a measure lifetime of 30 years and a discount rate of 4 percent, the annualised incremental costs of the SLED moderate scenario over 2015–2030 are EUR 2.9/m^2. Average saved energy costs are around EUR 3.8/m^2 of new or retrofitted floor area over the modelling period. This means that investments in better existing and new buildings will pay back. It is important to note that the saved energy costs are higher than the annualised investment costs for the scenario as a whole at country level, but not for all building categories. For a few building categories, saved energy costs are lower than the annualised incremental investment costs, thus for them the incremental investments do not pay back. Raising the discount rate higher than 6.5 percent would make the SLED moderate scenario unattractive if only saved energy costs are considered as scenario benefits. The analysis is carried out assuming a likely increase in energy prices.

We provided an analysis of the efforts of different actors if Serbia aims to follow the SLED moderate scenario. The analysis was carried out assuming a market loan interest rate of 10 percent; a loan interest rate of 0 percent, subsidised by the government; a loan term of 10 years; and a discount rate of 4 percent.

Figure 52 Floor area of new and retrofitted buildings in the SLED moderate scenario, 2015–2030

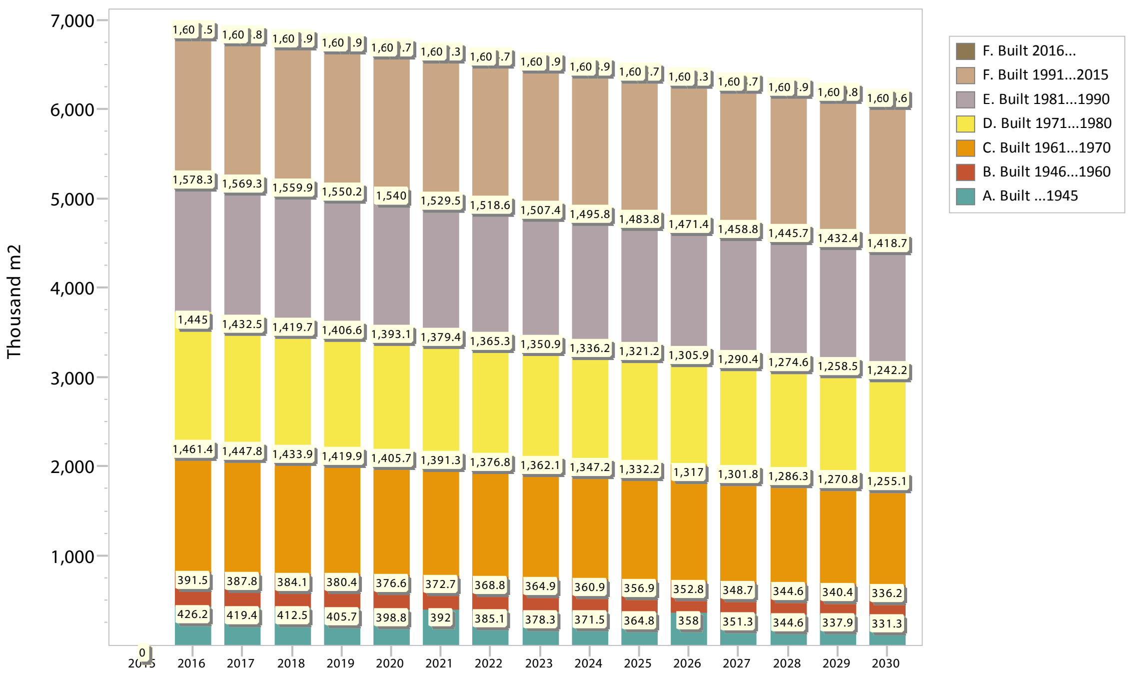
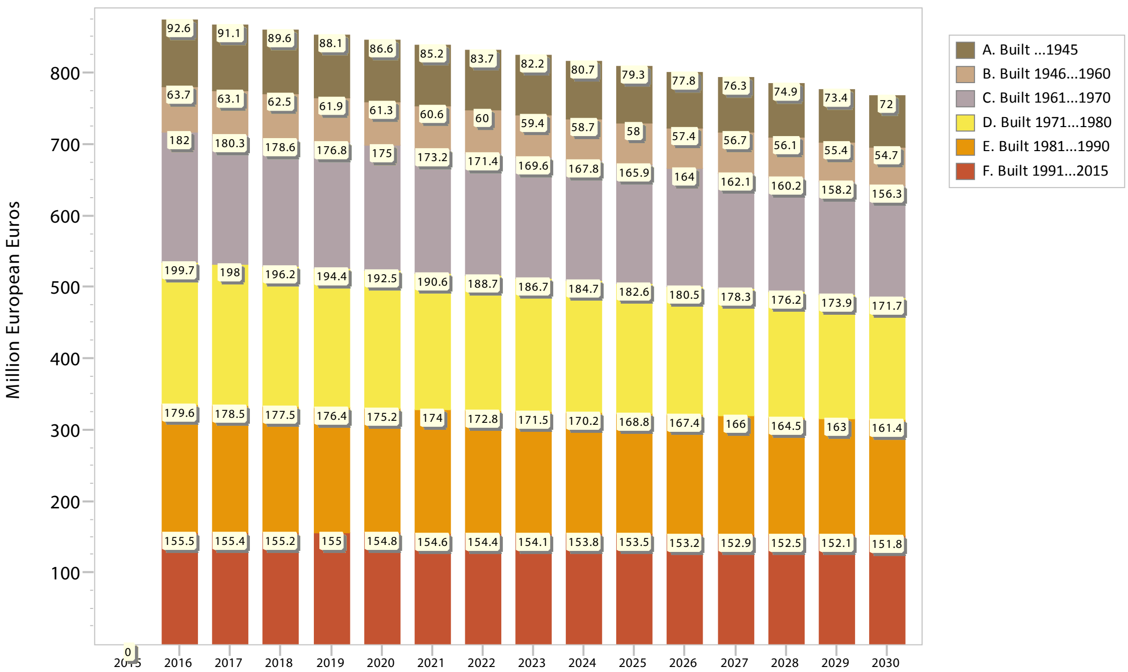


Figure 53 Total investment costs in the SLED moderate scenario, 2015–2030



In the model, we provided the option to assume eligible costs as a share of the total investment costs for each policy incentive in order to regulate the desired level of support. In our calculations, we assumed that around 46 percent of the total investment cost is supported by grants or low-interest loans for single-family and terraced houses, and around 48 percent for multi-dwelling houses and apartment blocks. This is approximately equal to the share of incremental investment costs in the SLED moderate scenario.

The mechanism of low-interest loans works in such a way that households borrow capital from commercial banks at a low interest rate, and the government compensates the commercial banks for the difference between the market loan interest rate and the subsidised low-interest rate. Figure 55 shows the finance borrowed by residential stakeholders for the purposes of building retrofitting. Given our assumptions, the eligible costs of building retrofitting that investors would borrow are around EUR 313 million per year, or around EUR 5 billion over the modelling period.

Figure 56 shows the compensation paid by the government to commercial banks. Since the lending period is 10 years, the amount of compensation paid by the government to commercial banks is at its highest in 10 years. After this point, the amount of compensation stays almost the same until the end of the modelling period. Over the modelling period, the government provides EUR 2.2 billion to commercial banks as compensation for the low interest rate.

The government also provides grants for the retrofitting of existing buildings, as described in the assumptions in Section X (page 76). As Figure 57 shows, the value of the grants is around EUR 67 million per year, or EUR 1 billion over the modelling period.

Figure 54 Incremental investment costs in the SLED moderate scenario, 2015–2030

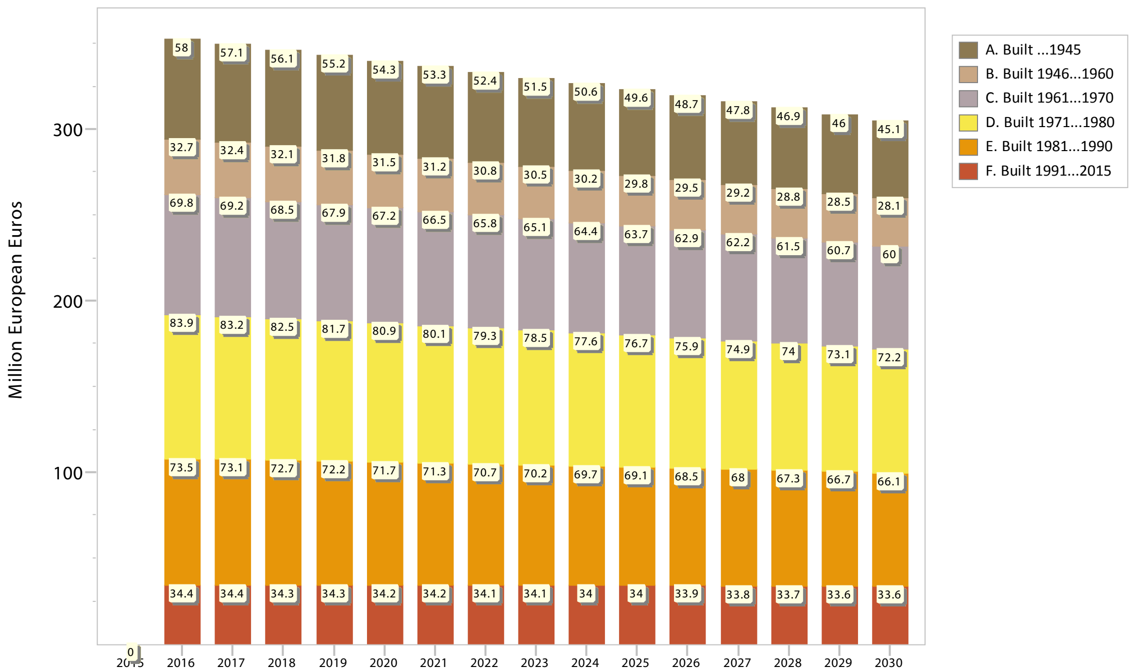


Figure 55 Private (eligible) investments stimulated by low-interest loans in the SLED moderate scenario, 2015–2030

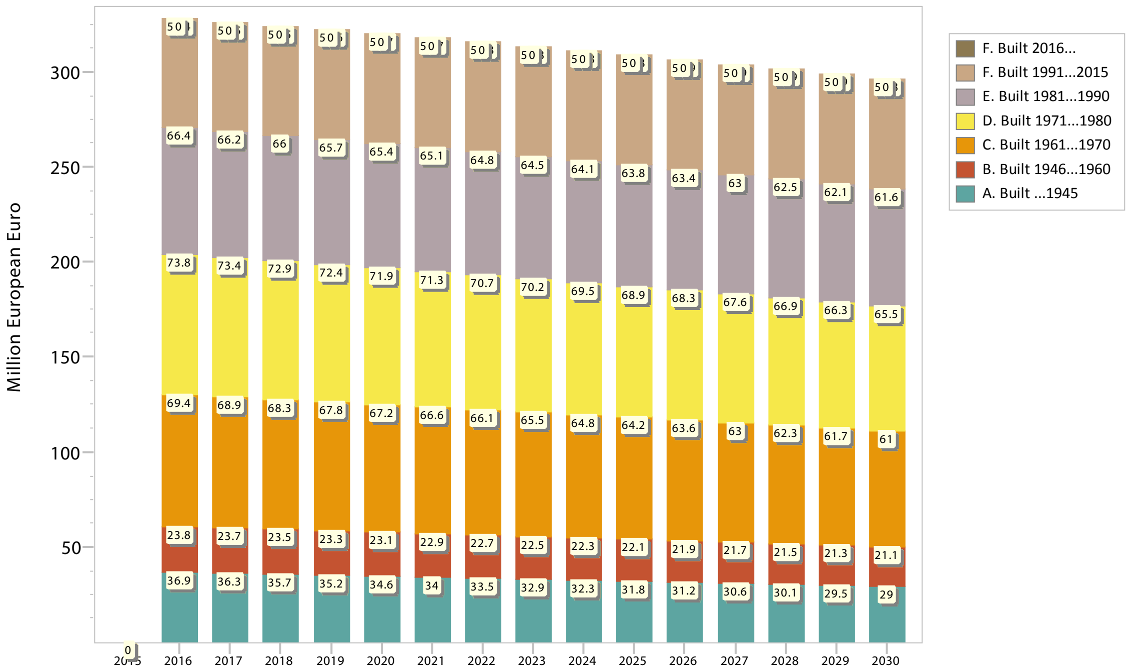


Figure 56 Cost to the government of low-interest loans in the SLED moderate scenario, 2015–2030

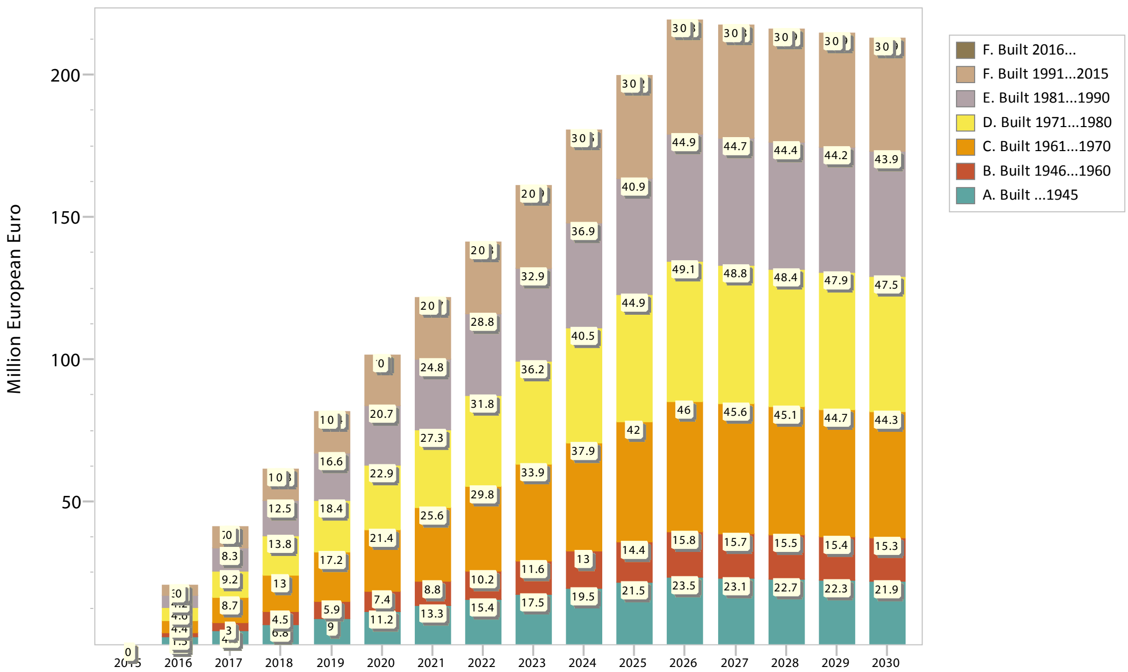
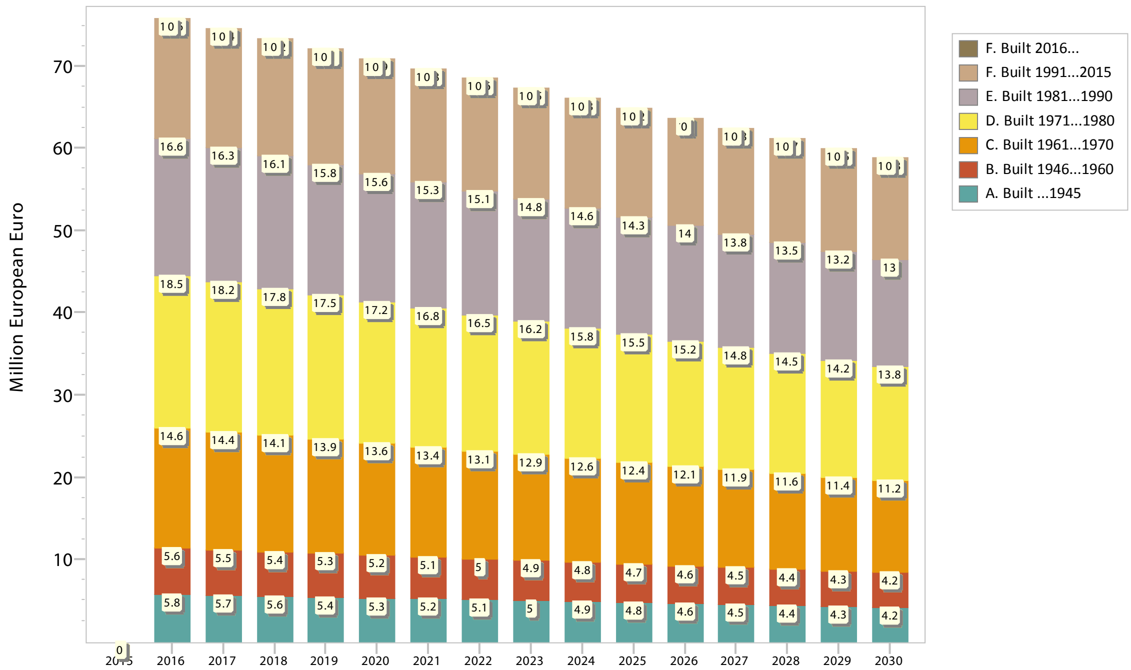


Figure 57 Cost to the government of grants in the SLED moderate scenario, 2015–2030



XIII. SLED ambitious scenario: Results

Final energy consumption

In 2030, final energy consumption in the SLED ambitious scenario will be around 29 billion kWh, or 27 percent lower than the business-as-usual level (Figure 58).

The biggest final energy savings are associated with wood (Figure 59). Avoided wood consumption is around 8.3 billion kWh, or 34 percent of business-as-usual wood consumption in 2030. Avoided lignite consumption is about 1.3 billion kWh, or 43 percent of business-as-usual lignite consumption in 2030. Avoided electricity consumption is about 0.8 billion kWh, or 13 percent of business-as-usual electricity consumption in 2030.

Figure 60 shows that, similar to the SLED moderate scenario, the biggest share of final energy savings is associated with the retrofitting of the thermal envelope of buildings constructed in 1971–1980, 1981–1990 and 1961–1970. In addition, the category of new buildings constructed after 2016 has very big potential for final energy savings. The category of buildings constructed in 1991–2015 is significant, although if split by decade the respective final energy savings are much smaller.

Figure 61 shows the structure of final energy savings by building type. The figure shows that the majority of final energy savings originate from single-family houses. This is because of their dominant share in the sector's floor area, as well as their greater potential for energy savings. Retrofitting single-family houses is a clear priority for policy making in Serbia.

The breakdown of final energy savings by building age and type shows that the key categories are single-family houses constructed in 1961–1970, 1971–1980, 1981–1990 and after 2016 (Figure 62).

As Figure 63 shows, the biggest final energy savings are possible in space heating. Similar to the SLED moderate scenario, final energy consumption for water heating increases because of a fuel switch to energy sources that are less efficient for heating water.

The average final energy consumption per square metre will be 27 percent lower in 2030 as compared to the business-as-usual level, and will reach around 81 kWh/m^2 (Figure 64). The reduction in final energy demand per square metre originates mainly from the retrofitting of existing buildings.

Figure 58 Final energy consumption in the SLED ambitious scenario and final energy savings vs. the reference scenario, 2015–2030

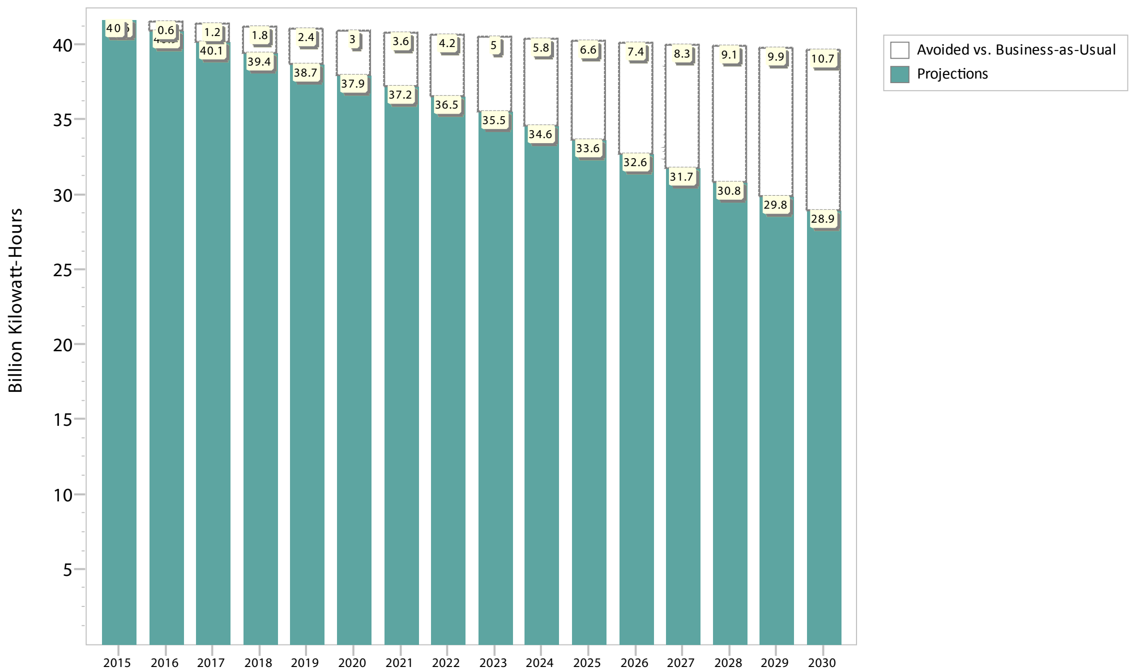


Figure 59 Final energy savings by energy source in the SLED ambitious scenario vs. the reference scenario, 2015–2030

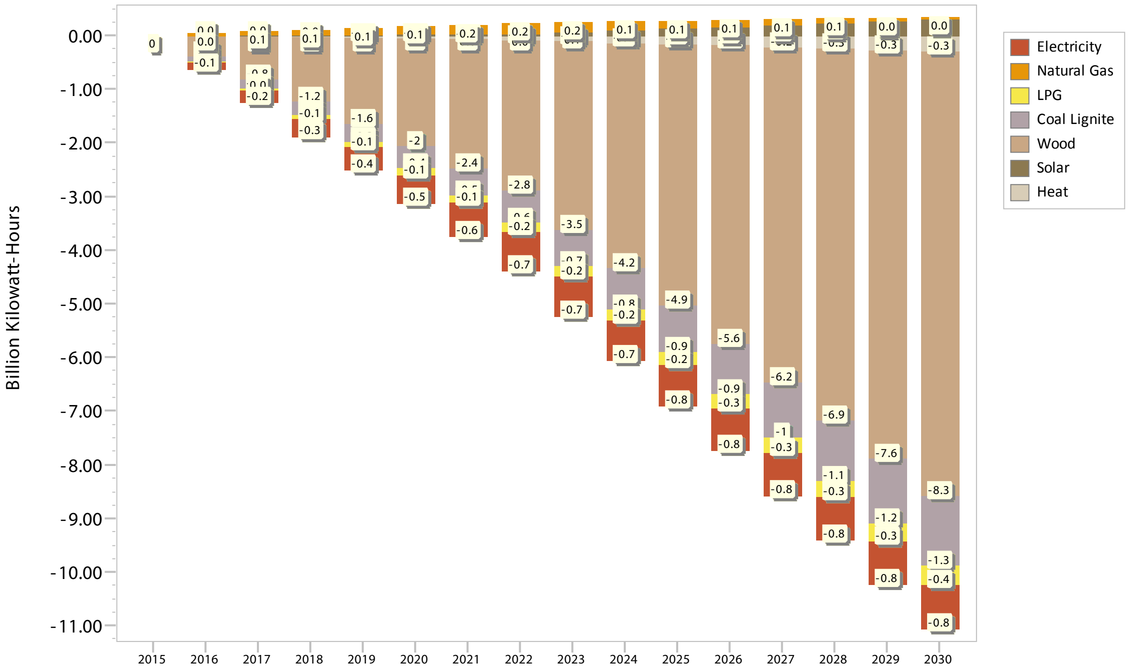


Figure 60 Final energy savings in the SLED ambitious scenario vs. the reference scenario by building age category, 2015–2030

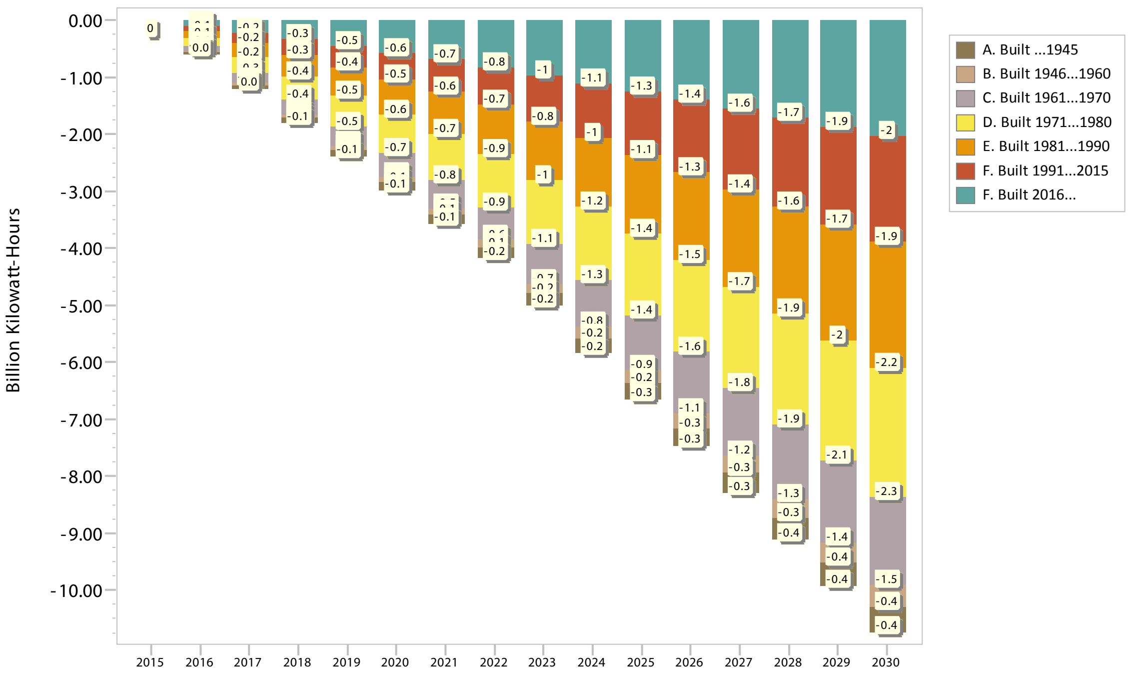


Figure 61 Final energy savings by building type in the SLED ambitious scenario vs. the reference scenario, 2015–2030

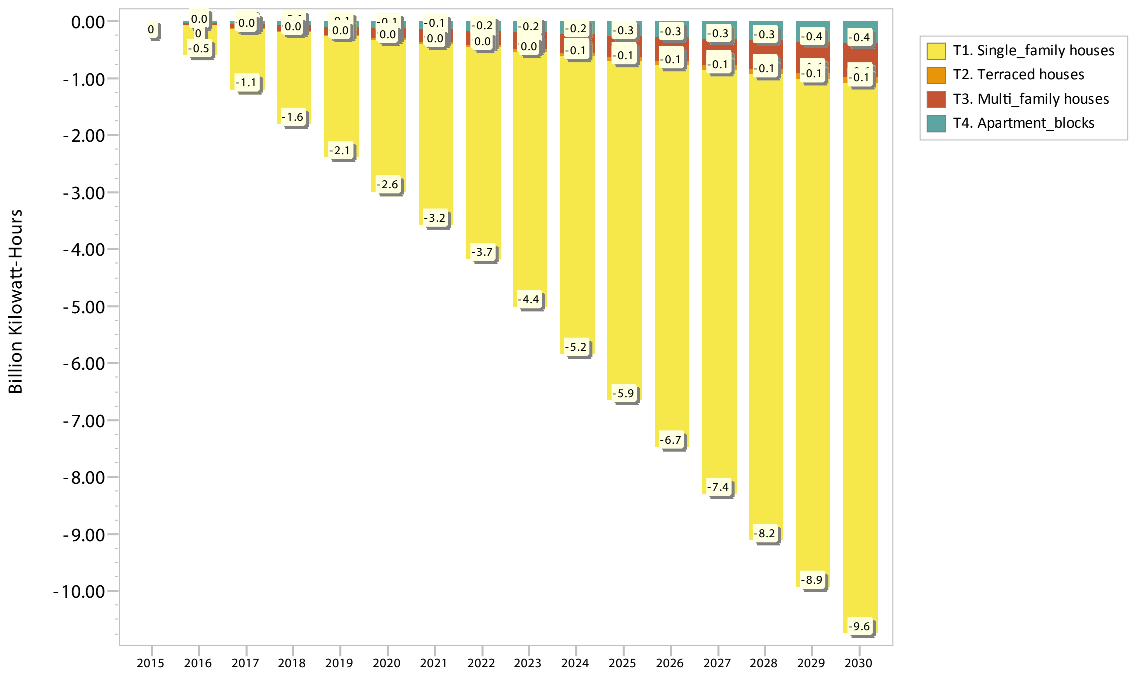


Figure 62 Final energy savings in the SLED ambitious scenario vs. the reference scenario by building age and type, 2015–2030

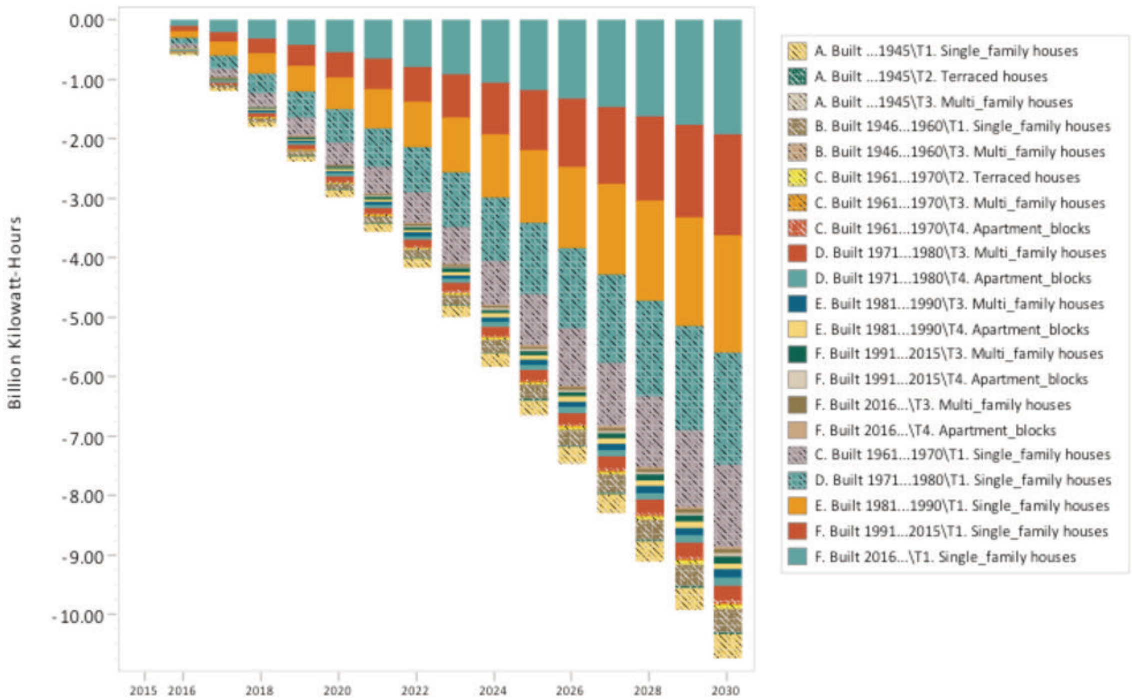


Figure 63 Final energy savings by end use in the SLED ambitious scenario vs. the reference scenario, 2015–2030

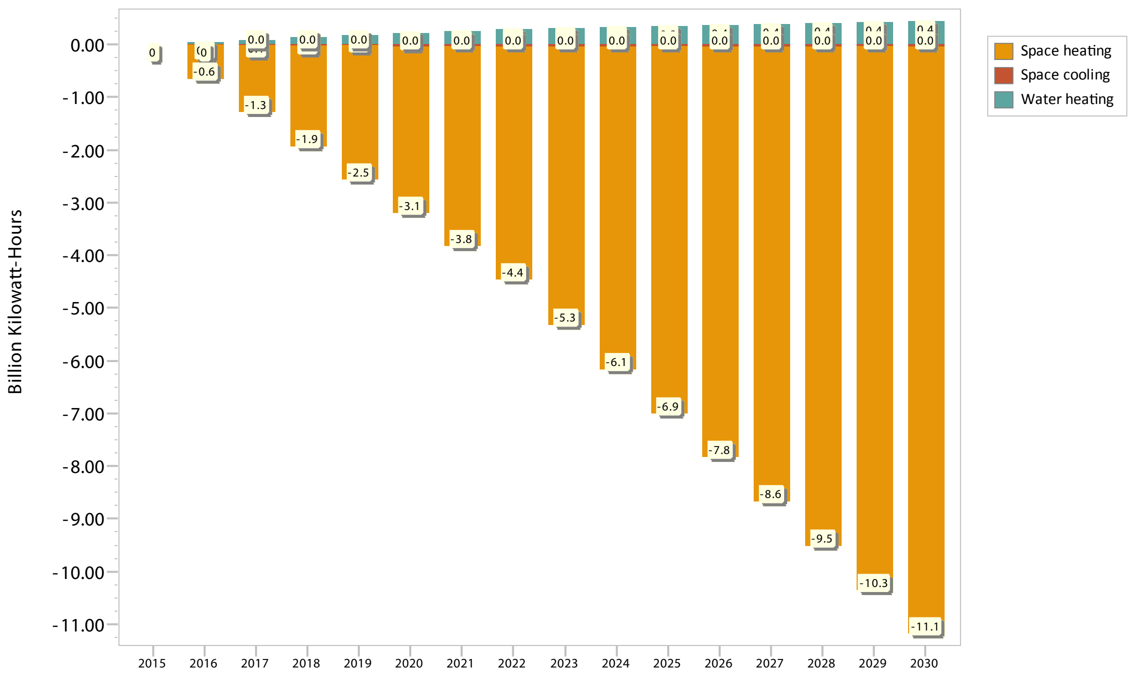
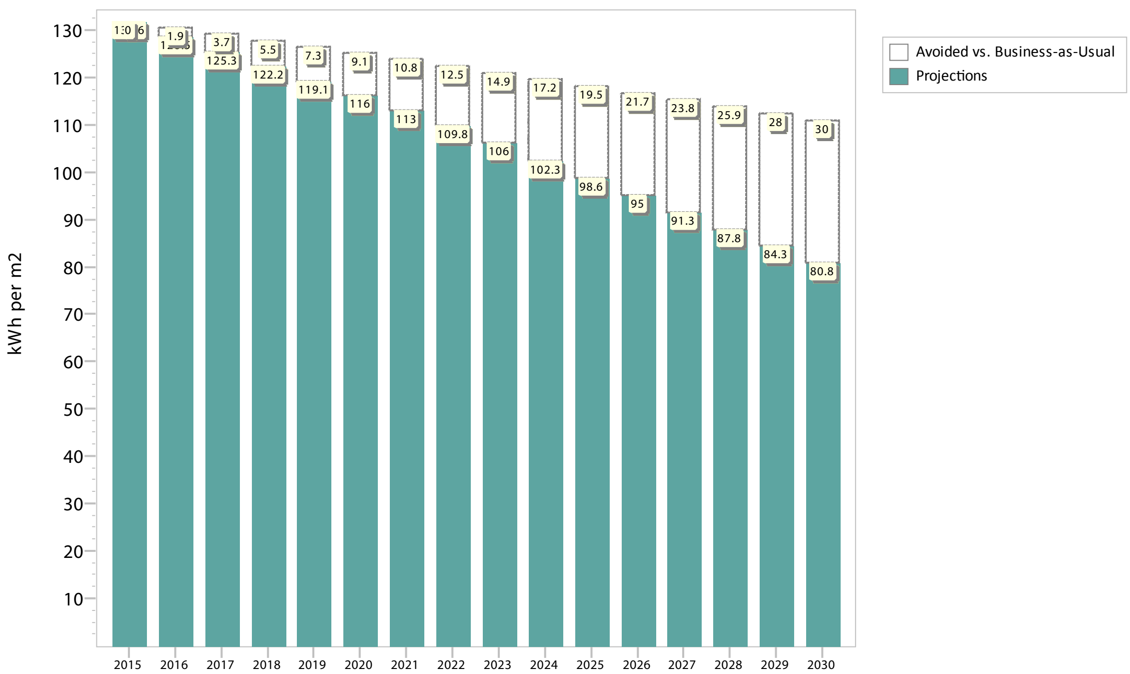


Figure 64 Final energy consumption per m^2 in the SLED ambitious scenario and its reduction vs. the reference scenario, 2015–2030



CO_2 emissions

As Figure 65 shows, emissions from the residential sector will be 16 percent lower in 2030 as compared to their business-as-usual level. The reduction in CO_2 emissions is mostly associated with electricity and lignite use.

Saved energy costs

In 2030, energy costs to residential consumers in the SLED ambitious scenario will be 24 percent lower than energy costs in the business-as-usual case in 2030. In absolute terms, this difference represents EUR 0.6 billion (Figure 66).

Figure 67 shows saved energy costs per square metre of the total building floor area. The figure illustrates that, in the case of the SLED ambitious scenario, in 2030 residential consumers will pay around EUR 1.6/m^2 per year less for thermal services than they will in the business-as-usual case.

Investments

Section XII (page 88) defines the total and incremental investment costs of the SLED scenarios, thus the information will not be repeated here. Section XII also elaborates on the importance and cost-effectiveness of integrating thermal efficiency improvements to buildings with business-as-usual renovations. The retrofitting rate of the SLED ambitious scenario is higher than the retrofitting rate of the reference scenario, which is why the incremental costs of the SLED ambitious scenario include the incremental investment costs of thermal efficiency retrofitting for part of the retrofitted building stock and the total investment costs of thermal efficiency retrofitting for the rest of the retrofitted building stock.

Similar to the SLED moderate scenario, in order to calculate the retrofitting costs at sector level we multiplied the costs of building improvement by the floor area affected by the SLED ambitious scenario. The costs of building improvement 2 per square metre are documented in Section VI. The costs of the business-

Figure 65 CO_2 emissions in the SLED ambitious scenario and CO_2 emissions avoided vs. the reference scenario, 2015–2030

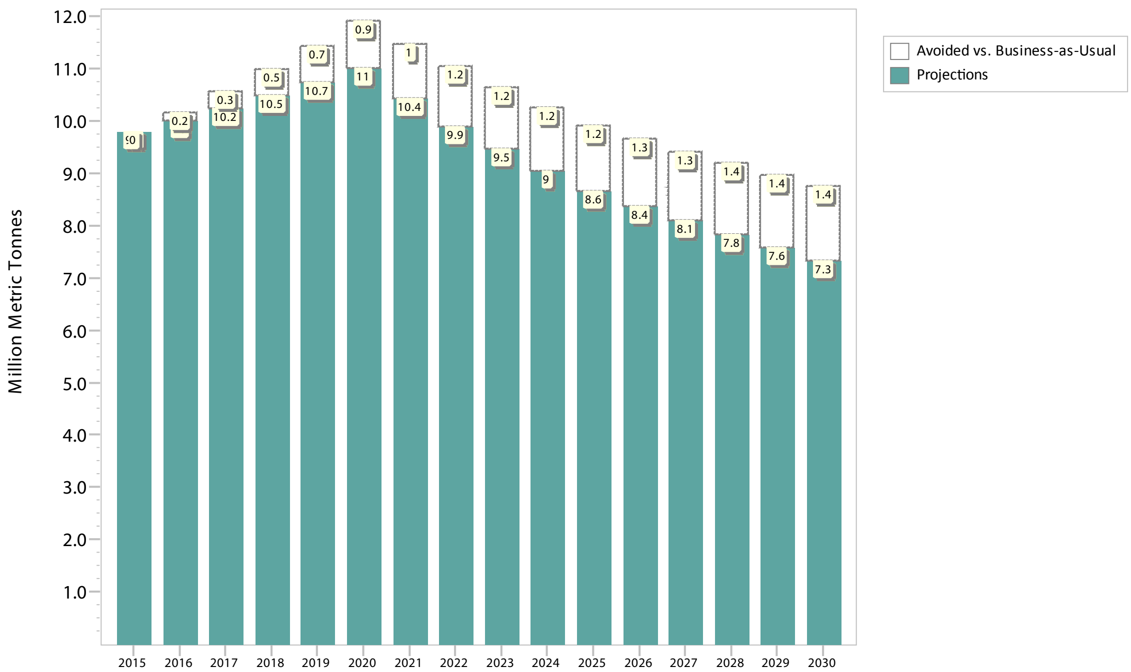


Figure 66 Energy costs in the SLED ambitious scenario and saved energy costs vs. the reference scenario, 2015–2030

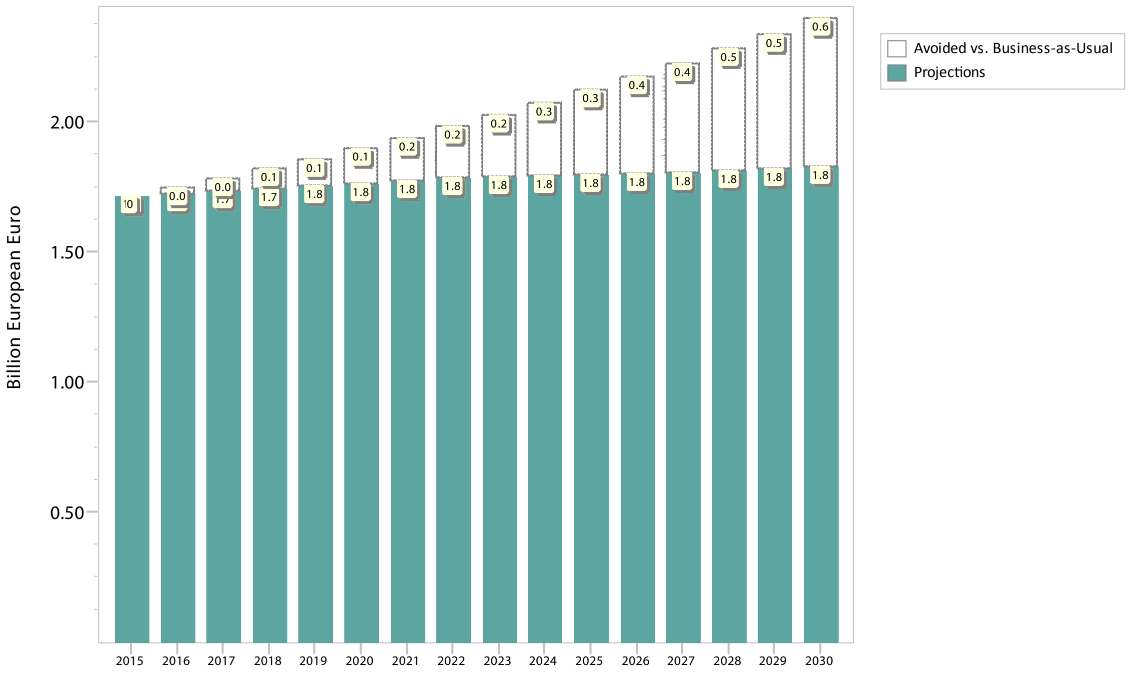
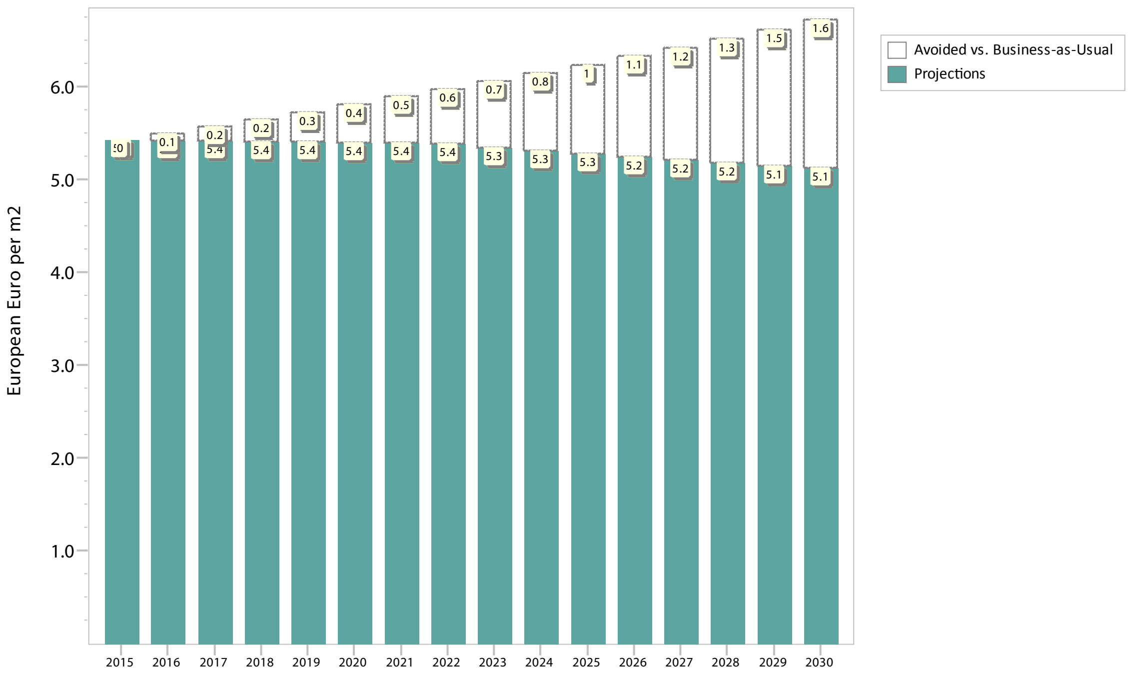


Figure 67 Energy costs per m² in the SLED ambitious scenario and saved energy costs per m² vs. the reference scenario, 2015–2030



as-usual improvement of existing buildings are the same as in the SLED moderate scenario.

Figure 68 shows the floor area affected by the SLED ambitious scenario. According to this figure, on average 7 million m², or 2.1 percent of the total building floor area per year, are retrofitted between 2015 and 2030. In addition, all new floor area — that is, around 5.2 million m² per year — is included in our scenario.

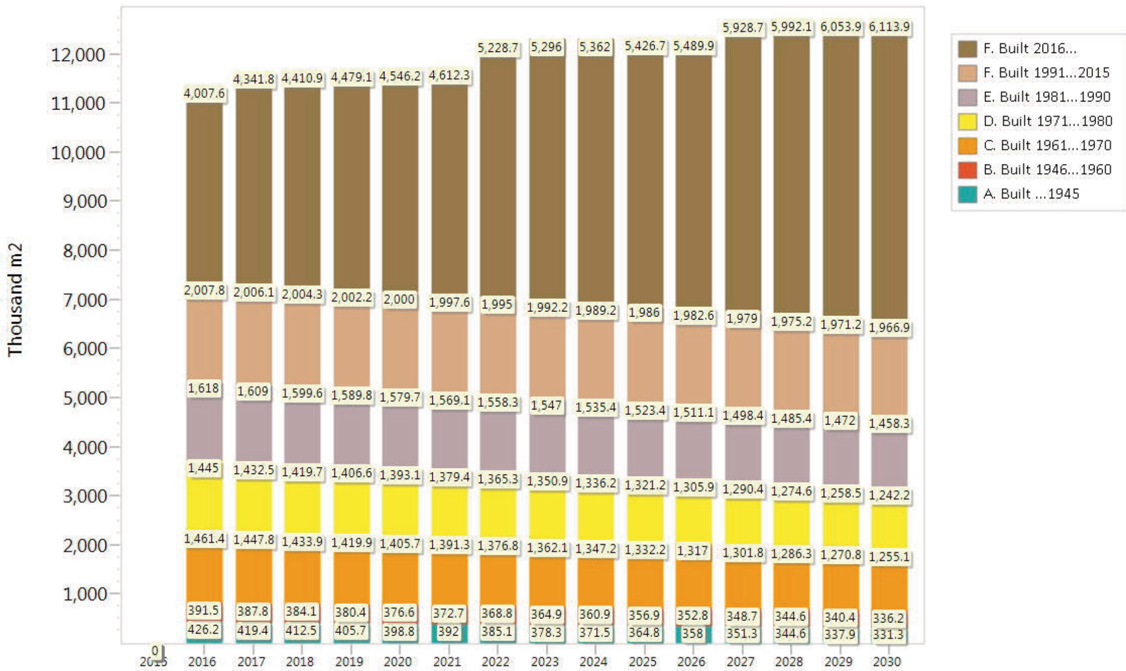
The retrofitting of the existing floor area is supported by low-interest loans and grants over the whole modelling period, as discussed in the assumptions in Section X (page 76). The whole of the new building floor area is supported by low-interest loans up to 2022 in order to reach a level of performance according to improvement 2. Starting from 2023, the whole of the new building floor area is regulated by the building code, corresponding to improvement 2 as discussed in the assumptions in Section X.

For new buildings, we estimated that the average incremental investment into better energy efficiency is EUR 102 to EUR 292/m², depending on the building type and age. For existing buildings, we found the average total investment cost to be in the range of EUR 102 to EUR 354/m², depending on the building type and age, between 2023 and 3050. The average total investment cost between 2016 and 2022 is the same as in the SLED moderate scenario. If the business-as-usual costs are deducted from the total investment costs, the incremental cost of retrofitting existing buildings is around EUR 60 to EUR 271/m², depending on the building type and age, between 2023 and 2030. The average incremental investment cost between 2016 and 2022 is the same as in the SLED moderate scenario.

Figure 69 shows the total investment costs of the SLED ambitious scenario in the thermal efficiency retrofitting of buildings over the modelling period. We estimated that, on average, the total retrofitting costs would be around EUR 1.1 billion per year between 2015 and 2030. Over the modelling period, the cumulative total investment costs of the SLED ambitious scenario are around EUR 16.1 billion.

The model also provides an opportunity to break down the total investment costs into the technologi-

Figure 68: Floor area of new and retrofitted buildings in the SLED ambitious scenario, 2015–2030



cal measures required. According to this analysis, the biggest share in the costs is for insulation, followed by the replacement of space-heating systems, the replacement of water-heating systems, new windows, and finally the replacement of space-cooling systems.

Figure 70 shows the incremental investment costs in the SLED ambitious scenario in the thermal efficiency retrofitting of buildings, and in advanced construction over the modelling period. The figure illustrates the clear benefit of coupling thermal efficiency improvements with the business-as-usual retrofitting of existing buildings. We estimated that the incremental investment costs of building retrofitting are on average EUR 583 million per year between 2015 and 2030. The cumulative incremental costs of building retrofitting in the SLED ambitious scenario over the modelling period are around EUR 8.7 billion. In addition, the incremental investment costs of new, more efficient buildings are on average around EUR 264 million per year, or EUR 4.2 billion over the modelling period.

Assuming a measure lifetime of 30 years and a discount rate of 4 percent, the annualised incremental costs of the SLED ambitious scenario over 2015–2030 are EUR 4.2/m². The average saved energy costs are around EUR 2.7/m² of new or retrofitted floor area over the modelling period. This means that the investments in the SLED ambitious scenario will not pay back, if only saved energy costs are considered as scenario benefits.

We also analysed the efforts of different actors if Serbia aims to follow the SLED ambitious scenario. All assumptions in the financial analysis in the SLED ambitious scenario are the same as the respective assumptions in the SLED moderate scenario. In the SLED ambitious scenario, we assumed that around 63 percent of the total investment costs for retrofitting would be supported by grants or low-interest loans for single-family and terraced houses, and around 66 percent for multi-dwelling buildings and apartment blocks. Also, around 34 percent of the related total investment costs are supported for new single-family houses and around 53 percent for multi-dwelling buildings and apartment blocks. This level of support is approximately equal to the share of incremental investment costs in the SLED moderate scenario.

Figure 69 **Total investment costs in the SLED ambitious scenario, 2015–2030**

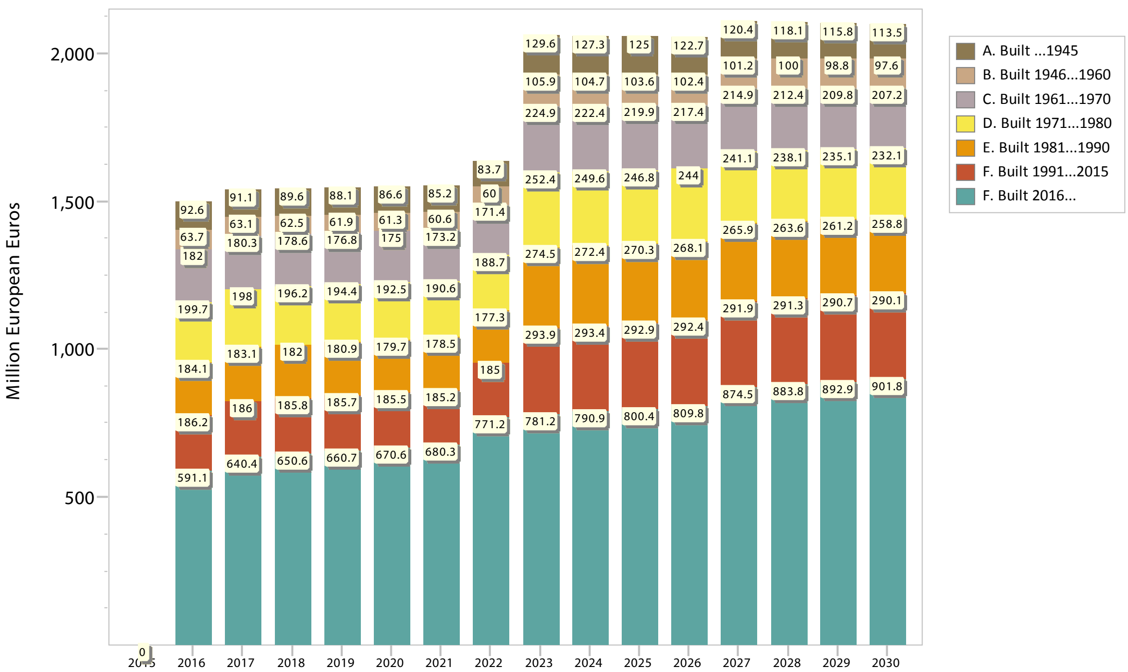


Figure 70 Incremental investment costs in the SLED ambitious scenario, 2015–2030

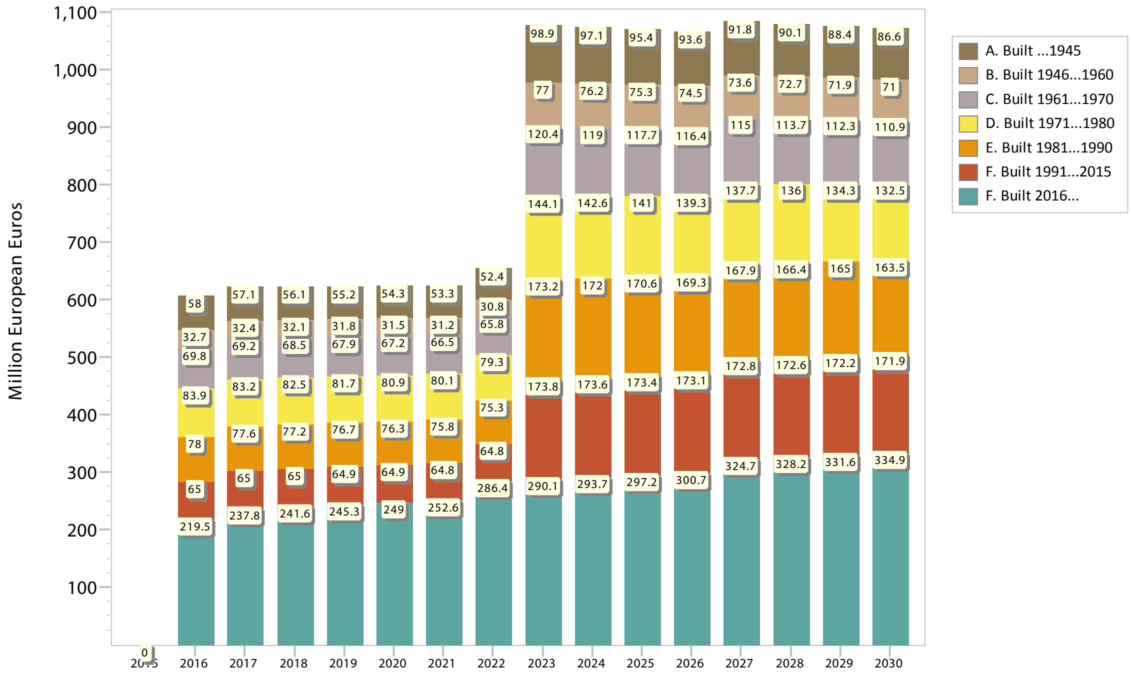


Figure 71 shows the costs to residential stakeholders of achieving compliance with the building code adopted in 2022, according to the SLED ambitious scenario. On average, these actors will bear EUR 842 million of incremental investment costs per year, as compared to the business-as-usual case.

Figure 72 shows the finance borrowed by residential stakeholders for the purposes of building retrofitting. Given our assumptions, the eligible costs of building retrofitting that investors would have to borrow are around EUR 564 million per year, or around EUR 8.5 billion over the modelling period. The eligible costs of more efficient construction are around EUR 116 million per year, or EUR 1.7 billion over 2016–2022.

Figure 73 shows the compensation paid by the government to commercial banks. Since the lending period is 10 years, the amount of compensation paid by the government to commercial banks is at its highest in 10 years. After this point, the compensation for loans directed to building retrofitting stays almost the same until the end of the modelling period, while the amount of compensation for loans directed towards efficient construction decreases. Over the modelling period, the government provides EUR 3.6 billion to commercial banks as compensation for subsidising low-interest loans for building retrofits, and EUR 1.5 billion as compensation for low-interest loans for more efficient construction.

The government provides grants for the retrofitting of existing buildings, as described in the assumptions in Section X (page 76). As Figure 74 illustrates, the value of grants is around EUR 117 million per year, or EUR 1.5 billion over the modelling period.

Figure 71 Private investments to achieve compliance with the building code in the SLED ambitious scenario, 2015–2030

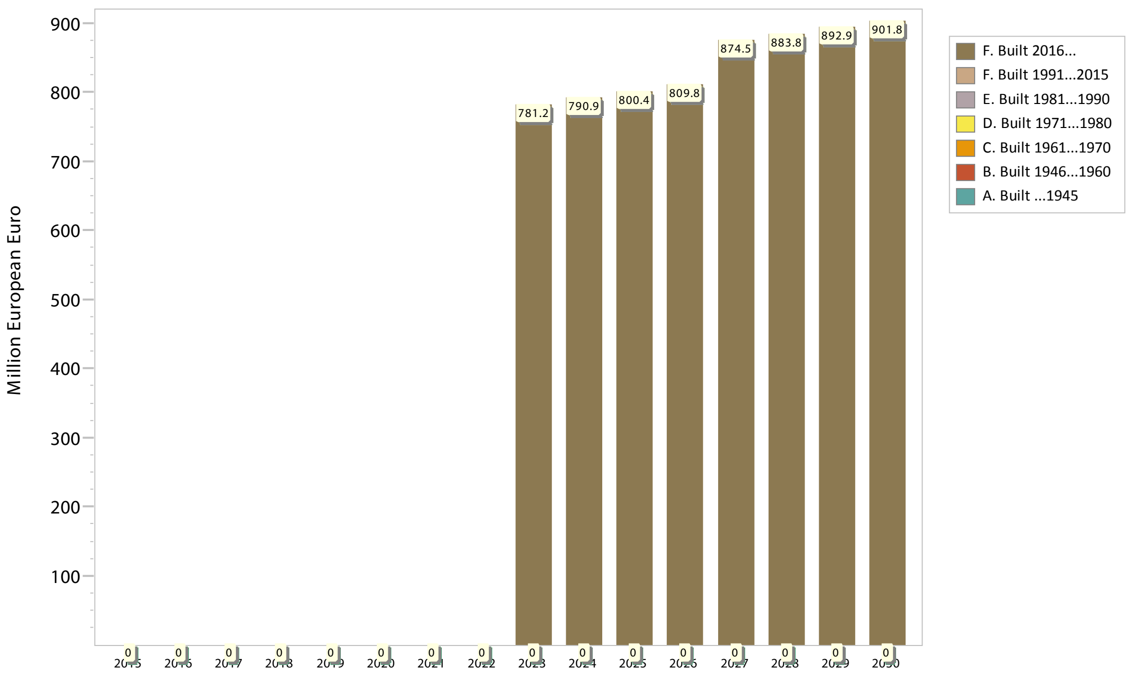


Figure 72 Private (eligible) investments stimulated by low-interest loans in the SLED ambitious scenario, 2015–2030

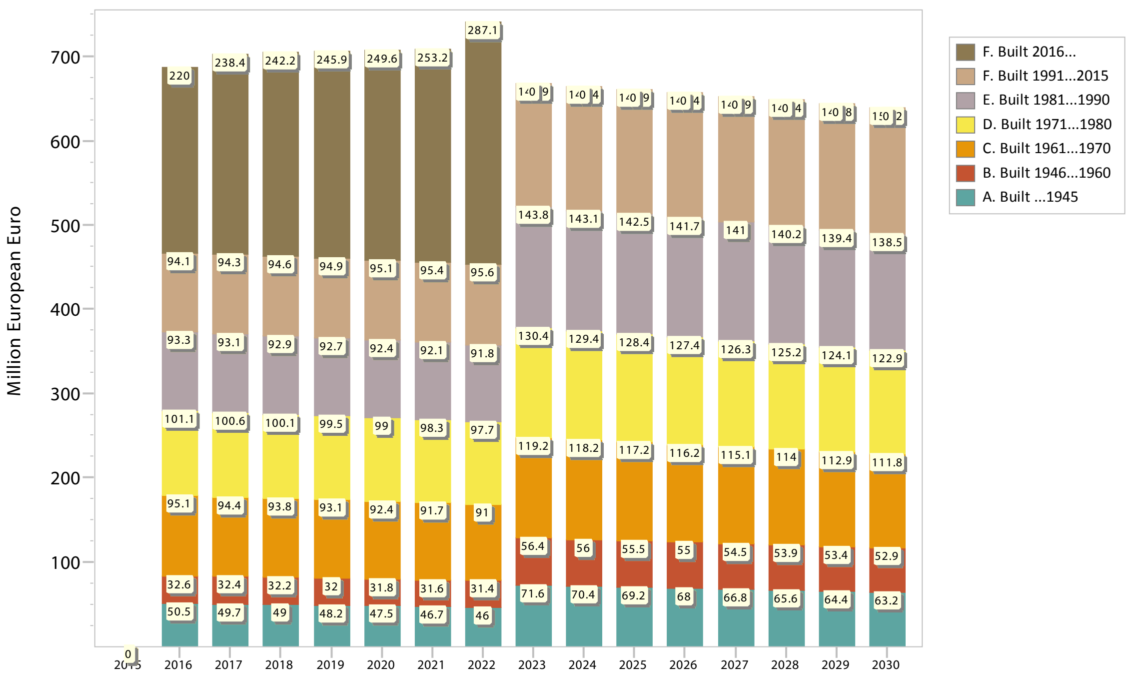


Figure 73 Cost to the government of low-interest loans in the SLED ambitious scenario, 2015–2030

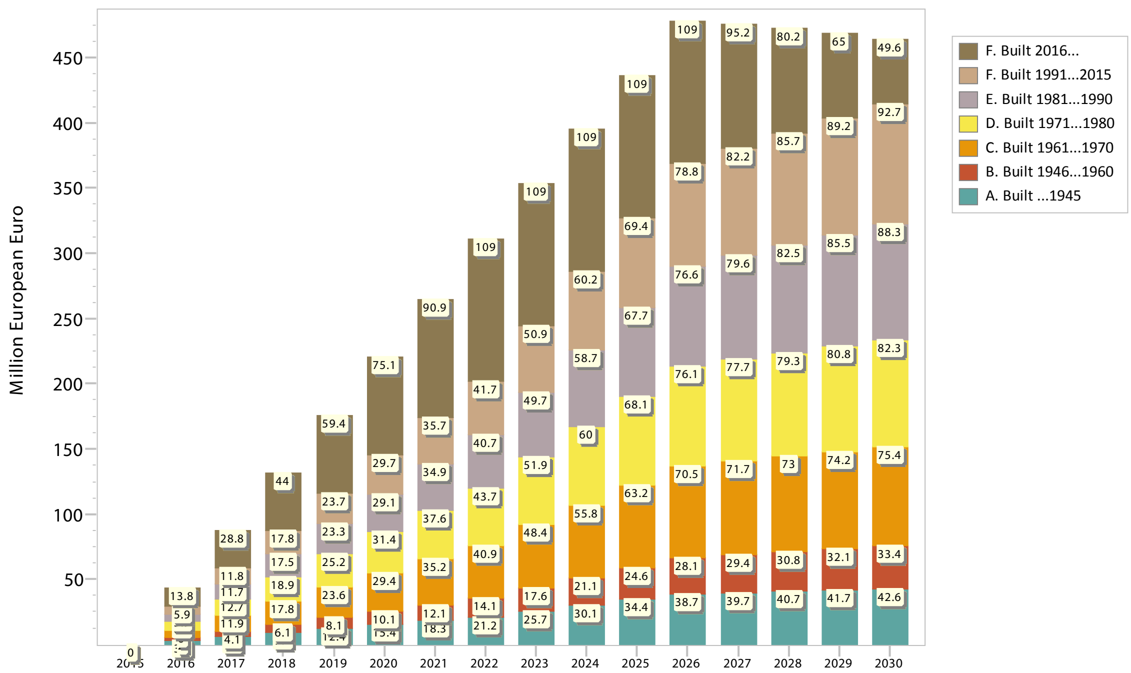
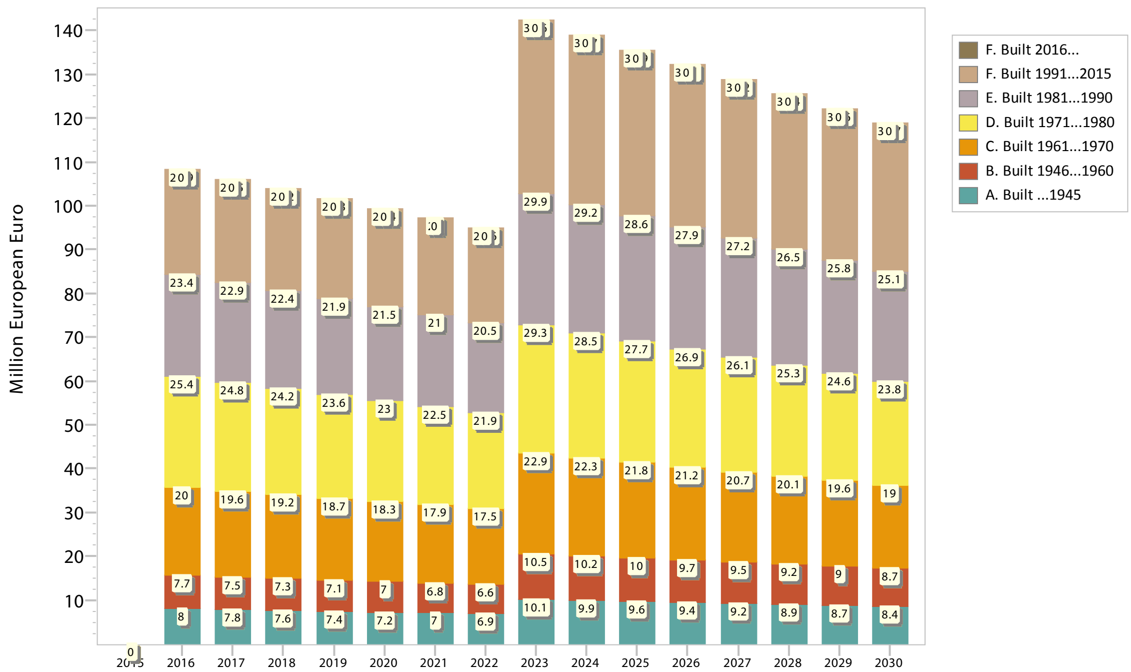


Figure 74 Cost to the government of grants in the SLED ambitious scenario, 2015–2030

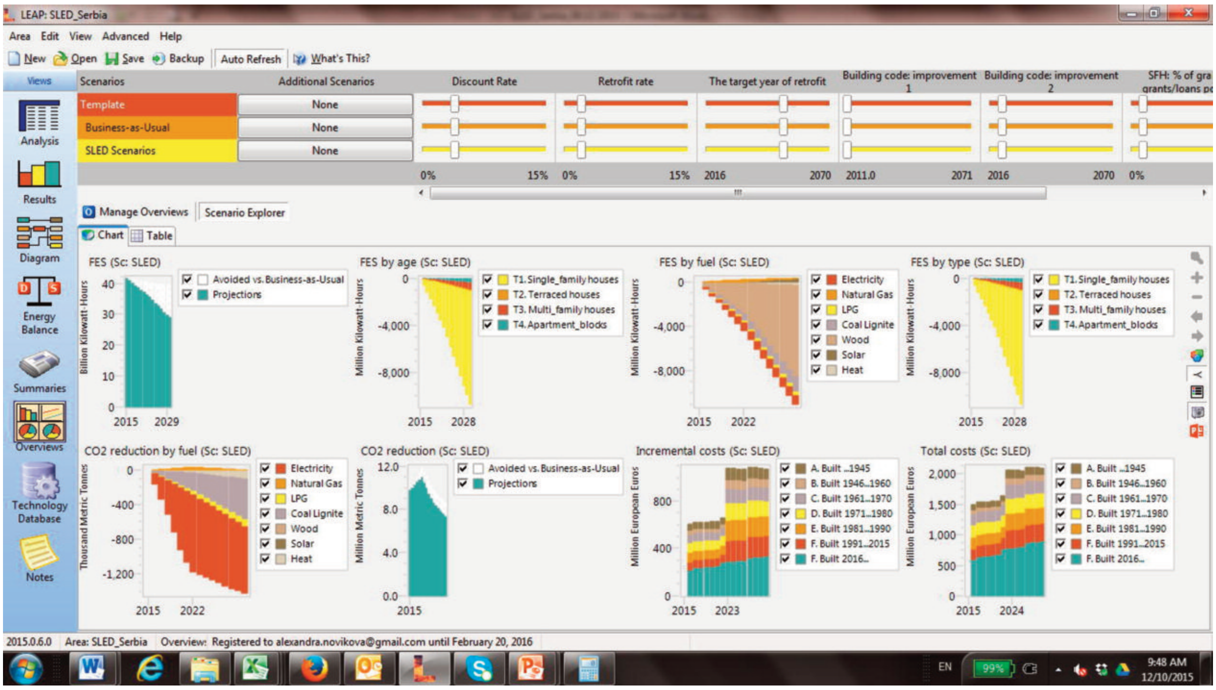


XIV. Sensitivity analysis and other possible scenarios

In the model it is possible easily to change key assumptions within given intervals and thus to obtain results when a sensitivity analysis is needed. We premodelled assumptions such as discount rate, business-as-usual retrofitting rate, the target year when the whole stock is retrofitted, the year in which the building code is adopted, the shares of loans and grants, and the share of eligible costs in the package of financial incentives. Figure 75 shows a screenshot of the sensitivity analysis in the model.

In addition to the SLED moderate and ambitious scenarios, we premodelled scenarios with only building codes, only grants, and only low-interest loans. The model allows easy changes in the content of these scenarios.

Figure 75 The sensitivity analysis in the Serbian SLED model



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