Building capacity of policy-makers in South East Europe on the modelling of low carbon transformation of the residential building stock

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Abstract

The energy demand in the residential building sector represents a big challenge for Albania, Montenegro, and Serbia. Within our project entitled "Support for Low Emission Development in South East Europe", we developed residential building topologies and using them as an input, designed and applied bottom-up simulation models to assess the impact of decarbonisation policy packages applied to this sector. The models were prepared in co-operation with national policy-makers in the LEAP software, for which they were trained in a parallel project. The final models and input data were provided to them for further use and modification. The paper describes the methodology and provides selected examples of results placing a special focus on our cooperation with the policy-makers.

Specifically for the focus countries, we found that partial heating and intermittent heating as well as uncertainties of wood share in the national energy balance are typical problems. Energy demand could be significantly reduced through building thermal retrofits even though they imply higher thermal comfort. Both moderate and ambitious policy scenarios, which include building codes and financial incentives, may realize a large share of energy savings in all three countries, but sector priorities for policy-making differ. The scenario investment are very high therefore it is important to couple scenario retrofits with business-as-usual renovations as well as consider other co-benefits additionally to saved energy costs. All results presented in the paper could be easily obtained from the models on any level of the building stock segmentation, i.e. on the level of building type, age, climate zone, or end-use. Such detailed analysis has never been done before for these countries and it will provide substantial impetus on the policy process.

Introduction

Energy demand in the residential buildings of Albania, Montenegro, and Serbia represents a big challenge. In 2013, the building sector was responsible for 38 - 44% of the final energy consumption and 66% - 74% of the electricity consumption in these countries (EUROSTAT 2015). The residential buildings contributed the largest share to these figures. The quality of energy services delivered in the households is much lower than that in the households in the European Union (EU). It is typical that only the main room of a dwelling is heated for a few hours a day. The continued use of outdated wood stoves in homes results in high air pollution. Cutting down forests for household energy services brings numerous environmental problems (Legro 2014).

During the last twenty years, the countries have achieved significant progress in adopting and implementing energy efficiency policies (Legro 2014). A big push for this was their becoming the contracting parties of the Energy Community Treaty. According to the Treaty, the countries are obliged to introduce EU energy efficiency legislation including that addressing the building sector. It takes time for the countries to gather information and experience on demand-side energy efficiency and this is why their policy-makers benefit from international support and assistance in this process.

The Regional Environmental Center of Central and Eastern Europe (REC) was contracted by the Austrian Development Agency (ADA) to design and implement a project entitled "Support for

Low-Emission Development in South Eastern Europe" (SLED). One of the project tasks was to assist the evidence-based design of energy efficiency and climate mitigation policies in the residential buildings in Albania, Montenegro, and Serbia with necessary information. To implement this task, we prepared a topology of representative building types and using it as an input designed a bottom-up model, which simulates scenarios for the sector's low energy and carbon transformation in the future. Such detailed analysis has never been done before for these countries and it will provide substantial impetus on the policy process of energy efficiency target setting, the design of national support programs and the better utilization of international donor support. We designed the model in such way that it could be further used by national policy-makers and experts according to their needs. The paper describes the methodology and the results of the project placing a special focus on our cooperation with policy-makers.

Approach and methodology

Our project consisted of two parts. The first part was prepared by our team of international architects with the help of national architects and engineers. Within it we prepared country building topologies and assessed energy performance by end-use, possible building retrofit packages and the associated costs on the level of individual representative buildings.

The second part was prepared by international policy analysts in cooperation with national policies-makers. Within this part, we prepared an analysis on the sector level, for which we designed and applied a bottom-up simulation model. With the help of the model, we calculated energy balances and carbon dioxide (CO_2) emissions on the sector level, compared and calibrated the calculated energy balances to those available from national public statistics, and extrapolated sector's energy consumption and associated CO_2 emissions to the future according to business-as-usual assumptions. Then, we formulated policy packages, which aim to transform the residential building stock to zero energy and carbon levels in the long-term future, and evaluated energy savings, saved energy costs, avoided CO2 emissions, and cost-effectiveness of the packages.

Methodology to set up the building topologies and to calculate building energy performance

To prepare the building topologies, we relied on the methodology adopted in Tabula/Episcope project supported by the Intelligent Energy Europe Programme (IEE Tabula - Episcope online). The Tabula/Episcope project created a uniformly structured typology of residential buildings, which was applied in the countries of the European Union.

To calculate the energy demand on the level of representative buildings, we selected the monthly method according to the standard EN ISO 13790 "Energy performance of buildings -- Calculation of energy use for space heating and cooling". To run calculations, for Albania we used das Passivhaus-Projektierungspaket (PhPP software) of the German Passive House Institute. Although this tool was especially developed for passive houses, it is also suitable for the energy calculation of conventional buildings. We selected this tool because it delivers reliable results not only for the heating energy demand, but also for cooling. The energy performance on the level of representative buildings in Albania was calculated by climate zone.

For Serbia and Montenegro, we used the same calculation method. The starting point for Serbia was the already existing building typology with estimated energy performance prepared by the expert team of University of Belgrade (Jovanović Popović et al. 2013), which was modified according to the project needs. The Serbian building topology was adapted also for Montenegro, because the building stocks of the two countries have significant overlaps. The energy performance on the level of representative buildings in Montenegro was calculated by climate zone; for Serbia, the energy performance was calculated for the average country climate.

Identification of possible retrofit packages

We identified and assessed business-as-usual (BAU) and two more advanced building retrofit packages. All retrofit packages implied not only lower energy consumption, but also higher thermal comfort, i.e. larger heated and cooled floor area for a longer period of time.

The BAU improvement includes the most frequently applied renovation options. The "standard" improvement includes interventions on each building component in order to comply with the minimum requirements foreseen by existing or forthcoming in the nearest future building codes in the case of major renovation. Such retrofit includes a set of interventions upgrading the building envelope from an insulation point of view as well as the installation of more efficient building service systems, using sometimes another energy source. The "ambitious" improvement goes beyond the building regulations regarding the building envelope and considers often even more efficient building service systems than the "standard" retrofit does.

The investment costs of the retrofit packages were estimated based on the current market prices. These costs were provided by our national experts per building type and measure. Tables 1-3 provide the examples of retrofit measures and associated costs of standard retrofit for all countries.

Table 1. The costs of standard retrofit: climate zones A and B, Albania, €/m^2 floor area, incl. VAT

Building types\ Measures	**A1**	**A2**	**A3**	**A4**	**B1**	**B2**	**B3**	**B4**	**C1**	**C2**	**C3**	**C4**	**D1**	**D2**	**D3**	**D4**	**E1**	**E2**	**E3**	**E4**
Wall	24	23	15	13	28	33	17	18	27	17	10	18	21	22	19	15	19	10	24	6
Roof	19	19	9.3	6.2	9.3	9.3	9.3	3.7	19	9.3	3.7	3.7	9.3	19	3.7	3.1	19	8.3	9.3	2.1
Floor	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Windows	13	11	14	13	14	16	8	9	11	11	17	9	9	10	17	11	11	13	13	13
Heating	42	42	42	42	42	42	42	42	28	42	42	45	42	42	50	42	31	45	45	45
Hot water	13	11	10	7.0	7.0	7.8	7.0	7.2	6.5	11	15	6.5	7.0	13	7.0	5.3	4.9	6.5	5.0	1.6
Total	**110**	**106**	**90**	**81**	**100**	**108**	**83**	**80**	**92**	**90**	**88**	**83**	**88**	**106**	**96**	**77**	**84**	**83**	**97**	**68**

Notes: The letter in the building type category means age, the number means building size. A - buildings built before 1960, B - buildings built between 1961 and 1980, C - buildings built between 1981 and 1990, D - buildings built between 1991 and 2000, E – buildings built between 2001 and 2015. 1 - detached houses, 2 - semi-detached houses, 3 - row houses, 4 - multi-residential buildings.

Table 2. The costs of standard retrofit: all climate zones, Montenegro, €/m^2 floor area, incl. VAT

Measures\Building types	**A1**	**A2**	**A3**	**A4**	**A5**	**B1**	**B2**	**B3**	**B4**	**B5**	**C1/2**	**C3**	**C4**	**C5**
Walls (and arcade ceilings)	48.2	39.3	44.8	33.8	34.9	68.5	42.6	26.6	19.1	23.3	24.1	25.5	23.2	23.3
Windows	33.8	34.7	36.8	32.5	23.4	49.0	46.2	31.9	38.8	24.5	30.5	37.1	34.2	26.7
Floor c. to attic	25.0	25.8	12.9	11.5	12.8	9.5	4.9	4.8	3.8	3.9	3.2	2.0	2.6	3.2
Floor c. to unheated below (cellar)	0.0	0.0	16.1	2.3	3.6	11.9	6.1	5.9	4.0	5.0	4.0	3.0	3.2	5.6
Flat roof	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	3.0	0.0	0.2
Pitched roof	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	1.3	1.9
Floor c. on ground	0.0	0.0	0.0	0.0	22.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heating system	25.0	25.0	25.0	25.0	25.0	22.5	22.5	22.5	22.5	22.5	35.0	35.0	35.0	35.0
Hot water system	25.0	25.0	25.0	25.0	25.0	22.5	22.5	22.5	22.5	22.5	40.0	40.0	40.0	40.0
Total	**157**	**150**	**161**	**130**	**143**	**184**	**145**	**114**	**111**	**103**	**137**	**143**	**139**	**136**

Notes: The letter in the building type category means building size, the number means building age. A - small buildings, B - medium buildings, C - large buildings. 1 – buildings built before 1945, 2 - buildings built between 1946 and 1970, 3 – buildings built between 1971 and 1990, 4 – buildings built between 1991 and 2000, 5 – buildings built between 2001 and 2015.

Table 3. The costs of standard retrofit: all climate zones, Serbia, €/m^2 floor area, incl. VAT

Measures\Building types	**A1**	**B1**	**C1**	**D1**	**E1**	**F1**	**A2**	**C2**	**A3**	**B3**	**C3**	**D3**	**E3**	**F3**	**C4**	**D4**	**E4**	**F4**
Walls (and arcade ceilings)	48.2	28.8	29.3	32.9	24.8	4.5	36.7	25.7	58.9	36.4	20.6	22.6	16.4	20.0	19.4	22.6	20.5	20.4
Windows	33.8	34.7	31.9	36.8	32.5	23.4	37.7	36.5	49.0	46.2	30.5	31.9	38.8	24.5	30.8	37.1	34.2	26.7
Floor c. to attic	25.0	30.9	11.5	9.0	8.1	9.0	23.6	16.1	6.7	3.4	2.3	3.3	2.7	2.8	0.0	1.4	1.8	2.3
Floor c. to unheated below (cellar)	0.0	0.0	0.0	11.6	1.6	2.6	34.8	5.2	21.4	4.4	2.9	4.3	2.9	3.6	2.6	2.7	2.3	4.0
Flat roof	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	9.2	3.3	0.0	0.3
Pitched roof	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	1.6	2.2
Floor c. on ground	0.0	0.0	0.0	0.0	0.0	22.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heating system	49.0	32.6	27.6	28.9	28.1	8.2	31.1	44.8	27.7	26.6	26.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Hot water system	24.0	7.6	2.6	3.9	3.1	8.2	6.1	19.8	2.7	1.6	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**180**	**135**	**103**	**123**	**98**	**75**	**170**	**148**	**174**	**123**	**90**	**69**	**68**	**57**	**66**	**75**	**69**	**64**
Cooling (optional)	6.4	6.8	7.0	6.9	5.5	6.6	5.4	5.3	14.5	8.5	6.6	6.4	5.5	5.9	6.0	8.4	7.6	5.6

Notes: The letter in the building type category means age, the number means building size. A – buildings built before 1945, B – buildings built between 1946 and 1960, C – buildings built between 1961 and 1970, D – buildings built between 1971 and 1980, E – buildings built between 1981 and 1990, F – buildings built between 1991 and 2015. 1 - single family houses, 2 - terraced houses, 3 - multi-residential houses, 4 - apartment blocks.

The building stock model

The building stock model was prepared in Excel spreadsheets. For Albania, the building stock model was constructed until 2050 and for Serbia and Montenegro - until 2070. Based on the expected trends of population growth and persons per household, we estimated the total number of households and their demand for dwellings in the future. The demolition rate of the dwelling stock was calculated using a Weibull curve, which describes a fraction of remaining units over time (Weibull 1951). The construction of new dwellings was estimated as a gap between the demand for dwellings represented by the number of households and the remaining stock of existing dwellings. The calculated dwellings stock was also corrected for inhabitance rates provided by country censuses.

The choice of the modelling tool for the sector level analysis

In order to select the modelling tool to calculate the energy consumption and CO2 emissions on the sector level, we analyzed the existing capacities of policy-makers in the focus countries to understand and replicate such analysis themselves. We have learnt that the Working Group 1 of the Environment and Climate Regional Accession Network (ECRAN) financed by EU was conducting a series of regional training workshops on quantitative models and scenario development to assess sustainable energy and climate mitigation targets and scenarios. The key beneficiaries of the ECRAN trainings were representatives of ministries of environment of the Western Balkan countries, including Albania, Montenegro, and Serbia. Additionally, representatives of other relevant ministries and institutions were involved as soon as the focus of their work concerned energy efficiency and climate mitigation. Operationally, the beneficiaries were performing a series of exercises in class and at home with the help of Long range Energy Alternatives Planning System (LEAP) software. LEAP is a widely-used software tool for energy and climate policy analysis.

Since the aim of our project was not only to supply results to policy-makers, but also to increase their capacity to conduct their own assessment, we decided to prepare the model in LEAP. Further, in order to maximize the use of project, we worked closely with national policy-makers on the design and assumptions of the models. We conducted interviews in the beginning of the project and made two rounds of presentations of modelling results in the middle and towards the end of the project to receive additional data, comments, and wishes to the model.

After the project was completed, the models with the underlying input data were provided to national policy-makers and experts. Following the ECRAN training, they are able to run and modify our model themselves according to their needs. The model is also available on the request to other experts subject to proper referencing and acknowledging, when used.

Construction of the sector energy balance and its calibration

The calculations described in the next sections were conducted using the LEAP software. The energy demand of each representative building was estimated as a sum of its energy demand for space heating, water heating and space cooling. Then we multiplied the number of representative buildings by their energy demand in each climate zone and summed up the results across all climate zones, building types, and building age categories (for Serbia, we did not differentiate climate zones).

Formulation of policy packages

In order to formulate reference and low energy/carbon emission scenarios, we reviewed the barriers for energy efficiency penetration in the residential buildings of our focus countries. We also reviewed existing, planned and further relevant policies to overcome these barriers. In order to further improve our policy packages, we also discussed them with national policy-makers.

In the reference scenario, we assumed business-as-usual technological, policy, and market changes. In the moderate scenario, we assumed that by 2050 the energy performance of all new and existing buildings of Albania will correspond to that after the standard improvement. The moderate scenarios for Montenegro and Serbia assumed the same by 2070. The ambitious scenario assumed that by 2050 the largest part of the new and existing buildings of all three focus countries will achieve the level of ambitious improvement. The details of the policy packages designed for the moderate and ambitious scenarios are provided in Tables 4 and 5.

Table 4. The policy package of the moderate scenario

New buildings	**Albania**: The new building code is introduced in 2016 and all new buildings comply with it. **Montenegro**: All new buildings comply with the building code adopted in 2013. **Serbia**: All new buildings comply with the building code adopted in 2011. These three codes correspond to the characteristics of the measures of the “standard” improvement.
Existing buildings	**Albania, Montenegro, Serbia**: All existing buildings, which will remain by 2050 in Albania and by 2070 in Serbia and Montenegro, will be retrofitted by these time points and will get financial support for that. Households will be eligible for the financial support, if they comply with the “standard” improvement. Grants will be provided to cover eligible costs for: • Low income households in detached/semi-detached houses: 10% of the stock over 2016 – 2050 in Albania and over 2016 – 2070 in Serbia and Montenegro • Households in row houses and apartment buildings: 90% of the retrofitted households in 2016 declining to 10% of them by 2050 in Albania and by 2070 in Serbia and Montenegro Low interest loans will be provided to cover eligible costs for: • The rest of the households in detached/semi-detached houses: 90% of the stock over 2016 – 2050 in Albania and 2016 – 2070 in Serbia and Montenegro • The rest of the households in row houses and apartment buildings: 10% of the retrofitted households in 2016 increasing to 90% of them by 2050 in Albania and by 2070 in Serbia and Montenegro

Table 5. The policy package of the ambitious scenario

<table>
<tr><th></th><th>2016 - 2022</th><th>2023 – 2050</th></tr>
<tr><td rowspan="2">New buildings</td><td>Albania:
The new building code is introduced in 2016 and all new buildings comply with it.
Montenegro:
All new buildings comply with the building code adopted in 2013.
Serbia:
All new buildings comply with the building code adopted in 2011.
These three codes correspond to the characteristics of the measures of the “standard” improvement.</td><td>Albania, Montenegro, Serbia:
The new building code is introduced in 2023 and all new buildings comply with it. The codes corresponds to the characteristics of the measures of the “ambitious” improvements.</td></tr>
<tr><td>Albania, Montenegro, Serbia: New buildings are eligible for low-interest loans to cover eligible costs, if their performance achieves the performance of the building code to be introduced in 2023.</td><td></td></tr>
<tr><td rowspan="2">Existing buildings</td><td colspan="2">Albania, Montenegro, Serbia:
All existing buildings, which will remain by 2050, will be retrofitted by this time point and will get the financial support for that.
Grants will be provided to cover eligible costs for:
• Low income households in detached/semi-detached houses: 10% of the stock over 2016 - 2050
• Households in row houses and apartment buildings: 90% of the retrofitted households in 2016 declining to 10% of them in 2050
Low interest loans will be provided to cover eligible costs for:
• The rest of the households in detached/semi-detached houses: 90% of the stock over 2016 - 2050
• The rest of the households in row houses and apartment buildings: 10% of the retrofitted households in 2016 increasing to 90% of them in 2050</td></tr>
<tr><td>Albania, Montenegro, Serbia: Households will be eligible for the indicated financial support, if they comply with the “standard” improvement</td><td>Albania, Montenegro, Serbia: Households will be eligible for the indicated financial support, if they comply with the “ambitious” improvement</td></tr>
</table>

The scenarios assumed the introduction of building codes and financial incentives (low interest loans and grants) for building retrofit and construction. The structure of the financial incentives depended on the building type as well as on the maturity of the market. For small buildings we assumed a higher share of low interest loans whereas for large buildings – a larger share of grants. In the long-term, we allowed for a higher share of loans versus a higher share of grants at present. We assumed that the financial incentives in moderate and ambitious scenarios will be provided to cover the share of eligible investment costs of better buildings, which approximately equals to the share of incremental investment costs into improvements as compared to the business-as-usual improvement.

Model possibilities and boundaries

Due to the nature of the scenario models and their assumptions, they are applicable until 2030. We assessed only thermal energy services delivered in the residential buildings, namely space heating, space cooling and water heating. We did not cover energy use for electrical appliances, lighting and cooking. We considered both direct and indirect CO_2 emissions in our analysis[1].

The models allow for changing their key assumptions or components of policy packages. We premodelled user-friendly changes of such assumptions as the discount rate, BAU retrofit rate, the target year when the whole stock is desired to be retrofitted, the year of building code adoption, the shares of loans and grants and the share of eligible costs in the package of financial incentives, and

1 Direct emissions are those originating from fuel combustion, which occurs in buildings. Indirect emissions are those, which are produced in the transformation sector and are accounted on the supply side according to the IPCC guidelines, but which are associated with energy commodities consumed in energy-using sectors.

others. Figure 1 illustrates the screen where such changes are made in the Serbian model.

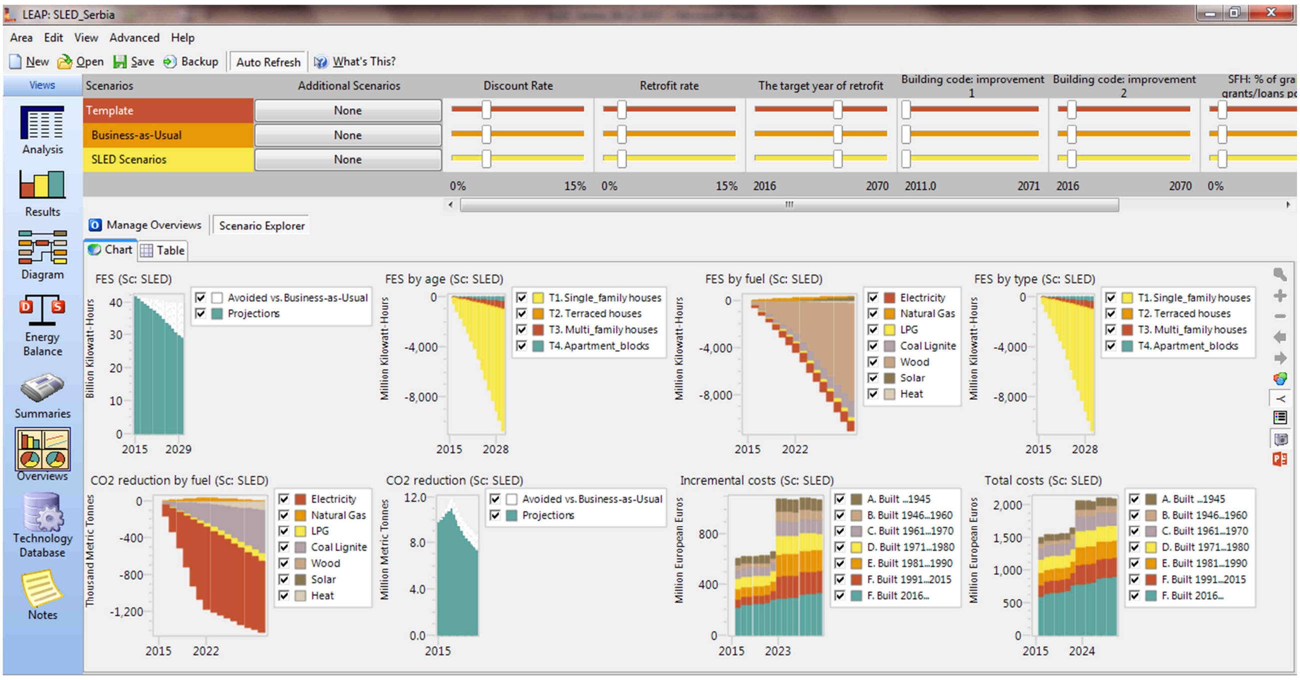


Figure 1. The illustration of the assumptions and results in the Serbian SLED model

Results

Building typology

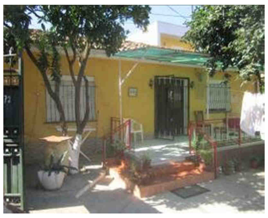
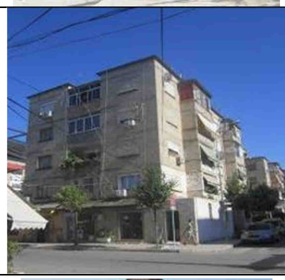
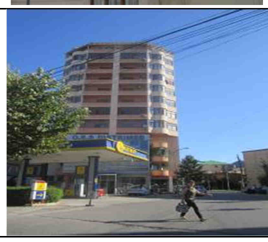
Classifying the residential building stock of Albania, Serbia, and Montenegro, we concluded that the most important aspects for its energy performance that needs consideration are building type, construction period, climate zones, as well as building energy systems and energy sources. We classified the whole stock of Albania into six age categories, four type categories, and three climate zones; the stock of Montenegro - into six age categories, three type categories, and three climate zones; and the stock of Serbia – into seven age categories and four type categories. The example of the Albanian residential building topology is provided in Table 6. The building stock for Albania was further divided into three climatic zones: zone A is the mildest along the sea, B is the medium zone and C is the coldest in the mountainous area.

The number of building and dwelling units of Albania, Serbia and Montenegro was split according to the topologies based on censuses, expertise of our team, and assumptions. The further breakdown of the stock according to energy sources by end-use and/or building energy systems was conducted based on literature, expertise of our team, interviews, assumptions, and calculations.

Energy performance on the building level and the retrofit packages

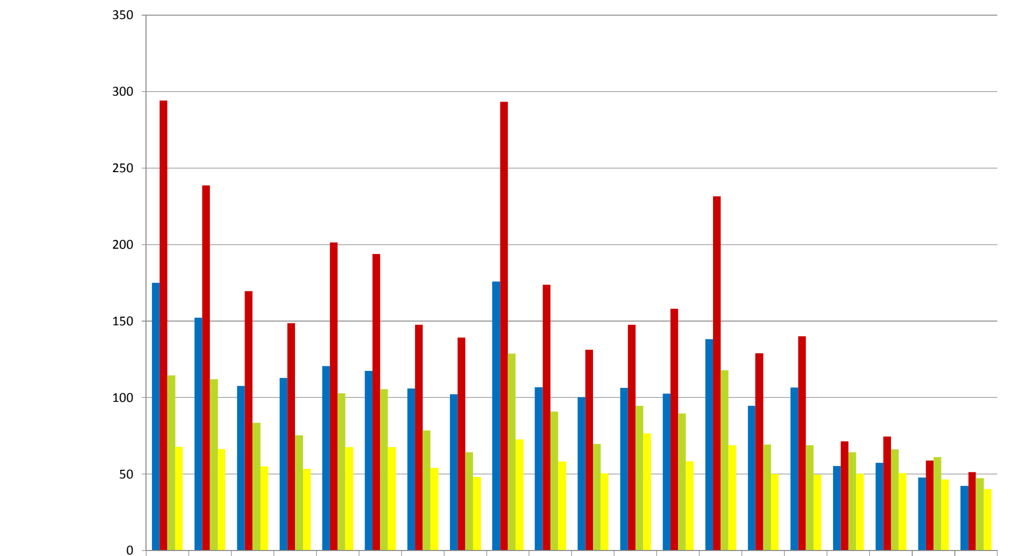
Figure 2 presents an example of calculated energy demand on the building level at present and in case of BAU retrofit, standard retrofit (improvement 1), and ambitious retrofit (improvement 2) for the Albanian representatives buildings in climate zone B. The progress in the net heating demand shows that the thermal characteristics of the building stock somewhat improved over time, but significant improvement is remarkable only in the last decade. In general, detached houses have higher heating demand than large buildings due to the unfavourable surface-to-volume ratio. In most building types heating is dominant in the total energy demand (not shown in this figure).

Table 6. Albanian residential building typology (Simaku, Thimjo, and Plaku 2014)

Age\ Type	1. Detached house	2. Semi-detached house	3. Row (or terraced) house	4. Multifamily Apartment
A ... 1960				
B 1961-1980				
C 1981-1990				
D 1991-2000				
E 2001-2011				

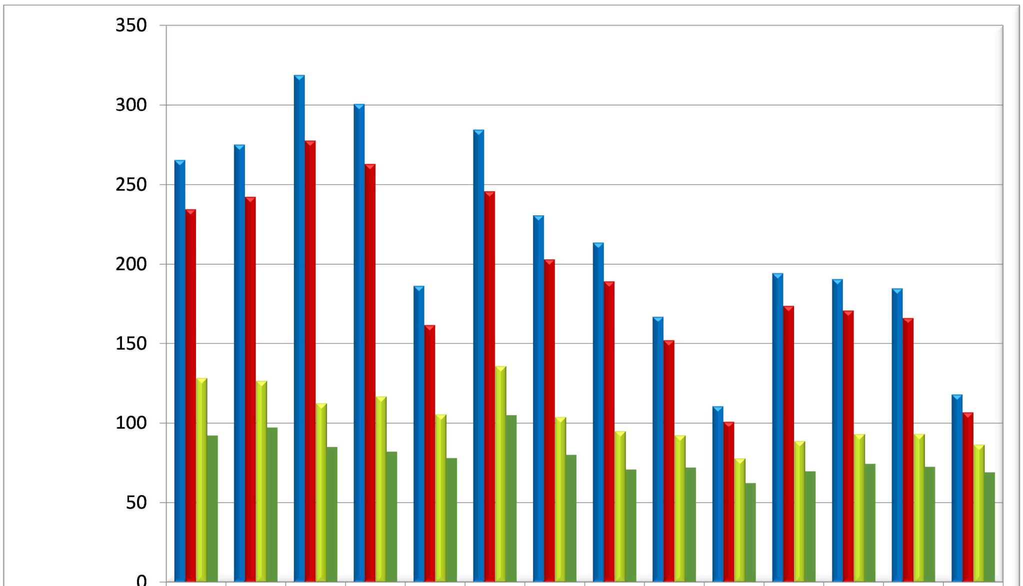
A special phenomenon in the focus countries is that households traditionally heat only the main room(s) only for a part of the day. Hence we calculated a full and a partial heating option with correction factors derived from the calibration of the model. For Albania for instance, the net energy demand with partial heating and cooling is only 25-45% of the values for full heating and cooling, but still accounts for 100-180 kWh/m2yr in buildings built before 2000.

In case of all retrofits, we assumed longer heating and cooling hours of larger floor areas than at present. Energy savings due to business-as-usual improvement are less than the energy demand increase due to higher thermal comfort, this is why the building energy consumption after business-as-usual improvement is higher than it is before it. Energy savings due to improvements in case of standard and ambitious retrofits exceed the energy demand increase due to higher thermal comfort; in these two cases energy demand can be drastically reduced to a very low energy performance for buildings in spite of higher comfort standards. The exception is the buildings, which are built within the last fifteen years, where energy performance is better than in the past and energy savings are not so high. The largest energy savings occur in space heating; energy savings in hot water preparation and space cooling are much smaller. Similar conclusions were also made for Montenegro and Serbia (Figure 3 and Figure 4).



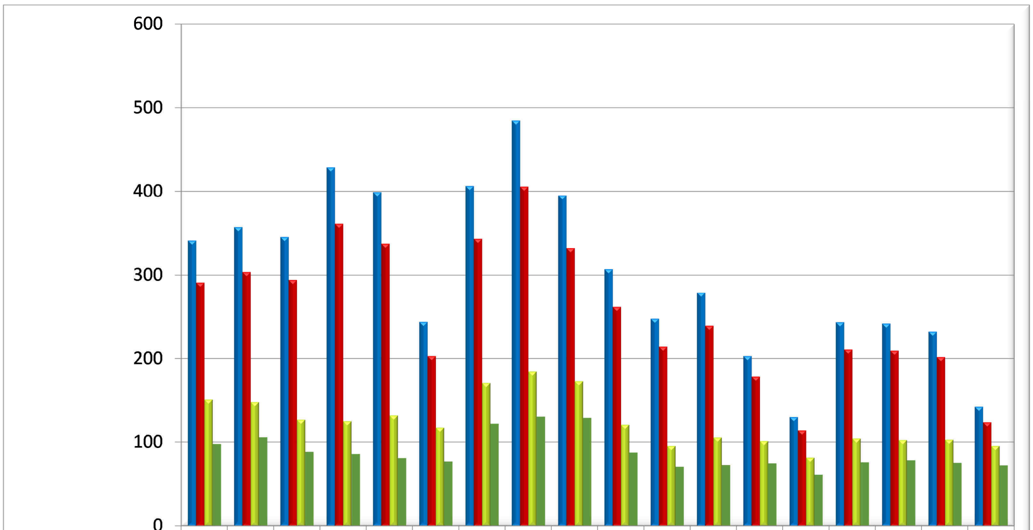
	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4	D1	D2	D3	D4	E1	E2	E3	E4
present state	175	152	108	113	121	117	106	102	176	107	100	106	103	138	95	107	55	57	48	42
improvement BAU	294	239	170	149	201	194	148	139	293	174	131	148	158	232	129	140	71	75	59	51
improvement 1	115	112	83	75	103	105	79	64	129	91	70	95	90	118	69	69	64	66	61	47
improvement 2	68	66	55	53	68	68	54	48	73	58	51	77	58	69	50	50	50	51	46	40

Figure 2. Net energy demand (kWh/m2-yr.) by building type at present and in case of retrofits, Albania, climate zone B (central)
Notes: the same as to Table 1



	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1,C2	C3	C4	C5
present state	265	275	319	301	186	284	231	213	167	111	194	191	185	118
improvement 1	235	242	278	263	162	246	203	189	152	101	174	171	166	107
improvement 1	128	126	113	117	106	136	104	95	92	78	88	93	93	86
improvement 2	92	97	85	82	78	105	80	71	72	62	70	74	72	69

Figure 3. Net energy demand (kWh/m2-yr.) by building type at present and in case of retrofits, Montenegro, climate zone I (coastline)
Notes: the same as to Table 2



	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 4. Net energy demand (kWh/m2-yr.) by building type at present and in case of retrofits, Serbia
Notes: the same as to Table 3

Residential building sector performance at present and in the future

Figure 5 provides an example of our modelling results. The figure depicts the final energy consumption of the residential sector level of Albania in the reference case in 2015 – 2030. The figure illustrates that the model allows obtaining very illustrative for decision-making results, namely the breakdown of final energy consumption could be broken down by energy source, building age, building type, climate zone, energy use, or a combination of any of these parameters.

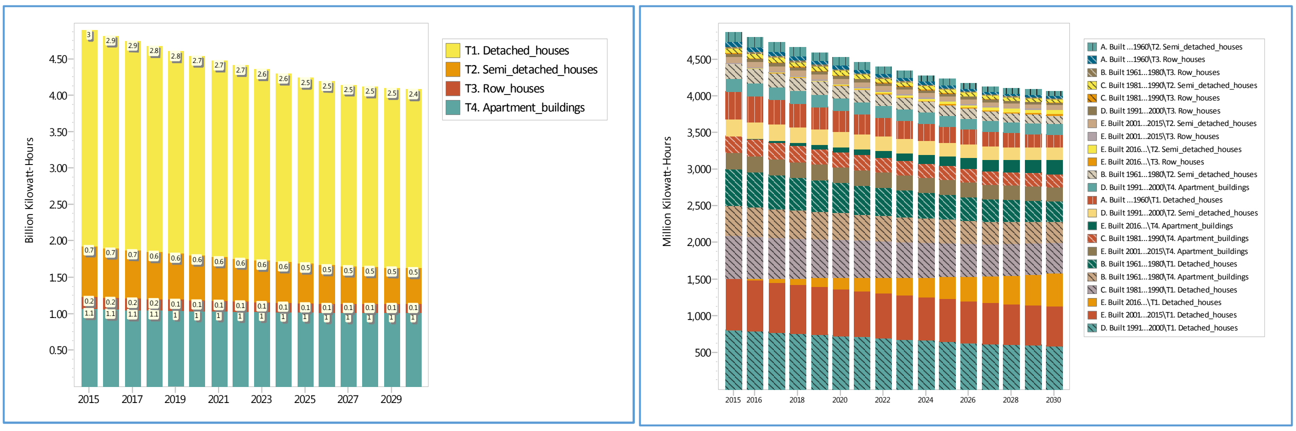


Figure 5. Final energy consumption in the reference case by energy source, building age, building type, climate zone, end-use, and a combination of building age and type, Albania, 2015-2030

Further, we provide the results of our modelling with selected conclusions for policy-makers. We only provide illustrative conclusions on the sector level, but the model allows going further in depth into any sector segment.

According to our estimates, in Albania the final energy consumption of the residential sector for thermal energy services in 2015 was 4.9 billion kWh, of which 54% was addressed by electricity, 37% by wood and 9% by LPG. The sector emitted 96 thousand tons of CO_2 emissions associated with LPG consumption. In the reference scenario, the final energy consumption is expected decline by 17% over 2015 - 2030. The electricity consumption will grow at ca. 2.2%/yr. while wood and LPG consumption will decrease at ca. 11%/yr. and 10%/yr. respectively. In 2030, the CO_2 emission will account for 23% of their 2015 level influenced mostly by the fuel switch from LPG.

In Montenegro, the final energy consumption in 2015 was 2.6 billion kWh, of which 24% was from electricity and 76% from wood. The sector emitted 365 thousand tons of CO_2 emissions associated with electricity consumption. In the reference scenario, the final energy consumption will grow by ca. 2% over 2015 – 2030. In 2030, the CO_2 emission will account for 60% of their 2015 level due to the decreasing emission factor of electricity.

In Serbia, the final energy consumption in 2015 was 42 billion kWh, of which 61% was wood, 16% electricity, 9% district heat, 7% coal, 6% natural gas, and 2% LPG. The sector emitted 9.8 million tons of CO_2 emissions; the largest share is associated with electricity consumption. In the reference scenario, the final energy consumption will decline by ca. 5% over 2015 – 2030. In 2030, the CO_2 emission will account for 89% of their 2015 level. The changes in the structure of consumed energy sources in Montenegro and Serbia will not be significant.

Priority sector segments for policy-making

As the analysis of the results presented in Figure 5 illustrates, the models allow setting sectoral priorities for policy-making. For instance, the Albanian model shows that it is important to retrofit buildings constructed after 1991 because they will be responsible for ca. 43% of the sector final energy consumption in 2030. New buildings of Albania will consume 18% of the sector final energy consumption in 2030, if the new building code required by the European Performance of Buildings Directive will not be introduced within the nearest years. This is why, it is important to prioritize the urgent introduction and enforcement of the new building code in order to avoid the necessity to retrofit these buildings in the future. Detached and semi-detached houses are a clear priority for policy making because 72% of final energy consumption for thermal energy uses will originate in these buildings in 2030. Improving energy efficiency in the medium climate zone is important because at least a half of the final energy consumption will originate from here. Furthermore, space heating is and will remain the main energy consuming end-use.

In Montenegro and Serbia, it is important to ensure that the buildings built between 1971 and 1990 are retrofitted. While these buildings occupy respectively 32% and 34% of the buildings floor area in 2030, they contribute 40% and 46% to the total final energy consumption and therefore are a clear priority for policy intervention. In Serbia, another important category is buildings built in 1961 – 1970, which will be responsible for 17% of final energy consumption. Small buildings are a clear target for policy making in both countries because in 2030, more than 80% of final energy consumption for thermal energy uses will originate in small buildings of these countries. More than 80% of final energy consumption for thermal energy services in both countries will be attributed to space heating.

Evaluation of mitigation scenarios in terms of final energy savings

The models allow evaluating mitigation scenarios versus the reference case in terms of final energy savings and CO_2 emissions. Further, we exemplify conclusions, which policy-makers of our focus countries could make from our analysis.

In Albania, the moderate scenario allows decreasing the final energy consumption by 27% as compared to its reference level in 2030. The associated CO_2 emissions would be 73% lower than their reference level. The scenario would lead to a 44% reduction of the business-as-usual electricity consumption. The majority of the final energy savings will originate from the buildings built in 1991-2000 and new buildings. In terms of building type, the largest share of final energy savings will be located in detached houses. Climate zone B (medium zone) dominates in possible the final energy savings, followed by climate zone A (coastline), and finally by climate zone C (mountains). The largest energy savings would be associated with space heating. The ambitious scenario allows a further decrease of final energy consumption by additional 8% and electricity consumption by additional 5%.

In Montenegro, the final energy consumption and the associated CO2 emissions of the moderate scenario in 2030 would be lower by 15% and 23% respectively than those in the reference case. The scenario would lead to a 14% reduction of the reference wood consumption and to a 19% reduction of the reference electricity consumption. Almost 72% of the final energy savings would originate from the small buildings located in climate zones 1 and 3, which were built in 1946 – 2015 and which would still remain in 2070. The largest energy savings would be associated with space heating. The ambitious scenario would lead to an additional reduction of the final energy consumption and associated emissions by 8% and 23% respectively. Even higher reductions of wood and electricity consumption would be possible.

In Serbia, the moderate scenario would reduce the final energy consumption by 17% in 2030 versus the reference case. The associated CO2 emissions would be 27% lower than their reference level. The scenario would lead to a 15% reduction of the reference wood consumption and to a 33% reduction of the reference electricity consumption on one hand, but to a 26% increase of the natural gas consumption versus the reference case on another hand. More than 60% of the final energy savings would originate from single family buildings built in 1961 - 1990. The largest energy savings would be associated with space heating. The ambitious scenario would lead to an additional 10% reduction in final energy consumption. Overall, the scenario would allow a 34% reduction of the business-as-usual wood consumption, a 13% reduction of the business-as-usual electricity consumption, and a 43% reduction of lignite consumption.

Economic evaluation of the mitigation scenarios

Further, the model allowed conducting economic evaluation of scenarios in terms of saved energy costs and investment costs. Table 7 presents the results of this analysis.

The moderate scenario envisions the annual retrofit of 1.6%-2.5 of the total buildings floor area in 2016 – 2030 that would require high investments. The largest investments are required by building categories: 2001-2015 of Albania, 1971 – 1990 and in 2001 – 2015 of Montenegro, and 1961-1970, 1971-1980, and 1981-1990 of Serbia. When the costs of the reference scenario are deducted from the costs of the moderate scenario, the incremental costs would be significantly lower. Assuming the discount rate of 4%, the annualized incremental costs of the moderate scenario over 2016-2030 are EUR 1.9 - 2.9/m2 in average. Saved energy costs are EUR 3.6 - 3.8 per m2 of new or retrofitted floor area in average over this time period. That means that the investments into the moderate scenario are cost-effective. It is important to note, that the saved energy costs are higher than the annualized investment costs for the scenario as a whole on the country level, but not for all building categories. For a few building categories, saved energy costs are lower than the annualized incremental investment costs and thus for them the incremental investments do not pay back. Raising the discount rate higher than 6% in Serbia, 9% in Albania, and 10% in Montenegro would make the moderate scenario not attractive. There are however other numerous benefits of these scenarios such as positive impacts on human health, environment, higher productivity, higher comfort and many others. If these benefits will be quantified, the cost-effectiveness of the scenarios will be significantly higher. The analysis is conducted assuming a likely to happen increase in energy prices.

Table 7. Economic analysis of the moderate and ambitious scenarios

Indicators	Country	Albania				Montenegro				Serbia			
	Scenario	Moderate		Ambitious		Moderate		Ambitious		Moderate		Ambitious	
	Unit\Time	2016-2030	Annual average	2016-2030	Annual average	2016-2030	Annual average	2016-2030	Annual average	2016-2030	Annual average	2016-2030	Annual average
Floor area retrofitted	million m2	26	1.7	26	1.7	4.7	0.31	6.8	0.43	99	6.6	105	7.0
Share of the floor area	%		2.5		2.5		1.6		2.4		2.0		2.1
New floor area affected	million m2	17	1.1	17	1.1			4.0	0.25			77	5.2
Total costs, retrofits	million EUR	2,291	153	2,698	180	692	46	1,202	80	12,334	822	16,138	1,076
Incremental costs, retrofits	million EUR	1,075	72	1,482	99	285	19	796	53	4,941	329	8,745	583
Incremental costs, new buildings	million EUR	593	40	1,075	72			220	15			4,233	265
Annualized incremental costs*	EUR/m2		2.3		3.5		1.9		5.4		2.9		4.2
Saved energy costs**	EUR/m2		3.8		4.1		3.6		5.5		3.8		2.7
Private investments raised by low-% loans, retrofits	million EUR	548	37	1,103	74	183	12	481	30	4,692	146	8,457	564
Private investments raised by low-% loans, construction***	million EUR			612	38			97	6			1,737	116
Governmental costs for low-% loans, retrofits	million EUR	599		803		84		204		2,191		3,629	
Governmental costs for low-% loans, construction	million EUR			516				64				1,147	
Governmental costs for grants	million EUR	327	22	451	30	89	6	179	11	1,008	67	1,756	117
Private investments, construction****	million EUR	593	37	591	74			124	15			6,735	842

Notes: * the discount rate is 4%; ** costs are per m2 of new and retrofitted buildings;*** for 2016-2022, **** moderate scenario: for 2016-2030, ambitious scenario: for 2023-2030

In the moderate scenario, given the assumed amount of low-interest loans, the eligible investments into building retrofits, which the investors should borrow over 2016-2030 are EUR 37 million/yr. for Albania, EUR 12 million/yr. for Montenegro, and EUR 146 million/yr. for Serbia. Assuming the market loan interest rate of 15% for Albania and 10% for Serbia and Montenegro, the subsidized interest rate of 0%, and the loan term of 10 years, the government would provide to commercial banks EUR 599 million in Albania, EUR 84 million in Serbia, and EUR 2,191 million in Serbia as compensations for lowering the interest rate over this period of time. Additionally, given the assumed amount of allocated grants, their costs for the government are EUR 22 million/yr. in Albania, EUR 6.0 million/yr. in Montenegro, and EUR 67 million/yr. in Serbia.

In the ambitious scenario, 2.1-2.4% of the total buildings floor area is retrofitted per annum in 2016 - 2030. Additionally, the scenario requires higher energy performance of all new floor area that is 1.1 billion m2/yr. for Albania, 0.25 million m2/yr. for Montenegro, and 5.2 billion m2/yr. for Serbia. Assuming the same discount rate as in the moderate scenario and comparing the annualized incremental costs of the SLED ambitious scenario with saved energy costs, it can be concluded that the scenario is cost-effective for Albania, on the boarder of cost-effectiveness for Montenegro, and not cost-effective for Serbia.

For Albania, both scenarios are slightly more cost-effective due to somewhat lower retrofit costs. For Serbia, the costs-effectiveness of both scenarios is lower than in Montenegro and Albania due to higher retrofit costs.

Conclusions and discussion of results

The energy demand in the residential building sector represents a big challenge for Albania, Montenegro, and Serbia. Besides the energy security issue, unsustainable energy consumption of energy sources causes numerous health and environmental problems. The quality of energy services delivered in the residential buildings is very low.

Our project aimed to assist the design of energy efficiency and climate mitigation policies for the residential building sector of these countries with necessary information. Furthermore, we aimed not only to supply ready results to policy-makers, but also to increase their capacity to conduct their own assessment. For all countries, we developed residential building topologies and using them as an input, designed and applied a bottom-up simulation model in LEAP software to assess the impact of policy packages applied to the residential building sector in the future. We selected this software because the representatives of ministries of environment and other institutions involved into climate mitigation policies were taking part in the training using it and therefore they could run and modify themselves our model later according to their needs. The models with all underlying input data were provided to these stakeholders after the end of the project. We also worked closely with these policy-makers on the design and assumptions of the models. The paper presented selected examples of results and conclusions, which could be drawn from them.

Using the methodology of Tabula/Episcope project, we classified the residential building stock of Albania, Montenegro, and Serbia by age and type categories as well as calculated their energy consumption by climate zone at present and incase of business-as-usual and advanced retrofits. From the architectural point of view, the building stock in Serbia and Montenegro show similar characteristics, whilst the Albanian building stock is very is different. In all countries partial heating and intermittent heating is a typical problem as well as uncertainties of wood share in the national energy balance. Energy demand could be significantly reduced in case of standard and ambitious retrofits even though these retrofits assume higher thermal comfort.

For reality check, we compared the calculated final energy consumption with the sector energy balances available on the macro level. The calculated final energy consumption appeared to be significantly different from the official sector energy balances. Based on the consultation with national policy-makers and experts, we concluded on three factors causing such difference. First, the households of the focus countries heat and cool only a part of their dwellings. Second, they heat and cool their dwellings not the whole day. Third, the actual breakdowns on energy sources especially for space heating are different from those reported by official statistics. More specifically, wood consumption is likely to be significantly underestimated in the official balances.

In all three countries, both moderate and ambitious policy scenarios may deliver significant energy savings but sector priorities for policy-making are different for each country. For instance, in Albania it is important to ensure that buildings built after 1991 will be retrofitted, whereas in Serbia and Montenegro it is important to retrofit the building stock constructed in 1971 – 1990. In terms of building type, for all countries it makes sense to focus on energy savings in small buildings. Space heating is identified as the largest energy use for energy savings.

The investment required to decrease the final energy consumption are high in all three countries. This is why, it is important to couple thermal efficiency improvement of existing buildings with their business-as-usual renovation when it is possible to take the advantage of anyway occurring costs. The investments into all scenarios except for the Serbian ambitious scenario are cost-effective or on the border of cost-effectiveness. However, it is important to note that the saved energy costs are higher than the annualized investment costs for the scenario as a whole on the country level, but not for all building categories in all climate zones. This is why, it is important to couple the benefits of mitigation scenarios with their other benefits such as health, energy security, economic growth, and others. The realization of the scenarios requires a careful design and massive provision of financial products for the residential energy efficiency as well as the introduction and enforcement of building codes.

All results listed in the paper, i.e. final energy consumption, CO2 emissions, final energy savings, CO2 emission savings, saved energy costs, investment costs, and others could be easily seen on any level of the building stock segmentation, i.e. on the level of building type, age, climate zone, or end-use. Such detailed analysis has never been done before for these countries and it will provide substantial impetus on the policy process of energy efficiency target setting, the design of national support programs and the better utilization of international donor support.

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