  

The typology of the public building stock in Albania and the modelling of its low-carbon transformation

Albania

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

REGIONAL ENVIRONMENTAL CENTER

WITH FUNDING FROM
AUSTRIAN DEVELOPMENT COOPERATION

The typology of the public building stock in Albania and the modelling of its low-carbon transformation

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

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Executive summary

The goal of this study is to provide background information for the sectoral modelling of the public building stock in Albania. A key element of the work was the development of the very first public building typology for Albania.

The Albanian expert panel involved in the SLED project carried out surveys of existing public buildings, which served as the basis for the creation of the building typology. Public buildings were classified into six categories according to the function of the building: dormitories, hospitals, kindergartens, offices, schools and universities.

As a next step, the energy demand of each building type was estimated. Indicators such as delivered energy per energy source, primary energy, and CO_2 emissions were determined for heating, domestic hot water and cooling. Finally, we defined complex retrofitting options as well as a standard and an ambitious retrofitting package, and determined the resulting energy savings. Specific investment costs are also presented per building type and measure.

The report concludes with a country-wide analysis of the costs and benefits of the thermal efficiency retrofitting of Albanian public buildings. First, we undertook a traditional financial analysis based on the comparison of financial inflows and outflows related to the thermal efficiency retrofitting of public buildings. The financial analysis takes into account capital investment, installation and maintenance costs, as well as saved energy costs.

Secondly, we made an initial attempt to identify and monetise other benefits of thermal efficiency improvements, beyond saved energy costs. These benefits include thermal comfort, avoided CO_2 emissions, avoided economic impacts of airborne pollutants, impacts on employment, and economic growth.

Thirdly, we carried out an analysis using the approach of energy conservation supply curves. In our case, the supply curve of conserved energy characterises the potential energy savings from a set of thermal energy retrofitting packages applied to different building types as a function of the cost per unit.

We estimated that the floor area of the main types of public buildings is 6.6 million m^2, and that it will not change significantly in the short term. About three-quarters of this floor area is occupied by buildings used for educational purposes. Around 13 percent of the floor area is occupied by offices and 11 percent by hospitals. The majority of the floor area of public buildings — that is, 57 percent — is located in climate zone A; 26 percent is located in climate zone B; and 17 percent in climate zone C.

In order to retrofit all Albanian public buildings to the level of improvement 1, around EUR 500 million are needed. According to building type, the investment costs per square metre are the lowest for dormitories, followed by kindergartens and schools. The differences between climate zones are not significant. Building types requiring the biggest investment at national scale are kindergartens and schools, followed by offices and hospitals. If classified by climate zone, the biggest investment is required in climate zone A.

The highest primary and final energy demand savings, and the biggest CO_2 emissions reductions per square metre, are unequivocally in buildings in climate zone C. These indicators have half these values in climate zones A and B, while the difference between zones A and B is not significant. The highest primary and final energy demand savings per square metre are in dormitories, hospitals and offices, with a different ranking for these indicators among climate zones.

Climate zone A shows the biggest share of final energy savings in absolute terms because of the larger number of buildings here than in climate zone C. In terms of the absolute potential for primary and final energy demand savings by building type, kindergartens rank first, followed by schools, then hospitals. In terms of the potential CO_2 emissions savings, the greatest potential is in hospitals and kindergartens.

Average energy savings over the measure lifetime are approximately EUR 4.4/m^2 annually, or EUR 76/m^2 for the whole measure lifetime. The total energy cost savings are EUR 29 million per year, or EUR 502 million over the measure lifetime. Almost 45 percent of the savings are in climate zone A, due to the large number of buildings there. The highest energy cost savings per square metre are in hospitals, followed by dormitories. Saved energy costs per square metre in climate zone C are more than double those in climate zone A, and are 65 percent higher than in climate zone B.

The retrofitting of universities is not financially feasible if only saved energy costs are taken as benefits (the payback time is longer than the measure lifetime, the cost-benefit ratio is greater than 1, negative net present value [NPV], negative internal rate of return [IRR]). The retrofitting of schools and kindergardens is likewise not financially attractive (negative NPV, cost-benefit ratio greater than 1). Retrofitting is financially feasible in dormitories and hospitals, while offices are at the limit of feasibility.

Other benefits of thermal efficiency retrofits are cumulatively comparable to saved energy costs, even though only a limited number of co-benefits are quantified. Beneficial impacts on GDP and employment are particularly high. If all these benefits are taken into account in the financial analysis, the cost-effectiveness of the thermal efficiency retrofitting of all types of public buildings would be far greater.

Figure 1 shows the cumulative potential for final energy savings as a function of the cost of energy conserved for the whole country in the case of improvement 1. The figure shows that building types that are cumulatively able to supply the greatest potential are kindergartens, schools and hospitals. Offices also offer big potential for energy savings. If all the retrofits were to be carried out in the country, it would help to save around 210 GWh per year (16 ktoe). If only those retrofits that cost less than EUR 0.1/kWh were to be carried out, then the savings would be around 62 GWh per year (5.3 ktoe).

A comparison between the cost of the energy conserved and the price of energy helps to identify cost-effective retrofitting packages. If buildings are fully served with electricity, at the current price the retrofitting of all building types, with the exception of schools in climate zone C and dormitories in climate zones A and B, would be cost-effective. If the electricity price were to rise by 1.5 percent per year in real terms, the retrofitting of all building types in climate zone C, as well as dormitories and hospitals in climate zone B, would become cost-effective. Similar conclusions can also be drawn from a comparison of the cost of energy conserved with other energy prices.

Improvement 2 was analysed for dormitories, hospitals, kindergartens and offices. The retrofitting of these types of public buildings to the level of improvement 2 would require around EUR 440 million. Kindergartens would require the biggest investment on a national scale. In terms of climate zone, the largest investment is required in climate zone A.

Average energy savings over measure lifetime are around EUR 4.2/m^2 annually, or EUR 73/m^2 over the whole measure lifetime. Total energy cost savings are EUR 28 million per year, or EUR 480 million over the measure lifetime. Almost half the savings are in climate zone A, due to the large number of buildings.

The retrofitting of schools and universities is not financially attractive if only saved energy costs are taken as benefits (very long payback time that is still lower than the measure lifetime, cost-benefit ratio greater than 1, negative NPV). The retrofitting of dormitories and hospitals is financially feasible. If other benefits taken into account in the financial analysis, the cost-effectiveness of the thermal efficiency retrofitting of all types of public buildings would be far higher.

Figure 2 presents the cumulative potential for final energy savings as a function of the cost of energy conserved for the whole country in the case of improvement 2. The figure shows that building types that are cumulatively able to supply the greatest potential are kindergartens and hospitals. Offices also offer large potential for energy savings. If all retrofits were to be carried out in the country, it would help save around 200 GWh per year (16 ktoe). If only those retrofits that cost less than EUR 0.1/kWh were to be carried out, the savings would be around 83 GWh per year (7.2 ktoe).

If buildings are fully served with electricity, at the current price the retrofitting of all building types in climate zone C, as well as dormitories in climate zones A and B and hospitals in climate zone B, would be cost-effective. If the electricity price were to rise by 1.5 percent per year in real terms, the retrofitting of all building types in climate zone C, as well as dormitories and hospitals in climate zones A and B, would become cost-effective. Similar conclusions can also be drawn from a comparison of the cost of energy conserved with other energy prices.

The analysis presented is rather basic and offers many opportunities for improvement. Besides a more detailed analysis of the benefits of thermal efficiency improvement, an assessment of comfort levels, among other things, and in particular an assessment of risk and uncertainty, should be carried out. Such an assessment should include the sensitivity of key critical variables such as energy prices, and key risks affecting different stakeholders in the scheme.

Although the spreadsheet model presented is rather basic and limited, it can still help stakeholders involved in the scheme to make their decisions. For instance, it can be used to assist in the preparation of the second and third National Energy Efficiency Action Plans (NEEAPs) of Albania. The plans include an indicative budget of EUR 40 million for the period 2017–2020.

Figure 1: Supply curve of energy saved, improvement 1

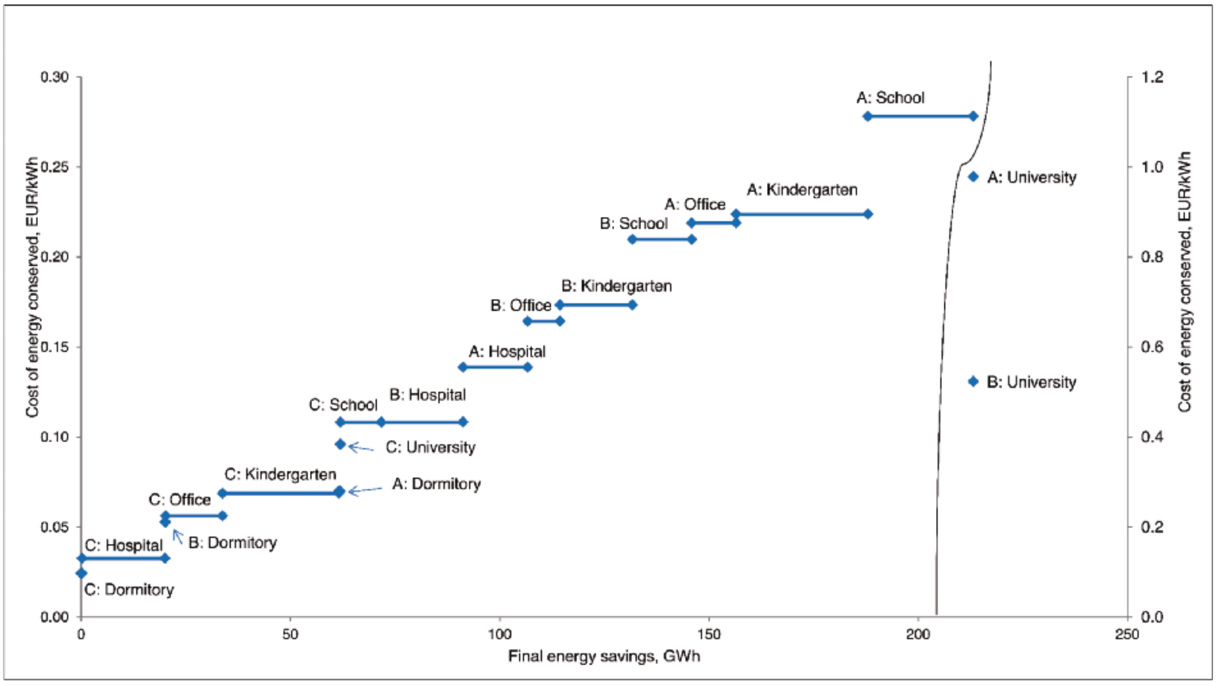


Figure 2: Supply curve of energy saved, improvement 2

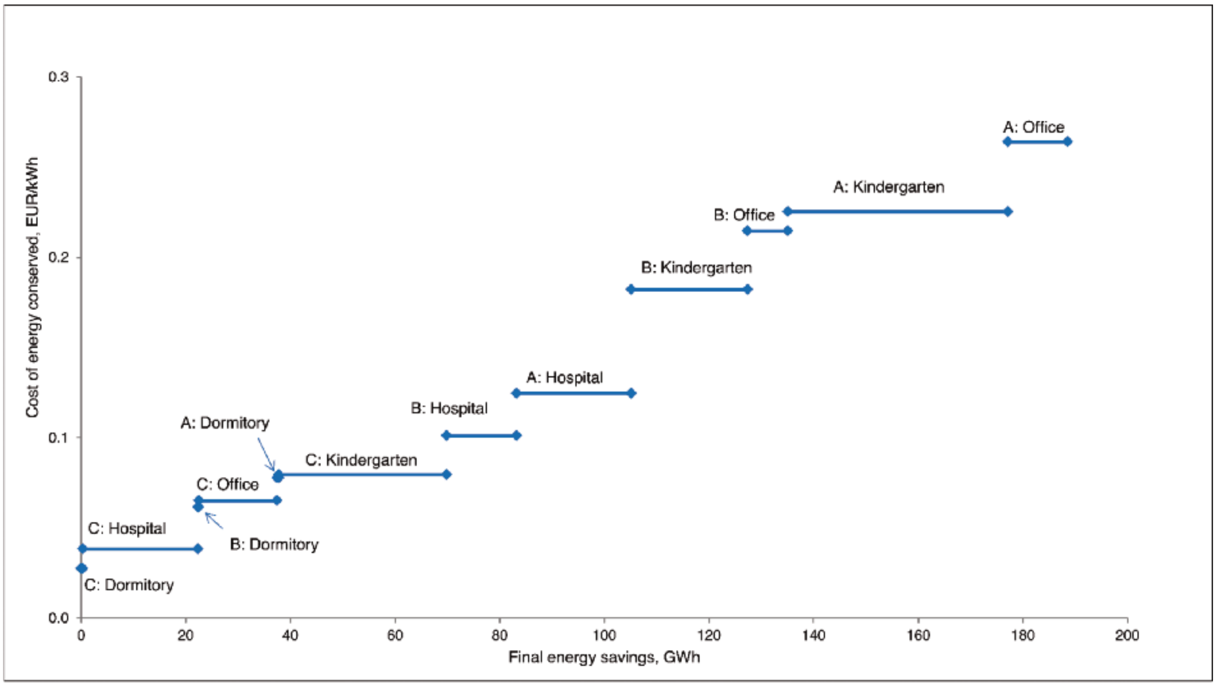


Table 1 presents the possible options, focusing on the building types where retrofitting is cost-effective, and which could be selected as a priority from a social point of view. If all kindergartens and hospitals in climate zone C were to be retrofitted to the level of performance defined by improvement 1, the total investment required would be exactly EUR 40 million.

Table 2 presents another option for funding allocation, disbursed according to the breakdown of building floor area by building type. The EUR 40 million budget allows for the retrofitting of 8 percent of the floor area in each building type according to improvement 1. The table presents the total and the average characteristics of the plan.

Other potential fund allocations are easy to model in spreadsheets, inserting the share of the floor area to be retrofitted by building type according to either cost-effectiveness, or to prioritisation based on other criteria.

Table 1: Retrofitting plan for the most cost-effective and socially acceptable options

Plan characteristics	Hospitals	Kindergartens
Floor area retrofitted (x 1,000 m^2)	126	419
Costs of energy conserved (EUR/kWh)	0.03	0.07
Investment costs (EUR million)	10	30
CO_2 reductions (tCO_2)	3,841	1,072
Primary energy demand savings (GWh [ktoe])	18 (1.5)	13 (1.1)
Final energy demand savings (GWh [ktoe])	20 (1.7)	28 (2.4)
Saved energy costs, annual over measure lifetime (EUR million)	3.4	2.0
Simple payback period (years)	3	15
IRR (%)	23	5
NPV (EUR/m^2)	46	5
Cost-benefit ratio	0.2	0.9
GDP increase (EUR million)	6.6	19.3
Labour income (EUR million)	3.0	8.8
Employment (number of jobs)	1,490	4,383
Monetised CO_2 emissions avoided (EUR million)	1.8	0.5
Air quality, including health impacts (EUR million)	0.5	0.7
Improved comfort and services of buildings (EUR million)	0.8	2.5

Table 2: Retrofitting plan with funding allocation in proportion to the breakdown of building floor area by building type

Characteristics	Dormitories	Hospitals	Kindergartens	Offices	Schools	Universities	Total/ average
Floor area retrofitted (x 1,000 m^2)	0.7	61	202	68	197	0.9	**530**
Costs of energy saved (EUR/kWh)	0.05	0.09	0.16	0.14	0.21	0.35	**0.15**
Investment costs (EUR million)	0.0	5	15	5	15	0.1	**41**
CO_2 reductions (tCO_2)	4	713	416	198	211	2	**1,544**
Primary energy demand savings (GWh [ktoe])	0.1	4	5	2	4	0.0	**15**
Final energy demand savings (GWh [ktoe])	0.1	4	6	3	5	0.0	**17**
Saved energy costs, annual over measure lifetime (EUR million)	0.15	12	13	5	10	0.03	**40**
Simple payback period (years)	5	7	20	17	27	n/a	**17**
IRR (%)	15.7	11.1	3.0	4.0	1.1	-0.2	**3.9**
NPV (EUR/m^2)	0.1	6.7	-2.1	0.0	-5.1	0.0	**-0.4**
Cost-benefit ratio	0.3	0.4	1.2	1.0	1.5	2.1	**1.0**
GDP increase (EUR million)	0.03	3.2	9.8	3.5	9.7	0.04	**26**
Labour income (EUR million)	0.01	1.4	4.5	1.6	4.5	0.02	**12**
Employment (number of jobs)	6.8	717	2,238	804	2,212	10	**5,987**
Monetised CO_2 emissions avoided (EUR million)	0.00	0.3	0.2	0.1	0.1	0.00	**1**
Air quality, including health impacts (EUR million)	0.00	0.1	0.1	0.1	0.1	0.00	**0.4**
Improved comfort and services of buildings (EUR million)	0.00	0.4	1.2	0.4	1.2	0.01	**3**

1. Introduction

Background

Following a steep decline in the 1990s, Albania experienced economic growth reaching an annual 7.5 percent in 2008 (World Bank online). Following the global financial crisis, economic growth declined, but it has been on the rise again since 2014. In order to maintain high rates of economic growth, Albania needs access to a long-term, secure, affordable and sustainable energy supply. On the other hand, the country needs to use its available energy resources and its purchased energy in the most efficient and rational way.

Energy demand in the building sector represents a particular challenge. In 2012, final energy consumption in the building sector was 35 percent of the national total (EUROSTAT 2015). The sector also accounted for 75 percent of the electricity available for final energy consumption (ibid.). The quality of energy services delivered in Albanian buildings is far lower than the EU average. Most notably, Albanian public buildings are heated partially, and for only a few hours a day.

As a contracting party to the Energy Community Treaty, Albania is obliged to introduce EU energy efficiency legislation. As of April 2015, the country has transposed Directive 2006/32/EC on Energy End-Use Efficiency and Energy Services (ESD) and Directive 2010/30/EU on the Labelling of Energy-Related Products (Recast Directive 92/75/EEC). It is expected that Directive 2010/31/EU on the Energy Performance of Buildings (EPBD) and Directive 2012/27/EC on Energy Efficiency (EED) will be transposed in 2016: the implementing by-laws are to be prepared and adopted. In accordance with the ESD, the country has to meet an energy-saving target equal to 9 percent of total energy sales in 2018, compared to 2010. According to the EED, Albania will have to achieve 1.5 percent per year energy sales savings compared to the recent three-year period through the use of a utility obligation scheme or other, alternative approach. Achieving such targets will require 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 implementation of 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 public building sector, the policy mix in Albania to address these opportunities could be significantly improved. Designing an intelligent policy package is not easy, however, as energy efficiency potential is spread among different types of buildings and fragmented among end uses. There is a lack of understanding about how to structure the building sector in terms of policy making; how much potential there is for energy saving and CO_2 emissions reductions; where this potential is located; and how much it would cost to realise.

Research questions

The present publication aims to contribute to the evidence-based design of energy efficiency and climate mitigation policies in Albania that target the public building sector by providing the necessary information.

The report addresses the following questions:

1. How should existing public buildings in Albania be classified? What are the representative building types in the Albanian public building stock? What is the structure of the public building stock according to these types?
2. For each representative building type, what are the energy demand; the delivered energy by energy source; primary energy consumption; and CO_2 emissions from space heating, water heating, space cooling and ventilation?
3. 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?
4. Which building types offer the largest and/or the most cost-effective energy savings? What are the priority sector segments for policy making?
5. How financially attractive are the suggested retrofitting packages? Do they pay back in terms of energy cost savings? How significant are the co-benefits of building retrofitting packages if they are monetised?

Research boundaries

The present report assesses only thermal energy services delivered in public buildings — namely space heating, space cooling, ventilation and water heating. Other energy services are not covered. These latter energy services consume a large share of the public sector balance, thus it is important to bear in mind that, if they were taken into account, building energy consumption and CO_2 emissions would be higher.

The retrofitting options include both the improvement of the thermal envelope and the exchange of technical systems, which often imply a fuel switch. The improvement of the thermal envelope means the retrofitting of walls, roofs, floors and windows. Better technical systems are better systems for water heating, space heating, ventilation and space cooling. Depending on the technical and economic feasibility, public buildings may switch to solar, biomass, liquefied petroleum gas (LPG), diesel oil or electricity as energy sources. We do not consider the impact of climate change on space heating and cooling patterns.

The building stock statistics on which the estimates are based are dated as of 2012. Energy consumption is not calibrated to the sector energy balance, although building energy demand is calibrated to energy bills.

In terms of environmental impacts, we calculated only CO_2 emissions. We considered both direct and indirect emissions in our analysis. Direct emissions are those originating from fuel combustion that takes place in buildings. Indirect emissions are those produced in the transformation sector, which are 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.

2. Building typology of existing buildings

The Albanian expert panel surveyed a total of 48 public buildings and determined the main input data for an energy performance calculation. Metered consumption figures were also available in most buildings. Although this sample cannot be regarded as representative, the number of surveys was sufficient to draw conclusions about the present state of the public building stock. The surveys provided a basis for defining representative buildings.

In the public building typology, the following building types were distinguished:

- dormitories;
- hospitals;
- kindergartens;
- public offices (including municipal and government offices);
- schools; and
- universities.

Below, we summarise the main findings of the surveys and describe the present state of the surveyed public buildings.

Dormitories

Five dormitories were surveyed by the Albanian expert panel (see Figure 3). The sample includes small, medium-sized and large dormitories, with a total net floor area ranging between 1,300 and 4,900 m^2 and an average number of occupants ranging from 74 to 518. One dormitory is located in zone A, two in zone B and two in zone C.

- Construction period and renovation: The surveyed dormitories were built between 1950 and 1975. Most dorms were last renovated 10 to 15 years ago. Renovation included plastering and changing the windows to aluminium-framed single-glazed windows. In some dorms, the boiler was also changed.
- Construction materials: The typical material for wall construction is plastered solid brick with a U-value of around 1.6 W/m^2K. Most dormitories have flat roofs or unused loft spaces with no or limited insulation. Windows are single glazed with aluminium frames.

Figure 3: Some of the surveyed dormitory buildings

- Technical building systems: The two dorms in zone C have a central heating system with an oil boiler. The other three, in zones A and B, have a decentralised system with electric radiant heating. Domestic hot water is produced by small electric water heaters (boilers). There are no ventilation or cooling systems, and no renewables are used.
- Use: Some dormitories are open all year round, while others close during the summer months. Typically, only the rooms are heated (45 to 80 per-cent of the total floor area) and for only about five to eight hours a day.

Hospitals

Five hospitals were surveyed by the Albanian expert panel (see Figure 4). The total net floor area ranges from 2,000 to 12,800 m^2. One surveyed hospital is located in zone A, two in zone B and two in zone C.

- Construction period and renovation: The surveyed hospitals were built between 1959 and 1987. Two were renovated recently, and the other three about 15 years ago. In the recently renovated buildings, windows were changed for double-glazed units with plastic frames. In the earlier renovations, win-dows were changed to single-glazed aluminium frames. In some of the hospitals the heating system was also upgraded. In two buildings, efficient light-ing systems were installed.
- Construction materials: The typical material for wall construction is plastered solid brick with a U-value of around 1.3 W/m^2K. Most hospitals have flat roofs with limited insulation. Windows are either single glazed with aluminium frames, or double glazed in recently retrofitted buildings.
- Technical building systems: All surveyed buildings have a central heating system, mostly supplied by an oil boiler. One recently renovated hospital has a central pellet boiler. In two buildings, a secondary, centralised air-heating system meets part of the de-mand based on a heat pump. Hot water is typically produced using decentralised electric boilers. No ventilation systems are used. Cooling typically does

Figure 4: Some of the surveyed hospital buildings

not exist: only one of the recently renovated buildings has a central cooling system, supplemented by decentralised split-type air conditioners.

- Use: Hospitals are open all year round, 24 hours a day. Typically only the rooms are heated (50 to 80 percent of the total area) for between 10 and 20 hours a day.

Kindergartens

Seven kindergartens were surveyed by the Albanian expert panel (see Figure 5). The total net floor area of the buildings ranges between 290 and 720 m^2, and the total number of users is between 100 and 200. Two of the buildings are located in zone A, two in zone B and three in zone C.

- Construction period and renovation: The surveyed kindergartens were built between 1960 and 1990, and most of them have been renovated in the last decade. Renovations included changing windows for single-glazed aluminium-framed windows, with double glazing introduced in only the more recent renovations. Heating systems have also been upgraded. In the two most recently retrofitted buildings the walls were additionally insulated with 5 cm of polystyrene.
- Construction materials: The typical material for wall construction is plastered solid brick with a U-value of around 1.3 W/m^{2}K. Most kindergartens have flat roofs or unused loft space with no or limited insulation. In the recently retrofitted buildings, the flat roofs are insulated. Buildings typically have single-glazed aluminium-framed windows, although the recently retrofitted buildings have double-glazed windows.
- Technical building systems: Both decentralised and central heating systems exist. Decentralised systems include wooden stoves in zone C and direct electric heating in zones A and B. Recently renovated buildings have central gas, oil or biomass

Figure 5: Some of the surveyed kindergartens

boilers. Most kindergartens have no domestic hot water system: only a few have electric boilers. No ventilation or cooling systems are installed.

- Use: Kindergartens are open on average 220 days a year, for about 40 hours a week, and are closed for the summer holidays and at the weekends. Typically only the rooms are heated (65 to 90 percent of the total area), and for only about five to eight hours a day.

Public offices

Public offices in our categorisation include government offices (four buildings) and municipal offices (three buildings) (see Figure 6). The sample includes buildings with a total net floor area ranging between 110 and 1,680 m^2 and an average number of users ranging between 9 and 104. One office building is located in zone A, two in zone B and four in zone C.

- Construction period and renovation: The surveyed offices were built between 1952 and 1982, and renovated between 5 and 14 years ago. Renovations included changing the windows to single-glazed aluminium-framed windows: double-glazed windows were installed in only one building. Renovation also included plastering and roof repair, with no energy-related measures.
- Construction materials: The typical material for wall construction is plastered solid brick with a U-value of around 1.5 W/m^2K. Most offices have flat roofs or unused loft space with no or limited insulation. Windows are usually single glazed with aluminium frames.
- Technical building systems: The surveyed offices have decentralised heating systems supplied with low-efficient heat pumps, although electric direct heating and wood stoves also exist. Only one office building has a central system with an oil boiler. There is usually no domestic hot water or ventilation system. In zones A and B, cooling is provided by decentralised split-type air conditioners.
- Use: Offices are open on weekdays for eight hours a day. Typically only the office rooms are heated (35 to 80 percent of the total area) for about six to eight hours a day.

Schools

A total of 17 schools were surveyed by the Albanian expert panel (see Figure 7). The sample includes small, medium-sized and large schools, with a total net floor area ranging between 1,000 and 4,000 m^2 and an average number of users ranging from 130 to 1,160. Most of the surveyed schools are located in zone C (12), three are located in zone A and two in zone B.

- Construction period and renovation: The schools were built between 1950 and 2000, with most of the surveyed buildings built in the 1960s and 1970s. Some of the schools have undergone renovation in the last decade, and some were renovated in the 1990s. Renovations included standard measures such as plastering and the rebuilding of roof covering, although in some cases energy-related measures were applied. Windows were changed in many schools, usually for single-glazed aluminium-framed windows, although in some cases for double-glazed aluminium or plastic windows. Some schools were additionally insulated with polystyrene, but this is not a common measure. In some buildings, the heating system was also upgraded and new oil boilers were added. The installation of an efficient lighting system is mentioned in only one school.
- Construction materials: The typical material for wall construction is plastered solid brick with a U-value of around 1.4 W/m^2K. Most schools have flat roofs or unused loft space with no or limited insulation. Windows are either single glazed with aluminium frames, or double glazed in recently retrofitted buildings.
- Technical building systems: About half of the surveyed schools have centralised heating systems using an oil boiler and radiators. The other half have decentralised systems: in zone C, typically biomass stoves are used, while in zones A and B electric radiant heating is common. There are no hot water, ventilation or cooling systems in schools.
- Use: Schools are open on average for 160 to 220 days annually, for about 40 hours a week, and are closed for the summer holidays and at the weekends. Typically only the classrooms and offices are heated (50 to 70 percent of the total area), and for only about four or five hours a day.

Figure 6: Some of the surveyed public office buildings

Universities

Seven universities were surveyed by the Albanian expert panel (see Figure 8). The sample includes small, medium-sized and large university buildings with a total net floor area ranging from 740 to 5,200 m^2 and an average number of users ranging from 350 to 2,500. Six of the surveyed universities are located in zone B, and one in zone A.

- Construction period and renovation: Most surveyed universities were built between 1965 and 1979, and renovated in the last 5 to 10 years. Renovations included plastering and changing the windows to single-glazed aluminium-framed windows. In one building, the heating system was also upgraded. One of the surveyed buildings was built in 2006, and another in 2009.

Figure 7: Some of the surveyed school buildings

- Construction materials: The typical material for wall construction is plastered solid brick with a U-value of around 1.5 W/m^{2}K. The new buildings were built from hollow clay blocks. Most universities have flat roofs with no or limited insulation. Windows are either single glazed with aluminium frames, or double glazed in recently built buildings.
- Technical building systems: Most buildings have centralised heating systems with an oil boiler or heat pump. One building has decentralised direct electric heating and one has decentralised heat pumps with fan coils. Domestic hot water systems exist in only three of the buildings, where electric boilers are installed. No ventilation systems exist. For cooling, one of the new buildings has a central cooling system, and some other buildings have decentralised split air conditioners.
- Use: Universities are open on average 220 days annually, for about 50 hours a week, and are closed for the summer holidays and at weekends. Typically, only the classrooms and offices are heated (50 to 70 percent of the total area) and for only about four to eight hours a day.

Calculated and measured consumption values

Energy performance calculations were made for each surveyed building according to the methodology described in Section 3. For most buildings, consumption bills were also provided by the expert panel. The measured and calculated consumption of the surveyed buildings can be found in Annex 1: the table shows the measured consumption divided by the calculated consumption, thus values lower than 1 represent a higher calculated demand than measured demand. The Albanian expert panel took into consideration the measured to calculated ratios when considering under-heating.

Building typology

Bottom-up modelling is usually based on a representative set of buildings, or, in case of a lack of data, on a selection of real example buildings. The TABULA project, which aimed to create a harmonised structure for building typologies, defined three approaches to classifying building types (EE Tabula – Episcope):

- Real Example Building: The most representative building selected by a panel of experts, usually applied if statistical data are not available.
- Real Average Building: Real building with similar characteristics to the mean geometrical and construction features of a statistical sample.
- Synthetic Average Building: Virtual building or archetype that is a "statistical composite of the features found within a category of buildings in the stock. (IEA Annex 31 2004)

The size of the available building sample was limited and the sample cannot be considered as representative. In our model, we created one Synthetic Average Building for each public building type to reduce uncertainties. The geometric parameters and thermal values of the constructions are the mean values for the available sample. For the technical building systems, the typical systems and their national share were determined by the local expert panel. Some surveyed buildings were very specific (e.g. under protection as monuments) and were thus excluded from the average.

Figure 8: Some of the surveyed university buildings

3. Energy demand calculation method and main assumptions

Energy demand calculations

The energy calculations included thermal energy services — that is, space heating, space cooling, domestic hot water production, and in some cases mechanical ventilation. Demand for lighting and appliances was not considered.

Space heating and cooling were calculated according to the quasi-steady-state seasonal method defined in EN ISO 13790:2008. The energy balance includes the following components:

- transmission heat transfer between the conditioned space and the external environment;
- ventilation heat transfer (by natural ventilation or by a mechanical ventilation system);
- transmission and ventilation heat transfer between adjacent zones;
- internal heat gains (e.g. persons, appliances, lighting);
- solar heat gains (direct or indirect);
- storage of heat in, or release of stored heat from, the mass of the building;
- energy need for heating: if the zone is heated, a heating system supplies heat in order to raise the internal temperature to the required minimum level (the set-point for heating); and
- energy need for cooling: if the zone is cooled, a cooling system extracts heat in order to lower the internal temperature to the required maximum level (the set-point for cooling).

A quasi-steady-state method considers a sufficiently long period to make it possible to take into account dynamic effects (storage and release of heat) according to an empirically determined gain and/or loss utilisation factor. For heating, internal and solar heat gains are multiplied by a gain utilisation factor to take into account the fact that only part of the gains are utilised to reduce the energy need for heating, with the rest leading to an undesired increase in the internal temperature above the set point. For cooling, we applied a utilisation factor for losses (a mirror image of the approach for heating), describing the fact that only part of the transmission and ventilation heat transfer is utilised to reduce cooling needs.

As public buildings are usually not used all day round, correction factors for intermittent heating and cooling were introduced based on the number of heated/cooled hours. In addition, in Albania it is common for only continuously occupied spaces to be heated. This means that, for example, only classrooms and offices in schools are heated, while corridors and restrooms have no heating at all, or the heating is not used (Simaku 2016).

Many public buildings have no central heating systems, and especially no cooling systems. Even if a central system does exist, there is typically no automatic regulation. A simplified method was therefore applied to take into account partial and intermittent heating (cooling), in which the continuous heating (cooling) need is multiplied by a correction factor based on the fraction of the heated (cooled) area and the number of hours in the week with a normal heating (cooling) set point. The set-point temperature was assumed to be 20°C for heating and 26°C for cooling.

For building service systems, we calculated several options according to the heating system typical for the type of building and the climate zone. In the baseline option, we calculated the energy demand of all building types for the climate of Tirana (climate zone B) and adapted the results to the other climate zones using correction factors based on heating and cooling degree days. As there is a high level of uncertainty in the input data, the results should be regarded as estimates only.

Definition of retrofitting options

In the model, three renovation options were developed for all building types, two of them representing a complex retrofitting package. The complex packages consist of measures to upgrade the building envelope and the heating, cooling and domestic hot water systems.

The **"business as usual" option (BAU improvement)** includes the currently most frequently applied renovation option — that is, the changing of windows, the insulation of roofs and/or loft spaces, the installation of individual direct electric water heaters, and low-efficiency decentralised split cooling units in some rooms. However, we assume that in the BAU improvement the comfort level rises. The heating system is used more frequently, and demand for cooling and hot water is higher (in the current state hot water is not installed in most of the buildings).

The **"standard" option (improvement 1)** includes interventions related to each building component in order to comply with the minimum requirements foreseen in the case of major renovation. In the case of buildings constructed before 2000, major renovations are rather likely. The standard option in this case therefore includes a set of interventions for upgrading the building envelope from an insulation point of view. In addition, efficient building service systems are introduced: reversible heat pumps with better coefficient of performance (SCOP=3), efficient wood pellet boilers (85 percent efficiency), low-temperature gas boilers or efficient oil boilers. In terms of water heating, either direct electric heating (as for BAU) or, if not electric, combined systems with heating are applied. In climate zones A and B, cooling has no additional cost (reversible heat pumps). In zone C, we assume the same simple cooling units as for BAU to keep the costs low.

The **"ambitious" option (improvement 2)** goes beyond building regulations regarding the building envelope. Efficient building service systems are introduced, such as reversible heat pumps with better coefficient of performance (SCOP=4), efficient wood pellet boilers (85 percent efficiency), condensing gas boilers or efficient oil boilers. In terms of water heating, heat pumps with high coefficient of performance (SCOP=4, independent from heating), or combined systems with heating are applied. In addition, central solar heating systems are introduced to cover 8 to 20 percent of hot water demand (with the exception of schools and universities, where solar is not applied). In climate zones A and B, cooling has no additional cost (reversible heat pumps). In zone C, we assume the same simple cooling units as for BAU to keep the costs low. We assume balanced ventilation with heat recovery only for improvement 2.

Climate data

Albania is divided into three climate zones: zone A is the mildest along the coastline; zone B is the medium zone; and zone C is the coldest, in the mountainous region (Figure 9).

Albanian regulations provide heating degree days for the largest cities in Albania, but other climate data are missing. The free version of the Meteonorm database contains information on the climate of Tirana (global, diffuse and direct horizontal radiation, air and dew point temperature, and wind speed). Radiation on vertical surfaces for each orientation was approximated based on the climate dataset of the Passive House Planning Package (PHPP) software for the Italian city of Bari, which has a very similar climate to Tirana (difference in air temperature of 2 percent, and difference in radiation of 5 percent).

For climate zones A and C, heating and cooling energy use were corrected based on the degree days of the corresponding climate zones, as provided by Albanian regulations. As data were missing, radiation for climate zones A and B was assumed to be the same, and for climate zone C it was estimated based on the Italian city of L'Aquila in the mountainous area of Abruzzo.

The length of the heating season was fixed at six months, from October to March, with the cooling season as the six months from April to September (three months in climate zone C). According to the calculation method of EN ISO 13790, the fixed length should be long enough to include months with heating/cooling demand, although its value is not critical as the actual length of the season is determined by the gain (loss) utilisation factor. Global radiation and degree days were also calculated for this fixed season length (Table 3). The climate data for Albania are estimates, which can be corrected in the future when more accurate data become available.

Building structures and parameters

Currently, with the exception of buildings constructed in the last decade, Albanian buildings have limited or no insulation. The U-values in our calculations are the weighted mean values of the survey results. The standard renovation includes the addition of 5 to 10 cm of insulation for walls, roofs and floors, and the changing of windows to double-glazed units. The ambitious option involves 8 cm of insulation for walls, 10 cm for roofs and 5 to 8 cm for floors, along with triple-glazed windows. In most cases, expanded polystyrene with thermal conductivity in the range of 0.031 to 0.045 W/mK was assumed. Details are provided in Tables 4 and 5.

Main input data

We used internal dimensions corrected by the effect of thermal bridges, as provided by the Albanian expert panel (Simaku 2016). To calculate solar gains, we assumed average orientation and average shading in the winter (80 percent reduction factor) and temporary external sun protection for the summer. The input data were based on the weighted mean values

Figure 9: Climate zones and prefectures in Albania (Simaku, Thimjo and Plaku 2014; Wikipedia 2015; Wikimedia 2015)

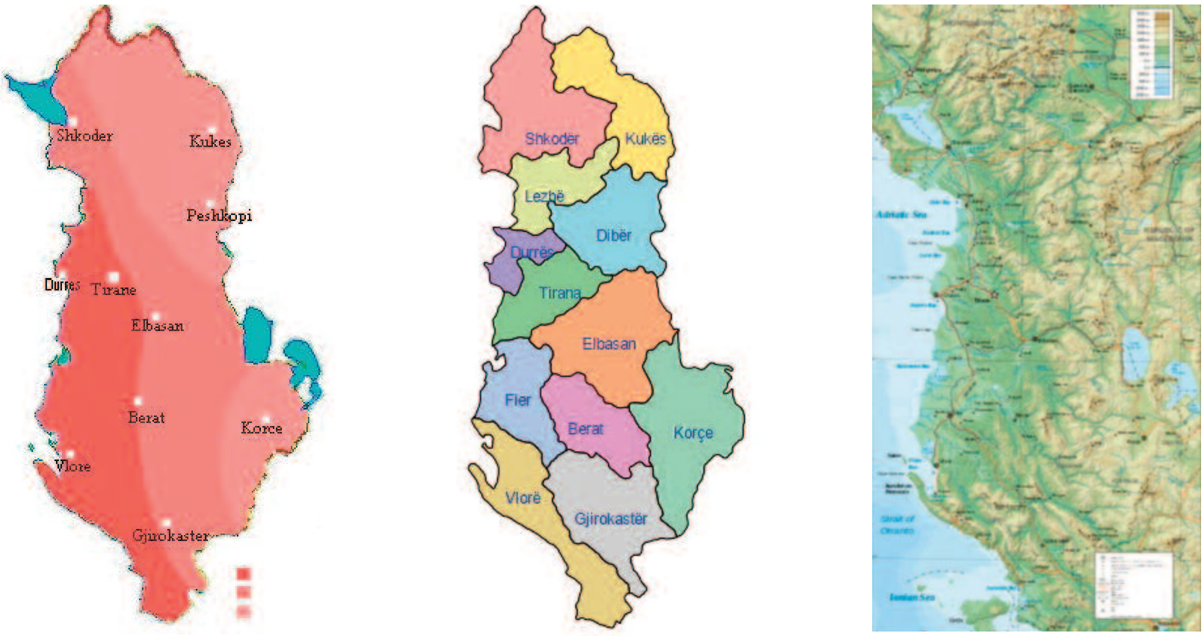


Table 3: Estimated climate data for all climate zones

	Heating		Cooling		Yearly global radiation				
	HDD	Length	CDD	Length	North	East	South	West	Global
	hK/a	h/a	hK/a	h/a	kWh/(m²a)				
Zone A	1,330	4,368	665.3	4,392	372	951	1,234	924	1,552
Zone B	1,674	4,368	756.8	4,392	372	951	1,234	924	1,552
Zone C	2,600	4,368	385.1	2,208	362	922	1,195	878	1,480

Table 4: Thickness of additional insulation (cm)

	BAU renovation	Improvement 1	Improvement 2
External walls	0	5	8
Floor of attic space	5	10	10
Cellar ceiling	3	5	8
Floor above outdoor space	0	10	10
Flat roof	3	5	5
Pitched roof	10	10	10
Perimeter insulation	0	5	5
Walls to the ground	3	5	5

of the survey results. We considered poor airtightness due to badly fitting windows in the present state, resulting in excess infiltration in the winter. For the retrofitting options, no excess infiltration was assumed, due to the replacement of the windows. The main design input data are summarised in Table 6. The internal design temperature was assumed to be 20°C in winter and 26°C in summer in the baseline option.

Space heating systems

The most typical energy sources and heating systems were modelled for the current situation: electricity (air-to-air heat pumps and direct electric heating), wood (mostly wood stoves), constant-temperature gas boilers and oil boilers. The typical system and the energy source depend on the function of the building and on the climate zone. In climate zone C wood is dominant, while in climate zones A and B all three energy sources are significant. The proportions were provided by the Albanian expert panel (Simaku 2016). In the absence of statistics, these can be regarded as expert estimates.

The BAU option assumes that heat pumps will be more widely used, typically with low efficiency. Direct electric heating also remains, and in some building types its share is increasing. In improvement 1, heat pumps with higher efficiency are assumed, to replace direct electric heating. Gas boilers replace oil boilers in many buildings. In climate zone C, central pellet boilers replace wood stoves. In improvement 2, heat pumps with an even higher efficiency were assumed, along with condensing gas boilers. In universities and schools, no improvement 2 is taken into account. The assumptions for each building type are summarised in Tables 7 to 12.

Table 5: Added insulation in the retrofitting options

	Dormitories	Hospitals	Kindergartens	Offices	Schools	Universities
Present state	Limited or no insulation, single-glazed windows with metal frames	Limited or no insulation, single-glazed windows with metal frames and double-glazed windows with wood/plastic frames	Limited or no insulation, single-glazed windows with metal frames	Limited or no insulation, single-glazed windows with metal frames	Limited or no insulation, single- or double-glazed windows with metal frames	Limited or no insulation, single-glazed windows with metal frames
BAU renovation	Additional insulation, single-glazed windows with metal frames	Additional insulation, single-glazed windows with metal frames and double-glazed windows with wood/plastic frames	Additional insulation, single-glazed windows with metal frames	Additional insulation, single-glazed windows with metal frames	Additional insulation, single- or double-glazed windows with metal frames	Additional insulation, single-glazed windows with metal frames
Improvement 1 (standard)	Additional insulation, double-glazed windows with metal frames and noble gas filling	Additional insulation, double-glazed windows with metal frames and noble gas filling	Additional insulation, double-glazed windows with metal frames and noble gas filling	Additional insulation, double-glazed windows with metal frames and noble gas filling	Additional insulation, double-glazed windows with metal frames and noble gas filling	Additional insulation, double-glazed windows with metal frames and noble gas filling
Improvement 2 (ambitious)	Additional insulation, triple-glazed windows with metal frames and noble gas filling	Additional insulation, triple-glazed windows with metal frames and noble gas filling	Additional insulation, triple-glazed windows with metal frames and noble gas filling	Additional insulation, triple-glazed windows with metal frames and noble gas filling	Additional insulation, triple-glazed windows with metal frames and noble gas filling	Additional insulation, triple-glazed windows with metal frames and noble gas filling

Table 6: Assumed main building input data

	Dormitories	Hospitals	Kindergartens	Offices	Schools	Universities
Average air exchange rate in the heating season (l/h)	0.50	0.90	0.90	0.80	0.90	0.90
Average internal heat gain (W/m²)	7.50	9.00	7.50	8.50	7.50	8.75
Design temperature in winter (°C)	20					
Design temperature in summer (°C)	26					

Table 7: Dormitories — National share and efficiency of heating systems and energy sources in the present state, BAU, standard and ambitious retrofitting options

	Present and BAU	Improvement 1 (standard)	Improvement 2 (ambitious)
Climate zone A	Direct electric heating, 80% η_b = 100%	Heat pump, 80% SCOP = 300%	Heat pump, 60% SCOP = 400%
	Wood stove, 0% η_b = 60%	Pellet boiler, 0% η_b = 85%	Pellet boiler, 20% η_b = 85%
	Gas boiler, 0% η_b = 80%	Gas boiler (low temperature), 20% η_b = 90%	Gas boiler (condensing), 20% η_b = 98%
	Oil boiler, 20% η_b = 80%	Oil boiler (low temperature), 0% η_b = 90%	Oil boiler (low temperature), 0% η_b = 95%
Climate zone B	Direct electric heating, 80% η_b = 100%	Heat pump, 80% SCOP = 300%	Heat pump, 60% SCOP = 400%
	Wood stove, 0% η_b = 60%	Pellet boiler, 0% η_b = 85%	Pellet boiler, 20% η_b = 85%
	Gas boiler, 0% η_b = 80%	Gas boiler (low temperature), 20% η_b = 90%	Gas boiler (condensing), 20% η_b = 98%
	Oil boiler, 20% η_b = 80%	Oil boiler (low temperature), 0% η_b = 90%	Oil boiler (low temperature), 0% η_b = 95%
Climate zone C	Direct electric heating, 15% η_b = 100%	Heat pump, 40% SCOP = 300%	Heat pump, 40% SCOP = 400%
	Wood stove, 50% η_b = 60%	Pellet boiler, 40% η_b = 85%	Pellet boiler, 40% η_b = 85%
	Gas boiler, 0% η_b = 80%	Gas boiler (low temperature), 20% η_b = 90%	Gas boiler (condensing), 20% η_b = 98%
	Oil boiler, 35% η_b = 80%	Oil boiler (low temperature), 0% η_b = 90%	Oil boiler (low temperature), 0% η_b = 95%

Table 8: Hospitals — National share and efficiency of heating systems and energy sources in the present state, BAU, standard and ambitious retrofitting options

	Present and BAU	Improvement 1 (standard)	Improvement 2 (ambitious)
Climate zone A	Heat pump, 75% SCOP = 220%	Heat pump, 90% SCOP = 300%	Heat pump, 100% SCOP = 400%
	Wood stove, 0% η_b = 60%	Pellet boiler, 0% η_b = 85%	Pellet boiler, 0% η_b = 85%
	Gas boiler, 0% η_b = 80%	Gas boiler (low temperature), 0% η_b = 90%	Gas boiler (condensing), 0% η_b = 98%
	Oil boiler, 25% η_b = 80%	Oil boiler (low temperature), 10% η_b = 90%	Oil boiler (low temperature), 0% η_b = 95%
Climate zone B	Heat pump, 75% SCOP = 220%	Heat pump, 90% SCOP = 300%	Heat pump, 100% SCOP = 400%
	Wood stove, 0% η_b = 60%	Pellet boiler, 0% η_b = 85%	Pellet boiler, 0% η_b = 85%
	Gas boiler, 0% η_b = 80%	Gas boiler (low temperature), 0% η_b = 90%	Gas boiler (condensing), 0% η_b = 98%
	Oil boiler, 25% η_b = 80%	Oil boiler (low temperature), 10% η_b = 90%	Oil boiler (low temperature), 0% η_b = 95%
Climate zone C	Heat pump, 15% SCOP = 220%	Heat pump, 50% SCOP = 300%	Heat pump, 50% SCOP = 400%
	Wood stove, 50% η_b = 60%	Pellet boiler, 30% η_b = 85%	Pellet boiler, 50% η_b = 85%
	Gas boiler, 0% η_b = 80%	Gas boiler (low temperature), 0% η_b = 90%	Gas boiler (condensing), 0% η_b = 98%
	Oil boiler, 35% η_b = 80%	Oil boiler (low temperature), 20% η_b = 90%	Oil boiler (low temperature), 0% η_b = 95%

Table 9: Kindergartens — National share and efficiency of heating systems and energy sources in the present state, BAU, standard and ambitious retrofitting options

	Present and BAU	Improvement 1 (standard)	Improvement 2 (ambitious)
Climate zone A	Direct electric heating, 80% η_b = 100%	Heat pump, 74% SCOP = 300%	Heat pump, 73% SCOP = 400%
	Wood stove, 4% η_b = 60%	Pellet boiler, 12% η_b = 85%	Pellet boiler, 15% η_b = 85%
	Gas boiler, 10% η_b = 80%	Gas boiler (low temperature), 8% η_b = 90%	Gas boiler (condensing), 12% η_b = 98%
	Oil boiler, 12% η_b = 80%	Oil boiler (low temperature), 6% η_b = 90%	Oil boiler (low temperature), 0% η_b = 95%
Climate zone B	Direct electric heating, 74% η_b = 100%	Heat pump, 74% SCOP = 300%	Heat pump, 73% SCOP = 400%
	Wood stove, 4% η_b = 60%	Pellet boiler, 12% η_b = 85%	Pellet boiler, 15% η_b = 85%
	Gas boiler, 10% η_b = 80%	Gas boiler (low temperature), 8% η_b = 90%	Gas boiler (condensing), 12% η_b = 98%
	Oil boiler, 12% η_b = 80%	Oil boiler (low temperature), 6% η_b = 90%	Oil boiler (low temperature), 0% η_b = 95%
Climate zone C	Direct electric heating, 21% η_b = 100%	Heat pump, 45% SCOP = 300%	Heat pump, 40% SCOP = 400%
	Wood stove, 60% η_b = 60%	Pellet boiler, 35% η_b = 85%	Pellet boiler, 40% η_b = 85%
	Gas boiler, 4% η_b = 80%	Gas boiler (low temperature), 10% η_b = 90%	Gas boiler (condensing), 10% η_b = 98%
	Oil boiler, 15% η_b = 80%	Oil boiler (low temperature), 10% η_b = 90%	Oil boiler (low temperature), 10% η_b = 95%

Table 10: Offices — National share and efficiency of heating systems and energy sources in the present state, BAU, standard and ambitious retrofitting options

	Present and BAU	Improvement 1 (standard)	Improvement 2 (ambitious)
Climate zone A	Direct electric heating and heat pump, 70% SCOP = 150%	Heat pump, 80% SCOP = 300%	Heat pump, 70% SCOP = 400%
	Wood stove, 10% η_b = 60%	Pellet boiler, 5% η_b = 85%	Pellet boiler, 10% η_b = 85%
	Gas boiler, 0% η_b = 80%	Gas boiler (low temperature), 15% η_b = 90%	Gas boiler (condensing), 20% η_b = 98%
	Oil boiler, 20% η_b = 80%	Oil boiler (low temperature), 0% η_b = 90%	Oil boiler (low temperature), 0% η_b = 95%
Climate zone B	Direct electric heating and heat pump, 70% SCOP = 150%	Heat pump, 80% SCOP = 300%	Heat pump, 70% SCOP = 400%
	Wood stove, 10% η_b = 60%	Pellet boiler, 5% η_b = 85%	Pellet boiler, 10% η_b = 85%
	Gas boiler, 0% η_b = 80%	Gas boiler (low temperature), 15% η_b = 90%	Gas boiler (condensing), 20% η_b = 98%
	Oil boiler, 20% η_b = 80%	Oil boiler (low temperature), 0% η_b = 90%	Oil boiler (low temperature), 0% η_b = 95%
Climate zone C	Direct electric heating and heat pump, 21% SCOP = 150%	Heat pump, 20% SCOP = 300%	Heat pump, 15% SCOP = 400%
	Wood stove, 54% η_b = 60%	Pellet boiler, 60% η_b = 85%	Pellet boiler, 60% η_b = 85%
	Gas boiler, 4% η_b = 80%	Gas boiler (low temperature), 10% η_b = 90%	Gas boiler (condensing), 15% η_b = 98%
	Oil boiler, 15% η_b = 80%	Oil boiler (low temperature), 15% η_b = 90%	Oil boiler (low temperature), 10% η_b = 95%

Efficiency is calculated from the assumed share of heat pumps and direct electric heaters (efficiency of direct heater = 1; efficiency of heat pump = 2.2)

Table 11: Schools — National share and efficiency of heating systems and energy sources in the present state, BAU and standard retrofitting options

	Present and BAU	Improvement 1 (standard)
Climate zone A	Direct electric heating, 76% η_b = 100%	Heat pump, 80% SCOP = 300%
	Wood stove, 4% η_b = 60%	Pellet boiler, 0% η_b = 85%
	Gas boiler, 4% η_b = 80%	Gas boiler (low temperature), 15% η_b = 90%
	Oil boiler, 16% η_b = 80%	Oil boiler (low temperature), 5% η_b = 90%
Climate zone B	Direct electric heating, 76% η_b = 100%	Heat pump, 80% SCOP = 300%
	Wood stove, 6% η_b = 60%	Pellet boiler, 0% η_b = 85%
	Gas boiler, 4% η_b = 80%	Gas boiler (low temperature), 15% η_b = 90%
	Oil boiler, 14% η_b = 80%	Oil boiler (low temperature), 5% η_b = 90%
Climate zone C	Direct electric heating, 27% η_b = 100%	Heat pump, 20% SCOP = 300%
	Wood stove, 54% η_b = 60%	Pellet boiler, 60% η_b = 85%
	Gas boiler, 4% η_b = 80%	Gas boiler (low temperature), 10% η_b = 90%
	Oil boiler, 15% η_b = 80%	Oil boiler (low temperature), 10% η_b = 90%

Table 12: Universities — National share and efficiency of heating systems and energy sources in the present state, BAU and standard retrofitting options

	Present and BAU	Improvement 1 (standard)
Climate zone A	Heat pump, 84% SCOP = 220%	Heat pump, 95% SCOP = 300%
	Wood stove, 0% η_b = 60%	Pellet boiler, 0% η_b = 85%
	Gas boiler, 0% η_b = 80%	Gas boiler (low temperature), 0% η_b = 90%
	Oil boiler, 20% η_b = 16%	Oil boiler (low temperature), 5% η_b = 90%
Climate zone B	Heat pump, 80% SCOP = 220%	Heat pump, 95% SCOP = 300%
	Wood stove, 0% η_b = 60%	Pellet boiler, 0% η_b = 85%
	Gas boiler, 0% η_b = 80%	Gas boiler (low temperature), 0% η_b = 90%
	Oil boiler, 20% η_b = 80%	Oil boiler (low temperature), 5% η_b = 90%
Climate zone C	Heat pump, 15% SCOP = 220%	Heat pump, 35% SCOP = 300%
	Wood stove, 45% η_b = 60%	Pellet boiler, 55% η_b = 85%
	Gas boiler, 5% η_b = 80%	Gas boiler (low temperature), 0% η_b = 90%
	Oil boiler, 35% η_b = 80%	Oil boiler (low temperature), 10% η_b = 90%

Cooling systems

In the present state, cooling is not typical in schools and dormitories, but it exists in most other public buildings in climate zones A and B. No mechanical cooling was assumed in climate zone C.

In Albania, air-conditioning systems are predominantly decentralised systems (split units). Most of the cooling units are reversible, meaning they are also used for heating, although this cannot be supported by statistical data. For the present state, and for the BAU option, a low level of efficiency of EER=2 was taken into account. For the standard and ambitious retrofitting options, reversible systems with EER=3 were considered (Table 13). In our assumptions, all cooling equipment is the same in each scenario, but the cooled area and hours depend on the building type and renovation level (Simaku 2016).

Reversible split systems are typically applied for heating in Albania. As a consequence, cooling is available without extra measures. In the case of heat pumps used for heating, cooling is supplied from the same source as heating.

Table 13: Definition of current state and retrofitting options for cooling systems in Albania

	Present state and BAU renovation	Improvement 1	Improvement 2
Climate zone A	Heat pump, EER=2	Heat pump, EER=3	Heat pump, EER=3
Climate zone B	Heat pump, EER=2	Heat pump, EER=3	Heat pump, EER=3

Partial heating and cooling

In Albania, typically only a part of the building is heated to save energy and costs. Corridors, staircases, toilets and other areas with secondary functions do not have heating at all, or the heating is not used in these areas. It is also typical for a heating system not to be turned on all day long. This is also common in public buildings in other countries, as these buildings are usually open only for a part of the day, and during closing hours the technical systems operate in set-back mode or are turned off. In Albania, however, there is no automatic regulation of the systems, or the automatic regulation is outdated, and it is difficult to quantify energy use.

In the future, the unheated area in the buildings is expected to decrease as comfort expectations increase. In the retrofitting options we therefore assume an increase in the heated floor area and in the daily heated hours. The heated/cooled floor area and daily heated/cooled hours applied in the modelled options are detailed in Tables 14 to 16. It is important to emphasise that the estimated figures should be handled with caution, since no statistics are available on partial heating and cooling. Statistical surveys are recommended in order to obtain a more accurate picture.

Table 14: Assumptions for partial and intermittent heating in the present state, BAU, standard and ambitious retrofitting options (Simaku 2016)

Heated floor area (%)					
Renovation options		Present	BAU	Improvement 1 (standard)	Improvement 2 (ambitious)
Climate zone A	Dormitories	69	90	90	100
	Hospitals	58	80	100	100
	Kindergartens	78	80	100	100
	Offices	61	90	100	100
	Schools	70	80	100	n/a
	Universities	72	80	80	n/a
Climate zone B	Dormitories	69	90	90	100
	Hospitals	58	80	100	100
	Kindergartens	78	80	100	100
	Offices	61	90	100	100
	Schools	70	80	100	n/a
	Universities	72	80	80	n/a
Climate zone C	Dormitories	69	90	90	100
	Hospitals	58	80	100	100
	Kindergartens	78	80	100	100
	Offices	61	90	100	100
	Schools	70	80	100	n/a
	Universities	72	80	80	n/a
Heated hours/week					
Renovation options		Present	BAU	Improvement 1 (standard)	Improvement 2 (ambitious)
Climate zone A	Dormitories	42	56	70	126
	Hospitals	56	84	126	168
	Kindergartens	30	40	50	50
	Offices	30	40	50	50
	Schools	20	30	40	n/a
	Universities	20	30	40	n/a
Climate zone B	Dormitories	42	56	70	126
	Hospitals	56	84	126	168
	Kindergartens	30	40	50	50
	Offices	30	40	50	50
	Schools	20	30	40	n/a
	Universities	20	30	40	n/a
Climate zone C	Dormitories	49	63	77	133
	Hospitals	63	91	133	168
	Kindergartens	35	45	55	55
	Offices	35	45	55	55
	Schools	25	35	45	n/a
	Universities	25	35	45	n/a

Table 15: Assumptions for partial and intermittent cooling in the present state, BAU, standard and ambitious retrofitting options (Simaku 2016)

Cooled floor area (%)					
Renovation options		Present	BAU	Improvement 1 (standard)	Improvement 2 (ambitious)
Climate zone A	Dormitories	0	20	50	70
	Hospitals	17	50	80	90
	Kindergartens	22	30	50	80
	Offices	40	70	90	100
	Schools	0	30	50	n/a
	Universities	40	40	40	n/a
Climate zone B	Dormitories	0	20	50	70
	Hospitals	17	50	80	90
	Kindergartens	22	30	50	80
	Offices	40	70	90	100
	Schools	0	30	50	n/a
	Universities	40	40	40	n/a
Climate zone C	Dormitories	0	0	0	0
	Hospitals	0	0	0	0
	Kindergartens	0	0	0	0
	Offices	0	0	0	0
	Schools	0	0	0	n/a
	Universities	0	0	0	n/a
Cooled hours/week					
Renovation options		Present	BAU	Improvement 1 (standard)	Improvement 2 (ambitious)
Climate zone A	Dormitories	0	0	56	56
	Hospitals	42	56	70	70
	Kindergartens	30	40	50	50
	Offices	40	50	50	50
	Schools	15	30	30	n/a
	Universities	15	30	30	n/a
Climate zone B	Dormitories	0	0	56	56
	Hospitals	42	56	70	70
	Kindergartens	30	40	50	50
	Offices	40	50	50	50
	Schools	15	30	30	n/a
	Universities	15	30	30	n/a
Climate zone C	Dormitories	0	0	0	0
	Hospitals	0	0	0	0
	Kindergartens	0	0	0	0
	Offices	0	0	0	0
	Schools	0	0	0	n/a
	Universities	0	0	0	n/a

Table 16: **Assumptions for partial and intermittent ventilation in the present state, BAU, standard and ambitious retrofitting options** (Simaku 2016)

Ventilated floor area (%)					
Renovation options		Present	BAU	Improvement 1 (standard)	Improvement 2 (ambitious)
Climate zone A	Dormitories	0	20	30	50
	Hospitals	0	30	40	60
	Kindergartens	0	0	20	50
	Offices	0	10	50	60
	Schools	0	0	50	NA
	Universities	0	5	5	NA
Climate zone B	Dormitories	0	20	30	50
	Hospitals	0	30	40	60
	Kindergartens	0	0	20	50
	Offices	0	10	50	60
	Schools	0	0	50	NA
	Universities	0	5	5	NA
Climate zone C	Dormitories	0	20	30	50
	Hospitals	0	30	40	60
	Kindergartens	0	0	20	50
	Offices	0	10	50	60
	Schools	0	0	50	NA
	Universities	0	5	5	NA
Ventilated hours/week					
Renovation options		Present	BAU	Improvement 1 (standard)	Improvement 2 (ambitious)
Climate zone A	Dormitories	42	56	70	126
	Hospitals	56	84	126	168
	Kindergartens	30	40	50	50
	Offices	30	40	50	50
	Schools	20	30	40	n/a
	Universities	20	30	40	n/a
Climate zone B	Dormitories	42	56	70	126
	Hospitals	56	84	126	168
	Kindergartens	30	40	50	50
	Offices	30	40	50	50
	Schools	20	30	40	n/a
	Universities	20	30	40	n/a
Climate zone C	Dormitories	49	63	77	133
	Hospitals	63	91	133	168
	Kindergartens	35	45	55	55
	Offices	35	45	55	55
	Schools	25	35	45	n/a
	Universities	25	35	45	n/a

Domestic hot water systems

Net hot water demand was estimated by the Albanian expert panel based on current practice and European norms. There are two expected future trends: on the one hand, water heaters will be installed in buildings where no hot water is used today due to the absence of appropriate facilities (e.g. schools), leading to increased demand. On the other hand, the installation of water-saving taps is considered in improvements 1 and 2, which will lead to a reduction in water use. These two trends are reflected in the assumptions about hot water demand (Table 17).

In the present state, domestic hot water is typically provided by decentralised electric water heaters. In buildings with central gas or oil boilers, hot water is produced in combination with space heating. In climate zone C, wood stoves are also used in some buildings. Solar collectors are installed only in hospitals (Simaku 2016).

In the BAU option, the share of electric heaters is expected to rise (see Tables 18 to 23). In improvement 1, low-temperature gas or oil combi-boilers replace the existing boilers. Wood stoves are replaced by pellet boilers. Where demand is low, direct electric water heaters remain. In some building types, solar collectors are installed. In improvement 2, direct electric heaters are replaced by efficient heat pumps (independent from the space-heating system). The share of efficient condensing gas boilers is increasing. In zone C, central pellet boilers, used also for space heating, replace wood stoves. Solar collectors are installed in all building types except schools and universities to cover part of the hot water demand.

Table 17: **Assumptions about domestic hot water demand** (Simaku 2016)

		Dormitories	Hospitals	Kindergartens	Offices	Schools	Universities
DHW demand (kWh/m²yr)	Present	20	20	8	2	0	5
	BAU renovation	20	20	12	2	8	5
	Improvement 1 (standard)	20	16	10	1.5	7	10
	Improvement 2 (ambitious)	20	16	8	1.5	7	10

Table 18: Dormitories — National share (Simaku 2016) and efficiency of water heating systems and energy sources in the present state, BAU, standard and ambitious retrofitting options

	Present	BAU	Improvement 1 (standard)	Improvement 2 (ambitious)
Climate zone A	Direct electric heating, 80% η_b = 98%	Direct electric heating, 90% η_b = 98%	Direct electric heating, 80% η_b = 98%	Heat pump, 60% SCOP = 400%
	Wood stove, 0% η_b = 60%	Wood stove, 0% η_b = 60%	Pellet boiler, 0% η_b = 85%	Pellet boiler, 0% η_b = 85%
	Gas boiler, 0% η_b = 80%	Gas boiler, 0% η_b = 80%	Gas boiler (low temperature), 20% η_b = 90%	Gas boiler (condensing), 20% η_b = 98%
	Oil boiler, 20% η_b = 80%	Oil boiler, 10% η_b = 80%	Oil boiler (low temperature), 0% η_b = 90%	Oil boiler (low temperature), 0% η_b = 95%
	Solar collector, 0%	Solar collector, 0%	Solar collector, 0%	Solar collector, 20%
Climate zone B	Direct electric heating, 80% η_b = 98%	Direct electric heating, 90% η_b = 98%	Direct electric heating, 80% η_b = 98%	Heat pump, 60% SCOP = 400%
	Wood stove, 0% η_b = 60%	Wood stove, 0% η_b = 60%	Pellet boiler, 0% η_b = 85%	Pellet boiler, 0% η_b = 85%
	Gas boiler, 0% η_b = 80%	Gas boiler, 0% η_b = 80%	Gas boiler (low temperature), 20% η_b = 90%	Gas boiler (condensing), 20% η_b = 98%
	Oil boiler, 20% η_b = 80%	Oil boiler, 10% η_b = 80%	Oil boiler (low temperature), 0% η_b = 90%	Oil boiler (low temperature), 0% η_b = 95%
	Solar collector, 0%	Solar collector, 0%	Solar collector, 0%	Solar collector, 20%
Climate zone C	Direct electric heating, 35% η_b = 98%	Direct electric heating, 50% η_b = 98%	Direct electric heating, 40% η_b = 98%	Heat pump, 50% SCOP = 400%
	Wood stove, 30% η_b = 60%	Wood stove, 40% η_b = 60%	Pellet boiler, 40% η_b = 85%	Pellet boiler, 20% η_b = 85%
	Gas boiler, 0% η_b = 80%	Gas boiler, 0% η_b = 80%	Gas boiler (low temperature), 20% η_b = 90%	Gas boiler (condensing), 20% η_b = 98%
	Oil boiler, 35% η_b = 80%	Oil boiler, 10% η_b = 80%	Oil boiler (low temperature, 0% η_b = 90%	Oil boiler (low temperature), 0% η_b = 95%
	Solar collector, 0%	Solar collector, 0%	Solar collector, 0%	Solar collector, 10%

Table 19: **Hospitals — National share** (Simaku 2016) **and efficiency of water heating systems and energy sources in the present state, BAU, standard and ambitious retrofitting options**

	Present	BAU	Improvement 1 (standard)	Improvement 2 (ambitious)
Climate zone A	Direct electric heating, 45% η_b = 98%	Direct electric heating, 55% η_b = 98%	Direct electric heating, 80% η_b = 98%	Heat pump, 80% SCOP = 400%
	Wood stove, 0% η_b = 60%	Wood stove, 0% η_b = 60%	Pellet boiler, 0% η_b = 85%	Pellet boiler, 0% η_b = 85%
	Gas boiler, 0% η_b = 80%	Gas boiler, 0% η_b = 80%	Gas boiler (low temperature), 0% η_b = 90%	Gas boiler (condensing), 0% η_b = 98%
	Oil boiler, 50% η_b = 80%	Oil boiler, 40% η_b = 80%	Oil boiler (low temperature), 10% η_b = 90%	Oil boiler (low temperature), 0% η_b = 95%
	Solar collector, 5%	Solar collector, 5%	Solar collector, 10%	Solar collector, 20%
Climate zone B	Direct electric heating, 45% η_b = 98%	Direct electric heating, 55% η_b = 98%	Direct electric heating, 80% η_b = 98%	Heat pump, 80% SCOP = 400%
	Wood stove, 0% η_b = 60%	Wood stove, 0% η_b = 60%	Pellet boiler, 0% η_b = 85%	Pellet boiler, 0% η_b = 85%
	Gas boiler, 0% η_b = 80%	Gas boiler, 0% η_b = 80%	Gas boiler (low temperature), 0% η_b = 90%	Gas boiler (condensing), 0% η_b = 98%
	Oil boiler, 50% η_b = 80%	Oil boiler, 40% η_b = 80%	Oil boiler (low temperature), 10% η_b = 90%	Oil boiler (low temperature), 0% η_b = 95%
	Solar collector, 5%	Solar collector, 5%	Solar collector, 10%	Solar collector, 20%
Climate zone C	Direct electric heating, 100% η_b = 98%	Direct electric heating, 100% η_b = 98%	Direct electric heating, 40% η_b = 98%	Heat pump, 50% SCOP = 400%
	Wood stove, 0% η_b = 60%	Wooden stove, 0% η_b = 60%	Pellet boiler, 30% η_b = 85%	Pellet boiler, 30% η_b = 85%
	Gas boiler, 0% η_b = 80%	Gas boiler, 0% η_b = 80%	Gas boiler (low temperature), 0% η_b = 90%	Gas boiler (condensing), 0% η_b = 98%
	Oil boiler, 0% η_b = 80%	Oil boiler, 0% η_b = 80%	Oil boiler (low temperature), 20% η_b = 90%	Oil boiler (low temperature), 0% η_b = 95%
	Solar collector, 0%	Solar collector, 0%	Solar collector, 10%	Solar collector, 20%

Table 20: Kindergartens — National share (Simaku 2016) and efficiency of water heating systems and energy sources in the present state, BAU, standard and ambitious retrofitting options

	Present	BAU	Improvement 1 (standard)	Improvement 2 (ambitious)
Climate zone A	Direct electric heating, 74% η_b = 98%	Direct electric heating, 74% η_b = 98%	Direct electric heating, 69% η_b = 98%	Heat pump, 63% SCOP = 400%
	Wood stove, 4% η_b = 60%	Wooden stove, 4% η_b = 60%	Pellet boiler, 12% η_b = 85%	Pellet boiler, 15% η_b = 85%
	Gas boiler, 10% η_b = 80%	Gas boiler, 10% η_b = 80%	Gas boiler (low temperature), 8% η_b = 90%	Gas boiler (condensing), 12% η_b = 98%
	Oil boiler, 12% η_b = 80%	Oil boiler, 12% η_b = 80%	Oil boiler (low temperature), 6% η_b = 90%	Oil boiler (low temperature), 0% η_b = 95%
	Solar collector, 0%	Solar collector, 0%	Solar collector, 5%	Solar collector, 10%
Climate zone B	Direct electric heating, 74% η_b = 98%	Direct electric heating, 74% η_b = 98%	Direct electric heating, 69% η_b = 98%	Heat pump, 63% SCOP = 400%
	Wood stove, 4% η_b = 60%	Wooden stove, 4% η_b = 60%	Pellet boiler, 12% η_b = 85%	Pellet boiler, 15% η_b = 85%
	Gas boiler, 10% η_b = 80%	Gas boiler, 10% η_b = 80%	Gas boiler (low temperature), 8% η_b = 90%	Gas boiler (condensing), 12% η_b = 98%
	Oil boiler, 12% η_b = 80%	Oil boiler, 12% η_b = 80%	Oil boiler (low temperature), 6% η_b = 90%	Oil boiler (low temperature), 0% η_b = 95%
	Solar collector, 0%	Solar collector, 0%	Solar collector, 5%	Solar collector, 10%
Climate zone C	Direct electric heating, 21% η_b = 98%	Direct electric heating, 21% η_b = 98%	Direct electric heating, 42% η_b = 98%	Heat pump, 35% SCOP = 400%
	Wood stove, 60% η_b = 60%	Wood stove, 60% η_b = 60%	Pellet boiler, 35% η_b = 85%	Pellet boiler, 40% η_b = 85%
	Gas boiler, 4% η_b = 80%	Gas boiler, 4% ηb = 80%	Gas boiler (low temperature), 10% η_b = 90%	Gas boiler (condensing), 10% η_b = 98%
	Oil boiler, 15% η_b = 80%	Oil boiler, 15% η_b = 80%	Oil boiler (low temperature), 10% η_b = 90%	Oil boiler (low temperature), 10% η_b = 95%
	Solar collector, 0%	Solar collector, 0%	Solar collector, 3%	Solar collector, 5%

Table 21: Offices — National share (Simaku 2016) and efficiency of water heating systems and energy sources in the present state, BAU, standard and ambitious retrofitting options

	Present	BAU	Improvement 1 (standard)	Improvement 2 (ambitious)
Climate zone A	Direct electric heating, 70% η_b = 98%	Direct electric heating, 75% η_b = 98%	Direct electric heating, 75% η_b = 98%	Heat pump, 62% SCOP = 400%
	Wood stove, 10% η_b = 60%	Wood stove, 5% η_b = 60%	Pellet boiler, 5% η_b = 85%	Pellet boiler, 10% η_b = 85%
	Gas boiler, 0% η_b = 80%	Gas boiler, 10% η_b = 80%	Gas boiler (low temperature), 15% η_b = 90%	Gas boiler (condensing), 20% η_b = 98%
	Oil boiler, 20% η_b = 80%	Oil boiler, 10% η_b = 80%	Oil boiler (low temperature), 0% η_b = 90%	Oil boiler (low temperature), 0% η_b = 95%
	Solar collector, 0%	Solar collector, 0%	Solar collector, 5%	Solar collector, 8%
Climate zone B	Direct electric heating, 70% η_b = 98%	Direct electric heating, 80% η_b = 98%	Direct electric heating, 75% η_b = 98%	Heat pump, 62% SCOP = 400%
	Wood stove, 10% η_b = 60%	Wood stove, 5% η_b = 60%	Pellet boiler, 5% η_b=85%	Pellet boiler, 10% η_b=85%
	Gas boiler, 0% η_b = 80%	Gas boiler, 5% η_b = 80%	Gas boiler (low temperature), 15% η_b = 90%	Gas boiler (condensing), 20% η_b = 98%
	Oil boiler, 20% η_b = 80%	Oil boiler, 10% η_b = 80%	Oil boiler (low temperature), 0% η_b = 90%	Oil boiler (low temperature), 0% η_b = 95%
	Solar collector, 0%	Solar collector, 0%	Solar collector, 5%	Solar collector, 8%
Climate zone C	Direct electric heating, 21% η_b = 98%	Direct electric heating, 15% η_b = 98%	Direct electric heating, 12% η_b = 98%	Heat pump, 10% SCOP = 400%
	Wood stove, 54% η_b = 60%	Wood stove, 60% η_b = 60%	Pellet boiler, 60% η_b = 85%	Pellet boiler, 60% η_b = 85%
	Gas boiler, 0% η_b = 80%	Gas boiler, 10% η_b = 80%	Gas boiler (low temperature), 10% η_b = 90%	Gas boiler (condensing), 15% η_b = 98%
	Oil boiler, 25% η_b = 80%	Oil boiler, 15% η_b = 80%	Oil boiler (low temperature), 15% η_b = 90%	Oil boiler (low temperature), 10% η_b = 95%
	Solar collector, 0%	Solar collector, 0%	Solar collector, 3%	Solar collector, 5%

Table 22: Schools — National share (Simaku 2016) and efficiency of water heating systems and energy sources in the present state, BAU and standard retrofitting options

	Present	BAU	Improvement 1 (standard)
Climate zone A	Direct electric heating, 0% η_b = 98%	Direct electric heating, 100% η_b = 98%	Direct electric heating, 100% η_b = 98%
	Wood stove, 0% η_b = 60%	Wood stove, 0% η_b = 60%	Pellet boiler, 0% η_b = 85%
	Gas boiler, 0% η_b = 80%	Gas boiler, 0% η_b = 80%	Gas boiler (low temperature), 0% η_b = 90%
	Oil boiler, 0% η_b = 80%	Oil boiler, 0% η_b = 80%	Oil boiler (low temperature), 0% η_b = 90%
	Solar collector, 0%	Solar collector, 0%	Solar collector, 0%
Climate zone B	Direct electric heating, 0% η_b = 98%	Direct electric heating, 100% η_b = 98%	Direct electric heating, 100% η_b = 98%
	Wood stove, 0% η_b = 60%	Wood stove, 0% η_b = 60%	Pellet boiler, 0% η_b = 85%
	Gas boiler, 0% η_b = 80%	Gas boiler, 0% η_b = 80%	Gas boiler (low temperature), 0% η_b = 90%
	Oil boiler, 0% η_b = 80%	Oil boiler, 0% η_b = 80%	Oil boiler (low temperature), 0% η_b = 90%
	Solar collector, 0%	Solar collector, 0%	Solar collector, 0%
Climate zone C	Direct electric heating, 0% η_b = 98%	Direct electric heating, 100% η_b = 98%	Direct electric heating, 100% η_b = 98%
	Wood stove, 0% η_b = 60%	Wooden stove, 0% η_b = 60%	Pellet boiler, 0% η_b = 85%
	Gas boiler, 0% η_b = 80%	Gas boiler, 0% η_b = 80%	Gas boiler (low temperature), 0% η_b = 90%
	Oil boiler, 0% η_b = 80%	Oil boiler, 0% η_b = 80%	Oil boiler (low temperature), 0% η_b = 90%
	Solar collector, 0%	Solar collector, 0%	Solar collector, 0%

Table 23: **Universities — National share** (Simaku 2016) **and efficiency of water heating systems and energy sources in the present state, BAU and standard retrofitting options**

	Present	BAU	Improvement 1 (standard)
Climate zone A	Direct electric heating, 100% η_b = 98%	Direct electric heating, 100% η_b = 98%	Direct electric heating, 100% η_b = 98%
	Wood stove, 0% η_b = 60%	Wood stove, 0% η_b = 60%	Pellet boiler, 0% η_b = 85%
	Gas boiler, 0% η_b = 80%	Gas boiler, 0% η_b = 80%	Gas boiler (low temperature), 0% η_b = 90%
	Oil boiler, 0% η_b = 80%	Oil boiler, 0% η_b = 80%	Oil boiler (low temperature), 0% η_b = 90%
	Solar collector, 0%	Solar collector, 0%	Solar collector, 0%
Climate zone B	Direct electric heating, 100% η_b = 98%	Direct electric heating, 100% η_b = 98%	Direct electric heating, 100% η_b = 98%
	Wood stove, 0% η_b = 60%	Wood stove, 0% η_b = 60%	Pellet boiler, 0% η_b = 85%
	Gas boiler, 0% η_b = 80%	Gas boiler, 0% η_b = 80%	Gas boiler (low temperature), 0% η_b = 90%
	Oil boiler, 0% η_b = 80%	Oil boiler, 0% η_b = 80%	Oil boiler (low temperature), 0% η_b = 90%
	Solar collector, 0%	Solar collector, 0%	Solar collector, 0%
Climate zone C	Direct electric heating, 100% η_b = 98%	Direct electric heating, 100% η_b = 98%	Direct electric heating, 100% η_b = 98%
	Wood stove, 0% η_b = 60%	Wood stove, 0% η_b = 60%	Pellet boiler, 0% η_b = 85%
	Gas boiler, 0% η_b = 80%	Gas boiler, 0% η_b = 80%	Gas boiler (low temperature), 0% η_b = 90%
	Oil boiler, 0% η_b = 80%	Oil boiler, 0% η_b = 80%	Oil boiler (low temperature), 0% η_b = 90%
	Solar collector, 0%	Solar collector, 0%	Solar collector, 0%

System efficiencies

Delivered energy is calculated using 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 systems was calculated as follows:

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

where

η_b = boiler (source) efficiency

η_p = piping (distribution) efficiency

η_c = control (regulation) efficiency

Taking into account that there are no further data concerning the characteristics of heating devices per building type (no survey has been carried out in connection with these data in Albania), the most frequent systems were incorporated in the building type models.

In climate zones A and B, both direct electric heaters and heat pumps are common. To simplify the modelling, these two systems were modelled together with a virtual efficiency, calculated according to the ratio of the buildings with direct electric heating and heat pump, assuming an efficiency of 1 for direct electric heating and 2.2 for heat pumps.

Primary energy factors and CO_2 emissions

Primary energy consumption ($Q_{primary}$) is the sum of the delivered energy ($Q_{delivered}$) multiplied by the primary energy factors ($f_{p,source}$) of the energywares:

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

Annual CO_2 emissions for space heating and DHW are determined as follows:

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

where

$f_{CO2,source\ i}$ = the CO_2 emission factor of the energyware used by heat generator i.

The conversion factors for the determination of annual primary energy and specific CO_2 emissions per energy carrier are shown in Table 24. As there was no information available for the primary energy factors and specific CO_2 emissions, standard values were used for wood and LPG, and the values determined from the electricity sector modelling scenarios for electricity. The low values for electricity can be explained by the fact that electricity supply in Albania is based on hydro generation.

Table 24: Primary energy factors and CO_2 emission factors for Albania (IPCC and Szabo et al. 2015)

Energy carrier	Primary-to-final energy factor (kWh/kWh)	Specific CO_2 emissions (kg/kWh)
Wood biomass	0.2	0
Electrical energy	1.01	0
LPG	1.1	0.227
Oil	1.2	0.267
Solar energy	0	0

4. Calculation results

Net energy demand in the existing building stock and retrofitting options

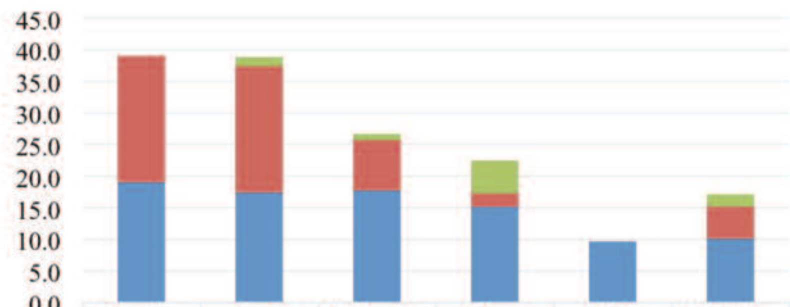
As shown by the summary diagrams of the results (Figures 10 to 12), space heating and domestic hot water demand are the most important at present, although the picture is strongly dependent on the building type. As explained above, in Albanian public buildings intermittent heating and partial heating are typical, making heating demand moderate. It is not exceptional for some rooms to be heated for only a couple of hours a day, while in the rest of the rooms building users suffer a lower level of comfort to save costs. In the calculations we assumed between 25 and 63 heating hours per week, and a heated floor area of between 61 and 78 percent of the total net floor area (see also page 37).

In some building types, particularly in schools, there is no hot water system installed at all. On the other hand, in dormitories and hospitals hot water demand is significant because of the particular user profile. Although the climate is hot, in many public buildings there is no cooling system installed, with the exception of public offices, where cooling has a notable and increasing share. All values related to users' habits applied in the model were determined by the Albanian expert panel (Simaku 2016).

The highest energy demand is in hospitals and dormitories, because of the high level of need for hot water. The heating energy demand is also high in these building types: weekly heated hours are more than double the respective figure for schools and universities. The number of heated hours in schools and offices is in the middle of the range. In general, it can be stated that, in the present state, users' profiles have a bigger influence on energy demand than the buildings themselves. However, it should be noted that if comfort demands increase in the future, energy demand will be significantly higher (Simaku 2016).

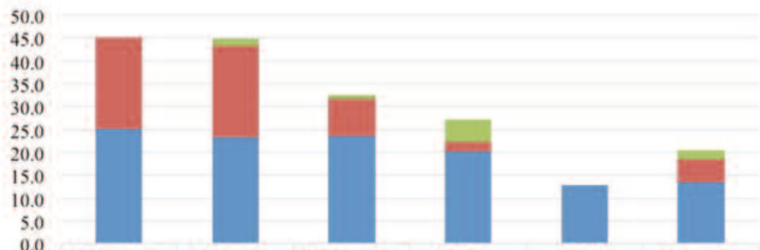
In terms of the retrofitting packages (see Figures 13 to 15), although the performance of both the building envelope and the technical building systems is significantly better, this is not reflected in the results for energy demand, because it is assumed that the comfort level significantly increases in the retrofitting options (see also page 37): the number of heated, ventilated and cooled hours increases with retrofitting, and hot water systems are installed in building types where there was originally no hot water. This is particularly notable in the BAU renovation, where only minor energy efficiency measures are introduced, but the comfort level rises.

Figure 10: Net energy demand in building types (present state, climate zone A)



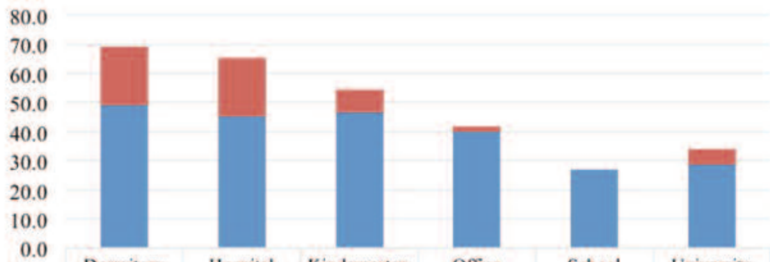
	Dormitory	Hospital	Kindergarten	Office	School	University
Cooling [kWh/m2]	0.0	1.5	1.0	5.2	0.0	2.1
DHW [kWh/m2]	20.0	20.0	8.0	2.0	0.0	5.0
Heating [kWh/m2]	19.1	17.4	17.7	15.2	9.6	10.1

Figure 11: Net energy demand in building types (present state, climate zone B)



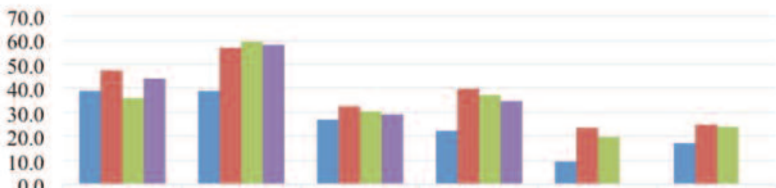
	Dormitory	Hospital	Kindergarten	Office	School	University
Cooling [kWh/m2]	0.0	1.4	1.0	5.0	0.0	2.0
DHW [kWh/m2]	20.0	20.0	8.0	2.0	0.0	5.0
Heating [kWh/m2]	25.2	23.4	23.6	20.2	12.8	13.5

Figure 12: Net energy demand in building types (present state, climate zone C)



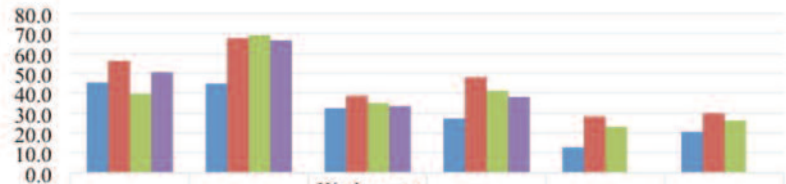
	Dormitory	Hospital	Kindergarten	Office	School	University
Cooling [kWh/m2]	0.0	0.0	0.0	0.0	0.0	0.0
DHW [kWh/m2]	20.0	20.0	8.0	2.0	0.0	5.0
Heating [kWh/m2]	49.2	45.3	46.5	39.8	27.1	28.8

Figure 13: Net energy demand in building types (partial and intermittent heating, climate zone A)



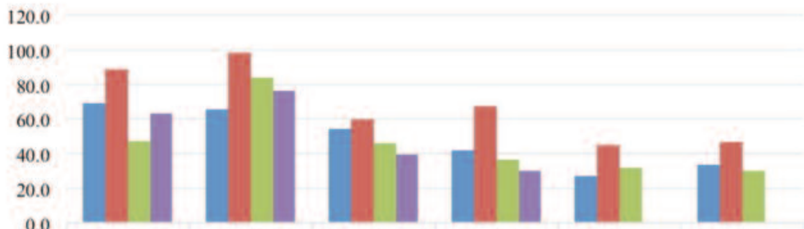
	Dormitory	Hospital	Kindergarte n	Office	School	University
Present state	39.1	38.9	26.8	22.4	9.6	17.2
BAU renovation	47.4	57.0	32.5	39.8	23.5	24.7
Improvement 1	35.8	59.4	30.3	37.3	19.7	23.8
Improvement 2	44.1	58.1	29.3	34.7	0.0	0.0

Figure 14: Net energy demand in building types (partial and intermittent heating, climate zone B)



	Dormitory	Hospital	Kindergarten	Office	School	University
Present state	45.2	44.8	32.6	27.2	12.8	20.5
BAU renovation	56.3	67.4	38.8	47.7	28.2	29.8
Improvement 1	39.5	69.0	35.3	41.2	23.1	26.4
Improvement 2	50.4	66.8	33.8	38.0	0.0	0.0

Figure 15: Net energy demand in building types (partial and intermittent heating, climate zone C)



	Dormitory	Hospital	Kindergarten	Office	School	University
Present state	69.2	65.3	54.5	41.8	27.1	33.8
BAU renovation	88.9	97.8	59.7	67.5	44.8	46.4
Improvement 1	47.4	83.7	45.7	36.3	31.6	30.1
Improvement 2	63.2	76.1	39.4	29.9	0.0	0.0

Delivered energy by energy source, primary energy consumption and CO_2 emissions

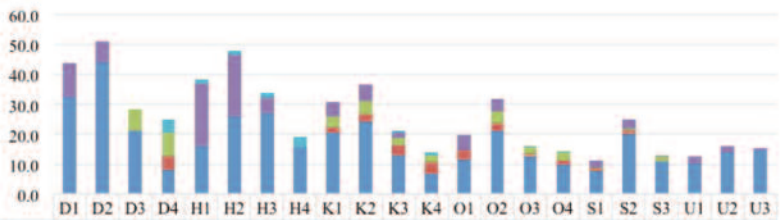
For the sectoral analysis it is important to know the delivered energy consumption per energy source. For both the present and the retrofitted states, we used energy mix estimates provided by the Albanian expert panel. Results are presented in Figures 16 to 18. In climate zones A and B, the most important energy source is electricity, while in climate zone C it is wood. In the figures, D = dormitories; H = hospitals: K = kindergartens; O = public offices; S = schools; U = universities; 1 = present state; 2 = BAU renovation; 3 = standard renovation (improvement 1); and 4 = ambitious renovation (improvement 2).

Primary energy consumption is presented per renovation option and building type in Figures 19 to 21, while CO_2 emissions are shown in Figures 22 to 24. Primary energy consumption and CO_2 emissions are greatly influenced by the primary energy and CO_2 emissions factors. In Albania, the primary energy factor for electricity is 1.01, which is very low compared to the European average. Solar energy was considered renewable, with a primary factor of zero, which further reduced the primary energy demand for hot water production. The results for CO_2 emissions differ from the primary energy results, as in Albania both electricity and wood are considered carbon neutral. Even in the present state, only stoves burning LPG and diesel oil produce CO_2 emissions, which explains why the national emissions are so low. With the use of wood and electric heat pumps it is possible to achieve a carbon-neutral building stock.

With respect to the retrofitting packages, although the performance of the building envelope and the technical building systems are significantly better following renovation, this is not reflected in the results for the delivered and primary energy consumption, because it is assumed that the comfort level significantly increases with retrofitting (see also page 37): the number of heated, ventilated and cooled hours increases with retrofitting, and hot water systems are installed in building types that previously had no DHW at all. This is particularly notable in the case of the BAU renovation, where only minor energy efficiency measures are taken, but the comfort level rises. Savings are slightly bigger in climate zone C, because cooling is not applied and does not appear as a demand-increasing factor.

As explained above, in the calculations we assumed intermittent partial heating, with increasing comfort levels in the more ambitious renovations. This makes energy savings moderate, but reflects reality. However, in order to show the clear impact of the technical measures only, without the negative impact of improved comfort, we made calculations for the renovation options for full heating as well. The result diagrams are summarised in Annex 2 (page 88).

Figure 16: Delivered energy per building type and renovation option (climate zone A)

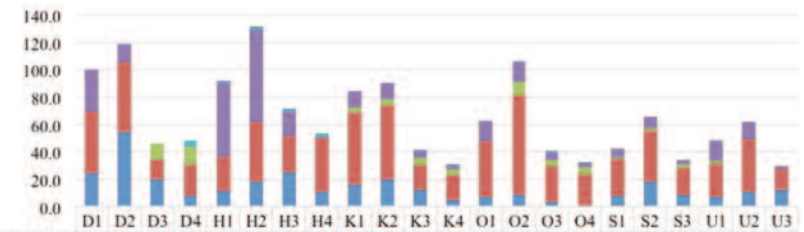


	D1	D2	D3	D4	H1	H2	H3	H4	K1	K2	K3	K4	O1	O2	O3	O4	S1	S2	S3	U1	U2	U3
Solar [kWh/m2]	0.0	0.0	0.0	4.3	1.1	1.1	1.7	3.4	0.0	0.0	0.5	0.9	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Oil [kWh/m2]	11.4	6.9	0.0	0.0	21.0	20.6	5.2	0.0	4.5	5.3	1.7	0.0	5.0	4.0	0.0	0.0	2.3	3.2	0.5	2.4	2.3	0.4
Gas [kWh/m2]	0.0	0.0	7.4	8.0	0.0	0.0	0.0	0.0	3.8	4.4	2.3	2.6	0.0	4.0	2.5	2.6	0.6	0.8	1.6	0.0	0.0	0.0
Wood [kWh/m2]	0.0	0.0	0.0	4.4	0.0	0.0	0.0	0.0	2.0	2.4	3.7	3.8	3.3	2.6	0.9	1.5	0.7	1.0	0.0	0.0	0.0	0.0
Electricity [kWh/m2]	32.4	44.3	21.1	8.1	16.2	26.1	27.1	15.6	20.4	24.4	12.8	6.7	11.5	21.1	12.4	9.8	7.7	20.1	10.9	10.2	13.9	14.8

Figure 17: Delivered energy per building type and renovation option (climate zone B)

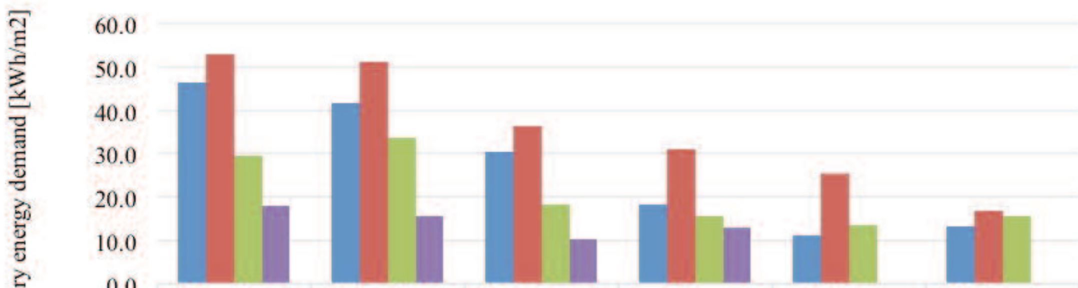
	D1	D2	D3	D4	H1	H2	H3	H4	K1	K2	K3	K4	O1	O2	O3	O4	S1	S2	S3	U1	U2	U3
Solar [kWh/m2]	0.0	0.0	0.0	4.3	1.1	1.1	1.7	3.4	0.0	0.0	0.5	0.9	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Oil [kWh/m2]	13.2	8.2	0.0	0.0	23.2	23.8	6.5	0.0	5.5	6.4	2.1	0.0	6.5	5.3	0.0	0.0	2.6	3.8	0.7	4.0	3.0	0.6
Gas [kWh/m2]	0.0	0.0	8.3	9.5	0.0	0.0	0.0	0.0	4.6	5.4	2.8	3.2	0.0	2.8	3.4	3.5	0.7	1.1	2.2	0.0	0.0	0.0
Wood [kWh/m2]	0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	2.4	2.9	4.4	4.6	4.2	3.4	1.2	2.0	1.4	2.1	0.0	0.0	0.0	0.0
Electricity [kWh/m2]	37.5	52.8	22.1	9.1	18.3	30.1	30.1	17.8	24.9	29.3	14.1	7.6	13.8	26.5	13.5	10.3	10.2	23.8	11.9	11.3	16.0	15.7

Figure 18: Delivered energy per building type and renovation option (climate zone C)



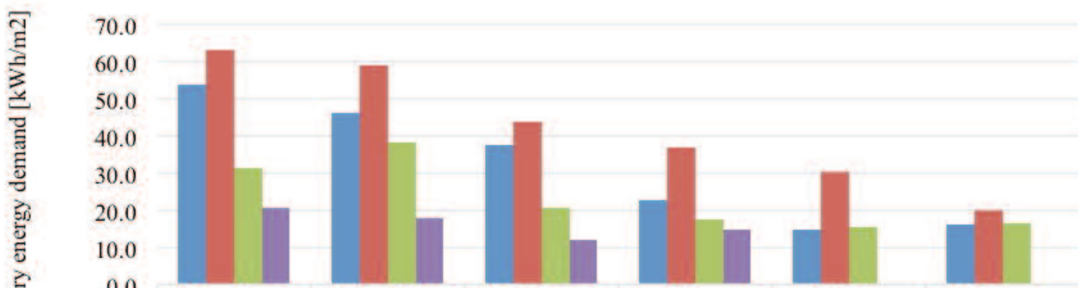
	D1	D2	D3	D4	H1	H2	H3	H4	K1	K2	K3	K4	O1	O2	O3	O4	S1	S2	S3	U1	U2	U3
Solar [kWh/m2]	0.0	0.0	0.0	4.3	1.1	1.1	1.7	3.4	0.0	0.0	0.5	0.9	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Oil [kWh/m2]	31.0	13.0	0.0	0.0	54.4	68.6	18.6	0.0	11.6	12.6	5.1	3.6	15.1	14.7	6.1	3.2	5.9	8.1	3.0	14.8	12.1	2.5
Gas [kWh/m2]	0.0	0.0	11.7	13.8	0.0	0.0	0.0	0.0	3.9	4.5	5.4	4.5	0.0	9.9	4.4	5.0	1.6	2.2	3.0	2.1	0.0	0.0
Wood [kWh/m2]	45.5	51.1	14.3	22.5	25.2	43.2	26.5	39.2	52.4	54.1	17.9	17.9	40.2	73.0	26.0	22.4	27.1	36.8	19.3	24.0	38.4	14.4
Electricity [kWh/m2]	24.1	54.6	20.2	7.5	11.4	18.7	24.9	11.1	16.3	19.6	12.7	4.6	7.3	8.4	3.5	1.4	7.7	18.6	8.9	7.2	11.1	12.7

Figure 19: Primary energy demand in building types (climate zone A)



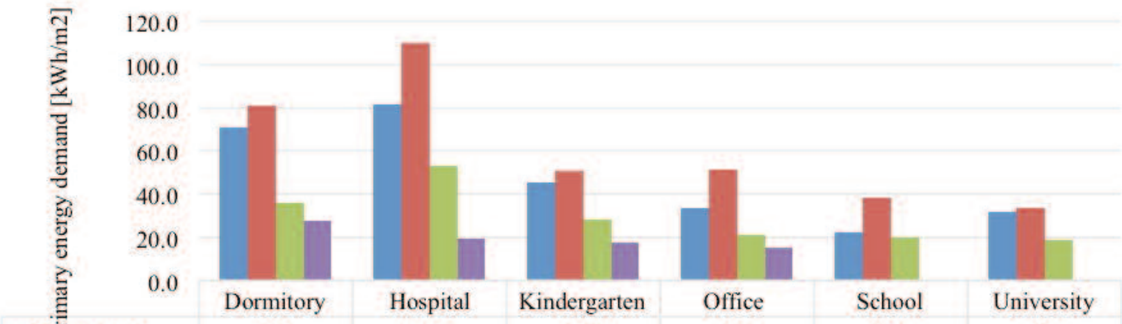
	Dormitory	Hospital	Kindergarten	Office	School	University
Present state	46.4	41.5	30.5	18.3	11.2	13.1
BAU renovation	53.0	51.2	36.5	31.1	25.2	16.7
Improvement 1	29.4	33.6	18.3	15.5	13.5	15.5

Figure 20: Primary energy demand in building types (climate zone B)



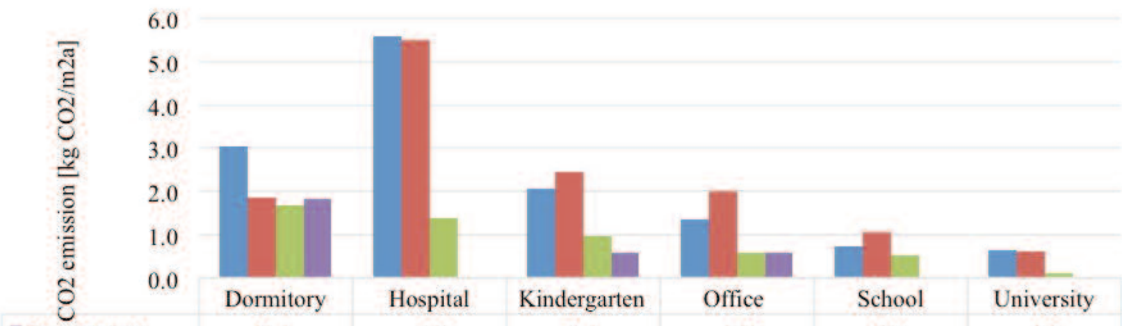
	Dormitory	Hospital	Kindergarten	Office	School	University
Present state	53.8	46.3	37.4	22.6	14.6	16.1
BAU renovation	63.2	59.0	43.8	36.9	30.2	19.8
Improvement 1	31.5	38.1	20.7	17.6	15.4	16.5

Figure 21: Primary energy demand in building types (climate zone C)



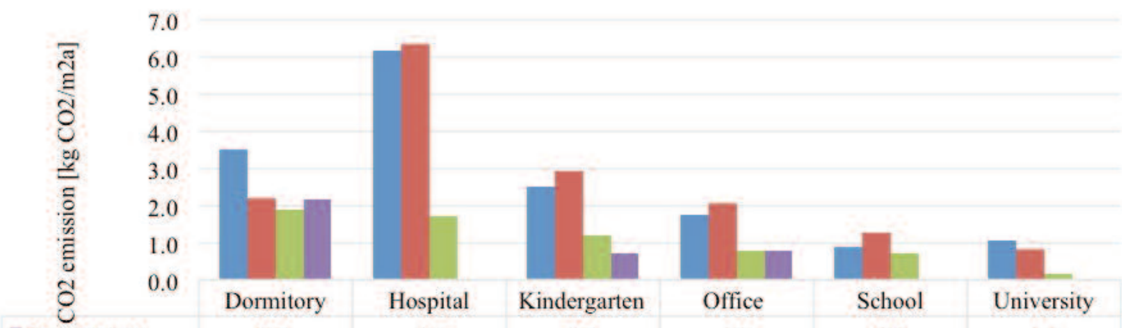
	Dormitory	Hospital	Kindergarten	Office	School	University
Present state	70.6	81.7	45.2	33.6	22.0	32.1
BAU renovation	81.0	109.8	50.7	51.6	38.2	33.4
Improvement 1	36.0	52.8	28.5	20.9	19.8	18.7

Figure 22: CO_2 emissions in building types (climate zone A)



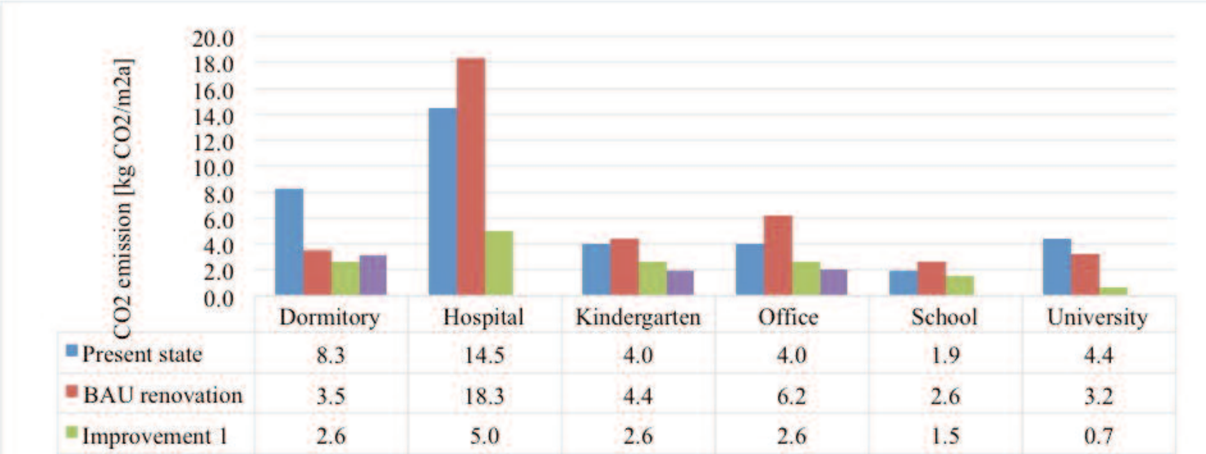
	Dormitory	Hospital	Kindergarten	Office	School	University
Present state	3.1	5.6	2.1	1.3	0.7	0.6
BAU renovation	1.8	5.5	2.4	2.0	1.0	0.6
Improvement 1	1.7	1.4	1.0	0.6	0.5	0.1

Figure 23: CO_2 emissions in building types (climate zone B)



	Dormitory	Hospital	Kindergarten	Office	School	University
Present state	3.5	6.2	2.5	1.7	0.9	1.1
BAU renovation	2.2	6.4	2.9	2.1	1.3	0.8
Improvement 1	1.9	1.7	1.2	0.8	0.7	0.2

Figure 24: CO_2 emissions in building types (climate zone C)



5. Costs of the retrofitting options

Costs per measure and floor area: Building envelope

The investment costs were provided by the Albanian expert panel per building type and measure (see Table 25). 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. Prices include labour costs and VAT. For the national extrapolation we transferred the prices to units per net floor area (Table 26).

Costs per floor area: Building service systems

The building service system prices were provided by the Albanian expert panel per building type and measure (see Table 27). 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. Prices include labour costs and VAT. The applied technical building systems reflect the expected national energy mix of the corresponding retrofitting level envisaged by the Albanian expert panel. As a consequence, the proposed technical solutions are not applicable to one, single building (it is not realistic that the national energy mix be applied in one single building), but rather to a large number of buildings. In other words, this approach is suitable for the objectives of the present task (national-level extrapolation), but not for the conceptual planning of individual buildings.

Table 28 shows specific technical building system prices as an average of the different systems, weighted with the corresponding energy mix. Modifications in the heated/cooled/ventilated floor ratio are also taken into account in the prices.

Total costs per floor area

The total specific retrofitting costs are the sum of the cost of the building envelope refurbishment and the cost of the modernisation of the technical building systems per net floor area unit (Table 29).

Table 25: Investment costs per measure by insulated/exchanged unit area in standard and ambitious retrofitting (EUR/m²)

	BAU renovation	Improvement 1	Improvement 2
External wall	0	5–8	8
Wall to unheated space	0	5	8
Floor of attic space	5	10	10
Cellar ceiling	3	5	8
Floor above outdoor space	0	10	10
Flat roof	3	5	5
Pitched roof	10	10	10
Floors of heated spaces to ground	0	5	5
External walls between heated spaces and ground	3	5	5
External unglazed doors	80	150	150
Glazed windows, glazed doors	0	85	120

Table 26: Investment costs per measure by net floor area for standard and ambitious retrofitting (EUR/m²)

BAU renovation	Dormitories	Hospitals	Kindergartens	Offices	Schools	Universities
Cellar ceiling	n/a	0.42	n/a	n/a	0.09	n/a
Flat roof	0.60	0.76	0.50	0.80	0.74	0.76
Pitched roof	1.00	n/a	3.86	1.00	1.22	n/a
External walls between heated spaces and ground	n/a	0.17	n/a	n/a	n/a	n/a
Improvement 1 (standard)	**Dormitories**	**Hospitals**	**Kindergartens**	**Offices**	**Schools**	**Universities**
External wall	3.03	2.12	3.11	3.74	4.45	4.49
Cellar ceiling	n/a	0.70	n/a	n/a	0.15	n/a
Floor above outdoor space	2.43	n/a	n/a	n/a	n/a	n/a
Flat roof	1.01	1.26	0.83	1.33	1.23	1.27
Pitched roof	1.00	n/a	3.86	1.00	1.22	n/a
Floors of heated spaces to ground	1.44	0.50	2.76	1.57	1.64	1.35
External walls between heated spaces and ground	n/a	0.29	n/a	n/a	n/a	n/a
Glazed windows	7.86	10.53	15.25	13.61	12.44	15.58
Improvement 2 (ambitious)	**Dormitories**	**Hospitals**	**Kindergartens**	**Offices**	**Schools**	**Universities**
External wall	4.84	3.40	4.98	5.99	n/a	n/a
Cellar ceiling	n/a	1.13	n/a	n/a	n/a	n/a
Floor above outdoor space	2.43	n/a	n/a	n/a	n/a	n/a
Flat roof	1.01	1.26	0.83	1.33	n/a	n/a
Pitched roof	1.00	n/a	3.86	1.00	n/a	n/a
Floors of heated spaces to ground	1.44	0.50	2.76	1.57	n/a	n/a
External walls between heated spaces and ground	n/a	0.29	n/a	n/a	n/a	n/a
Glazed windows	11.09	18.58	21.53	19.22	n/a	n/a

Table 27: Investment costs of building service systems per system floor area for BAU retrofitting (EUR/m^2)

BAU renovation	Dormitories	Hospitals	Kindergartens	Offices	Schools	Universities
Heating system based on electricity	0	0	0	0	0	0
Heating system based on wood	0	0	0	0	0	0
Heating system based on gas	0	0	0	0	0	0
Heating system based on oil	0	0	0	0	0	0
DHW system based on electricity	0.8	0.8	0.8	0.8	0.8	0.8
DHW system based on wood	0.9	0.9	0.9	0.9	0.9	0.9
DHW system based on gas	0.9	0.9	0.9	0.9	0.9	0.9
DHW system based on oil	0.9	0.9	0.9	0.9	0.9	0.9
DHW system based on solar thermal	3.2	3.2	3.2	3.2	3.2	3.2
Ventilation system	0	0	0	0	0	0
Cooling system	0	0	0	0	0	0
Improvement 1 (standard)	**Dormitories**	**Hospitals**	**Kindergartens**	**Offices**	**Schools**	**Universities**
Heating system based on electricity	40	55	50	50	50	50
Heating system based on wood	60	60	32	32	60	60
Heating system based on gas	40	40	40	40	40	40
Heating system based on oil	40	40	40	40	40	40
DHW system based on electricity	0.8	0.8	0.8	0.8	0.8	0.8
DHW system based on wood	0.9	0.9	0.9	0.9	0.9	0.9
DHW system based on gas	0.9	0.9	0.9	0.9	0.9	0.9
DHW system based on oil	0.9	0.9	0.9	0.9	0.9	0.9
DHW system based on solar thermal	3.2	3.2	3.2	3.2	3.2	3.2
Ventilation system	1	1	1	1	1	1
Cooling system	15	15	15	15	15	15
Improvement 2 (ambitious)	**Dormitories**	**Hospitals**	**Kindergartens**	**Offices**	**Schools**	**Universities**
Heating system based on electricity	40	55	55	55	n/a	n/a
Heating system based on wood	60	60	32	32	n/a	n/a
Heating system based on gas	40	40	50	50	n/a	n/a
Heating system based on oil	40	40	50	50	n/a	n/a
DHW system based on electricity	5	5	5	5	n/a	n/a
DHW system based on wood	0.9	0.9	0.9	0.9	n/a	n/a
DHW system based on gas	0.9	0.9	0.9	0.9	n/a	n/a
DHW system based on oil	0.9	0.9	0.9	0.9	n/a	n/a
DHW system based on solar thermal	1.5	1.5	1.5	1.5	n/a	n/a
Ventilation system	20	20	20	20	n/a	n/a
Cooling system	15	15	15	15	n/a	n/a

Table 28: Investment costs of building service systems per net floor area for all renovation options in all climate zones (EUR/m²)

Climate zone A		Dormitories	Hospitals	Kindergartens	Offices	Schools	Universities
BAU renovation	Heating system	0.00	0.00	0.00	0.00	0.00	0.00
	DHW system	0.81	0.96	0.83	0.83	0.80	0.80
	Cooling system	0.00	0.00	0.00	0.00	0.00	0.00
	Ventilation system	0.00	0.00	0.00	0.00	0.00	0.00
Improvement 1 (standard)	Heating system	40.00	53.50	46.44	47.60	48.00	49.50
	DHW system	0.82	1.05	0.95	0.94	0.80	0.80
	Cooling system	7.50	12.00	7.50	13.50	7.50	6.00
	Ventilation system	0.30	0.40	0.20	0.50	0.50	0.05
Improvement 2 (ambitious)	Heating system	44.00	55.00	50.95	51.70	n/a	n/a
	DHW system	3.48	4.30	3.54	3.49	n/a	n/a
	Cooling system	10.50	13.50	12.00	15.00	n/a	n/a
	Ventilation system	10.00	12.00	10.00	12.00	n/a	n/a
Climate zone B		**Dormitories**	**Hospitals**	**Kindergartens**	**Offices**	**Schools**	**Universities**
BAU renovation	Heating system	0.00	0.00	0.00	0.00	0.00	0.00
	DHW system	0.81	0.96	0.83	0.83	0.80	0.80
	Cooling system	0.00	0.00	0.00	0.00	0.00	0.00
	Ventilation system	0.00	0.00	0.00	0.00	0.00	0.00
Improvement 1 (standard)	Heating system	40.00	53.50	46.44	47.60	48.00	49.50
	DHW system	0.82	1.05	0.95	0.94	0.80	0.80
	Cooling system	7.50	12.00	7.50	13.50	7.50	6.00
	Ventilation system	0.30	0.40	0.20	0.50	0.50	0.05
Improvement 2 (ambitious)	Heating system	44.00	55.00	50.95	51.70	n/a	n/a
	DHW system	3.48	4.30	3.54	3.49	n/a	n/a
	Cooling system	10.50	13.50	12.00	15.00	n/a	n/a
	Ventilation system	10.00	12.00	10.00	12.00	n/a	n/a
Climate zone C		**Dormitories**	**Hospitals**	**Kindergartens**	**Offices**	**Schools**	**Universities**
BAU renovation	Heating system	0.00	0.00	0.00	0.00	0.00	0.00
	DHW system	0.85	0.80	0.88	0.88	0.80	0.80
	Cooling system	0.00	0.00	0.00	0.00	0.00	0.00
	Ventilation system	0.00	0.00	0.00	0.00	0.00	0.00
Improvement 1 (standard)	Heating system	48.00	53.50	41.70	39.20	54.00	54.50
	DHW system	0.86	1.09	0.93	0.96	0.80	0.80
	Cooling system	7.50	12.00	7.50	13.50	7.50	6.00
	Ventilation system	0.30	0.40	0.20	0.50	0.50	0.05
Improvement 2 (ambitious)	Heating system	48.00	57.50	44.80	39.95	n/a	n/a
	DHW system	3.01	3.07	2.37	1.34	n/a	n/a
	Cooling system	10.50	13.50	12.00	15.00	n/a	n/a
	Ventilation system	10.00	12.00	10.00	12.00	n/a	n/a

Table 29: Total investment costs per net floor area for all renovation options in all climate zones (EUR/m²)

Climate zone A		Dormitories	Hospitals	Kindergartens	Offices	Schools	Universities
BAU renovation	Envelope cost	1.60	1.35	4.36	1.80	2.05	0.76
	HVAC system cost	0.81	0.96	0.83	0.83	0.80	0.80
	Total cost	**2.41**	**2.31**	**5.18**	**2.63**	**2.85**	**1.56**
Improvement 1 (standard)	Envelope cost	16.76	15.40	25.81	21.26	21.14	22.69
	HVAC system cost	48.62	66.95	55.09	62.54	56.80	56.35
	Total cost	**65.38**	**82.35**	**80.90**	**83.80**	**77.94**	**79.04**
Improvement 2 (ambitious)	Envelope cost	21.81	25.15	33.96	29.11	n/a	n/a
	HVAC system cost	67.98	84.80	76.49	82.19	n/a	n/a
	Total cost	**89.79**	**109.95**	**110.45**	**111.30**	**n/a**	**n/a**
Climate zone B		**Dormitories**	**Hospitals**	**Kindergartens**	**Offices**	**Schools**	**Universities**
BAU renovation	Envelope cost	1.60	1.35	4.36	1.80	2.05	0.76
	HVAC system cost	0.81	0.96	0.83	0.83	0.80	0.80
	Total cost	**2.41**	**2.31**	**5.18**	**2.63**	**2.85**	**1.56**
Improvement 1 (standard)	Envelope cost	16.76	15.40	25.81	21.26	21.14	22.69
	HVAC system cost	48.62	66.95	55.086	62.54	56.8	56.35
	Total cost	**65.38**	**82.35**	**80.90**	**83.80**	**77.94**	**79.04**
Improvement 2 (ambitious)	Envelope cost	21.81	25.15	33.96	29.11	n/a	n/a
	HVAC system cost	67.98	84.8	76.493	82.19	n/a	n/a
	Total cost	**89.79**	**109.95**	**110.45**	**111.30**	**n/a**	**n/a**
Climate zone C		**Dormitories**	**Hospitals**	**Kindergartens**	**Offices**	**Schools**	**Universities**
BAU renovation	Envelope cost	1.60	1.35	4.36	1.80	2.05	0.76
	HVAC system cost	0.85	0.80	0.88	0.88	0.80	0.80
	Total cost	**2.45**	**2.15**	**5.24**	**2.68**	**2.85**	**1.56**
Improvement 1 (standard)	Envelope cost	16.76	15.40	25.81	21.26	21.14	22.69
	HVAC system cost	56.66	66.99	50.327	54.157	62.80	61.35
	Total cost	**73.42**	**82.39**	**76.14**	**75.42**	**83.94**	**84.04**
Improvement 2 (ambitious)	Envelope cost	21.81	25.15	33.96	29.11	n/a	n/a
	HVAC system cost	71.51	86.07	69.165	68.29	n/a	n/a
	Total cost	**93.32**	**111.22**	**103.12**	**97.40**	**n/a**	**n/a**

6. Economic and financial analysis

Approach

This chapter provides a country-wide analysis of the costs and benefits of the thermal efficiency retrofitting of public buildings in Albania. In order to design successful, evidence-based policies targeted at reducing energy demand in buildings, it is important to have information about the biggest energy-consuming building types and end uses; the prioritisation of possible actions in terms of energy saved and cost-effectiveness; as well as the costs and benefits of such opportunities for society.

First, we undertake a traditional financial analysis based on the comparison of financial inflows and outflows related to the thermal efficiency retrofitting of public buildings. The outflows are the associated costs — that is, capital investment, installation and maintenance costs. The inflows are the monetised benefits, which include saved energy costs. More information about the financial analysis for public buildings is available in EXERGIA (2013). The analysis includes the calculation of indicators such as investment size, simple payback period, net present value (NPV), internal rate of return (IRR), and benefit-cost ratio:

- The investment size illustrates the total amount of incremental investment required for the thermal efficiency improvement of public buildings.
- The simple payback period is the time required (in years) for the repayment of the investment through its benefits (not discounted).
- The IRR is a discount rate that equates the present value of the expected outflows with the present value of the expected inflows.
- The NPV is the present value of the project cash flow over the measure lifetime.
- The benefit-cost ratio is the ratio between the NPV of benefits and costs.

Second, we make an initial attempt to identify other benefits of thermal efficiency improvements, besides the saved energy costs. Unfortunately, the timeframe of the project does not allow us to build up our own model to monetise these benefits, which is why we rely on proxies gathered from similar projects implemented in Albania or other comparable countries. These benefits include thermal comfort, avoided CO_2 emissions, avoided economic impacts of airborne pollutants, employment, and economic growth. Other benefits are not included in the financial analysis due to the lack of time to do a thorough analysis. Nevertheless, they can serve as a good argument for policy makers to pay greater attention to thermal efficiency measures. More information about the benefits of energy efficiency can be found in IEA (2014). Several of the sub-sections on page 67 and following explain the assumptions we used to calculate these benefits.

Third, we carry out an analysis using the approach of energy conservation supply curves. In our case, a supply curve of conserved energy characterises the potential energy savings from a set of thermal energy retrofitting packages applied to different building types as a function of the cost per unit. Comparing the cost of energy conserved, illustrated by the curve, with energy prices makes it possible to prioritise energy saving options or building types in terms of potential energy savings and their cost-effectiveness, and suggests an investment schedule. Typically, energy conservation supply curves are prepared on a more granular level for a set of technological measures applied to each building type. In our case, the individual measures were merged into packages applicable to building types. This is because the technical possibilities in public buildings usually enable the implementation of complex measures. The installation of individual assessed measures is technically not feasible because:

- exchanging windows without insulation measures often results in fabric degradation and mould growth;
- improving the building envelope without modernising the heating system results in overheating and wasted energy;
- the standalone modernisation of the heating system can lead to lower maintained temperatures and, in the case of poor building shell quality, can lead to fabric degradation and mould growth; and
- individual measures that are implemented step by step result in higher total costs than complex measures carried out simultaneously.

The cost of energy saved (CCE_j, EUR/kWh) is estimated as:

$$CEE_j = \frac{\Delta AIC_j - \Delta MC_j}{\Delta FEC_j}$$

where ΔAIC_j is the difference in annualised investment costs, ΔMC_j is the difference in annual maintenance costs, ΔFEC_j is the difference in final energy consumption, and *j* is the building type. ΔAIC_j can be calculated as:

$$\Delta AIC_j = a_j \times \Delta IC_j$$

where ΔIC_j is the difference in investment costs and a_j is the annuity factor, which can be calculated as:

$$a_j = \frac{(1+DR)^{n_j} \times DR}{(1+DR)^{n_j} - 1}$$

where DR is the discount rate and n_j is the technology lifetime.

Retrofitting packages are cost-effective if the energy source price is greater than the cost of the energy conserved. More information about energy conservation supply curves is available in Meier, Wright and Rosenfeld (1983).

Statistical data on the building stock

Most public buildings in Albania are owned and managed by either the central or the local government. Table 30 shows the most important categories of public buildings, their types by building purpose, and the level of government that owns or is responsible for them. The table also shows the level of thermal comfort in terms of the availability of space heating.

Table 30: Categories of public buildings

	Building types by purpose, and level of government responsible	Availability of space heating
Public health	- Central and regional hospitals (central) - Local hospitals (municipal) - Clinics (central or municipal)	- Central and regional hospitals (central) - Local hospitals (municipal) - Clinics (central or municipal)
Education	- University (central) - Scientific institutions - Universities (central) and colleges (central or municipal) - Schools (municipal) - Child daycare centres (municipal) - Dormitories at educational institutions (central or municipal) - Kindergartens (municipal)	- The majority of these institutions are heated
Culture	- Museums and galleries (central or municipal) - Libraries (central or municipal) - Cultural centres (central or municipal) and theatres - Sports halls (central or municipal)	- The majority of these institutions are not heated
Internal affairs	- Police headquarters, police stations, institutions and other - Emergency services	- The majority of these institutions are not heated
Defence	- Military units, other military buildings and other institutions	- The majority of these institutions are not heated
Justice	- Courts and prisons (central) - Other institutions	- The majority of these institutions are not heated
Local government	- Municipality buildings	- The majority of these institutions are heated
Energy and industry	- Scientific institutions - Post offices throughout Albania, other buildings and other institutions	- The majority of these institutions are not heated
Council of ministries buildings	- Real estate register offices and archives	- The majority of these institutions are heated
Social affairs and youth	- Asylums, orphanages, institutions and other - Orphanages (municipal) - Homes for the elderly (municipal)	- The majority of these institutions are heated

Table 31: Floor area of public buildings by building type, 2012 (x 1,000 m²)

Building type	Total	Climate zone		
		A	B	C
Total	6,629	3,809	1,700	1,119
Hospitals	759	424	208	126
Offices	856	448	245	163
Education (total)	5,014	2,937	1,247	830
Schools	2,464	1,443	613	408
Kindergartens	2,531	1,482	629	419
Universities	11	6	3	2
Dormitories	9	5	2	1

Source: Estimates based on information provided by the Albanian expert panel. The panel relied on figures from the Albanian National Strategy of Energy (Republic of Albania 2003), updated based on the UNDP project "Penetration of Solar Water Heaters" (UNDP and Ministry of Economy, Trade and Energy 2010)

Based on the information provided by the Albanian expert panel, it was estimated that in 2012 the main types of public buildings covered a floor area of 6.6 million m². Table 31 shows the structure of this floor area: 76 percent of the floor area is occupied by buildings used for educational purposes; around 13 percent is occupied by offices; and 11 percent is occupied by hospitals.

The majority of the floor area of public buildings — that is, 57 percent — is located in climate zone A; 26 percent is located in climate zone B; and 17 percent in climate zone C.

Based on the data series provided by the statistical records of Albania (INSTAT 2013; INSTAT 2014), it was estimated that the floor area of public buildings has not changed significantly over the last five years. The floor area of buildings used for education, health care and office space has grown, but this growth applies almost exclusively to privately owned buildings used for these purposes. For this reason, we do not assume a growth in the publicly owned floor area of these building types until 2016.

Costs of thermal efficiency retrofitting

The direct costs of the thermal efficiency retrofitting of public buildings include:

- the capital and installation costs of thermal efficiency measures; and
- the costs of system maintenance over the measure lifetime.

The capital and installation costs of thermal efficiency measures are described in Chapter 5. The maintenance costs are estimated by the Albanian expert panel at EUR 0.5/m² of floor area for improvements 1 and 2.

There are other, additional costs related to retrofitting if the retrofitting is carried out within a programme designed and implemented by the government. These costs include:

- at state level: pre-feasibility evaluation, programme design and preparation, technical assistance, outreach, administration, monitoring and evaluation; and
- at local level (municipalities): energy audits, energy performance contracting, detailed design, supervision, implementation and evaluation.

Typically, these other costs are around 10 percent of the investment costs. In the currently planned programme under the National Energy Efficiency Action Plan of Albania, these other costs are 15 percent of the investment costs.

Assumptions of the financial analysis

The financial analysis is conducted based on real prices — that is, not taking into account the impact of inflation. The investment costs of the technological options are estimated including VAT (and other taxes included in the price). The lifetime of the retrofitting packages is assumed to be 30 years.

The results of the financial and energy conservation supply curve analyses are highly dependent on the assumption of the discount rate. A wide range of discount rates are used in studies prepared for the analysis of energy efficiency and mitigation programmes. This is due to the fact that discount rates are highly dependent on national circumstances and, most importantly, that there are differences in defining discount rates. Studies often use consumer discount rates that are based on the expected rates of return of competing investments. Sometimes, somewhat lower discount rates are used to identify economic potential from a social perspective. Sathaye and Meyers (1995) propose not discounting the costs and benefits of GHG emissions at all, since not discounting them assumes the future economic damage caused by a GHG increase at the real rate. This is probably realistic, since this effect is likely to increase dramatically and is largely unknown. Another approach is to set the discount rate as high as 100 percent, based on observed consumer behaviour (often referred to as the "hurdle" rate) and taking into consideration all possible costs associated with the implementation of mitigation measures discounting direct investment, operation and maintenance costs (Rufo 2003).

The European Commission (European Commission online) recommends using a social discount rate in order to plan "smart" policies, as this usually takes into account costs and benefits from the point of view of the whole of society rather than from the point of view of an individual stakeholder. The European Commission recommends a social discount rate of 4 percent applied to costs and benefits in constant prices, which is why this rate is used in our assessment.

Benefits of thermal retrofits and assumptions for their monetisation

Energy is a "commodity" that is not demanded for its own sake, but for the various services it provides. Similarly, improving energy efficiency is rarely a policy goal in its own right: it is rather used as a means of achieving other important social, political and economic ends. Among the most frequently sought benefits of improved energy efficiency are energy cost savings for consumers; thermal comfort, especially given that many public buildings in Albania do not have, or have only inadequate, space heating, space cooling and water heating; a reduced need for energy, especially electricity, given the growing demand in industry and commerce required by the country's economic growth; the reduced exploitation of finite natural resources; health benefits due to reduced air pollution and better compliance with health standards; greater economic growth due to investments in the construction sector performing the works, and due to the multiplying effects of the investments; and the related reduction in GHG emissions.

While it is difficult to calculate the impact of these benefits in monetary terms, we have attempted to identify some of the important benefits. Since our timeframe did not allow us to build our own model to estimate all benefits, we calculated benefits based on studies prepared for Albania and other countries with similar conditions. These include a study on green, energy-efficient schools for Albania prepared by Arizona State University (2015) and a study on the development of an investment programme for the refurbishment of public buildings prepared for Romania within the JASPERS financing tool of the European Investment Bank (EXERGIA S.A. 2013).

Thermal comfort

As mentioned above, one big challenge for Albania is that at present the level of energy services delivered in public buildings is inadequate. As Table 30 illustrates, despite low temperatures during the cold season, there is no space heating in a large proportion of public buildings. In buildings that are heated, as described on page 37, the floor space is heated partially, leaving out corridors, staircases, toilets and other areas with secondary functions. In many buildings (e.g. schools), there is no hot water supply due to the absence of appropriate facilities.

In the BAU renovation of public buildings, the level of these services rises but remains low. In the more ambitious renovations presented in Chapter 3 we assume that Albania moves towards a level of thermal services that is in line with the minimum health and comfort standards required by these facilities and typical for the European Union.

Due to the higher level of thermal comfort provided in retrofitted buildings, their real estate value grows. Based on EXERGIA (2013), we assume this growth as 2 percent. The assumed real estate value is EUR 300/m^2, based on statistics provided by the Albanian Statistical Office online (INSTAT).

Saved energy costs

One of the most common reasons for improving the thermal efficiency of buildings is to cut energy bills. In this regard, there are two challenges when estimating energy cost savings. The first is how to make correct assumptions for policy makers about the amount of energy demand reduced; and the second is how to make correct assumptions about expected energy prices.

As discussed in the previous section, more ambitious renovations assume higher levels of thermal services than at present, and higher than observed in the case of BAU retrofitting. Higher energy service levels in the case of the ambitious renovations make energy savings far smaller, but this reflects the reality of increasing welfare in Albania. In order to make the recommended advanced packages — that is, improvements 1 and 2 — comparable to the BAU renovations, we prepared a country-wide analysis according to the level of comfort suggested by the advanced retrofitting packages. Within the project, we also provided an analysis of the recommended retrofitting packages versus the BAU renovations, corresponding to the thermal comfort levels observed in reality.

There is no single source or agency that collects, reports and forecasts the dynamics of energy and fuel prices in Albania. The current energy source prices were therefore gathered from different sources. Where information was missing, we made our best estimate. All future dynamics of energy prices are estimated for the purposes of this research. The current energy source prices and their forecasts are presented in Table 32.

The present price of electricity for budgetary consumers is EUR 0.10/kWh (Enti rregullator I Energjisë online). This price is only marginally higher than the electricity wholesale price calculated in the electricity decarbonisation model prepared within the SLED project (Szabo et al. 2015). Electricity has historically been regulated for consumers in Albania. If consumers do not pay the full costs of their energy services, it obviously hinders investments in efficient building retrofits. This means that regulated energy prices, which are lower than those reflecting the full cost of energy and externalities, provide insufficient incentives for policy makers to devote time and attention to energy efficiency.

When the Albanian market is liberalised and integrated into the EU market, the price of electricity is likely to grow. Nevertheless, there is great uncertainty about the future dynamics of electricity price rises. In agreement with the Albanian expert panel, the electricity price is assumed to grow by 1.5 percent per year in real terms, reaching EUR 0.16/kWh in 30 years.

The current price of LPG is EUR 0.41/litre, and the current price of diesel oil is EUR 0.17/litre (Global petrol prices online). We assumed that, in the future, LPG and diesel oil prices will grow in line with the price of oil. The oil price is assumed to grow by 5 percent per year over the next 30 years, according to the forecast of energy commodity prices provided by the World Bank (World Bank 2016).

The current price of wood was estimated at EUR 35/m^3. Since electricity is the main substitute for wood in the building sector, we assume that the price of wood will increase according to the same trend as the price of electricity.

Table 32: Energy source prices

Energy sources	Energy source price		
	2016 (EUR/kWh)	2045 (EUR/kWh)	Annual growth (%)
Electricity	0.104	0.160	1.5
Wood	0.024	0.037	1.5
LPG	0.061	0.247	5
Diesel oil	0.117	0.473	5

Air pollution reduction and health

Energy efficiency improves air quality, thereby contributing to better public health (e.g. increased life expectancy, reduced emergency room visits, reduced asthma attacks, fewer lost working days) and the prevention of structural damage to buildings and public works.

EXERGIA (2013) assessed and monetised the benefits of a lower incidence of illnesses caused by air pollution. In line with this study we assume that the avoided emissions of airborne pollutants result in savings of EUR 1.38/MWh/year.

Climate change mitigation

Energy savings result in a reduction in GHG emissions. Only CO_2 emissions reductions are calculated in our project. Reductions in CO_2 emissions can also be monetised by applying the CO_2 price. Based on EXERGIA (2013), we assumed that the cost of CO_2 will increase from its current level to EUR 45/tCO_2 in 2030. After this year, we keep the CO_2 price constant.

Job creation

Most studies agree that energy efficiency investments have a positive impact on employment by creating new business opportunities, and therefore jobs, via domestically produced energy-efficient technologies and services; and through the economic multiplier effects of spending in other ways the money saved on energy costs. A national policy that promotes both the production and use of energy-efficient technologies also helps all sectors in the country to compete internationally, thus contributing to economic development and job creation. The impacts on employment may be direct, indirect or induced:

- Direct impacts are due to employment in the construction industry and in associated services related to renovation work. Direct employment also includes the work of energy auditors, engineers, contractors and managers related to activities listed in other costs.
- Indirect impacts are due to jobs created for the manufacturing of materials, equipment, and other suppliers for building renovation.
- Induced impacts are due to the greater demand for services such as retail, healthcare and food due to the higher earnings of people employed as a result of direct and indirect impacts.

Researchers at Arizona State University (2015) prepared an input–output model for Albania, on the basis of which they estimated the impacts of converting Albanian schools into green and energy-efficient buildings. The study assumed four tiers of building improvement. Our retrofitting packages correspond to a combination of tiers 1, 2 and 3, thus we used the proxies calculated from the impacts of these tiers. Table 33 presents the proxies that we used for the quantification of employment effects.

Economic growth

One of the most important impacts of thermal retrofitting work is its contribution to economic growth. As for employment effects, experts from Arizona State University (2015) also calculated the increase in value added due to retrofitting work. From this study we calculated the proxies to make an estimate of multiplier effects for GDP due to thermal efficiency retrofitting in the public sector. Table 34 presents the proxies that we used for the quantification of GDP effects.

Table 33: Proxies used for the quantification of multiplier effects for employment

Effect	Unit	Value
Labour income	**EUR/EUR**	**0.30**
direct	EUR/EUR	0.17
multiplier effects	EUR/EUR	0.13
Annual employment	**jobs/EUR million**	**148**
employment	jobs/EUR million	85
multiplier effects	jobs/EUR million	63

Source: Assumed, based on Arizona State University (2015)

Table 34: Proxies used for the quantification of multiplier effects for GDP

Effect	Unit	Value
GDP increase	**EUR/EUR**	**0.65**
direct	EUR/EUR	0.30
multiplier effects	EUR/EUR	0.35

Source: Assumed, based on Arizona State University (2015)

Table 35: Costs of thermal energy efficiency retrofitting by building type and climate zone, improvement 1

	Dormitories	Hospitals	Kindergartens	Offices	Schools	Universities	Average or total
Investment costs (EUR/m²)							
Average	**64**	**80**	**75**	**80**	**76**	**78**	**77**
Climate zone A	63	80	76	81	75	77	77
Climate zone B	63	80	76	81	75	77	77
Climate zone C	71	80	71	73	81	82	76
Maintenance costs (EUR/m²/year)							
Average	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**
Investment costs (EUR million)							
Total	**0.6**	**61**	**190**	**68**	**187**	**0.9**	**507**
Climate zone A	0.3	34	112	36	108	0.5	292
Climate zone B	0.1	17	48	20	46	0.2	131
Climate zone C	0.1	10	30	12	33	0.1	85

Results

The analyses were carried out:

- per square metre and by climate zone for each improvement;
- per square metre and for the whole stock for each climate zone for both improvements that could be useful for municipalities; and
- per square metre and for the whole stock for the whole country for each improvement that could be useful for programme administrators.

Below we discuss the results of the analyses per square metre and for the whole country for each improvement by climate zone.

Costs and benefits by retrofitting package: Improvement 1

Table 35 presents the costs of retrofitting by building type and climate zone for improvement 1. Among building types, the table shows that investment costs per square metre are the lowest for dormitories, followed by kindergartens and schools. The differences between climate zones are not significant.

In order to retrofit all Albanian public buildings to the level of improvement 1, around EUR 500 million would be needed. The building types requiring the biggest investment on a national scale are kindergartens and schools, followed by offices and hospitals. If classified by climate zone, the biggest investment is required in climate zone A.

Table 36 presents the reduction in primary and final energy demand as well as potential CO_2 emissions reductions by building type and climate zone for improvement 1. The table shows that the biggest primary and final energy demand savings, as well as CO_2 emissions reductions, per square metre are unequivocally in buildings in climate zone C. These indicators have half the value in climate zones A and B, while the difference between these two latter zones is not as significant. The biggest primary and final energy demand savings per square metre are in dormitories, hospitals and offices, with a different ranking for these indicators among climate zones.

Climate zone A holds the biggest share of final energy savings in absolute values because of the larger number of buildings here than in climate zone C. In terms of the absolute potential for primary and final energy demand savings by building type, kindergartens rank first, followed by schools and hospitals. In terms of potential CO_2 emissions savings, the biggest potential is in hospitals and kindergartens.

Table 37 presents saved energy costs per square metre by building type and climate zone in the case of improvement 1. The table shows that the biggest energy cost savings per square metre are offered by hospitals and dormitories. The biggest absolute energy cost savings could be achieved in kindergartens, schools and hospitals. Saved energy costs per square metre in climate zone C are more than double those in climate zone A, and are 65 percent higher than in climate zone B. The average energy savings over measure lifetime are approximately EUR 4.4/m^2 annually, or EUR 76/m^2 over the whole measure lifetime. The table shows that the total energy cost savings are EUR 29 million per year, or EUR 500 million over measure lifetime. Almost 45 percent of the savings are in climate zone A, due to the large number of buildings there.

Table 38 presents the results of the financial analysis. The table shows that the retrofitting of universities is not financially feasible if only saved energy costs are taken as benefits (payback time longer than the measure lifetime, cost-benefit ratio higher than 1, negative NPV, negative IRR). Likewise, the retrofitting of schools and kindergartens is not financially attractive (negative NPV, cost-benefit ratio higher than 1). Retrofitting is financially feasible in the case of dormitories and hospitals, while offices are at the edge of feasibility.

Table 39 presents the results of the monetising of the benefits of thermal efficiency retrofitting other than energy cost savings. The table shows that these benefits are cumulatively comparable to saved energy costs. Effects on GDP and employment are especially high. It should be noted that we quantified only a limited number of co-benefits. If all of these benefits were taken into account in the financial analysis, the cost-effectiveness of the thermal efficiency retrofitting of all types of public buildings would be far higher.

Figure 25 and Table 40 present the cost of energy saved per square metre for the whole country. They show that by far the cheapest and largest potential per square metre is available in climate zone C. In terms of costs, the potential in climate zone A is more expensive than in climate zone B, although the amount of saved energy per square metre does not differ significantly.

Comparing the cost of energy saved with energy prices helps to identify cost-effective retrofitting packages. If buildings are fully served with electricity, at its current price the retrofitting of all building types except schools in climate zone C, as well as the retrofitting of dormitories in climate zones A and B, are cost-effective. If the electricity price rises as indicated in Table 32, the retrofitting of all building types in climate zone C, as well as the retrofitting of dormitories and hospitals in climate zone B, will become cost-effective. Similar conclusions can also be drawn from a comparison of the cost of energy saved with other energy prices.

Figure 26 presents the cumulative potential for final energy savings as a function of the cost of energy saved for the whole country. The figure illustrates that building types that are cumulatively able to supply the largest potential are kindergartens, schools and hospitals. Offices also offer big potential for energy savings. If all retrofitting in the country were carried out, it would help save approximately 210 GWh/year (16 ktoe). If only retrofitting that costs less than EUR 0.1/kWh were carried out, then around 62 GWh/year (5.3 ktoe) could be saved.

Costs and benefits by retrofitting package: Improvement 2

Table 41 presents the costs of retrofitting by building type and climate zone in the case of improvement 2. The analysis was carried out for dormitories, hospitals, kindergartens and offices. The table shows that the lowest investment costs per square metre are for dormitories. The respective costs are similar for hospitals, kindergartens and offices. The differences in costs between climate zones are not significant.

Table 36: Energy demand savings and CO_2 emissions reductions by building type and climate zone, improvement 1

	Dormitories	Hospitals	Kindergartens	Offices	Schools	Universities	Average or total
CO_2 emissions reductions (gCO_2/m^2)							
Average	**5,984**	**11,743**	**2,053**	**2,895**	**1,071**	**2,424**	**2,912**
Climate zone A	3,462	7,456	1,827	2,090	881	1,171	2,128
Climate zone B	4,655	9,133	2,248	2,734	964	1,995	2,702
Climate zone C	16,904	30,515	2,558	5,348	1,902	7,502	5,897
Primary energy demand savings (kWh/m^2)							
Average	**77**	**62**	**27**	**28**	**20**	**12**	**28**
Climate zone A	63	43	24	21	17	6	23
Climate zone B	83	54	31	28	22	11	30
Climate zone C	115	140	30	44	27	36	44
Final energy demand savings (kWh/m^2)							
Average	**86**	**59**	**30**	**37**	**24**	**14**	**32**
Climate zone A	59	36	21	24	17	5	22
Climate zone B	79	47	28	32	23	10	29
Climate zone C	189	157	66	84	48	55	72
CO_2 reductions (tCO_2)							
Total	**54**	**8,909**	**5,195**	**2,478**	**2,638**	**27**	**19,300**
Climate zone A	18	3,163	2,708	937	1,271	8	8,104
Climate zone B	10	1,904	1,415	669	591	5	4,595
Climate zone C	25	3,841	1,072	872	776	14	6,600
Primary energy demand savings (GWh)							
Total	**0.7**	**47**	**67**	**24**	**49**	**0.1**	**188**
Climate zone A	0.33	18	35	9	25	0.04	88
Climate zone B	0.19	11	19	7	13	0.03	51
Climate zone C	0.17	18	13	7	11	0.07	49
Primary energy demand savings (ktoe)							
Total	**0.8**	**45**	**77**	**32**	**59**	**0.2**	**213**
Climate zone A	0.3	15	32	11	25	0.0	83
Climate zone B	0.2	10	17	8	14	0.0	49
Climate zone C	0.3	20	28	14	20	0.1	81
Final energy demand savings (GWh)							
Total	**0.8**	**45**	**77**	**32**	**59**	**0.2**	**213**
Climate zone A	0.3	15	32	11	25	0.0	83
Climate zone B	0.2	10	17	8	14	0.0	49
Climate zone C	0.3	20	28	14	20	0.1	81
Final energy demand savings (ktoe)							
Total	**0.07**	**3.86**	**6.59**	**2.75**	**5.06**	**0.01**	**18.33**
Climate zone A	0.03	1.32	2.71	0.91	2.16	0.00	7.14
Climate zone B	0.02	0.84	1.49	0.66	1.22	0.00	4.23
Climate zone C	0.02	1.70	2.39	1.17	1.68	0.01	6.97

Table 37: Saved energy costs by building type and climate zone, improvement 1

	Dormitories	Hospitals	Kindergartens	Offices	Schools	Universities	Average or total
Total over measure lifetime (NPV) (EUR/m²)							
Average	**212.1**	**194.1**	**64.3**	**79.8**	**49.4**	**38.2**	**75.8**
Climate zone A	165.8	129.8	56.1	60.2	42.0	18.8	59.5
Climate zone B	218.1	163.5	71.8	80.1	52.9	33.9	77.6
Climate zone C	366.7	461.7	82.3	133.2	70.0	113.0	128.3
Annual over measure lifetime (EUR/m²)							
Average	**12.3**	**11.2**	**3.7**	**4.6**	**2.9**	**2.2**	**4.4**
Climate zone A	9.6	7.5	3.2	3.5	2.4	1.1	3.4
Climate zone B	12.6	9.5	4.2	4.6	3.1	2.0	4.5
Climate zone C	21.2	26.7	4.8	7.7	4.1	6.5	7.4
Total over measure lifetime (NPV) (EUR million)							
Total	**1.90**	**147**	**163**	**68**	**122**	**0.42**	**502**
Climate zone A	0.9	55.1	83.1	27.0	60.6	0.12	227
Climate zone B	0.5	34.1	45.2	19.6	32.4	0.09	132
Climate zone C	0.5	58.1	34.5	21.7	28.6	0.2	144
Annual over measure lifetime (EUR million)							
Total	**0.11**	**9**	**9**	**4**	**7**	**0.02**	**29**
Climate zone A	0.05	3.2	4.8	1.6	3.5	0.01	13
Climate zone B	0.03	2.0	2.6	1.1	1.9	0.01	8
Climate zone C	0.03	3.4	2.0	1.3	1.7	0.01	8

Table 38: Financial analysis, improvement 1

	Dormitories	Hospitals	Kindergartens	Offices	Schools	Universities	Total
Simple payback (years)	5	7	20	17	27	n/a	17
IRR (%)	15.7	11.1	3.0	4.0	1.1	-0.2	3.9
NPV (EUR/m²)	1.3	83.2	-25.8	0.2	-63.3	-0.4	-4.8
Cost-benefit ratio	0.3	0.4	1.2	1.0	1.5	2.1	1.0

Table 39: Co-benefits of the thermal efficiency retrofitting of public buildings, improvement 1

	Dormitories	Hospitals	Kindergartens	Offices	Schools	Universities	Average or total
Per m²							
GDP increase (EUR/m²)	42	52	49	52	49	51	50
Labour income (EUR/m²)	19	24	22	24	23	23	23
Employment (jobs/m²)	0.01	0.01	0.01	0.01	0.01	0.01	0.07
CO_2 avoided (EUR/m²)	2.8	5	1.0	1.3	0.5	1.1	1
Air quality (EUR/m²)	2.0	1.4	0.7	0.9	0.6	0.3	1
Improved comfort (EUR/m²)	6	6	6	6	6	6	6
For the whole floor area							
GDP increase (EUR million)	0.4	39.4	123.0	44.2	121.6	0.6	329
Labour income (EUR million)	0.2	18.1	56.4	20.3	55.8	0.3	151
Employment (jobs)	85	8,963	27,969	10,048	27,652	127	74,844
CO_2 avoided (EUR million)	0.02	4.1	2.4	1.2	1.2	0.0	9
Air quality (EUR million)	0.0	1.1	1.8	0.8	1.4	0.0	5
Improved comfort (EUR million)	0.1	4.6	15.2	5.1	14.8	0.1	40

Table 40: Cost of energy saved, improvement 1 (EUR/kWh)

	Dormitories	Hospitals	Kindergartens	Offices	Schools	Universities	Average
Average	**0.05**	**0.09**	**0.16**	**0.14**	**0.21**	**0.35**	**0.15**
Climate zone A	0.07	0.14	0.22	0.22	0.28	0.98	0.21
Climate zone B	0.05	0.11	0.17	0.16	0.21	0.52	0.16
Climate zone C	0.02	0.03	0.07	0.06	0.11	0.10	0.06

Figure 25: Cost of energy saved, improvement 1

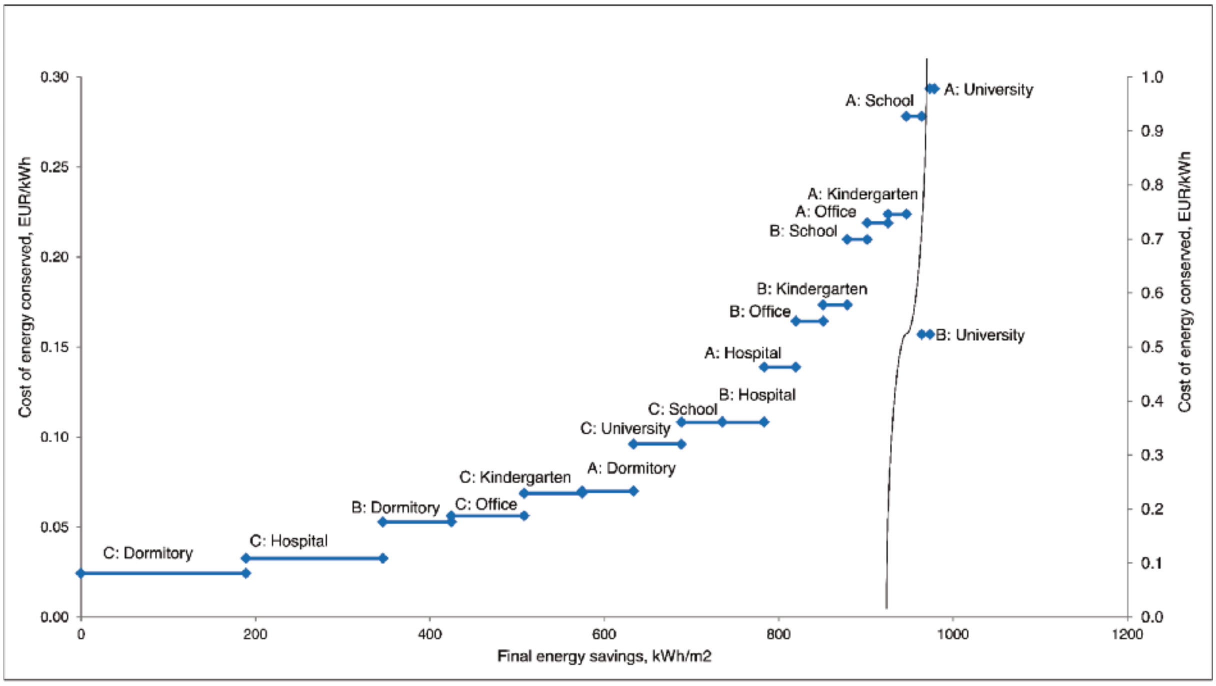
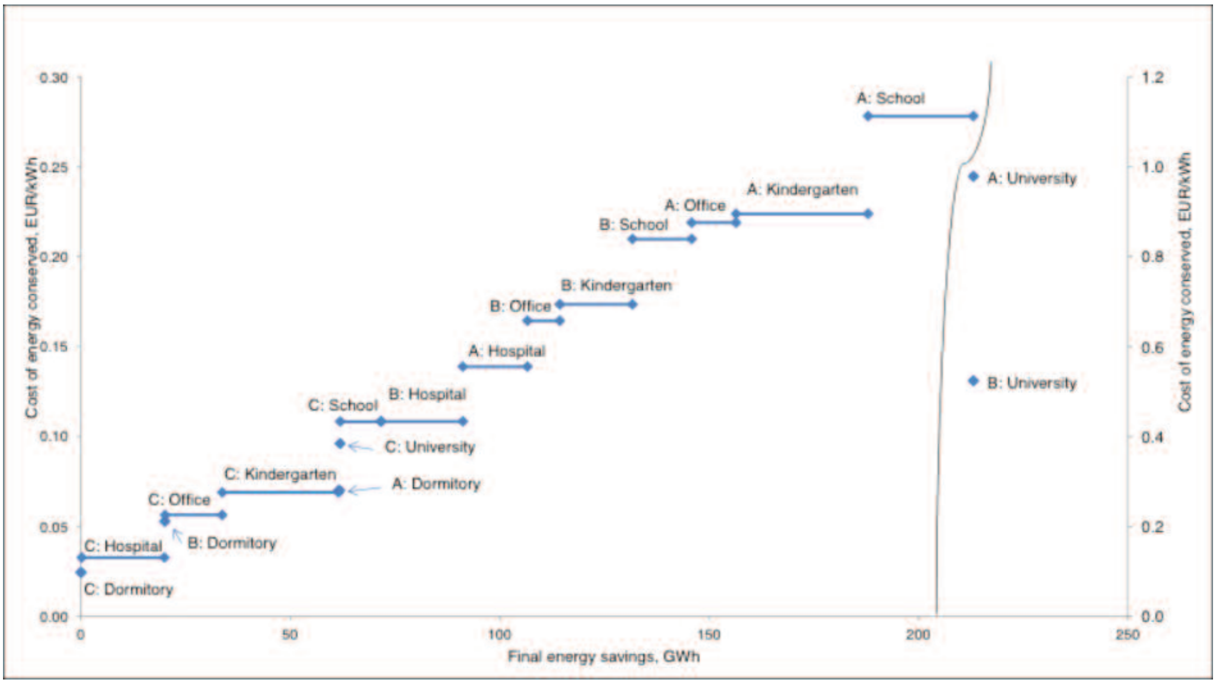


Figure 26: Supply curve of energy saved, improvement 1



In order to retrofit the analysed types of public buildings to the level of improvement 2, approximately EUR 440 million would be needed. According to building type, kindergartens require the biggest investment. If classified by climate zone, the largest investment is required in climate zone A.

Table 42 presents the reduction in primary and final energy demand, as well as potential CO_2 emissions reductions by building type and climate zone for improvement 2. The table shows that the highest primary and final energy demand savings, as well as CO_2 emissions reductions per square metre, are unequivocally in buildings in climate zone C. These indicators are smaller, or over half the value, in climate zone A, and almost half the value in climate zone B. The highest primary and final energy demand savings per square metre are in dormitories and hospitals.

Climate zone A holds the largest share of final energy savings in absolute terms due to the large number of buildings there. Kindergartens and hospitals offer the largest potential for primary and final energy savings by building type.

Table 43 presents saved energy costs per square metre by building type and climate zone in the case of improvement 2. The table shows that the highest energy cost savings per square metre are possible in dormitories and hospitals. Saved energy costs per square metre in climate zone C are 70 percent higher than those in climate zone B, and more than double those in climate zone A. Average energy savings over measure lifetime are approximately EUR 4.2/m^2 annually, or EUR 73/m^2 over the whole measure lifetime. The table shows that the total energy cost savings are EUR 28 million per year, or EUR 480 million over measure lifetime. Almost half the savings are in climate zone A, due to the large number of buildings there.

Table 44 presents the results of the financial analysis for improvement 2. The table shows that the retrofitting of kindergartens and offices is not financially attractive if only saved energy costs are taken as benefits (very long payback time that is still shorter than the measure lifetime, cost-benefit ratio higher than 1, negative NPV). The retrofitting of dormitories and hospitals is financially feasible.

Table 45 presents the results of monetising benefits of thermal efficiency retrofitting other than energy cost savings. The table illustrates that these benefits are cumulatively comparable to saved energy costs. Effects on GDP and employment are especially high. It should be noted that we quantified only a limited number of co-benefits. If all such benefits were taken into account in the financial analysis, the cost-effectiveness of the thermal efficiency retrofitting of all types of public buildings would be far higher.

Figure 27 and Table 46 present the cost of energy saved per square metre in the case of improvement 2. They show that by far the cheapest and biggest potential per square metre is available in climate zone C. The potential in climate zone A is more expensive than in climate zone B.

A comparison of the cost of energy saved with energy prices helps to identify cost-effective retrofitting packages. If buildings are fully served with electricity, at its current price the retrofitting of all building types in climate zone C, as well as the retrofitting of dormitories in climate zones A and B and the retrofitting of hospitals in climate zone B, are cost-effective. If the electricity price rises as indicated in Table 32, the retrofitting of all building types in climate zone C, as well as dormitories and hospitals in climate zones A and B, will become cost-effective. Similar conclusions can also be drawn by comparing the cost of energy saved with other energy prices.

Figure 28 presents the cumulative potential for final energy savings as a function of the cost of energy saved for the whole country. The figure shows that building types that are able to supply the biggest potential are kindergartens and hospitals. Offices also offer large potential for energy savings. If all retrofitting in the country were carried out, it would help to save approximately 200 GWh/year (16 ktoe). If only retrofitting that costs less than EUR 0.1/kWh were to be carried out, then around 83 GWh/year (7.2 ktoe) could be saved.

Recommendations for the NEEAP

According to Law 124/2015 on Energy Efficiency, an energy efficiency fund will be established as an independent organisation with a government-appointed board of governors or a board of trustees comprising members from both the public and private sectors.

Even though the spreadsheet model presented in this publication is rather basic and limited, it can still help stakeholders in fund activities to make decisions. Stakeholders include policy makers at the state and local level, energy service companies (ESCOs), developers, architects, designers, contractors, suppliers/

Table 41: Costs of thermal energy efficiency retrofitting by building type and climate zone, improvement 2

	Dormitories	Hospitals	Kindergartens	Offices	Average or total
Investment costs (EUR/m^2)					
Average	**88**	**108**	**104**	**106**	**66**
Climate zone A	87	108	105	109	66
Climate zone B	87	108	105	109	68
Climate zone C	91	109	98	95	63
Maintenance costs (EUR/m^2/year)					
Average	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**
Investment costs (EUR million)					
Total	**0.8**	**82**	**263**	**91**	**437**
Climate zone A	0.5	45.7	156.0	48.7	251
Climate zone B	0.2	22.4	66.3	26.6	115
Climate zone C	0.1	13.7	41.0	15.5	70

manufacturers, inspectors, auditors, building maintenance/operators, and clients/users, as well as donors providing financing to Albania.

The financial volume of a fund depends on the available local and international funding and the expected demand. Table 47 shows indicative budget assumed in the second and third National Energy Efficiency Action Plans (NEEAPs) for the period 2017–2020.

There are several approaches to fund distribution, such as: according to the breakdown of building stock by type; according to the size of the potential that makes it easier to apply standardised methodologies; according to the cost-effectiveness of the investment; or according to the scale of other benefits, such as social benefits.

Table 48 presents a possible option that focuses on building types where retrofitting is cost-effective, and which could be selected as a priority from a social point of view. If all kindergartens and hospitals in climate zone C were retrofitted to the level of performance defined by improvement 1, the total investment required would be exactly EUR 40 million.

Table 49 presents another option for funding allocation, disbursed according to the breakdown of the building floor area by building type. The budget of EUR 40 million allows for the retrofitting of 8 percent of the floor area in each building type according to improvement 1.

The allocated budget allows for the retrofitting of 55 percent of the public buildings located in climate zone C (dormitories, kindergartens, offices, hospitals), where such retrofitting is the most cost-effective among all climate zones. If the funding is allocated according to the breakdown of the building floor area by building type, it allows for the retrofitting of 9 percent of the floor area according to improvement 2 (also including the four building types modelled).

Other potential fund allocations are easy to model in spreadsheets, inserting the share of the floor area to be retrofitted in building types where retrofitting is cost-effective or a priority according to any other criteria.

It should be understood that the success of the scheme depends not only on the allocation of the financing, but also on many other factors including the effective design of the scheme, the design of procurements and access to capital among ESCOs, given their typically small size.

As mentioned earlier, the analysis presented is rather basic and offers many opportunities for improvement. Besides a more detailed analysis of the benefits of thermal efficiency improvements, there should also be an analysis of levels of comfort and a risk and uncertainty assessment. This latter should include the sensitivity of key critical variables such as energy prices and significant risks borne by the different scheme stakeholders.

Table 42: Energy demand savings and CO_2 emissions reductions by building type and climate zone, improvement 2

	Dormitories	Hospitals	Kindergartens	Offices	Average or total
CO_2 emissions reductions (gCO_2/m^2)					
Average	**6,349**	**13,839**	**2,503**	**3,008**	**2,936**
Climate zone A	3,759	8,867	2,219	2,075	2,100
Climate zone B	5,012	10,886	2,719	2,734	2,741
Climate zone C	17,519	35,489	3,182	5,983	6,078
Primary energy demand savings (kWh/m^2)					
Average	**93**	**83**	**35**	**30**	**27**
Climate zone A	79	61	32	24	22
Climate zone B	100	75	39	28	28
Climate zone C	134	174	42	50	43
Final energy demand savings (kWh/m^2)					
Average	**95**	**76**	**38**	**40**	**28**
Climate zone A	67	52	28	26	20
Climate zone B	86	64	35	32	26
Climate zone C	205	175	77	92	62
CO_2 reductions (tCO_2)					
Total	**57**	**10,499**	**6,334**	**2,575**	**19,465**
Climate zone A	20	3,762	3,289	930	8,001
Climate zone B	11	2,270	1,711	669	4,661
Climate zone C	26	4,468	1,333	976	6,803
Primary energy demand savings (GWh)					
Total	**0.8**	**63**	**89**	**26**	**179**
Climate zone A	0.41	26	47	11	84
Climate zone B	0.22	16	25	7	48
Climate zone C	0.20	22	17	8	48
Primary energy demand savings (ktoe)					
Total	**0.07**	**5.44**	**7.67**	**2.21**	**15.39**
Climate zone A	0.04	2.22	4.05	0.91	7.21
Climate zone B	0.02	1.34	2.13	0.60	4.08
Climate zone C	0.02	1.88	1.50	0.70	4.10
Total final energy savings (GWh)					
Total	**0.8**	**57**	**96**	**34**	**189**
Climate zone A	0.4	22	42	11	76
Climate zone B	0.2	13	22	8	44
Climate zone C	0.3	22	32	15	69
Final energy demand savings (ktoe)					
Total	**0.07**	**4.93**	**8.28**	**2.93**	**16.21**
Climate zone A	0.03	1.88	3.61	0.99	6.51
Climate zone B	0.02	1.15	1.91	0.66	3.74
Climate zone C	0.03	1.89	2.76	1.28	5.96

Table 43: Saved energy costs by building type and climate zone, improvement 2

	Dormitories	Hospitals	Kindergartens	Offices	Average or total
Total over measure lifetime (NPV) (EUR/m²)					
Average	**247**	**251**	**85**	**86**	**73**
Climate zone A	199	176	75	65	57
Climate zone B	253	217	93	80	73
Climate zone C	406	559	108	150	126
Annual over measure lifetime (EUR/m²)					
Average	**14.3**	**14.5**	**4.9**	**5.0**	**4.2**
Climate zone A	11.5	10.2	4.4	3.8	3.3
Climate zone B	14.6	12.5	5.4	4.6	4.2
Climate zone C	23.5	32.3	6.2	8.7	7.3
Total over measure lifetime (NPV) (EUR million)					
Average	**2.2**	**190**	**215**	**73**	**481**
Climate zone A	1.0	75	112	29	217
Climate zone B	0.6	45	59	20	124
Climate zone C	0.6	70	45	24	141
Annual over measure lifetime (EUR million)					
Total	**0.13**	**11**	**12**	**4**	**28**
Climate zone A	0.06	4.3	6.5	1.7	13
Climate zone B	0.03	2.6	3.4	1.1	7
Climate zone C	0.03	4.1	2.6	1.4	8

Table 44: Financial analysis, improvement 2

	Dormitories	Hospitals	Kindergartens	Offices	Total
Simple payback (years)	6	7	21	21	16
IRR (%)	11.7	8.4	0.9	2.1	5.0
NPV (EUR/m²)	1.1	63	-97	-22	63
Cost-benefit ratio	0.4	0.6	1.6	1.3	0.9

Table 45: Co-benefits of the thermal efficiency retrofitting of public buildings, improvement 2

	Dormitories	Hospitals	Kindergartens	Offices	Average or total
Per m^2					
GDP increase (EUR/m^2)	57	70	68	69	43
Labour income (EUR/m^2)	26	32	31	32	20
Employment (jobs/m^2)	0.01	0.02	0.02	0.02	0.06
CO_2 avoided (EUR/m^2)	2.9	6	1.2	1.4	1
Air quality (EUR/m^2)	2.3	1.8	0.9	1.0	1
Improved comfort (EUR/m^2)	6	6	6	6	4
For the whole floor area					
GDP increase (EUR million)	0.5	53.1	170.8	58.9	283
Labour income (EUR million)	0.2	24.4	78.4	27.0	130
Employment (number of jobs)	116	12,075	38,844	13,388	64,423
CO_2 avoided (EUR million)	0.03	4.9	2.9	1.2	9
Air quality (EUR million)	0.0	1.4	2.3	0.8	4
Improved comfort (EUR million)	0.1	4.6	15.2	5.1	25

Table 46: Cost of energy saved, improvement 2 (EUR/kWh)

	Dormitories	Hospitals	Kindergartens	Offices	Average or total
Average	**0.06**	**0.09**	**0.17**	**0.17**	**0.13**
Climate zone A	0.08	0.12	0.23	0.26	0.20
Climate zone B	0.06	0.10	0.18	0.21	0.16
Climate zone C	0.03	0.04	0.08	0.07	0.06

Figure 27: Cost of energy saved, improvement 2

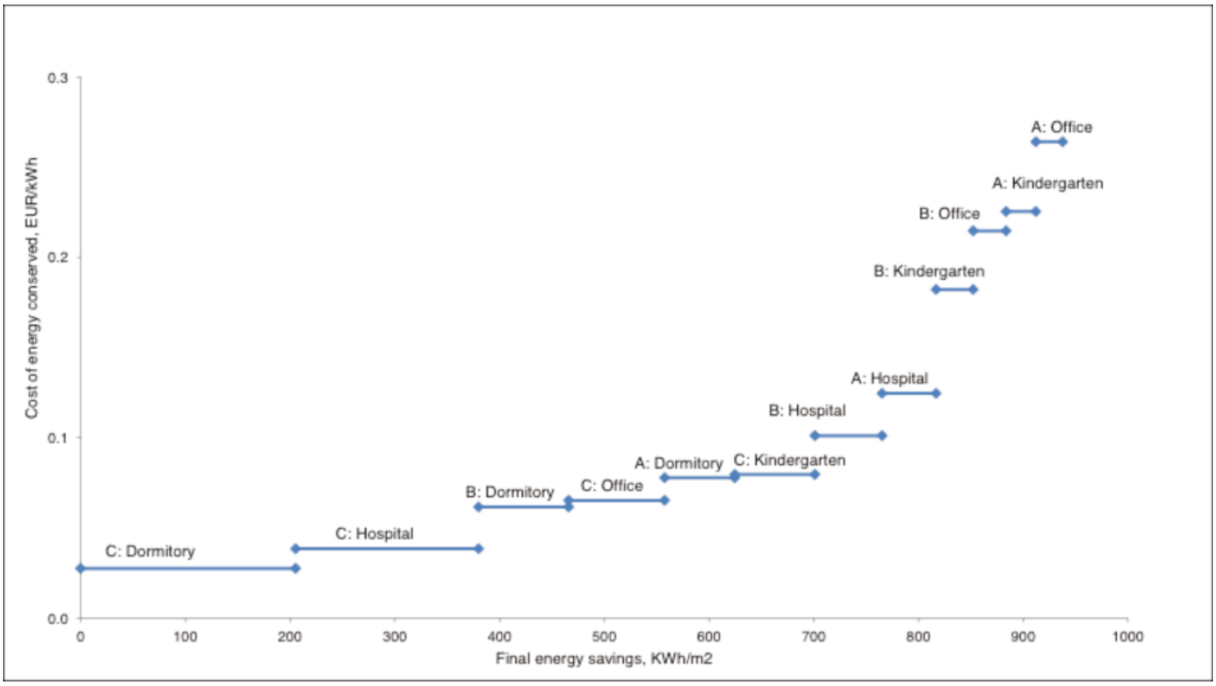


Figure 28: Supply curve of energy saved, improvement 2

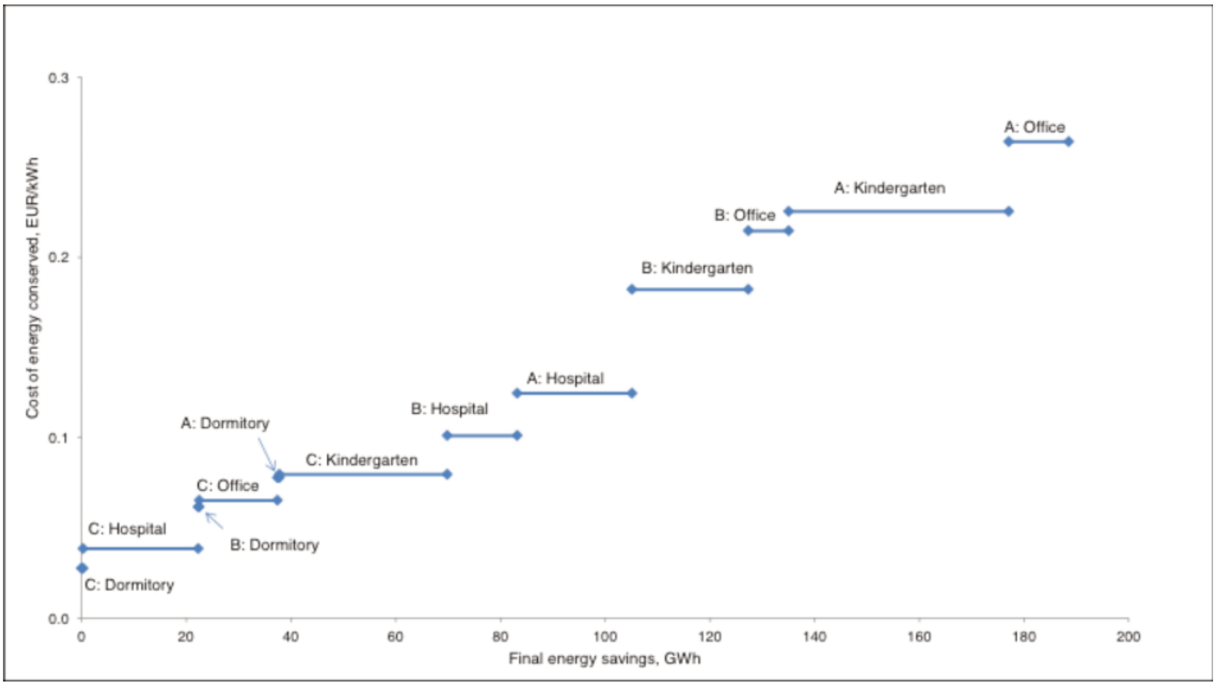


Table 47: Initial indicative budget for 2017–2020

Financial component: Total concessional loans, commercial loans and partial credit guarantees	EUR 40 million
Incremental costs: Investment grants, technical assistance, outreach, pre-feasibility, administration and monitoring verification platform	EUR 6 million
Total budget	EUR 46 million

Table 48: Retrofitting plan for the most cost-effective and socially acceptable options, improvement 1

Plan characteristics	Hospitals	Kindergartens
Floor area retrofitted (x 1,000 m^2)	126	419
Costs of energy saved (EUR/kWh)	0.03	0.07
Investment costs (EUR million)	10	30
CO_2 reductions (tCO_2)	3,841	1,072
Primary energy demand savings (GWh [ktoe])	18 (1.5)	13 (1.1)
Final energy demand savings (GWh [ktoe])	20 (1.7)	28 (2.4)
Saved energy costs, annual over measure lifetime (EUR million)	3.4	2.0
Simple payback period (years)	3	15
IRR (%)	23	5
NPV (EUR/m^2)	46	5
Cost-benefit ratio	0.2	0.9
GDP increase (EUR million)	6.6	19.3
Labour income (EUR million)	3.0	8.8
Employment (number of jobs)	1,490	4,383
Monetised CO_2 emissions avoided (EUR million)	1.8	0.5
Air quality, including health impacts (EUR million)	0.5	0.7
Improved comfort and services of buildings (EUR million)	0.8	2.5

Table 49: Retrofitting plan with funding allocation proportional to the breakdown of the building floor area by building type, improvement 1

Characteristics	Dormitories	Hospitals	Kindergartens	Offices	Schools	Universities	Total/ average
Floor area retrofitted (x 1,000 m^2)	0.7	61	202	68	197	0.9	530
Costs of energy conserved (EUR/kWh)	0.05	0.09	0.16	0.14	0.21	0.35	0.15
Investment costs (EUR million)	0.0	5	15	5	15	0.1	41
CO_2 reductions (tCO_2)	4	713	416	198	211	2	1,544
Primary energy savings (GWh)	0.1	4	5	2	4	0.0	15
Final energy savings (GWh)	0.1	4	6	3	5	0.0	17
Saved energy costs, annual over measure lifetime (EUR million)	0.15	12	13	5	10	0.03	40
Simple payback (years)	5	7	20	17	27	n/a	17
IRR (%)	15.7	11.1	3.0	4.0	1.1	-0.2	3.9
NPV (EUR/m^2)	0.1	6.7	-2.1	0.0	-5.1	0.0	-0.4
Cost-benefit ratio	0.3	0.4	1.2	1.0	1.5	2.1	1.0
GDP increase (EUR million)	0.03	3.2	9.8	3.5	9.7	0.04	26
Labour income (EUR million)	0.01	1.4	4.5	1.6	4.5	0.02	12
Employment (number of jobs)	6.8	717	2,238	804	2,212	10	5,987
Monetised CO_2 emissions avoided (EUR million)	0.00	0.3	0.2	0.1	0.1	0.00	1
Air quality, including health impacts (EUR million)	0.00	0.1	0.1	0.1	0.1	0.00	0.4
Improved comfort and services of buildings (EUR million)	0.00	0.4	1.2	0.4	1.2	0.01	3

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ANNEX 1:
Ratio of measured to calculated consumption in the surveyed buildings

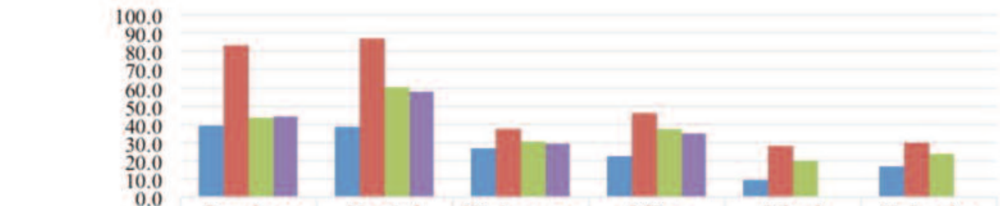
Building	Measured to calculated consumption (kWh/kWh)				
	Electricity	Wood	Gas	Oil	Solar
Dormitory 1				1.00	
Dormitory 2	1.81				
Dormitory 3	1.18				
Dormitory 4				1.31	
Dormitory 5	2.59				
Governmental office 1		2.36			
Governmental office 2	0.00			0.00	
Governmental office 3	6.48				
Governmental office 4					
Hospital 1	68.21			1.07	
Hospital 2	14.23	1.50			
Hospital 3				0.00	
Hospital 4				0.00	
Hospital 5				0.00	
Kindergarten 1		0.81			
Kindergarten 2			0.00		
Kindergarten 3			0.00		
Kindergarten 4		0.91			
Kindergarten 5	3.30				
Kindergarten 6				0.00	
Kindergarten 7		0.00			
Municipal office 1	0.80				
Municipal office 2	0.95				
Municipal office 3	1.10				

Building	Measured to calculated consumption (kWh/kWh)				
	Electricity	Wood	Gas	Oil	Solar
School 1				0.81	
School 2				0.66	
School 3				0.37	
School 4				0.38	
School 5				0.65	
School 6				0.72	
School 7				0.67	
School 8		0.60			
School 9				0.94	
School 10		0.72			
School 11		0.80			
School 12		0.66			
School 13	1.15				
School 14	0.47				
School 15	0.84				
School 16	0.88				
School 17	0.39				
University 1				2.42	
University 2	68.37			0.34	
University 3	2.88			0.25	
University 4				0.34	
University 5	6.23				
University 6	3.24				
University 7	1.55				

ANNEX 2:
Calculation results considering full heating in the renovation options

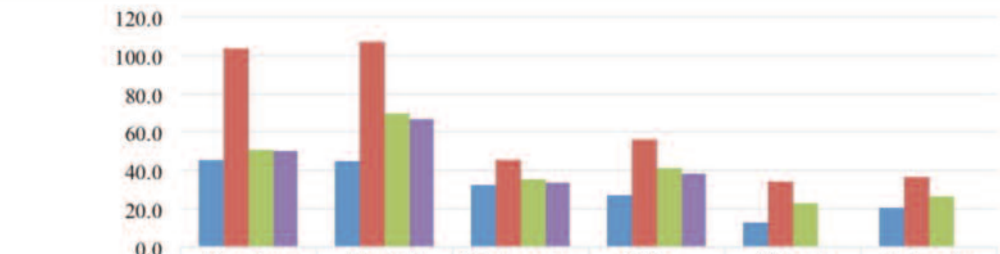
Note: In the current state, intermittent heating is considered.

Figure A1: Net energy demand of building types (full heating, climate zone A)



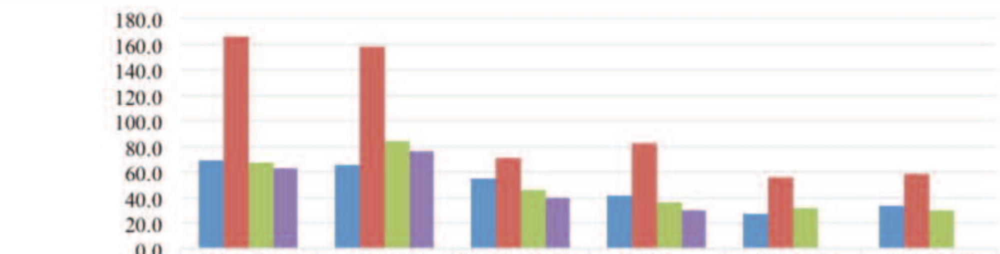
	Dormitory	Hospital	Kindergarten	Office	School	University
Present state	39.1	38.9	26.8	22.4	9.6	17.2
BAU renovation	83.1	86.8	37.6	46.2	28.1	29.9
Improvement 1	43.8	60.1	30.3	37.3	19.7	23.8
Improvement 2	44.1	58.1	29.3	34.7	0.0	0.0

Figure A2: Net energy demand of building types (full heating, climate zone B)



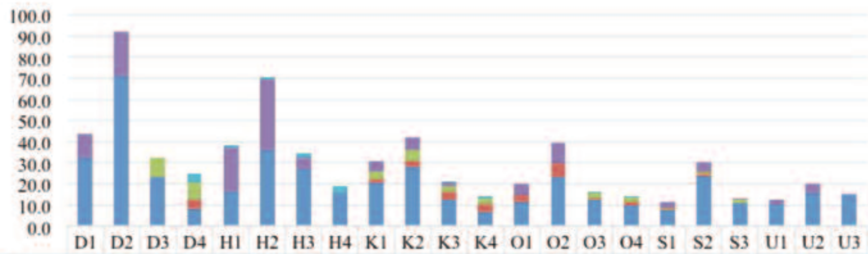
	Dormitory	Hospital	Kindergarten	Office	School	University
Present state	45.2	44.8	32.6	27.2	12.8	20.5
BAU renovation	103.2	107.2	45.5	56.3	34.4	36.7
Improvement 1	50.5	70.0	35.3	41.2	23.1	26.4
Improvement 2	50.4	66.8	33.8	38.0	0.0	0.0

Figure A3: Net energy demand of building types (full heating, climate zone C)



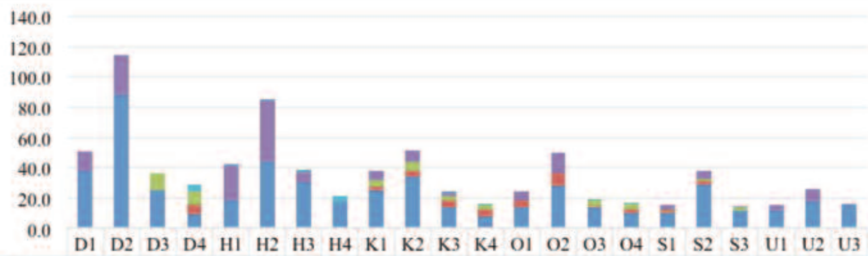
	Dormitory	Hospital	Kindergarten	Office	School	University
Present state	69.2	65.3	54.5	41.8	27.1	33.8
BAU renovation	165.5	158.2	70.3	82.1	55.3	58.3
Improvement 1	67.3	83.7	45.7	36.3	31.6	30.1
Improvement 2	63.2	76.1	39.4	29.9	0.0	0.0

Figure A4: Delivered energy in building types (climate zone A)



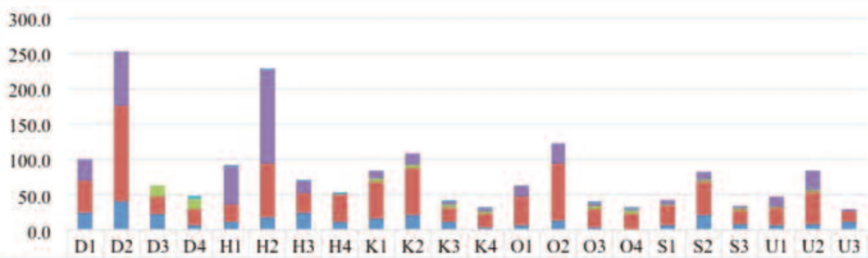
	D1	D2	D3	D4	H1	H2	H3	H4	K1	K2	K3	K4	O1	O2	O3	O4	S1	S2	S3	U1	U2	U3
Solar [kWh/m2]	0.0	0.0	0.0	4.3	1.1	1.1	1.7	3.4	0.0	0.0	0.5	0.9	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Oil [kWh/m2]	11.4	20.9	0.0	0.0	21.0	33.2	5.3	0.0	4.5	6.1	1.7	0.0	5.0	10.0	0.0	0.0	2.3	4.3	0.5	2.4	4.8	0.4
Gas [kWh/m2]	0.0	0.0	9.4	8.0	0.0	0.0	0.0	0.0	3.8	5.1	2.3	2.6	0.0	0.0	2.5	2.6	0.6	1.1	1.6	0.0	0.0	0.0
Wood [kWh/m2]	0.0	0.0	0.0	4.4	0.0	0.0	0.0	0.0	2.0	2.8	3.7	3.8	3.3	6.4	0.9	1.5	0.7	1.4	0.0	0.0	0.0	0.0
Electricity [kWh/m2]	32.4	71.0	23.3	8.1	16.2	36.3	27.3	15.6	20.4	28.3	12.8	6.7	11.5	23.2	12.4	9.8	7.7	23.8	10.9	10.2	15.5	14.8

Figure A5: Delivered energy in building types (climate zone B)



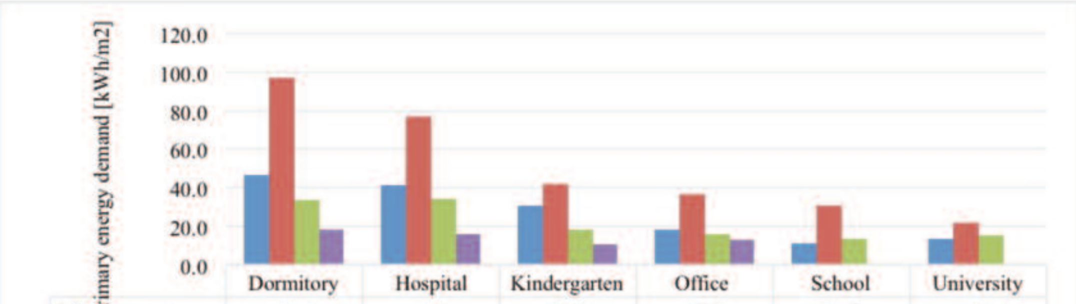
	D1	D2	D3	D4	H1	H2	H3	H4	K1	K2	K3	K4	O1	O2	O3	O4	S1	S2	S3	U1	U2	U3
Solar [kWh/m2]	0.0	0.0	0.0	4.3	1.1	1.1	1.7	3.4	0.0	0.0	0.5	0.9	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Oil [kWh/m2]	13.2	26.8	0.0	0.0	23.2	40.8	6.6	0.0	5.5	7.5	2.1	0.0	6.5	13.1	0.0	0.0	2.6	5.0	0.7	4.0	8.1	0.6
Gas [kWh/m2]	0.0	0.0	11.0	9.5	0.0	0.0	0.0	0.0	4.6	6.3	2.8	3.2	0.0	0.0	3.4	3.5	0.7	1.4	2.2	0.0	0.0	0.0
Wood [kWh/m2]	0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	2.4	3.3	4.4	4.6	4.2	8.4	1.2	2.0	1.4	2.7	0.0	0.0	0.0	0.0
Electricity [kWh/m2]	37.5	87.9	25.2	9.1	18.3	43.6	30.4	17.8	24.9	34.4	14.1	7.6	13.8	28.2	13.5	10.3	10.2	28.7	11.9	11.3	17.7	15.7

Figure A6: Delivered energy in building types (climate zone C)



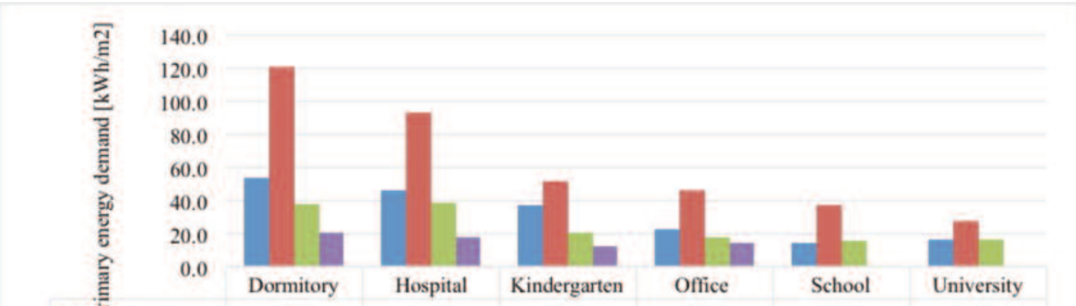
	D1	D2	D3	D4	H1	H2	H3	H4	K1	K2	K3	K4	O1	O2	O3	O4	S1	S2	S3	U1	U2	U3
Solar [kWh/m2]	0.0	0.0	0.0	4.3	1.1	1.1	1.7	3.4	0.0	0.0	0.5	0.9	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Oil [kWh/m2]	31.0	77.4	0.0	0.0	54.4	132.9	18.6	0.0	11.6	14.9	5.1	3.6	15.1	29.9	6.1	3.2	5.9	10.4	3.0	14.8	27.3	2.5
Gas [kWh/m2]	0.0	0.0	16.6	13.8	0.0	0.0	0.0	0.0	3.9	5.2	5.4	4.5	0.0	0.0	4.4	5.0	1.6	2.8	3.0	2.1	3.9	0.0
Wood [kWh/m2]	45.5	134.7	24.6	22.5	25.2	76.8	26.5	39.2	52.4	65.9	17.9	17.9	40.2	80.5	26.0	22.4	27.1	47.3	19.3	24.0	44.4	14.4
Electricity [kWh/m2]	24.1	41.3	23.0	7.5	11.4	17.8	24.9	11.1	16.3	22.0	12.7	4.6	7.3	13.2	3.5	1.4	7.7	21.6	8.9	7.2	8.9	12.7

Figure A7: Primary energy demand in building types (climate zone A)



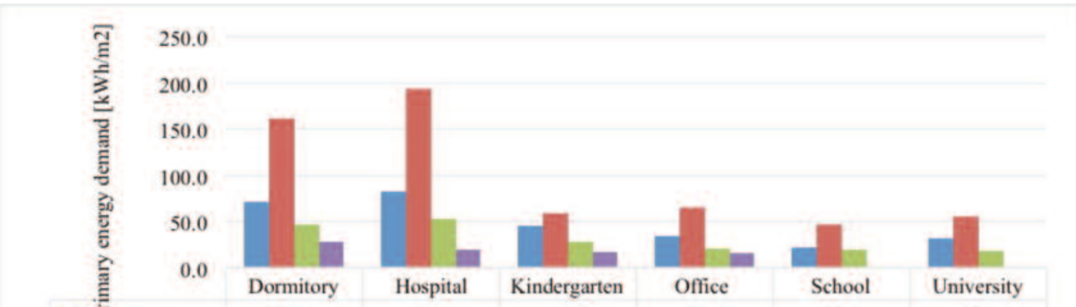
	Dormitory	Hospital	Kindergarten	Office	School	University
Present state	46.4	41.5	30.5	18.3	11.2	13.1
BAU renovation	96.8	76.5	42.1	36.7	30.6	21.4
Improvement 1	33.8	33.9	18.3	15.5	13.5	15.5
Improvement 2	17.9	15.7	10.4	13.0		

Figure A8: Primary energy demand in building types (climate zone B)



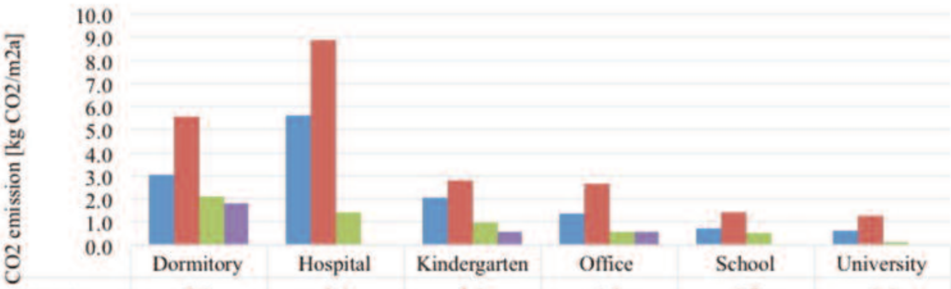
	Dormitory	Hospital	Kindergarten	Office	School	University
Present state	53.8	46.3	37.4	22.6	14.6	16.1
BAU renovation	121.0	92.9	51.4	45.9	37.2	27.6
Improvement 1	37.6	38.6	20.7	17.6	15.4	16.5
Improvement 2	20.8	18.0	12.1	14.6		

Figure A9: Primary energy demand in building types (climate zone C)



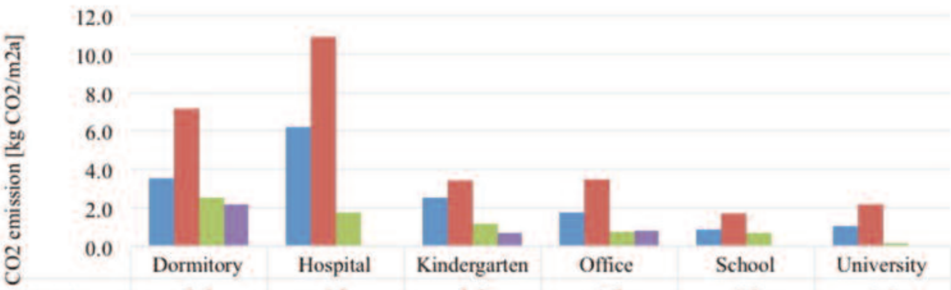
	Dormitory	Hospital	Kindergarten	Office	School	University
Present state	70.6	81.7	45.2	33.6	22.0	32.1
BAU renovation	161.6	192.9	58.9	65.3	46.8	54.9
Improvement 1	46.3	52.8	28.5	20.9	19.8	18.7
Improvement 2	27.4	19.1	17.4	15.2		

Figure A10: CO_2 emissions in building types (climate zone A)



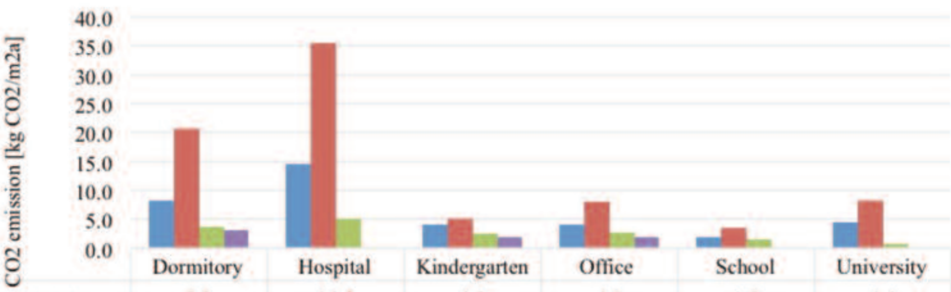
	Dormitory	Hospital	Kindergarten	Office	School	University
Present state	3.1	5.6	2.1	1.3	0.7	0.6
BAU renovation	5.6	8.9	2.8	2.7	1.4	1.3
Improvement 1	2.1	1.4	1.0	0.6	0.5	0.1
Improvement 2	1.8	0.0	0.6	0.6		

Figure A11: CO_2 emissions in building types (climate zone B)



	Dormitory	Hospital	Kindergarten	Office	School	University
Present state	3.5	6.2	2.5	1.7	0.9	1.1
BAU renovation	7.2	10.9	3.4	3.5	1.7	2.2
Improvement 1	2.5	1.8	1.2	0.8	0.7	0.2
Improvement 2	2.1	0.0	0.7	0.8		

Figure A12: CO_2 emissions in building types (climate zone C)



	Dormitory	Hospital	Kindergarten	Office	School	University
Present state	8.3	14.5	4.0	4.0	1.9	4.4
BAU renovation	20.7	35.5	5.2	8.0	3.4	8.2
Improvement 1	3.8	5.0	2.6	2.6	1.5	0.7
Improvement 2	3.1	0.0	2.0	2.0		

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