Low Carbon Urban Built Environment

European Carbon Atlas

Editors: Phil Jones, Paulo Pinho, Jo Patterson, Chris Tweed

Image on front cover

GIS map of an area of Neath Port Talbot County Borough Council with energy use illustrated with different colours – red high energy use, blue lower energy use.

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XV Serbia

Professor Dr. Aleksandra Krstic-Furundzic and Ass. Professor Aleksandra Djukic, Faculty of Architecture, University of Belgrade

National context

Serbia is located in South-eastern Europe in the heart of the Balkan Peninsula. It is bounded by seven countries. Serbian territory covers 88,361km^2. Within this territory there are 4706 (data for Kosovo and Metohia are missing) human settlements (Statistical Office of Serbia, 2000). Areas of Vojvodina and large river basins (the Sava, Danube and Velika Morava) are exposed to the heaviest urbanization pressures. The main rivers of Serbia include the Danube, Sava, Drina, Morava and Tisa. Forests and woodland cover 27% of Serbia, 40% is arable land and 21% of land is used as permanent pastures. It is a parliamentary republic. Serbia is divided into 24 districts plus the City of Belgrade. The districts and the City of Belgrade are further divided into municipalities.

The new legal framework for environmental protection was introduced in 2004 in the Republic of Serbia by the Law on Environment Protection, Law on Strategic Environmental Assessment, Law on Environmental Impact Assessment and Law on Integrated Prevention and Pollution Control. The new laws are harmonized with the EU Directives on Environmental Impact Assessment (85/337/EEC), Strategic Impact Assessment (2001/43/EC), IPPC (96/61/EC) and public participation (2003/35/EC). The Environmental Protection Agency (EPA) was established in 2004 as an institution within the Ministry of Science and Environment.

Climate

Climate of Serbia can be described as moderate-continental with more or less pronounced local characteristics. Spatial distribution of climate parameters are caused by geographic location, relief and local influence as a result of combination of relief, distribution of air pressure of major scale, terrain exposition, presence of river systems, vegetation, urbanization. The Republic of Serbia has two climatic zones with respect to construction requirements.

According to the Report prepared by Republic Hydrometeorological service of Serbia, the average annual air temperature during the last 50 years for the area with the altitude of up to 300m amounts to 10.9 C. The areas with the altitudes of 300 to 500m have average annual temperature of around 10 C, and over 1000m of altitude around 6.0 C. The lowest temperature in the period 1961-1990 was registered in January and ranged in the interval from –35.6% (Sjenica/mountain area) to –21.0 C (Belgrade). Absolute temperature maximum in observed period was measured in July and ranged in the interval from 37.1 to 42.3 C. Figure XV.i shows mean annual temperature for GMS Belgrade, through its deviation from the normal. The black line is the 5-year sliding mean, and blue pillars are the deviation from the normal, for each year.

The number of degree days (average DD), decisive for the heat demand, is between 2400DD and 3400DD for main part of the Serbian cities. Belgrade has an average value of 2450. The maximum value is about 5400DD for Kopaonik Mountain. There is a large potential for energy saving and a wide scope of viable energy efficiency measures in the building stock.

Major part of Serbia has continental precipitation regime with higher quantities in warmer part of the year. Majority of rains fall in June and May. February and October have the least precipitation. Due to the relief, slopes of high mountainous ranges and the influence of Mediterranean climate, the area of south western Serbia has the Mediterranean precipitation regime with the maximum in November, December and January, and the minimum in August.

The occurrence of snow cover is characteristic for the period from November to March, and sometimes even in April and October, while on mountains over 1000m it can also occur in other months. The majority of days with snow cover are in January when in average 30 to 40% of total annual number of days with snow cover occur.

Surface air circulation is to a great extent caused by topography. In winter part of the year winds from northwest and west prevail. During colder part of the year east and southeast wind, Koshava, dominates. Winds from southeast direction prevail in mountainous part of south-western Serbia.

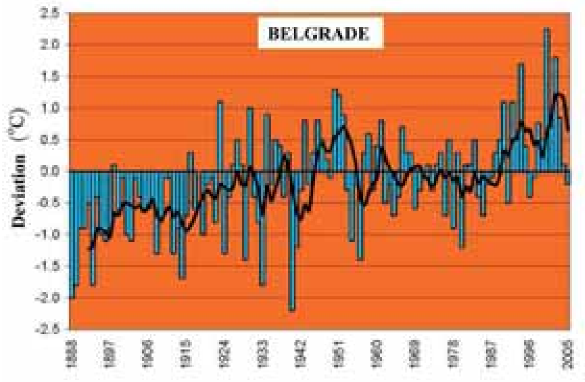

Figure XV.i - Deviation of main annual temperature in the period 1888-2005 in Belgrade from normal Reference period 1961-1990 (source: Republic Hydrometeorological service of Serbia)

Demographics

The population in Serbia is 7.5 million according to the 2002 census (Statistical Office of the Republic of Serbia). In 2000, 52% of population lived in urban areas. The main cities are Belgrade, the capital of Serbia (pop. 1,576,124), Novi Sad (243,151), Nis (177,823), and Kragujevac (145,890).

Carbon dioxide emissions

The total CO_2 emissions for 2004 for Serbia is 56.7 millions of tonnes, which is equivalent to 5.39 millions of tonnes per resident. According data for 2000, CO_2 emissions was divided into Solid fuels 29.15 millions of tonnes, Liquid fuels 7.9 millions of tonnes and Cement manufacturing 1 million of tonnes. Residential CO_2 emissions per capita is 242.5 kg CO_2 per person. Comparing the data for total CO_2 emissions per capita, for the period from 2000 to 2004, the increase of CO_2 emissions of 1.41 millions is noticed. (International Energy Agency (IEA) Statistics Division. 2006; WRI 2005, available at http://cait.wri.org)

A preliminary analysis estimates that the carbon abatement potential in Serbia is in the range of 20 Mt CO2eq to 25 Mt CO2eq per year.3 The resulting potential investment to mitigate greenhouse gas (GHG) emissions can be expected to range between 120 M EUR and 225 M EUR per year with valuated market prices ranging between 6 and 9 EUR/t of CO2eq (CDM Portfolio, Italian Ministry for the Environment, Land and sea, 2007).

Energy in Serbia

Serbia is not rich in energy resources. With the current level of production, which provides only 25% of the country's needs, Serbia (excluding Kosovo) is expected to exhaust its coal supplies within the next 55 years, and oil and gas supplies within 20 years (Environment in Serbia: an indicator-based review, EPA, Belgrade, 2007). Hydroelectric power capacity has been estimated at 14,200GWh per year. The potentials of other, renewable energy sources, including biomass, small hydroelectric power plants, geothermal, wind and solar energy, are very significant and exceed 3.8Mtoe. Some 63% (2.4Mtoe) of the potential renewable energy resources described lie in the utilization of biomass (wooden and agricultural biomass). Energy potential of the existing geothermal springs in Serbia is nearly 0.2Mtoe, and that of small hydroelectric power plants 0.4Mtoe. Figure XV.ii shows primary energy demands by fuels. There are 50 city heating plants in Serbia with total heat energy capacity of 6,597MW.

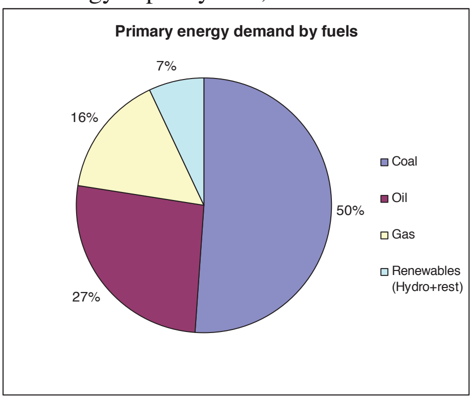

Figure XV.ii - Primary energy demand by fuel type

Serbia imports about half of its annual energy needs. This percentage has grown substantially over the past several years, mainly due to a rise in the consumption of oil derivates and gas, which are mainly imported (domestic sources cover one-fifth of crude oil consumption and one-tenth of gas consumption). Final energy consumption rose by some 18% in the period 2004-2006. The highest growth has been recorded in the industry sector (nearly 40%). When fuel sources are considered, it can be seen that solid fuel (coal and wood) consumption has risen by nearly 80% from 2004 to 2006. Gas consumption is also on the increase (with 15% rise over the same period). Liquid fuels and electricity still command the greatest share in Serbia's final energy consumption. Electricity consumption has been growing over the past years, mainly due to consumption by business; electricity consumption by households has also grown, especially in 2005, 2006 in relation to 2004.

Building regulations

The Serbian building regulations that might be considered as relevant to the implementation of EPBD (Energy Performances Building Design), include regulations that treat humidity prevention, thermal, air, acoustical and light comfort, standards and technical regulations relating to district (central) heating and hot water, ventilating and air conditioning systems. Serbian standards are based on DIN and ISO standards and have to be updated and brought in line with new DIN and ISO standards.

The Building Regulations are the responsibility of the Serbian Institute for Standardization. Development of building regulations is influenced by Ministry of Capital Investments and Ministry of Science, Agency for Energy Efficiency, Agency for Environmental Protection. The Serbian Institute for Standardisation is involved in regulations development. Regulations are by Ministry of Capital Investments, Ministry of Science and Serbian Chamber of engineers, put into effect. They finance and provide representatives for development of building regulations. Agency for Energy Efficiency and Agency for Environmental Protection are engaged in research and development of building regulations.

EPBD implementation

Until now EPBD (Energy Performances Building Design) legislation is not in use in Serbia.

Energy performance certificates

Energy performance certificates do not exist.

Other initiatives

Following measures with an aim to reduce energy and fuel consumption and CO_2 emissions are carried out:

- A special tax for different levels of electricity consumption.
- Tax payable for consumption of fuel.
- Different taxes presented for automobile registration according to the type of fuel.
- Sustainable transportation with railway electrification.
- Introduction of gas-lines.

Case study 1: Amadeo, energy efficient house in Belgrade

Context

In the Southeast part of Belgrade, in Zvezdara municipality, precisely in the part of Veliki Mokri Lug, the energy-efficient apartment house Amadeo is located. The location is in the larger-city area, close to the highway, on the northeast, and to the housing settlement Medakovic III, on the northwest (Figure XV.iii).

Figure XV.iii - Location of apartment house Amadeo on the map of central and south-east area of Belgrade

The location is characterised by low residential density. It is detached house with no shading obstructions in the surroundings, giving favourable conditions for solar systems integration. Belgrade has a moderate continental climate, with four seasons which influenced building construction design. The characteristic of Belgrade climate is also Košava - the southeast-east wind, with an average speed of 25-43km/h, but certain strokes can reach up to 130 km/h. Košava is the largest air cleaner of Belgrade.

Apartment house Amadeo is energy efficient building designed and constructed by Kuce Beodom, contractor that is committed to build apartments spending less than 90kWhpe/m²/year (kilowatt hour of primary energy for square meter and per year for heating, cooling, sanitary hot water, ventilation and light). Regarding the threshold of primary energy consumption apartments are rated as class B according to the France norm Effinergie (www.beodom.com). Low-energy consumption is obtained by energy efficient building construction and using renewable energy to replace the energy derived from fossil fuels (Figure XV.iv).

Figure XV.iv - South facade of Apartment house Amadeo (photo Kuće Beodom, www.beodom.com)

Apartment house Amadeo has 11 apartments, from 44 to 85m^2, on 3 levels (Figure XV.v). Usable floor area is 607m^2, but including balconies about 650 m^2.

Figure XV.v - Apartment house Amadeo-layouts of the first (left) and the second floor (right) www.beodom.com

The Building

Energy efficiency comes with excellent thermal insulation and smart choice of building materials and usage of renewable energy sources.

Building Structure
Structure of apartment house Amadeo is built with clay blocks, with thermal bridges break, and windows with low-e glazing filled with argon are applied.

Walls made of POROTHERM 38 clay blocks with thermal mortar (Figure XV.vi), have a thermal transmittance U=0.35W/m^2K, i.e. total thermal resistance R=2.86m^2K/W (www.beodom.com). The wall system fulfils both static and thermal insulation function, provides healthy indoor climate and very good thermal inertia needed for comfort in summer.

Figure XV.vi - Placing horizontal and vertical cerclage elements with thermal insulation on Apartment house Amadeo (photo Kuće Beodom, www.beodom.com)

The thickness of clay blocks allows thermal bridges to be broken on the floor slabs by placing a cerclage element with thermal insulation all around the concrete floor. For vertical reinforcements typical corner elements are used. They are specially designed to fit in a POROTHERM 38 wall together with 5cm of thermal insulation and a POROTHERM 8 brick. For the part of the ceiling that is directly under the roof, the insulating material is applied directly under the roof (20cm thick layer, or two 10cm thick layers of the same material). That gives a thermal transmittance around 0.18 W/m^2K.

Windows are a key component of a low-energy construction. Ideally, they should have a U-factor as close as possible to the one of the walls. Windows made of Alphacan 5-chambers PVC profiles, with low-e double-glazing and argon fill, having U-value around 1.2 W/m^2K, are selected. Rolling shutters with thermal insulation are integrated in the wall on top of the frame.

Usage of Renewable Energy
Because the construction of apartment house Amadeo is energy efficient, the demand on heating and cooling is greatly reduced. To further save energy, renewable energy is used to provide heating and cooling.

Figure XV.vii - Passage of the geothermal probes into Amadeo building (photo Kuće Beodom)

Geothermal energy is used for the low-temperature floor heating system in apartments in Amadeo house as well as to provide hot sanitary water. Ground source heat pumps offer excellent energy savings as up to 75% energy for heating can be extracted from the ground (www.beodom.com). Heat pump is connected to several vertical probes going 100m below ground. The closed loop of pipe is installed in the ground and filled with glycol anti-freeze mixture (Figure XV.vii). The fluid is warmed by the latent heat in the ground to about 10-12°C. It is pumped to the heat pump where the heat is transferred to the closed pressurized compressor circuit in the heat pump. The heat pump then provides warm water for the heating system. Electricity is used to run the compressor and circulate the fluids to exchange heat. Geothermal energy works best when used together with under floor heating, which requires low water temperature to heat the home. Additionally, each apartment is equipped with a Schiedel chimney allowing a complementary heating system such as wood or coal burning stove or a cooker to be connected, 75% of the energy used by the system comes from the ground for free.

One of the big advantages of the heat pump, besides cost saving on heating, is the possibility to reverse it in summer to provide cooling. The same under floor pipes used for heating can also be used in summer for cooling. Floor cooling is carefully controlled to prevent condensation. It works best on tiles and is not compatible with wood or laminate flooring. Additionally to floor cooling, ducted fan coil cooling is provided. The cold water coming from the heat pump is circulated in a fan coil which injects cool air in the room. Cooling with ducted fan coils can be used as an exclusive solution (instead of floor cooling) or as a complementary solution to the floor cooling.

Figure XV.viii - Solar thermal panels on the roof of Amadeo building (photo Kuće Beodom)

Solar thermal panels are the perfect solution to provide sanitary hot water, Solar energy in Belgrade can cover up to 85% of the annual need of hot water. That much is saving in electricity. 2 water cylinders of 500 litres each and 12 solar thermal panels for a total surface on the roof of 25.7m^2 are created (www.beodom.com). Solar thermal panels are installed on the south part of the roof (Figure XV.viii, XV.iv). In order to resist to strong gust of wind Kosava they are tilted with 30°, the same as roof surfaces. Solar thermal panels are connected to central water cylinders that provide hot water for all apartments in one building. Additionally, the same water cylinders are connected to the geothermal heat pump that can complement solar energy in the cold season. Solar energy combined with geothermal energy can provide close to 100% of sanitary hot water needed all year round. It is a combination that saves electrical energy traditionally used to provide hot water.

Ventilation in Amadeo apartments is implemented using a passive stack ventilation system (Figure XV.ix). Fresh air enters from Duco inlet vents located on the windows of the living space (living room and bedrooms) while stale air is drawn up Schiedel ventilation channels located in the bathroom and in the kitchen. They stack up together to create several channels going up to the roof. Each channel is reserved for the air extraction of one room in one apartment. This is the optimum solution where there is no chance to mix the air from different rooms or from different apartments. This ventilation system is based on the natural air movement through the dwelling as a result of internal and external temperature differences and wind induced pressure differences.

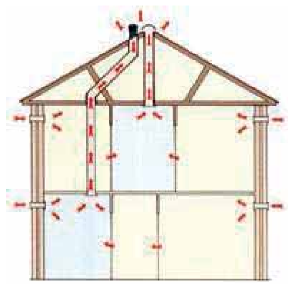

Figure XV.ix - Conception of natural ventilation in Amadeo building (source: www.ubbink.co.uk)

Cost analysis

The cost of flats in Amadeo house depends on the floor level and varies from €1350 to 1400 per m^2 (www.beodom.com). The price is relatively low for houses of this type and is aresult of the location that is in the larger-city area.

Carbon analysis

The high level of savings in terms of energy has been made by following design characteristics:

- Correct orientation and a compact building plan.
- Building construction of high levels of thermal insulation performances.
- The use of geothermal energy for space heating and cooling.
- The use of solar thermal collectors providing sanitary hot water; the use of the geothermal heat pump that can complement solar energy in the cold season.
- Natural and passive ventilation.

The renewable energy features reduce demand for fossil-fuels for heating and hot water provision. The remaining energy requirement is electricity for lighting, cooking and appliances.

The predicted energy collected by the solar thermal panels was estimated to be 21,450 KWh per year which could be described as “free” energy (www.beodom.com). Electricity costs are individually measured for each flat.

Key points

The beginning of 2009 is the deadline for completing the construction of the apartment house Amadeo. Monitoring data and evaluation of energy consumption are not still available. Some lessons learned include:

- Monitoring and evaluation of energy costs by comparisons of utility bills will be required in the future. At the moment, the figures are not readily available.
- Keeping checks on system performance is going to be an increasingly valuable investment in the low and zero carbon economy.

Case study 2: Improvement of housing settlement Konjarnik, Belgrade

Context

Until the seventies, in Belgrade, buildings were designed without consideration to energy demands and consumption. According to the data collected by Serbia Statistical Office, about 55% of the total of 583,908 existing housing units in Belgrade was built in this period (Krstić-Furundzic, Bogdanov, 2003). Rules of orientation of houses and flats were not observed and lot of flats with one-sided orientation, north or south, and too large windows were created. Insufficiency or absence of thermal insulation and improper construction details in terms of building physics are characteristics of mass post-war prefabricated apartment houses construction. Disregarding climatic conditions flat roofs were extensively used. They appeared functionally unsuitable, leaked, causing bad living conditions in flats underneath. Such buildings became “squanderers” of energy and poor ecology environments – “ill houses”, badly influencing human health. Due to the great number of such houses, significant energy savings can be expected by refurbishment of inherited building stock in sense of improvement of energy performances.

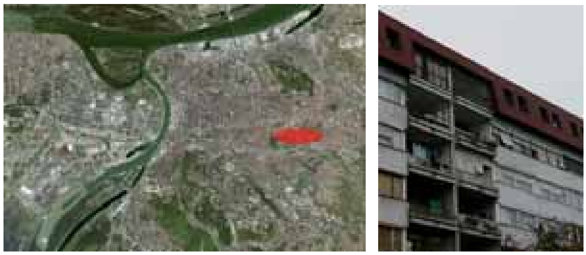

Figure XV.x - Location of Konjarnik on the Belgrade city map (left) and appearance of building (right)

Lots of housing settlements had been built in Belgrade after II World War. One of representatives of such architecture is housing settlement Konjarnik (Figure XV.x, left). Due to the city development, it is a part of the urban city zone about 4 km far from the city center nowadays. Konjarnik is selected as characteristic example of attic annex on the top of flat roofs, the action that is realized in significant number of housing settlements in Belgrade in the last twenty years.

So far, referential examples for improvement of energy performances of the existing building envelopes and usage of renewable energy can not be noticed in Belgrade. Because of that, hypothetical solutions for improvement of energy performances of the dwelling housing in Konjarnik and resulting environmental benefits are discussed. They represent results of the scientific research project “Development and demonstration of hybrid passive and active system of solar energy usage for heating, natural ventilation, cooling, daylighting and other needs for electrical power”, financed by Ministry of Science and

Environmental protection of the Republic of Serbia (head of project Prof. Dr. Aleksandra Krstic-Furundzic). As the numerous housing settlements are characterized by similar building layouts and appearance, discussed solutions might be applicable for refurbishment of large number of buildings, indicating that energy savings and reduction of CO_2 emissions can be valuable.

The Existing Building

The settlement is characterized by large rectangular shaped residential buildings with typical south-north orientation; more exactly deviation of 10˚ to southwest is present. Numerous buildings with the same or similar layouts are present.

Existing Building Structure

The existing building was built in the late sixties of the 20th century as reinforced concrete prefabricated structure, with poor energy characteristics. Facades oriented south and north consist rows of windows and parapets, which represent 70% and verticals of loggias, which represent 30% of facade surfaces (Figure XV.x). Parapets are three-layer prefabricated panels consisting of internal concrete 10cm, thermal insulation 5cm and external concrete 5cm with finishing layer in ceramic tiles. The concrete frame is present along the edge of facade parapet panels resulting in the presence of thermal bridges. Thermal transmittance value of external wall is $U=1.034W/m^2K$ (for Belgrade the limit value is $0.9W/m^2K$), while for wooden box type windows $U>3.0W/m^2K$ and the presence of the air infiltration is noticeable.

Attic Annex as the Refurbishment Measure

Existing refurbishment strategies applying on residential buildings in the settlement Konjarnik are transformations of flat roofs into slopping roofs by attic annex, which is municipality organized action and glazing of loggias, which is usually realized by tenants as illegal action.

For most cases, as well as for Konjarnik, situation before annex of attics was similar and can be described as follows (Krstic-Furundzic, 2007): :

- Mass postwar construction of housing structures with flat roofs.
- Suburban housing settlements looked monotonous and did not fit into the environment building spirit.
- The ratio of the number of inhabitants and free areas in the settlements allowed an increase in the housing stock.
- The flat roof proved to be functionally unsuitable in domestic climatic conditions.
- Inadequate technical solutions and building practice, as well as the poor quality of material, resulted in frequent leaking of the roofs, creating poor living conditions in flats underneath.
- Repair needs, as well as the insufficiency of housing space and high prices for newly constructed buildings, led to the phenomenon of mass building of attics on top of flat roofs, especially in suburban areas, as a kind of bioclimatic rehabilitation.

Decision making

During 90ties annex of attics was forced by township and government. Decision making about attics annex on flat roofs was managed in two directions: idea and benefits for the community (Krstic-Furundzic, 2007).

The idea was that by building attics on a top of flat roofs, it was possible to obtain:

- An increased number of housing units without increasing the number of buildings on the same site.
- The use of the existing infrastructure, thus reducing the costs per sq. m. built in the attic.
- A repair of flat roofs and improved living conditions on the original top floors, but improved technical conditions of the entire building.
- Better incorporation into the spirit of the environment and the existing structures.
- Visual identity of the existing buildings and suburban housing settlements from the Moderna period.

The most important benefits for the community, that gave support to annex of attics, were the following:

- Improvement of technical and living conditions in the whole building, especially on the original top floors.
- Efficient and cost-effective building of new dwellings, within the framework of the existing housing stock and infrastructure.
- Attainment of visual identity of buildings and settlements, with a positive effect upon the psycho-sociological condition of the users.

Construction principles

In general attic and existing standard floors construction can be in following relations (Krstic-Furundzic, 2007). (Figure XV.xi):

- Attic construction does not come from building system.
- Attic construction comes from building system.

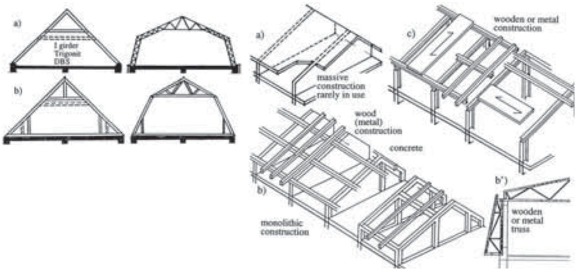

Figure XV.xi - Attic annex construction principles
Attic construction does not come from building system(left) and attic construction comes from building system (right) - a)the same material, b) mixed construction, c) construction continuity-different materials

In the case of attics annex at Konjarnik mixed construction with prefab wooden trusses is applied, as shown in Figures XV.xi-b' and XV.xii.

Figure XV.xii: Attic annex construction in Konjarnik

Cost analysis

Necessity for reconstruction of flat roofs and housing shortage, increased by great number of last civil war refugees from former Yugoslavia parts (about 300000 at Belgrade territory), and high prices for newly constructed buildings, caused massive annex of attics on top of flat roofs, built for the purpose of dwelling. Strategy is to increase the number of flats without increasing the number of buildings on the same site and to use the existing infrastructure, thus reducing the cost per sq. m. built in the attic that varies from €700 to 1200 per m^2, depending on location and structure type, while price of newly constructed flats ranges from €1200 to 2000/m^2 (luxury apartments are not taken into consideration).

Carbon analyses

Building of attics on a top of flat roofs improve technical and living conditions in the whole building, specially on the original top floors. It reduces energy consumption, but significant reduction of CO_2 emission can be obtained by improvement of thermal-insulation of existing external walls. Index of reduction of CO_2 emission will be the subject of next analyses.

Improvement of Energy Performances of Existing Building Envelope

Improvement of energy performances of the envelope of dwelling housing in Konjarnik includes following measures:

- Reduction of energy consumption for space heating by improvement of envelope structure.
- Reduction of energy consumption for water heating by application of solar thermal collectors.

Hypothetical models for improvement of building envelope are created and the annual energy savings for space and domestic water heating, as well as reductions of CO_2 emissions, according to the models are recognized. Yugoslav standards for Thermal Protection are in use for renovation of existing buildings.

As buildings in settlement Konjarnik consist of number of lamellas, the central lamella was the subject of consideration with effective heating surface of 1,250m^2.

Reduction of energy consumption for space heating by improvement of envelope structure

Decision making

Design for improvement of the envelope of the existing building is created according to Belgrade climatic conditions, building orientation and technical characteristics of the existing building structure. Two hypothetical models for improvement of building envelope are designed and for simulation of building energy performance 3D mathematical models are created (Kosić, Krstić-Furundžić, Rajčić, Maksimović, 2009).Measures for improvement of building envelope:

Model 1:

- Laying of 5cm of expanded polystyrene onto the facade parapet panels, resulting in total insulation thickness of 10cm and U=0.371W/m^2K.
- Replacement of existing windows with double glazed windows (4+12+4), made of five-chamber PVC profiles resulting in U=2.3W/m^2K. Predicted exchanges of the air flow for Model 1 is 2 - 3 exchanges per hour.

Model 2:

- Laying of 10cm of expanded polystyrene onto the facade parapet panels, resulting in total insulation thickness of 15cm and U=0.255W/m^2K.
- Replacement of existing windows with triple low-emission glazed windows with argon filler, made of five-chamber PVC profiles resulting in

U=0.255W/m^{2}K. Predicted exchanges of the air flow for Model 2 is 0.8 - 1 exchanges per hour.

Common measures for both models:

Laying of 10cm of hard mineral wool onto the attic slab resulting in total insulation thickness of 22cm and U=0.171W/m^{2}K.

Glazing of loggias with thermo insulating glass panels (4+12+4), laid in five-chamber PVC profiles (U=2.3W/m^{2}K).

Reduction of Energy Consumption for Space Heating

For existing building in Konjarnik, data of average annual energy consumption for space heating in the last two years (2006-2008, for the periods from 15th October to 15th April) are gathered from Belgrade Public Utility company for heat supply. According to these data estimation of annual energy consumption for heating of central lamella, as subject of observation, is realized. For simulation of building energy performance of improved models, 3D mathematical models are created.

Model of the building	Energy consumption (kWh)	Energy consumption (kWh/m^2)
Model of the existing building	353810.00	283,60
Model 1	37242.89	29.79
Model 2	18446.15	14.75

Table XV.i - Annual energy consumption for space heating according to the models

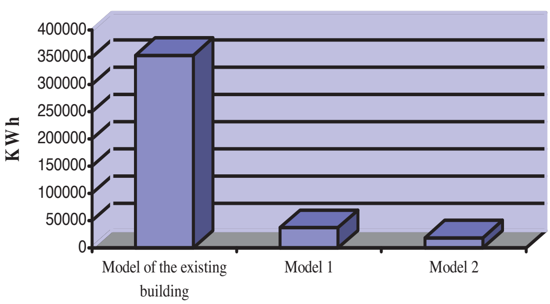

Figure XV.xiii - Annual energy consumption for space heating in existing building and improved models

Comparing to energy consumption for heating of existing building, the primary energy consumption for space heating is reduced by more then 66% in case of Model 1, while in case of Model 2 reduction amounts more than 83% (Figure XV.xiii and Table XV.i and XV.ii).

Model of the building	Yearly energy demand reduction. (kWh)	Yearly energy demand reduction (kWh/m^2)
Model 1	316568	254
Model 2	335364	269

Table XV.ii - Reduction of annual energy demands for space heating according to the models

Carbon analyses

District heating is available in housing settlement Konjarnik, and water heating is based on fuel oil. In Table XV.iii, values for yearly CO_2 emissions reduction by improvement of building envelope energy performances are presented for both models.

Model of the building	CO_2 reduction (kg/year)
Model 1	82307.45
Model 2	87194.61

Table XV.iii - CO2 reduction

According to presented results, significant reduction of CO_2 emissions can be achieved by improvement of building envelope.

Reduction of energy consumption for water heating by application of solar thermal collectors

Decision making

Hypothetical models for integration of solar thermal collectors are created with aim benefits of solar systems application on residential buildings in Belgrade climate conditions to be estimated. Four distinctive variants of positions for solar thermal panels integration on building facade were selected (Krstić-Furundžić, Kosorić, 2009):

I Design Variant: roof 40°, area of 100 m^2 (Figure XV.xiv-a) - solar panels with slope of 40° applied on the roof.

II Design Variant: parapet 90°, area of 90 m^2 (Figure XV.xiv-b) - vertical position of solar panels.

III Design Variant: parapet 45˚, area of 120 m^2 (Figure XV.xiv-c) - solar panels with slope of 45 applied on parapets.
IV Design Variant: sun shading 0˚, area of 55 m^2 (Figure XV.xiv-d) - horizontal position of solar panels.

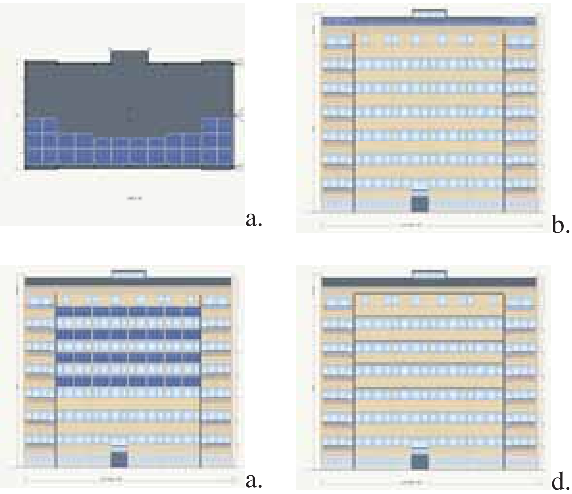

Figure XV.xiv - Design variants: a. I Design Variant: roof 40˚ (roof and facade layouts), b. II Design Variant: parapet 90˚, c. III Design Variant: para pet 45˚, d. IV Design Variant: sun shading 0˚

Consumer

There are 28 apartments in one lamella and 90 occupants inside them altogether. The initial idea was to explore potential and effects of solar thermal collectors to meet energy demands for hot water. In calculations, real thermal energy consumption was taken into consideration. Thermal energy for hot water: 80*l* of hot water per person per day, 80*l*x90=720*l* (20-50°C) per day for one lamella which presents 251kWh per day, i.e. 91618.3kWh per year for one lamella.

Solar Thermal System

Calculations and simulations of solar thermal systems for all design variants were done in Polysun 4 Version 4.3.0.1. In calculations, the existing water heating system fully based on electricity was substituted with the new system – solar thermal collectors (AKS Doma – manufacturer), with the auxiliary system powered by electricity.

Reduction of Energy Consumption for Water Heating

Energy performances for design variants of solar thermal collectors integrations in existing building envelope are presented in Figures XV.xv, XV.xvi, XV.xvii (Krstić-Furundžić, Kosorić, 2009). .

It can be noticed that in Belgrade climatic conditions, significant energy savings for water heating can be achieved by solar thermal collectors. Solar thermal panels with slope of 40° proved to be the best solution regarding heating energy demands satisfactions.

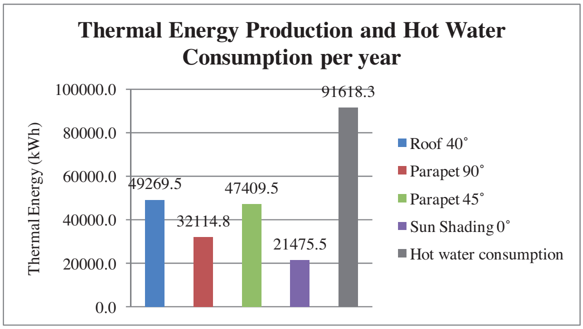

Figure XV.xv - Thermal Energy Production and Hot water Consumption per year

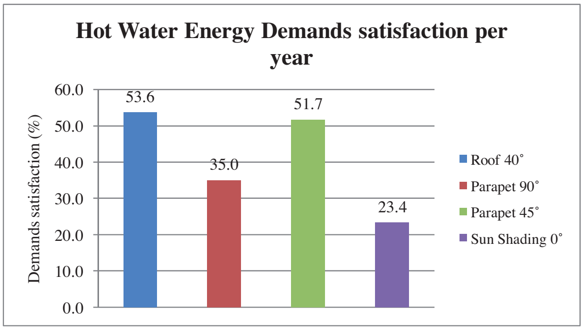

Figure XV.xvi - Hot Water Heating Energy Demands Satisfaction per year achieved by solar thermal collectors

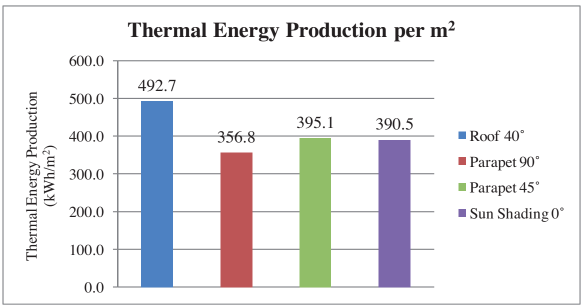

Figure XV.xvii - Hot Water Energy Production per m2 of Solar Thermal Collectors

Cost analysis

Simple payback periods for Design Variants 1, 2, 3 and 4 are sequent 7, 9, 8 and 8 years.

Carbon analyses

In Table XV.iv, values for CO_2 emissions reduction are presented for all proposed design variants.

Solar thermal collector position	CO_2 reduction kg/year
Roof 40°	39908
Parapet 90°	26013
Parapet 45°	38402
Sun Shading 0°	17395

Table XV.iv - CO_2 reduction achieved by solar thermal collectors

Lessons Learnt

In Belgrade, as well as in Serbia, there are a large number of housing settlements with the same or similar prefabricated buildings, as in case of settlement Konjarnik, indicating that significant energy savings and CO_2 emission reductions can be obtained.

Planning legislation

The new legal framework for planning and construction was introduced by the Law on Planning and Construction in the Republic of Serbia in 2003 (Published in the Official Herald of the Republic of Serbia no. 47/2003). Also, new Law on strategic environmental impact assessment was introduced in 2008.

City case study: Belgrade

Background

Belgrade is the capital and largest city of Serbia. The city lies on two international waterways, at the confluence of the Sava and Danube rivers. With a population of 1,630,000 (official estimate 2007), Belgrade is the largest city in the territory of the former Yugoslavia, second largest city on the Danube river and the fourth largest in Southeastern Europe, after Istanbul, Athens, and Bucharest. Belgrade has the status of a separate territorial unit in Serbia, with its own autonomous city government. Its territory is divided into 17 municipalities, each having its own local council. It covers 3.6% of the territory of Serbia, and 24% of the country's population lives in the city. Belgrade is the central economic hub of Serbia, and the capital of Serbian culture, education and science. The density of inhabitance is five times bigger from the average density in Serbia.

Context

The development of the Belgrade metropolitan region has mostly been a product of centralised power at the state level, but the noticeable imbalance has also been the result of uneven national development, as well as a consequence of wrong decisions and complex socio-economic conditions. For example, the majority of investments have been directed to Belgrade which has caused the stagnation of other Serbian cities and areas. The influx of people reached its peak between 1970s and 1990s when Belgrade gained approximately 15.000 inhabitants every year. Additionally, during the 1990s Belgrade also absorbed a considerable wave of immigrating population, including the war refugees from the former Yugoslav republics and internally displaced people from Kosovo and Metohija who looked for a new permanent residency. This situation has generated some serious problems for the increasing population triggering a spontaneous and uncontrolled development of city-edge settlements, usually without an adequate infrastructure. The traffic congestion with insufficient public transportation connections to the other parts of the city has become an unpleasant reality which, finally, caused higher costs of urbanisation.

Figure Xv.Xviii - Unplanned settlement in Kaludjerica (Belgrade)

The legacy of the 1990s and the current urban transformations both influence the level and the structure of CO2 emission. However, the available data could provide only a partial picture of existing problems, which are nowadays mostly caused by the scale and (dis)position of numerous unplanned settlements (Figure XV.Xviii) and traffic problems. For example, according to the data from 2000, about 30% of all CO2 emissions in Serbia were connected to the building stock. According to the researches from 1996, only 20% of the buildings in the peripheral areas of Belgrade were actually planned and/or regulated by some spatial plan, and only 35% of them had some kind of technical documentation Today, the estimations are that in ten Belgrade's municipalities there are over 200,000 illegally constructed objects. As a result, most of the settlements on the periphery do not have a basic infrastructure - around 90% of housing units (flats) have electricity, 65% are connected to the public water system, around 20% are connected to the sewage disposal system and only 5% have distant heating (Djukic, Stupar, 2009).

Objectives and solutions

The master plan of Belgrade 2021 underlines the problems of illegal construction, distribution of functions (Belgarde is monocentric city) and traffic, which cause a negative impact on living environment and - directly and indirectly - increase the level of CO2 emission. It includes several objectives and measures which should tackle this sensitive issues. Some of them are more general and they encourage efficient management and optimal usage of potentials of Belgrade for public benefits and coordinated general and individual interests. At the same time, the plan emphasizes the idea that the existing tissue should be completed with limited linear expansion, while the improvement of the existing networks, technical, communal and transportation systems represents a necessity for the future protection of environment, employment, education and public health. The city would transform from monocentric to multycentric (two more centres are planned – one in New Belgrade and another one next to Danube.

The set of objectives is also related to the economic, social and environmental improvement of poor and illegal settlements, their (re)arrangement and transformation - without compromising the public interest. According to the plan, these settlements should be urbanized, remediate, legalized and integrated into the city tissue, while an important role is given to various institutions - secretariats, the City Planning Agency and Agency for Urbanization that should prepare adequate procedures for quicker responses to investors' requests (Djukic, Stupar, 2009).

The importance of an efficient combination of market and planning measures and instruments is stressed instructing the new, socially acceptable city planning parameters and standards for market-oriented housing construction, socially financed dwellings and remediation of non-hygienic settlements.

However, we should be aware that even small, but well integrated interventions and initiatives could stimulate actions that gradually change the whole image of these neglected and chaotic urban areas. The first step should definitely be a renovation of existing buildings and improvement of their thermal isolation. Furthermore, the capacity of inadequate street networks should be adjusted to the current situation and new number of inhabitants which means that public transportation needs to be modernized and intensified. The next step could take these urban areas towards some new solutions - stimulating water and waste recycling, promoting alternative energy resources and supporting creative and 'clean' ideas which could prevent and/or decrease unnecessary emission of CO2.

Urban case study: Infrastructure case study – Light metro in Belgrade

Background

Belgrade is the capital and largest city of Serbia. The city lies on two international waterways, at the confluence of the Sava and Danube rivers. With a population of 1,630,000 (official estimate 2007), Belgrade is the largest city in the territory of the former Yugoslavia, second largest city on the Danube river and the fourth largest in Southeastern Europe, after Istanbul, Athens, and Bucharest. Belgrade has the status of a separate territorial unit in Serbia, with its own autonomous city government. Its territory is divided into 17 municipalities, each having its own local council. It covers 3.6% of the territory of Serbia, and 24% of the country's population lives in the city. Belgrade is the central economic hub of Serbia, and the capital of Serbian culture, education and science. The density of inhabitance is five times bigger from the average density in Serbia. The inflow of inhabitants to Belgrade was highest in the period from 1970 – 1990, when the annual growth was about 15,000 inhabitants. Simultaneously, during this period about 7000 apartments were built, mainly on the outskirts of the town, influencing the increment of the urban tissue area. Since Belgrade is mono-centrical town and the great majority of central functions is located in the historical town core, the increase of town territory caused numerous traffic problems. Capacities of the public transport did not adequately follow the increase in mobility of the inhabitants, the number of employees and school children (the number of tours was increased from 0.7 in 1975 to 1.5 in 2001, while the number of seats in busses for the same period was increased 50%; however in the period from 1990 -2000 was decreased for 30%).

Context

The idea to construct a metro-like system in Belgrade is a relatively old one, and originates from the 1950s when it was driven by Belgrade's blooming number of inhabitants and the lack of adequate transport infrastructure. In the first visionary plans in fifties, consideration about metro as the principal transport system in Belgrade started. Those were the first steps in metro project which were especially intensified after Master urban plan was completed in 1972. Despite the quality of the prepared studies and designs, various approaches of experts and politicians to the needs and possibilities of highly capacitated rail system in Belgrade were the reason that decision about construction has not been taken till now. However, the inability to decide between proposals to construct a modern tram system and a classic underground one meant that the project was to stay largely stagnating in years to come. The political turmoil of the 1990 and lack of potential funding extinguished further development of the idea. With the beginning of the 21st century, however, the idea came to life once again. BELAM, consequently, became an integral part of Belgrade's Master plan for the year 2021. The main criteria for choosing light rail over conventional metro was the comparatively low cost (Pre-feasibility study, Belgrade, 2004). .

Description of the case study

The relevant network of the public transport system in Belgrade comprises following systems: city railway system, bus system, tram system and trolleybus system. Following Belgrade's Master plan for the year 2021, light rail network was planed. It consists of three lines. The project was presented to the public on 3rd July 2004.Construction was planned for completion in 2012. Three lines operate within the system (Figure XV.xviii):

Line 1 - Centralia - will link Novi Beograd on the left bank of the Sava river to the city centre and the eastern suburbs. The line will run underground from Saborna crkva to Vukov spomenik, total length will be 12.5 km, from which about 4.6 km will be underground, with 20 stations. This line is to be constructed first. The pre-feasibility study has it denoted as "primary". There are approximately 270,000 inhabitants and 150,000 employees in the direct impact area of the corridor.

Line 2 - Vracarska - will only run on the left bank of the Sava river. All stations except Hipodrom-Topcider will be underground.

Figure XV.xviii - Central line of Belgrade Light Metro

Line 3 - Savska - will link the southern suburbs to Novi Beograd, running underground from Banovo Brdo to Pozeska Ulica. The new light rail system will complement the existing tram and Beovoz suburban rail network, which has two underground stations in the city centre, Vukov Spomenik and Karadjordjev park.

Aims

The objectives of BELAM project are:

- improved efficiency of public system;
- reduction of traffic congestions;
- improvement of environmental quality (restriction of atmosphere pollution);
- reduction of the consumption of conventional fuel;
- reduction of coasts incurred by accidents;
- giving back streets to people;
- humanization of inter-human relations.

Funding

The project of BELEM is to be executed in phases. The assumed investment dynamics for the first line is 6 years. Total investment for rolling stock, consisting of 46 vehicles, amounts to 126.500 EU, so together with the investment for infrastructure and equipment, the value of the investment is around 400 million EU. Pre-feasibility study has shown that internal rate of returns is 9% (Pre-feasibility study, Belgrade, 2004)..

Three alternatives of financing have been studied, and each alternative has its own management model:
Planned alternatives are:

- financing from public sources;
- public-private partnership;
- mixed system

Each of these modalities has been tested separately and on the basis of experience, advantages and disadvantages of each, modalities have been determined.

Overall assessment–from a low carbon perspective

Approximately 40 million passengers will use BELEM annually. The light metro will reduce the number of busses (on half) as shown in Table XV.v and cars and also the travelling time (23 million hours less on annual basis). That will cause the reduction of consumption of conventional fuel (1.500 l for busses in a pick hour, which is 4.5 million litres per year).

The light metro usage will cause less carbon emissions because of reduction of busses and reduction of use of the private cars (Pre-feasibility study, Belgrade, 2004).

	Variant network -"without investment"		Network with the first line of light metro - basic variant		Network with the first line of light metro – variant with the station Academy	
	2002	2021	2002	2021	2002	2021
Number of passengers in buses at system level in peak hour	79642	117786	77513	114440	77627	114618
Average capacity of an empty bus	129		129		129	
Number of passengers in single vehicle	90		90		90	
Required number of buses in peak hour (for occupancy of 70%)	882	1304	858	1267	860	1269

Table XV.v - Number of passengers and required number of buses in system according to variants and years (source: Pre-feasibility study, Belgrade, 2004)

Lessons learnt

After years of searching for the optimal solution for the problem of public transport, Belgrade has got the project for the first line of light metro. This will solve one of the biggest problems in the city / public transport and traffic congestions.The realization of project will cause reduction of carbon dioxide, air pollution and noise. The future development of the project (possibility for development of metro) will cause important future reductions.

Figure XV.xix - Metro line

Conclusions

Serbia signed a few different agreements: UN Framework Convention on Climate Change – UNFCCC in 2001, Kyoto Protocol (Signed by Serbia and Montenegro in 1997, ratified by Serbia in 2007), Montreal Protocol (ratified by Serbia in 2004) and Vienna Convention in 1992.

Residential CO_2 emissions per capita is 242.5 kg CO_2 per person. Rapid decrease of CO_2 emissions during the last decade of 20^{th} century has followed decrease of GDP. Comparing the data for total CO_2 emissions per capita, for the period from 2000 to 2004, the increase of CO_2 emissions of 1.41 millions is noticed and it has been followed by increase of GDP and the growth in industrial output. Different government departments and agencies are involved in development of environmental protection strategy and consequently the reduction of CO_2 emissions.

In favor to avoid harmful environmental impact, energy policy in Serbia stresses the importance of the following incentives:

- Energy sources diversification – with particular point to renewable energy sources;
- Rational use of energy – consumption management and energy audits;
- Energy efficiency;
- In accordance with EU directives, EU strategic and regulatory documents, attaining Kyoto protocol goals, etc., Energy Development Strategy of the Republic of Serbia incorporates the incentive measures for investments into energy sector and as well as for subjects that use RES as energy source;
- Strategy sets up priorities for operating and development of energy sectors, stressing RES as well.

The Serbian building sector is slow to implement the most energy efficient building methods. The past development has been characterised by research projects and individual examples of eco-housing projects. The objectives in major spatial plans and general urban plans, which were adopted during the last two decades, are tightly connected to sustainable urban design principles regarding energy efficiency and ecology protection.

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The Organisation of COST

COST- the acronym for European Cooperation in Science and Technology- is the oldest and widest European intergovernmental network for cooperation in research. Established by the Ministerial Conference in November 1971, COST is presently used by the scientific communities of 35 European countries to cooperate in common research projects supported by national funds.

The funds provided by COST - less than 1% of the total value of the projects - support the COST cooperation networks (COST Actions) through which, with EUR 30 million per year, more than 30 000 European scientists are involved in research having a total value which exceeds EUR 2 billion per year. This is the financial worth of the European added value which COST achieves.

A "bottom up approach" (the initiative of launching a COST Action comes from the European scientists themselves), "à la carte participation" (only countries interested in the Action participate), "equality of access" (participation is open also to the scientific communities of countries not belonging to the European Union) and "flexible structure" (easy implementation and light management of the research initiatives) are the main characteristics of COST.

As precursor of advanced multidisciplinary research COST has a very important role for the realisation of the European Research Area (ERA) anticipating and complementing the activities of the Framework Programmes, constituting a "bridge" towards the scientific communities of emerging countries, increasing the mobility of researchers across Europe and fostering the establishment of "Networks of Excellence" in many key scientific domains such as: Biomedicine and Molecular Biosciences; Food and Agriculture; Forests, their Products and Services; Materials, Physical and Nanosciences; Chemistry and Molecular Sciences and Technologies; Earth System Science and Environmental Management; Information and Communication Technologies; Transport and Urban Development; Individuals, Societies, Cultures and Health. It covers basic and more applied research and also addresses issues of pre-normative nature or of societal importance.

Web: http://www.cost.esf.org

This publication summarises the activities of the COST C23 Action entitled 'Strategies for a Low Carbon Urban Built Environments (LCUBE)' which took place over the period 2004 to 2009.

The main objective of the COST C23 Action was to investigate, through a network of nineteen countries across Europe,

'how carbon reductions can be achieved through appropriate design and management of the urban built environment'.

This involved investigating the built environment at building and urban scale, focusing on minimising energy use and associated carbon dioxide emissions.

The COST C23 Action investigated how nineteen EU member states were active in reducing carbon dioxide levels in the built environment, not only in line with buildings meeting the requirements of the Energy Performance of Buildings Directive (EPBD), but also taking standards beyond that and looking at how national and regional planning initiatives are being developed to reduce the energy use of urban areas. A collection of case studies are included that illustrate the development and implementation of low carbon strategies at urban and building scales.

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