Proposal of the Long-Term Strategy for Mobilising Investment in the Renovation of the National Building Stock of the Republic of Croatia

Zagreb, April 2014

CONTENTS

List of figures

List of Tables

Summary

All European Union Member States are required, under Article 4 of the EU Energy Efficiency Directive (hereinafter: the EE Directive)[1], to prepare their Long-term strategy for mobilising investment in the renovation of the national stock of residential and commercial buildings (hereinafter: the Strategy) and submit it to the Commission by 30 April 2014.

The main objective of the Strategy is to identify effective measures, pursuant to a predefined economical and energy-optimal model of building renovation, for a long-term mobilisation of cost-efficient integral renovation of the national building stock of the Republic of Croatia by 2050, including all residential and commercial buildings.

In accordance with the provisions of the EE Directive, the Strategy covers the topics listed below.

1. **An overview of the Croatian national building stock** includes data on the number, area, structural and energy characteristics of the national building stock, grouped by purpose into the following categories:
    - Apartment buildings;
    - Family houses;
    - Public buildings;
    - Commercial buildings.

An overview of the said building categories by the period of construction, climate zone, ownership and differentiation between rural and urban areas has been provided. In order to provide a more precise and accurate overview of the national building stock, the authors have systematically collected, processed and analysed data in the Statistical Yearbooks, published by the Croatian Bureau of Statistics in the period between 1952 and 2011. According to the results of an exhaustive and systematic research of the statistical yearbooks and expert estimates of missing data, Croatia's national [residential] building consists of 762 397 buildings with a total area of 142 176 678 m^2, of which 290 689 are multi-apartment buildings with a total area of 55 438 063 m^2 and 471 708 are family houses with a total area of 86 738 615 m^2. Croatia's national [non-residential? word missing] building stock consists of 124 924 buildings with a total area of 50 342 361 m^2, of which 44 728 are commercial buildings with a total area of 36 540 459 m^2 and 80 196 are public buildings with a total area of 13 801 902 m^2. In conclusion, on the basis of the analyses that have been conducted, Croatia's total current national building stock comprises 887 321 buildings with a total area of 192 519 039 m^2.
The annual heating energy requirements for coastal and continental Croatia have been estimated in the part relating to construction and energy characteristics of the building, also presenting the building's structural characteristics with heat transmittance coefficients of its structural parts and elements, depending on the period, and an overview of the heating systems in use in Croatia. According to the analysis conducted, buildings constructed prior to 1987 show the highest annual thermal energy requirements for heating and annual final energy requirements for heating, cooling, domestic hot water (DHW) generation and lighting.

[1] EU Energy Efficiency Directive (2012/27/EU), available at http://ec.europa.eu/energy/efficiency/

2. **An analysis of key elements of the building renovation programme** has taken into account an analysis of technical options for retrofitting by implementing energy efficiency measures and renewable energy sources, an analysis of the technical options of heating systems and has also identified possible sustainable building renovation models and the estimates of expected energy savings.

In order to select the optimal renovation method for each building category, in view of the currently applicable technical and financial parameters, five possible models of sustainable building renovation have been considered. Given the technical options of implementing various energy efficiency (EE) measures and renewable energy sources (RES) for each building category, as well as the scope of the measure packages for the five proposed sustainable renovation models for each of the four building categories, the Nearly Zero-Energy Building (nZEB) standard has been selected as the cost-optimal building renovation model. The specific amount of total costs has been discussed as a basic parameter in the comparison of various building renovation models (Annex 2, Annex 4, Annex 6, Annex 8, Annex 10, Annex 12, Annex 14 and Annex 16) and used as a basis for a chart, drawn for each building category to illustrate total cost dependence on the primary energy level after renovation according to a certain renovation model (Annex 3, Annex 5, Annex 7, Annex 9, Annex 11, Annex 13, Annex 15 and Annex 17). Even though the charts shown suggest that the active construction model might be the most commercially viable, it should be noted that viability depends on the status of preferential RES and cogeneration producer which is subject to quotas and covers a small fraction of the national building stock (very limited applicability), so building renovation according to the nZEB standard has been selected as the cost-optimal model.

3. **Policies and measures to stimulate cost-effective integral building renovation** include an overview of existing measures for and barriers to an integral energy renovation of buildings in Croatia, as well as proposed solutions and measures based on the situation in Croatia and on the analysis of successful measures and policies of European Union Member States.

Overall, it can be concluded that the main barriers to the national building stock renovation are not only of a legislative and financial nature, but that the integral energy renovation of buildings is also largely hampered by lack of information and motivation on the part of investors, the public and stakeholders.
This chapter gives an overview of successful policies and measures to mobilise investment in the renovation of different building types in EU Member States, and describes in more detail the examples of German and Estonian financial and legislative policies that, with minor adjustment to the current situation, could also be applied in Croatia.
In order to meet the set targets, the Croatian national policy of integral renovation of the national building stock needs to include the six categories of measures detailed below:

- strategic;
- legislative;
- technical;
- financial;
- communication measures and capacity enhancing measures;
- research and development measures.

4. **A long-term perspective to guide decisions by individuals and the construction industry, as well as financial investments by the year 2050** includes an estimate of required investments in the renovation of the national building stock by 2050, and also identifies available sources of financing and successful methods of stimulating investors.

Meeting the set energy renovation targets according to the nZEB standard requires a mobilisation of sizeable resources for investment and operating costs that are estimated to reach almost HRK 727 billion by 2050. The proposed pace of renovation will achieve an overall reduction in CO2 emissions by 87.22% and achieve the goals set in the EU Energy Roadmap[2]. Since the currently available sources of financing are insufficient to achieve the set goals, the introduction of new, innovative financing mechanisms, combining public and market instruments adjusted to a wide range of investors is proposed. EU Structural and Investment Funds will be the primary source of funds for removing barriers in the financial sector and will gradually enable a more intense involvement of financial institutions and private investors in the energy services market.

5. **An estimate of expected energy savings and wider benefits based on calculation and model data** takes into account the fact that investing in integral renovation of the national building stock yields far wider economic benefits than mere energy savings and improved housing and working quality.

Increased construction activity has a positive effect on gross domestic product (GDP), employment and budget revenues. If the proposed programme of integral renovation on 92% of the national building stock is completed by the end of 2049, the expected impact on employment could be between 62 000 new jobs in a scenario involving conservatively estimated multiplier effects, and as many as 102 000 in a scenario involving strong multiplication. Additionally, the expected impact on employment by the year 2020 would be between 23 000 and 39 000 added jobs, depending on the assessment of multiplier effects. The estimated impact of the integral renovation programme on GDP growth by 2050 ranges between 10% and 17%.
Wider economic benefits of integral renovation of the national building stock do not cease at the economic activity, budget revenues and increase in employment. Integral renovation of the national building stock certainly results in improved health and, consequently, in considerable cost reduction in the Croatian public health system, reduction of the energy poverty in Croatia and a steady increase of real estate value, while indirect benefits will be felt in the tourism sector, enhanced quality of life and strengthening of the overall national financial stability.

Thanks to all the above reasons, it can be concluded with absolute certainty that the implementation of the integral renovation programme of the Croatian national building stock, in accordance with the elements of this Strategy, will result in improvements of the Croatian economy in almost all its segments.

[2] http://ec.europa.eu/energy/publications/doc/2012_energy_roadmap_2050_en.pdf

1. Introduction

Energy security and the prevention of climate changes largely depend on considerable improvement of the energy efficiency of buildings. Individual EU countries have set a 20% energy saving target by 2020. Furthermore, the European Union[3] has set long-term target of reducing CO2 emissions from the buildings sector by 80–95% by the year 2050.

According to the obligations assumed under EU's Energy Efficiency Directive (hereinafter: the EE Directive)[4], the Republic of Croatia is required to submit to the European Commission by 30 April 2014 its *Long-term strategy for mobilising investment in the renovation of the national building stock* (hereinafter: the Strategy), which includes the following areas:

- an overview of the national building stock;
- an overview of construction and energy characteristics of buildings;
- an analysis of key elements of the building renovation programme;
- identification of a cost-effective approach to the renovation of buildings;
- policies and measures to stimulate cost-effective integral renovation of the national building stock;
- a long-term perspective to guide investment decisions by individuals, the construction industry and financial institutions by the year 2050;
- an estimate of expected energy savings and wider benefits of systematic investment into integral renovation of the national building stock (new job creation, reduction of energy poverty, increase in real estate value etc.).

Although the main goal of the EE Directive is to achieve the 20% headline energy efficiency target by 2020, Article 1 stipulates that the Directive is to "pave the way for further energy efficiency improvements beyond that date". Article 4 goes a step further by obliging EU Member States to establish a long-term strategy to mobilise investment in the renovation of the national building stock in order to realise the full potential of energy and financial savings. The main goal of the Strategy is to provide guidelines for a well-planned, realistic and ambitious approach to the renovation of the national building stock by 2050, which will include both the residential and the [commercial? word missing] national building stock. It is very important to find measures to mobilise investment in the renovation of existing buildings because they make up the single sector with the greatest potential for savings of all types of energy and, consequently, have a key role in reducing greenhouse gas emissions by 80-95% in the EU by 2050 compared to 1990.

The Strategy is updated every three years and submitted to the European Commission as part of National Energy Efficiency Action Plans. Croatia's second National Energy Efficiency Action Plan for the period through 2013 (hereinafter: the NEEAP) was adopted pursuant to Article 6(3) of the Energy End-Use Efficiency Act, in accordance with the requirements of Article 14.1 of Directive 2006/32/EC on energy end-use efficiency and energy services (hereinafter: the ESD) under which EU member states are required to prepare and submit to the European Commission (EC) every three years their plans, including measures which, once implemented, will achieve the set end-use energy savings targets by 2016. The NEEAP puts an emphasis on the preparation and implementation of detailed and comprehensive national programmes of integral renovation of residential and [commercial? word missing] buildings, which may generate savings of 10.4 PJ or 53% of the national target by 2016.

The methodology and terminology of the Strategy have been fully harmonised with the following documents at the national level:

[3] EU Roadmap: Moving to a competitive and low carbon economy, http://ec.europa.eu/energy/publications/doc/2011

[4] EU Energy Efficiency Directive (2012/27/EU), available at http://ec.europa.eu/energy/efficiency/

- National Energy Efficiency Programme for 2008–2016[5];
- 2nd National Energy Efficiency Action Plan for 2011–2013[6];
- 3rd National Energy Efficiency Action Plan for 2014-2017;
- Programme of energy renovation of residential buildings for the period between 2013 and 2020[7];
- Programme of energy renovation of commercial buildings for the period between 2013 and 2020 with a detailed plan of energy renovation of commercial buildings for 2013–2016[8];
- Programme of energy renovation of public buildings.[9]

In accordance with European Commission recommendations, the Strategy was based on the following guidelines:

- set very high long-term goals for the national building stock renovation – minimum 80% reduction in greenhouse gas emissions by 2050;
- provide an overview of the national building stock to include all buildings in Croatia;
- propose clear and practicable financial models of the national building stock renovation by 2050;
- estimate the impact of proposed policies and measures on the national economic development;
- estimate expected energy savings in the national building stock for the purpose of better planning and monitoring of results achieved in the Strategy implementation phase;
- propose new long-term financing mechanisms, as well as the plans and perspectives to ensure a stable investment climate for all market participants.

The Long-term strategy for mobilising investment in the renovation of the national building stock of the Republic of Croatia was commissioned by the Ministry of Construction and Physical Planning from the North-West Croatia Regional Energy Agency and revised by Ekonerg – Energy and Environmental Protection Institute.

5 National Energy Efficiency Programme for 2008–2016, Ministry of the Economy, March 2010, available at www.mgipu.hr

6 2nd National Energy Efficiency Action Plan for 2011–2013, Ministry of the Economy, December 2012, available at www.mingo.hr

7 Programme of energy renovation of residential buildings for the period between 2013 and 2020, November 2013, Ministry of Construction and Physical Planning, available at www.mgipu.hr

8 Programme of energy renovation of commercial buildings for the period between 2013 and 2020 with a detailed plan of energy renovation of commercial buildings for 2013–2016, December 2013, Ministry of Construction and Physical Planning, available at www.mgipu.hr

9 Programme of energy renovation of public buildings, October 2010, Ministry of Construction and Physical Planning, available at www.mgipu.hr

2. Overview of the Croatian national building stock

2.1 National building stock categories by purpose

For the purpose of compliance with energy renovation programmes for the period between 2013 and 2020[10] and with the classification of buildings in accordance with the EU Directive on the energy performance of buildings[11], Croatia's national building stock is organised into the following categories by purpose:

- apartment buildings;
- family houses;
- public buildings;
- commercial buildings;

In drafting the *Programme of energy renovation of residential buildings for the period between 2013 and 2020,* the results of the IPA project named *Citizen Participation in Energy Efficiency Action Planning (CENEP)*, classifying residential buildings into family houses and apartment buildings, have been used. The said classification of Croatia's residential building stock will also be used in this Strategy. A family house is any building wholly or with more than 50% of the gross floor area intended for housing, consisting of two residential units at most, built on a separate building plot and with a gross built up area of up to 400 m^2. An apartment building is any building wholly or with more than 50% of the gross floor area intended for housing, consisting of three or more residential units and managed by a building manager as a legal person, under the provisions of the Ownership and Other Real Rights Act.[12]

Under Article 22 of the *Rules of energy certification of buildings*[13], public buildings are buildings used primarily by government authorities and institutions providing public services, as well as buildings used for other purposes by which services are provided to a large number of people, which are organised into the following 13 subcategories:

1. office buildings used for the performance of administrative activities by legal and natural persons,
2. buildings of state administration authorities, local (regional) self-government bodies,
3. buildings of legal persons with public authority,
4. buildings of courts, prisons, military barracks,
5. buildings of international institutions, chambers, economic associations,
6. buildings of banks, savings-banks and other financial organisations,
7. shop, restaurant, hotel buildings,
8. buildings of travel agencies, marinas, other service and tourist activities,
9. railway, road, air and water traffic, post office, telecommunication centre etc. buildings,
10. buildings of higher education and similar institutions, schools, kindergartens, nurseries, pupils' and students' homes etc., old people's and similar home buildings,
11. buildings of sports associations and organisations, sports facilities,
12. buildings used for cultural purposes: cinemas, theatres, museums etc.,
13. hospitals and buildings of other institutions used for health, social welfare and rehabilitation purposes.

[10] Programme of energy renovation of residential buildings for the period between 2013 and 2020, November 2013; Programme of energy renovation of commercial buildings for the period between 2013 and 2020 with a detailed plan of energy renovation of commercial buildings for 2013–2016, December 2013; Programme of energy renovation of public buildings, October 2013, Croatian Ministry of Construction and Physical Planning; Programme of energy renovation of family houses for the period between 2014 and 2020 with a detailed plan for 2014–2016, January 2014, Croatian Ministry of Construction and Physical Planning; available at http://www.mgipu.hr/doc/

[11] Ministry of Construction and Physical Planning, Regulations/Directive_2010_31 [online] Available at:http://www.mgipu.hr/doc/Propisi/Direktiva 2010 31 19052010.pdf[18 June 2010]

[12] NN – Ownership and Other Real Rights Act, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/265285.html

[13] Rules of energy certification of buildings, NN No 76/07; available at http: //www.mgipu.hr/doc/Propisi/

Since commercial buildings have not been clearly defined within the scope of Croatia's relevant legislative framework, the Strategy will use a definition referred to in the Programme of energy renovation of commercial buildings for the period between 2013 and 2020 which, in accordance with the terms used in the Building Act[14], the Physical Planning Act [15] and the Technical regulation on energy economy and heat retention in buildings[16], the definition of public buildings in the commercial services sector referred to in the second National Energy Efficiency Action Plan and the definition of residential and apartment buildings given in the Programme of energy renovation of residential buildings for the period between 2013 and 2020, commercial buildings are all predominantly privately-owned buildings, in which more than 50% of the gross floor area is used for a commercial and/or service activity.

It is important to note that the adoption of a uniform classification of the national building stock, to be used in collecting statistical data and drafting all relevant documents at the national level, would greatly improve the quality of all analyses of the national building stock that have been conducted and facilitate the process of legislative document preparation.

2.2 Overview of the national building stock by construction period

An overview of the national building stock by the construction period is based on data from the following sources:

- Statistical Yearbooks of the Croatian Bureau of Statistics;
- Programme of energy renovation of apartment buildings for the period between 2013 and 2020;
- Programme of energy renovation of commercial buildings for the period between 2013 and 2020;
- Register of public buildings of the central government and a calculation of targets according to Directive 2012/27/EU on energy efficiency of 25 October 2012[17].

The *Methodology of energy audits of buildings*[18] defines the organisation of buildings in five periods, corresponding to the time of their construction:

1. prior to 1940,
2. 1941–1970,
3. 1971-1987,
4. 1988-2005,
5. 2006–present.

For the purpose of providing a more accurate and detailed overview of the national building stock, as well as harmonisation of the Strategy with the operational Programme[19] which, depending on the construction methods, materials used, applicable technical regulations, organises the building stock into 7 construction periods, the overview will be based on the following periods defined by the

[14] NN (2013) Building Act, Zagreb: *Narodne novine d.d.* (Inc.) (153), Art. 3; Available at: http://narodne-novine.nn.hr/clanci/sluzbeni/298830.tml

[15] (NN No 76/2007) Ownership and Other Real Rights Act, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/298830.html

[16] (NN No 76/2007) Technical regulation on energy economy and heat retention in buildings, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/341775.tml

[17] Register of public buildings of the central government and a calculation of targets according to Directive 2012/27/EU on energy efficiency of 25 October 2012, December 2013, Hrvoje Požar Energy Institute, available at http://www.mgipu.hr

[18] Ministry of Construction and Physical Planning (2012). *Methodology of energy audits of buildings* [online], Zagreb. http://www.mgipu.hr/doc/EnergetskaUcinkovitost/Metodologija provodenja EPG.pdf [31 December 2013]

[19] Programme of energy renovation of commercial buildings for the period between 2013 and 2020 with a detailed plan of energy renovation of commercial buildings for 2013–2016; December 2013, Ministry of Construction and Physical Planning, http://www.mgipu.hr/doc/

Programme[20]:

- prior to 1940,
- 1941–1970,
- 1971–1980,
- 1981–1987,
- 1988–2005,
- 2006–2009,
- 2010–2011.

Table 2.1 provides an overview of the national residential building stock and Table 2.2 an overview of the national non-residential building stock by the period of construction.

Table 2.1 Croatia's residential building stock by year of construction

Year of construction	Apartment buildings		Family houses	
	Number	Area	Number	Area
prior to 1940	37 201	5 830 983	64 391	10 092 805
1941–1970	85 959	13 473 337	151 507	23 747 572
1971–1980	59 882	10 398 113	93 109	16 167 887
1981–1987	44 434	9 401 527	68 348	14 461 473
1988–2005	38 358	8 177 401	75 615	16 120 249
2006–2009	18 256	6 199 252	13 762	4 673 079
2010–2011	6 600	1 957 449	4 976	1 475 551
TOTAL	290 689	55 438 063	471 708	86 738 615

Table 2.2 Croatian non-residential building stock by year of construction

Year of construction	Commercial buildings		Public buildings	
	Number	Area	Number	Area
prior to 1940	2 338	1 498 159	12 365	1 545 813
1941–1970	12 587	8 064 602	22 525	2 815 845
1971–1980	6 733	5 251 934	19 021	1 882 000
1981–1987	4 323	5 108 279	10 158	2 152 000
1988–2005	10 596	8 107 287	11 059	2 722 497
2006–2009	6 199	6 352 000	3 673	2 073 747
2010–2011	1 952	2 158 198	1 395	610 000
TOTAL	44 728	36 540 459	80 196	13 801 902

Since the first statistical data concerning building construction and areas refer to 1952, it has proved exceptionally difficult to find reliable data on the number and total area of the national building stock dating back to prior to 1952 on which to base the estimate. The estimate of Croatia's total national building stock area prior to 1940 was based on the fact that 16.4% of the total building stock had been built prior to 1940, and on the assumption that the share of residential buildings was 65% of the total constructed building stock. With official statistical records kept since 1953[21], the total number and area of Croatia's national building stock in the period between 1941 and 1970 has been determined as follows:

- by estimating data for the period between 1941 and 1952;
- according to Statistical Yearbook data for the period between 1953 and 1970.

[20] Programme of energy renovation of commercial buildings for the period between 2013 and 2020 with a detailed plan of energy renovation of commercial buildings for 2013–2016, December 2013, Ministry of Construction and Physical Planning, available at http://www.mgipu.hr/doc/

[21] Croatian Bureau of Statistics (1953–1970), *Statistical Yearbook of the Republic of Croatia* [online], Zagreb. Available at: http://www.dzs.hr/ [31 December 2013]

According to the results of systematic research of Statistical Yearbooks and expert estimates of missing data, Croatia's national residential building stock consists of 762 397 buildings with a total area of 142 176 678 m^2, of which 290 689 are apartment buildings with a total area of 55 438 063 m^2 and 471 708 family houses with a total area of 86 738 615 m^2.
Croatia's national non-residential building stock consists of 124 924 buildings with a total area of 50 342 361 m^2, of which 44 728 are commercial buildings with a total area of 36 540 459 m^2 and 80 196 public buildings with a total area of 13 801 902 m^2.
In conclusion, resulting from the analyses that have been conducted, Croatia's total current national building stock consists of 887 321 buildings with a total area of 192 519 039 m^2.

2.3 Overview of the national building stock by climate zone

Under Article 20 of the Rules of energy audits and energy certification of buildings[22], Croatia is divided into two climate zones depending on the number of annual heating degree days:

- Continental climate zone – cities and towns with 2 200 or more heating degree days per year;
- Coastal climate zone – cities and towns with fewer than 2 200 heating degree days per year.

An overview of the national building stock by the climate zone is based on data from the following sources:

- Statistical Yearbooks of the Croatian Bureau of Statistics;
- Programme of energy renovation of commercial buildings for the period between 2013 and 2020;
- Register of public buildings of the central government and calculation of targets according to Directive 2012/27/EU on energy efficiency of 25 October 2012[23].

Table 2.3 provides an overview of the national residential building stock and Table 2.4 an overview of the national non-residential building stock by their respective climate zone.

Table 2.3 Overview of the national residential building stock by climate zone

Climate zones	Apartment buildings		Family houses	
	Number	Area	Number	Area
Continental	186 922	35 648 303	303 322	55 775 475
Coastal	103 767	19 789 760	168 386	30 963 140
TOTAL	290 689	55 438 063	471 708	86 738 615

Table 2.4 Overview of the national non-residential building stock by climate zone

Climate zones	Commercial buildings		Public buildings	
	Number	Area	Number	Area
Continental	29 968	24 482 108	53 731	9 247 275
Coastal	14 760	12 058 351	26 465	4 554 628
TOTAL	44 728	36 540 459	80 196	13 801 902

The overview of Croatia's national building stock by climate zone shows that 490 244 buildings with a total area of 91 423 778 m^2 are situated in the continental zone, and 272 153 buildings with a total area of 50 752 900 m^2 in the coastal zone.

[22] Rules of energy audits and energy certification of buildings (NN No 78/13) available at www.mgipu.hr

[23] Register of public buildings of the central government and a calculation of targets according to Directive 2012/27/EU on energy efficiency of 25 October 2012, December 2013, Hrvoje Požar Energy Institute, available at www.mgipu.hr

The overview of the national non-residential building stock by climate zone shows that 83 699 buildings with a total area of 33 729 383 m^2 are situated in the continental zone, and 41 225 buildings with a total area of 16 612 979 m^2 in the coastal zone.

The above leads to the conclusion that, of the Croatian total national building stock, 573 943 buildings with a total area of 125 153 161 m^2 are situated in the continental zone, and 313 378 buildings with a total area of 67 365 879 m^2 in the coastal area.

2.4 Overview of the national building stock by ownership

The overview of national building stock according to their ownership is based on the data systematically gathered by queries into the Statistical Yearbooks published by the Croatian Bureau of Statistics. Since the first statistical data on construction and building area go back to no earlier than 1952 and the period under observation has seen major social changes, differences in the building categorisation by ownership are significant. Bearing in mind that almost all buildings (except family houses) were exclusively "socially owned" in the period of self-managing socialism until 1991, as reflected in statistical yearbooks, Table 2.5 provides an estimate of the national building stock by ownership based on the assumption that about 99% of Croatia's residential building stock has passed from such social to private ownership since 1991.

Table 2.5 Overview of the national residential building stock by ownership

Ownership	Apartment buildings		Family houses	
	Number	Area	Number	Area
Private	287 783	54 883 682	466 991	85 871 229
Public	2 907	554 381	4 717	867 386
TOTAL	290 689	55 438 063	471 708	86 738 615

Table 2.6 Overview of the national non-residential building stock by ownership

Ownership	Commercial buildings		Public buildings	
	Number	Area	Number	Area
Private	44 728	36 540 459	0	0
Public	0	0	80 196	13 801 902
TOTAL	44 728	36 540 459	80 196	13 801 902

The overview of the national building stock by ownership shows 799 502 buildings with a total area of 177 295 370 m^2 as being privately owned, and 87 820 buildings with a total area of 15 223 669 m^2 as being publicly owned.

2.5 Overview of the national building stock by area (urban/rural)

A division of the national building stock by area (urban/rural) has been conducted according to the Model of urban, rural and semi-urban settlement differentiation in the Republic of Croatia,[24] which defines the urban area as a unit of local self-government with a seat of the county and any other place with more than 10 000 inhabitants which represents an urban, historical, natural, economic and social entity.
Tables 2.7 and 2.8 provide an estimate of the national residential and non-residential building stock, respectively, by type of area.

Table 2.7 Overview of the national residential building stock by type of area

Type of area	Apartment buildings		Family houses	
	Number	Area	Number	Area
Urban	162 454	28 237 990	263 617	44 181 273
Rural	128 236	27 200 072	208 091	42 557 342
TOTAL	290 689	55 438 063	471 708	86 738 615

Table 2.8 Overview of the national non-residential building stock by type of area

Type of area	Commercial buildings		Public buildings	
	Number	Area	Number	Area
Urban	31 484	25 720 860	56 450	9 715 171
Rural	13 244	10 819 599	23 746	4 086 732
TOTAL	44 728	36 540 459	80 196	13 801 902

The overview of the national residential building stock by the type of area shows 426 071 buildings with a total area of 72 419 263 m^2 being situated in urban areas, and 336 327 buildings with a total area of 69 757 414 m^2 in rural areas.

The overview of the national non-residential building stock by the type of area shows 87 934 buildings with a total area of 35 436 031 m^2 being situated in urban areas, and 36 990 buildings with a total area of 14 906 331 m^2 in rural areas.

It may be concluded from the analyses conducted that of the Croatian total national building stock 514 005 buildings with a total area of 107 855 294 m^2 are situated in urban areas, and 373 317 buildings with a total area of 84 663 745 m^2 in rural areas.

[24] Model of urban, rural and semi-urban settlement differentiation in the Republic of Croatia, Methodological Guidelines 67, Croatian Bureau of Statistics, 2011; Available at: http://www.dzs.hr/ [31 December 2013]

2.6 Energy performance and building characteristics

2.6.1 U-coefficients of building components and elements

Energy performance and building characteristics, as well as their energy consumption, are largely determined by the construction period. While the level of energy consumption for heating in buildings can also be monitored through other parameters[25] (e.g. climate (temperature) conditions of the location and climate zone, building shape factor etc.), the construction period provides much information about construction characteristics and the types of structures applied, as well as (non-)compliance with heat retention regulations relevant for a particular construction period.[26]
The essential information in the analysis of energy performance and characteristics of building components and elements is that concerning a building's intended purpose and energy consumption specifics, that is, the building usage regime according to its purpose.[27] Building categories according to their purpose will not be elaborated further, but rather a description of the characteristics of structural elements of a typical building predominant in a particular construction period will be presented. Table 2.9 shows estimated annual thermal energy requirements and annual final energy consumption for heating, cooling, domestic hot water (DHW) generation and lighting per m^2 in coastal and continental Croatia, by category of the Croatian national building stock, according to building purpose as defined in Chapter 2.1.

Table 2.9 Annual thermal final energy requirement for heating and annual final energy consumption in continental and coastal Croatia (kWh/m^2a)[28]

Building purpose	Annual thermal energy requirement for heating (kWh/m^2a)													
	Continental Croatia							Coastal Croatia						
	prior to 1940	**1941 – 1970**	**1971 – 1980**	**1981 – 1987**	**1988 – 2005**	**2006 – 2009**	**2010 – 2011**	**to 1940**	**1941 – 1970**	**1971 – 1980**	**1981 – 1987**	**1988 – 2005**	**2006 – 2009**	**2010 – 2011**
Apartment buildings	270	200	190	180	150	90	70	122	90	86	81	68	41	32
Family houses	300	320	304	288	240	144	112	141	150	143	135	113	68	53
Non-residential public buildings	190	247	271	169	125	102	62	95	125	135	87	79	65	32
Non-residential commercial buildings	229	298	326	204	150	123	75	115	150	163	105	95	78	38
Building purpose	**Annual final energy consumption for heating, cooling, DHW generation and lighting (kWh/m^2a)**													
Apartment buildings	477	354	336	318	265	159	124	216	159	152	143	120	72	57
Family houses	530	566	537	509	424	255	198	249	265	253	239	200	120	94
Non-residential public buildings	237	367	473	374	332	282	148	119	224	336	281	385	305	139
Non-residential commercial buildings	286	443	570	451	400	340	178	143	270	404	339	464	368	167

[25] Ministry of Construction and Physical Planning (2013) *Programme of energy renovation of residential buildings for the period between 2013 and 2020* [online]. Available at: http://www.mgipu.hr/doc/EnergetskaUcinkovitost/Program_energetske_obnove stambeni zgrada 2013- 2020.pdf [31 December 2013]
[26] United Nations Development Program–UNDP (2010). *Priručnik za energetsko certificiranje* [Energy Certification Manual]. Zelina: Tiskara Zelina.
[27] United Nations Development Program–UNDP (2010). *Priručnik za energetsko certificiranje* [Energy Certification Manual]. Zelina: Tiskara Zelina.
[28] Programme of energy renovation of commercial buildings for the period between 2013 and 2020 with a detailed plan of energy renovation of commercial buildings for the 2013–2016 period, December 2013, Ministry of Construction and Physical Planning; Programme of energy renovation of residential buildings for the period between 2013 and 2020, November 2013, Ministry of Construction and Physical Planning, Table 2-4

2.6.1.1 Construction typical for the period prior to 1940

The main characteristic of buildings constructed in this period is the use of traditional techniques and materials, with no thermal protection applied.[29] Buildings were built as full-brick masonry or stone (primarily in coastal area) structures, with 30–60 cm walls producing satisfactory static building structure. Ceilings are mostly wooden or solid, made of brick, stone or concrete elements (ribbed concrete ceiling). Thanks to their large wall thickness and a relatively modest degree of interior space heating, such massive-walled buildings had rather lower heat losses than more recent light concrete structures without thermal protection. Thermal transmittance coefficient figures shown in Table 2.10 do not meet the requirements of currently regulations, so a considerable share of heat is lost and moisture appears as a consequence. Ventilated basements serve as a buffer layer between the ground and ground-floor space, while the ceilings bordering unheated attic are usually made of wood with (plastered board) underside, a layer of rubble and an upper board decking as the attic floor. Windows and doors of buildings of that period are mostly wooden, single or double, glazed with one or two sheets of glass per leaf and with no seals.

Table 2.10 Heat transmittance coefficients for typical structural elements[30]

Typical construction part	**Thermal transmittance coefficient, U [W/m^2K]**		
Typical period	**prior to 1940**	**1941–1970**	**1971–1980**
External wall, bordering garage or attic	1.40*[1]	3.56*[6]	1.13*[13]
Floor on ground level	2.67	2.67	0.89*[14]
Wall bordering unheated stairwell	1.64*[2]	2.84*[7]	-
External wall bordering outer space	1.15*[3]	4.42*[8]	4.42*[8]
Ceiling bordering unheated attic	1.16*[4]	4.20*[9]	
Ceiling above outer space	-	2.19*[10]	1.41*[15]
Inclined roof (residential space underneath)	-	-	0.63*[16]
Flat roof (residential space underneath)	-	0.96*[11]	0.96*[11]
Windows	3.6*[5]	5.2*[12]	4.0*[17]

*[1] 45 cm full brick (plastered on both sides).
*[2] 30 cm full brick (plastered on both sides).
*[3] 60 cm full brick (plastered on both sides).
*[4] 40 cm wooden ceiling with sand or rubble infill, plated with 6 cm full clay masonry elements.
*[5] Wooden frame, double single-glazed (4 mm) window, two window jambs at a distance of d=30cm, no seal.
*[6] 25 cm reinforced concrete (1.5 cm plaster layer on the inside).
*[7] 20 cm reinforced concrete (1.5 cm plaster layer on the inside).
*[8] 25 cm reinforced concrete.
*[9] 6 cm fine-ribbed ceiling slab, 40 cm in total height.
*[10] 16 cm reinforced concrete.
*[11] 16 cm concrete slab, 3 cm thermal insulation, cement screed and hydro-insulation.
*[12] Wooden frame, single-glazed (4 mm) window, no seals.
*[13] 15 cm reinforced concrete, 3 cm thermal insulation and 12cm façade brick.
*[14] Floor on ground level, 3 cm thermal insulation.
*[15] 14 cm clay brick elements + 6 cm concrete slab.
*[16] Timber joists with 5 cm thermal insulation infill.
*[17] Metal frame with no thermal bridge interruption, double (4/6–8/4) simple glazing, no seal.

It should be noted that since a regulation concerning heat retention in buildings was adopted under a JUS U.J5.600 standard in 1980, all typical structural elements of buildings are considered to have U-coefficients equal to those under the legislative framework applicable since 1980, which are stated for each typical period.

[29] United Nations Development Program–UNDP (2010). *Priručnik za energetsko certificiranje* [Energy Certification Manual]. Zelina: Tiskara Zelina.

[30] Ministry of Construction and Physical Planning (2012), *Methodology of conducting energy audit of buildings, Table 6, Table 7 and Table 8* [online], Zagreb. Available at: http://www.mgipu.hr/doc/Propisi/Metodologija provodenja epg.pdf

2.6.1.2 Construction typical for the period between 1941 and 1970

On the one hand, the main characteristic of construction in this period is the use of traditional techniques and materials described in the previous chapter and, on the other hand, early application of new materials and buildings with thinner, wide-span structural elements, large single-glazed glass surfaces, poor thermal performance and no thermal protection applied.[31] The use of reinforced concrete allows the structural elements to be thinner, resulting in major thermal losses in the absence of thermal insulation. In order to meet the requirements of structural analysis for buildings, metal profiles of extremely poor thermal performance were used. It may be concluded that the buildings constructed in the 1941–1970 period had generally poorer thermal performance than the buildings in the previous period – Table 2.10; they are characterised by the occurrence of moisture and condensation (mostly on the ground floor and the topmost heated floor), numerous thermal bridges and unsatisfactory window sealing.

2.6.1.3 Construction typical for the period between 1971 and 1980

The construction period between 1971 and 1980 is characterised by the adoption of a first regulation on thermal protection of buildings in 1970 (Regulation on technical measures and requirements for thermal protection of buildings, *Službeni list SFRJ* (SL; Official Gazette of the Socialist Federal Republic of Yugoslavia) No 35/70), which divided the Croatian territory into three construction climate zones, also laying down maximum permissible heat transmittance coefficient values k (W/m^{2}K) (currently: U) for individual elements of the outer building envelope.[32]

This period is characterised by modest application of 2–4 thermal insulation [Note: made of pressed wooden fibres, EPS and other materials] such as *heraklit, drvolit* or *okipor*. Reinforced concrete structures of buildings became thinner and lighter, but no energy concept was applied. Reinforced concrete walls were 16 cm and 18 cm, as minimum thickness values under structural analysis. Buildings are characterised by a number of thermal bridges, resulting in the occurrence of moisture and mould on inside walls. Insulated glass windows with profiles of very poor performance, with no thermal bridge interruption and with poor sealing were used for the most part. Total glazed surfaces grew in size compared to the previous period. Heat transmittance coefficients of some typical structural elements are given in Table 2.10, and the maximum permitted heat transmittance coefficient k in Table 2.11.

Table 2.11 Maximum permitted heat transmittance coefficients k [W/m^{2}K], according to the Regulation on technical measures and requirements for thermal protection of buildings – SL No 35/70[33]

Structural element	Construction climate zones		
	I.	II.	III.
External wall	1.69	1.45	1.28
Floor on ground level	0.93	0.93	0.93
Ceiling bordering attic	1.16	1.16	1.16
Ceiling above basement	1.05	1.05	1.05
Ceiling above open passages	0.70	0.58	0.52
Inclined and flat roof	0.93	0.93	0.93

[31] United Nations Development Program–UNDP (2010). *Priručnik za energetsko certificiranje* [Energy Certification Manual]. Zelina: Tiskara Zelina.

[32] Programme of energy renovation of commercial buildings for the period between 2013 and 2020 with a detailed plan of energy renovation of commercial buildings for 2013–2016, December 2013, Ministry of Construction and Physical Planning, available at: http://www.mgipu.hr/doc/

[33] Programme of energy renovation of residential buildings for the period between 2013 and 2020, November 2013, Ministry of Construction and Physical Planning: Available at: http://www.mgipu.hr/doc/

2.6.1.4 Construction typical for the period between 1981 and 1987

New requirements with regard to thermal protection of buildings were adopted in 1980 under the JUS U.J5.600 standard: Thermal equipment in the construction industry and technical requirements for the design and construction of buildings with a reduction in permitted heat transmittance coefficient values U(k) by approx. 30%[34].
All commercially available materials were used for construction, with reinforced concrete dominating because of its good static characteristics and market availability and despite its poor thermal properties, resulting in the occurrence of a large number of thermal bridges that significantly affect thermal losses in buildings[35].
Maximum permitted heat transmittance coefficients, k for structural elements are provided in Table 12.2, and those for windows and doors in Table 2.13.

Table 2.12 Maximum permitted heat transmittance coefficient k [W/m^{2}K], according to JUS U.J5.600: Thermal equipment in the construction industry and technical requirements for the design and construction of buildings, 1980[36]

Structural element	Construction climate zone		
	I.	II.	III.
External walls	1.225	0.93	0.83
Floor on ground level	0.93	0.76	0.68
Intermediate structure bordering attic	0.69	0.69	0.69
Intermediate structure above basement	0.75	0.63	0.52
Intermediate structure above open passages	0.50	0.46	0.43
Inclined or flat roof above heated spaces	0.78	0.65	0.55

Table 2.13 Heat transmittance coefficients k [W/m^{2}K] of windows and balcony doors, depending on the glazing and frame material according to the JUS U.J5.600 standard: Thermal equipment in the construction industry and technical requirements for the design and construction of buildings, 1980[37].

Glazing	Frame material – groups		
	1	2	3
Single with double insulating glass (6 mm air insulation)	3.3	3.5	3.8
Single with double insulating glass (12 mm air insulation)	3.0	3.3	3.5
Single with double-pane (push-out) casement	2.8	3.0	3.3
Single with double-pane casement (with insulating glass + 1 glass)	2.0	2.6	2.8
Single with double-pane casement (with two insulating glass sheaths)	1.7	2.0	2.3
Double with mullion post between panes	2.6	-	-

[34] Programme of energy renovation of commercial buildings for the period between 2013 and 2020 with a detailed plan of energy renovation of commercial buildings for 2013–2016, December 2013, Ministry of Construction and Physical Planning: Available at: http://www.mgipu.hr/doc/

[35] Programme of energy renovation of commercial buildings for the period between 2013 and 2020 with a detailed plan of energy renovation of commercial buildings for 2013–2016, December 2013, Ministry of Construction and Physical Planning, available at: http://www.mgipu.hr/doc/

[36] Programme of energy renovation of residential buildings for the period between 2013 and 2020, November 2013, Ministry of Construction and Physical Planning; Available at: http://www.mgipu.hr/doc/

[37] Programme of energy renovation of residential buildings for the period between 2013 and 2020, November 2013, Ministry of Construction and Physical Planning; Available at: http://www.mgipu.hr/doc/

2.6.1.5 Construction typical for the period between 1988 and 2005

New, stricter amended regulation defining the requirements for thermal protection was adopted under the name of HRN UJ5.600 in 1987. It is important to emphasise the imposition of limits on heat loss not only for individual elements of the outer envelope, but also for the building as a whole as a crucial novelty of this regulation. There was no substantial progress in thermal protection of buildings in the 1988–2005 period.[38]
All commercially available materials were used in construction, and thermal insulation was such that it complies with applicable regulations.
Maximum permitted heat transmittance coefficients, k for structural elements are provided in Table 12.4, and those for windows and doors in Table 2.15.

Table 2.14 Maximum permitted heat transmittance coefficient k [W/m^{2}K], according to JUS U.J5.600: Thermal equipment in the construction industry and technical requirements for the design and construction of buildings, 1987[39]

Structural element	Construction climate zone		
	I.	II.	III.
External walls and walls bordering unheated stairwells	1.20	0.90	0.80
Underground external wall	1.20	0.90	0.80
Floor on ground level	0.90	0.75	0.65
Intermediate structure bordering attic	0.95	0.80	0.70
Intermediate structure above basement	0.75	0.60	0.50
Intermediate structure above open passages or below the panel and floor heating	0.50	0.45	0.40
Inclined or flat roof above heated spaces	0.75	0.65	0.55

Table 2.15 Heat transmittance coefficients k [W/m^{2}K] for windows and balcony doors, depending on the glazing and frame material according to JUS U.J5.600: Thermal equipment in the construction industry and technical requirements for the design and construction of buildings, 1987[40]

Glazing	No window jamb	Frame material – groups		
		1	2	3
Insulating glass with 6–8 mm air insulation (two glass layers)	3.4	3.1	3.4	3.7
Insulating glass with 8–10 mm air insulation (two glass layers)	3.2	3.0	3.3	3.5
Insulating glass with 10-16 mm air insulation (two glass layers)	3.0	2.9	3.1	3.4
Double insulating glass with 2x6–8mm air insulation (three glass layers)	2.4	2.2	2.7	3.0
Double insulating glass with 2x8–10mm air insulation (three glass layers)	2.2	2.1	2.5	2.8
Double insulating glass with 2x10–18mm air insulation (three glass layers)	2.1	2.0	2.4	2.7

[38] Programme of energy renovation of commercial buildings for the period between 2013 and 2020 with a detailed plan of energy renovation of commercial buildings for 2013–2016, December 2013, Ministry of Construction and Physical Planning, available at: http://www.mgipu.hr/doc/

[39] Programme of energy renovation of residential buildings for the period between 2013 and 2020, November 2013, Ministry of Construction and Physical Planning; Available at: http://www.mgipu.hr/doc/

[40] Programme of energy renovation of residential buildings for the period between 2013 and 2020, November 2013, Ministry of Construction and Physical Planning; Available at: http://www.mgipu.hr/doc/

2.6.1.6 Construction typical for the period between 2006 and 2009

A new *Technical regulation on thermal energy savings and thermal protection in buildings (NN Nos 79/05, 155/05, 74/06)* adopted in 2005 represents a major breakthrough in thermal protection of buildings, and applies to both new-builds and the reconstruction of existing buildings. Building construction was based on an energy concept, taking account of building shape, positioning and orientation so as to reduce energy requirements for heating and cooling[41].
Load-bearing building structure was still mostly made of reinforced concrete. Requirements were laid down for the manufacturing and installation of building products for the purpose of thermal energy savings and thermal protection, depending on the type of building product.
Maximum permitted thermal transmittance coefficient, U, values for construction elements, according to the Technical regulation on thermal energy saving and heat retention in buildings (NN Nos 79/05, 155/05, 74/06), are shown in Table 2.16 and those referring to windows and doors in Table 2.17.

Table 2.16 Maximum permitted thermal transmittance coefficients, U [W/(m^{2}K)], structural elements with surface mass greater than 100 kg/m (according to the average monthly external air temperature in the building location)

Structural element	U [W/(m^{2}K)]	
	Qe, mth, min. > + 3°C	Qe, mth, min ≤ + 3°C
External walls, walls bordering garage or attic	1.00	0.80
Walls bordering unheated stairwell with a temperature above 0 °C, walls bordering unheated room	1.30	1.30
Walls bordering ground	1.00	0.80
Floors on ground level (to 5 m room depth)	0.80	0.65
Ceilings between apartments, ceilings between heated work rooms of different users	1.40	1.40
Ceilings bordering attic, ceilings bordering unheated room above	0.85	0.70
Ceilings bordering unheated basements, ceilings bordering unheated room below	0.65	0.50
Inclined or flat roof above heated spaces	0.70	0.55
Ceilings above open space, ceilings above garages	0.45	0.40

Table 2.17 Maximum permitted thermal transmittance coefficients U [W/(m^{2}K)] for windows and doors

Minimum heat retention			
Glazing	Heating at >12°C	Heating at >12 and <18°C	Heating at ≥18°C
Windows, balcony doors, skylights and other transparent elements		≤1.8	<3.0
Roll–up shutter casing	≤0.8		
Solid-leaf front door	≤2.9		

Additionally, the Regulation defines maximum permitted values of the following:

- annual thermal energy requirements per unit of the building's useful floor area;
- maximum permitted heat transmittance loss coefficient per unit of surface area of the building's heated part;
- air tightness of the building envelope and ventilation of the building space;
- efficiency of any heat recovery ventilation systems used.

[41] Programme of energy renovation of commercial buildings for the period between 2013 and 2020 with a detailed plan of energy renovation of commercial buildings for 2013–2016, December 2013, Ministry of Construction and Physical Planning, available at: http://www.mgipu.hr/doc/

2.6.1.7 Construction typical for the 2010–2011 period

The *Technical regulation on energy economy and heat retention in buildings* (NN Nos 110/08, 89/09) was adopted in 2008 and came into effect on 31 March 2009, superseding the Technical regulation on thermal energy saving and heat retention in buildings (NN Nos 79/05, 155/05, 74/06) from 2005 [42].

The regulation imposed significantly stricter permitted thermal transmittance coefficients of structural elements for new-builds and reconstruction interventions on existing buildings (especially on external walls and ceilings bordering the attic).

Maximum permitted thermal transmittance coefficient, U, values for construction elements, according to the Technical regulation on energy economy and heat retention in buildings (NN Nos 110/08, 89/09), are shown in Table 2.18 and those referring to windows and doors in Table 2.19.

Table 2.18 Maximum permitted thermal transmittance coefficients, U [W/(m^{2}K)], structural elements with surface mass greater than 100 kg/m (according to the average monthly external air temperature of the coldest month in the building location)

Structural element	U [W/(m^{2}K)]			
	Qi ≥18°C		12°C< Qi <18°C	
	Qe, mth, min>3°C	Qe, mth, min ≤3°C	Qe, mth, min>3°C	Qe, mth, min ≤3°C
External walls, walls bordering garage or attic	0.60	0.45	0.75	0.75
Windows, doors, skylights and other transparent façade elements	1.80	1.80	3.00	3.00
Flat and inclined roofs above heated space, ceilings bordering attic	0.40	0.30	0.50	0.40
Ceilings above outdoor space, ceilings above garage	0.40	0.30	0.50	0.40
Walls and ceilings bordering unheated spaces and unheated stairwells at temperatures above 0°C	0.65	0.50	2.00	2.00
Walls to the ground soil, floors on ground level	0.50	0.50	0.80	0.65
Solid-leaf front door, solid-leaf door bordering unheated stairwell	2.90	2.90	2.90	2.90
Roll-up shutter casing wall	0.80	0.80	0.80	0.80
Ceilings between apartments, ceilings between heated work rooms of different users	1.40	1.40	1.40	1.40

Table 2.19 Maximum permitted thermal transmittance coefficients U [W/(m^{2}K)] for windows and doors

Minimum heat retention			
Glazing	Heating at >12°C	Heating at >12 and <18°C	Heating at ≥18°C
Windows, balcony doors, skylights and other			
transparent elements	-	≤1.8	<3.0
Roll-up shutter casing	≤0.8	-	-
Solid-leaf front door	≤2.9	-	-

Furthermore, the Regulation defines maximum permitted values of the following:

- annual thermal energy requirements per unit of the building's useful floor area;
- maximum permitted heat transmittance loss coefficient per unit of surface area of the building's heated part;
- air tightness of the building envelope and ventilation of the building space;

[42] Programme of energy renovation of commercial buildings for the period between 2013 and 2020 with a detailed plan of energy renovation of commercial buildings for 2013–2016, December 2013, Ministry of Construction and Physical Planning

2.6.2 Heating systems

Heating systems are divided into individual (local) and central heating systems. Individual heating systems are characterised by a thermal source both generating and transmitting heat by radiation and convection to a heated room. Fireplaces, tile stoves and iron stoves were used for combustion of solid fuels, with gas, fuel oil, and electric heaters also in frequent use in individual heating systems. Central heating systems feature a thermal energy source located in a single place within the building, with heat distribution by a pipe system to heating units located in heated rooms and consisting of the following elements[43]:

- heat generator;
- flue system;
- thermal energy distribution subsystem;
- radiators;
- circulating pumps;
- closing and regulating valves;
- expansion system;
- regulation and management system.

District heating systems belong to a special group of centralised thermal systems. Firebox is located in the central heating plant supplying thermal energy to one or multiple buildings. Such plants have the ability to operate in the so-called cogeneration or trigeneration mode, meaning that they can generate electricity and cooling energy in addition to thermal energy. Such operation method allows greater system efficiency.

Historically, individual heat sources intended for heating of certain rooms, such as stoves, fireplaces and tile stoves, were in predominant use in the late 19th and early 20th century. Being far more complex, pipe systems were seldom used for heating at the time.[44] Even though the first central heating systems appeared in luxurious houses in the Roman period in the form of the so-called Roman hypocaust[45], it was only after 1941 that the first heating systems based on hot water circulation were introduced, primarily in industrial facilities.[46] Over the time, fuels changed, depending on their availability and other characteristics, so the following are currently in use:

- fuel oil;
- liquefied petroleum gas;
- timber (chopped woods);
- chips, pellets, briquettes;
- electricity;
- natural gas;
- solar energy, geothermal energy etc.

The period after 1960 saw a gas network and natural gas distribution development in the territory of Croatia, but to a limited extent,[47] with individual gas heaters in the form of regular heaters, infrared gas heaters and flued and non-flued individual gas heaters also in use.[48]

[43] Group of authors, *Priručnik za energetsko certificiranje zgrada* [Energy Certification Manual], UNDP, Zagreb, 2010.

[44] Programme of energy renovation of commercial buildings for the period between 2013 and 2020 with a detailed plan of energy renovation of commercial buildings for 2013–2016, December 2013, Ministry of Construction and Physical Planning, available at: http://www.mgipu.hr/doc/

[45] Balen I., *Grijanje-kratka povijest, podjela sustava grijanja* [Heating: a short history, classification of heating systems]. Faculty of Mechanical Engineering and Naval Architecture, Zagreb

[46] Programme of energy renovation of commercial buildings for the period between 2013 and 2020 with a detailed plan of energy renovation of commercial buildings for 2013–2016, December 2013, Ministry of Construction and Physical Planning, available at: http://www.mgipu.hr/doc/

[47] Programme of energy renovation of commercial buildings for the period between 2013 and 2020 with a detailed plan of energy renovation of commercial buildings for 2013–2016, December 2013, Ministry of Construction and Physical Planning

[48] Reknagel, Šprenger, Šramek, Čeperković2004), *Grejanje i klimatizacija uključujući toplu vodu i teniku lađenja* [Heating and air conditioning, including hot water and cooling equipment]. INTERKLIMA-GRAFIKA, Vrnjačka Banja.

The period after 1971 saw even growth of the gas distribution network, side-by-side with a growing number of connected buildings, which led to the development of central thermal energy generation and its distribution in the buildings. In addition, hot water and steam pipe system networks expanded and developed, and the number of connected facilities also increased, particularly in the industry.[49] Fuel oil was also largely in use for heating (oil furnaces etc.), primarily in the areas where no gas or hot water network was developed. The period after 1981 was characterised by continued side-by-side growth of the gas network and the number of connected buildings, as well as by increased natural gas consumption. Hot water and steam pipe system networks expanded and developed too, and the number of connected facilities also increased, particularly in the industry, albeit much less so than in the gas network. Because of uneven gas and hot water distribution network development in the territory of Croatia, fuel oil is also largely used for heating, and that results in a dominant share of liquid fuels in total consumption.[50]
The period between 1998 and 2004 saw a sudden expansion of the gas distribution network, along with an increase in the number of connected consumers. In addition, hot water and steam pipe system networks expanded and developed, and the number of connected facilities, particularly in the industry, also increased. Hot water and steam networks were developed in large Croatian towns (Sisak, Karlovac, Varaždin etc.). Because of uneven gas and hot water distribution network development in the territory of Croatia, fuel oil continued to be largely used for heating, thus resulting in dominant role of liquid fuel consumption in total energy for energy transformation.[51]
It is only in the period since 2005 that modern, advanced systems and energy-efficient technologies (low-temperature heating, condensing boilers, heat pumps, etc.) have been more extensively implemented.

Table 2.02 provides an overview of technical systems in use, as well as fuels and other data relevant for the energy efficiency of heating systems in coastal and continental Croatia by category of the Croatian national building stock, according to building purpose as defined in Chapter 2.1. Such data are the basis for an analysis of key elements of the buildings renovation programme.

[49] Programme of energy renovation of commercial buildings for the period between 2013 and 2020 with a detailed plan of energy renovation of commercial buildings for the 2013–2016 period, December 2013, Ministry of Construction and Physical Planning, available at: http://www.mgipu.hr/doc/

[50] Programme of energy renovation of commercial buildings for the period between 2013 and 2020 with a detailed plan of energy renovation of commercial buildings for the 2013–2016 period, December 2013, Ministry of Construction and Physical Planning, available at: http://www.mgipu.hr/doc/

[51] Programme of energy renovation of commercial buildings for the period between 2013 and 2020 with a detailed plan of energy renovation of commercial buildings for 2013–2016, December 2013, Ministry of Construction and Physical Planning, available at: http://www.mgipu.hr/doc/

Table 2.20 Overview of heating systems used in different construction periods in continental and coastal Croatia

Building purpose	Installed technical systems, fuels and other data relevant for heating system energy efficiency						
	Continental Croatia						
	prior to 1940	**1941–1970**	**1971–1980**	**1981–1987**	**1988–2005**	**2006–2009**	**2010–2011**
Apartment buildings*	- solid fuel (wood, coal) heating, 60–75% system efficiency, no heating distribution	- solid fuel, steam or fuel oil heating, inefficient systems with large losses – 60–75% system efficiency, predominantly with no heating distribution	- solid fuel, steam or fuel oil heating, gas and hot water network development – rising number of connected buildings, 60–75% system efficiency, central DHW generation and heating development	- solid fuel, steam or fuel oil heating, further gas and hot water network development, liquid fuel consumption still dominant, 65–90% system efficiency, heating distribution, central DHW generation	- solid fuel, steam or fuel oil heating, rapid gas network and consumer number increase with hot water and steam network expansion – uneven growth, liquid fuel consumption dominates, 80–95% system efficiency, heating distribution, central DHW generation	- storey-based natural gas or LNG heating, HVAC system automation, efficient (low-temperature, condensation, heat pump etc.) heating systems, 95–108% efficiency, efficient heating distribution (fan coils etc.)	- storey-based natural gas or LNG heating, HVAC system automation, efficient (low-temperature, condensation, heat pump etc.) heating systems, 95–108% efficiency, efficient heating distribution (fan coils etc.)
Family houses*	- solid fuel (wood, coal) heating, 60–75% system efficiency, no heating distribution	- solid fuel, steam or fuel oil heating, inefficient systems with large losses – 60–75% system efficiency, predominantly with no heating distribution	- solid fuel, steam or fuel oil heating, gas and hot water network development – rising number of connected buildings, 60–75% system efficiency, central DHW generation and heating development	- solid fuel, steam or fuel oil heating, further gas and hot water network development, liquid fuel consumption still dominant, 65–90% system efficiency, heating distribution, central DHW generation	- solid fuel, steam or fuel oil heating, rapid gas network and consumer number increase with hot water and steam network expansion – uneven growth, liquid fuel consumption dominates, 80–95% system efficiency, heating distribution, central DHW generation	- natural gas or LNG central heating, HVAC system automation, efficient (low-temperature, condensation, heat pump etc.) heating systems, 95–108% efficiency, efficient heating distribution (fan coils etc.)	- natural gas or LNG central heating, HVAC system automation, efficient (low-temperature, condensation, heat pump etc.) heating systems, 95–108% efficiency, efficient heating distribution (fan coils etc.)
Non-residential public buildings***	- solid fuel (wood, coal) heating, 60–75% system efficiency, no heating distribution	- solid fuel, steam or fuel oil heating, inefficient systems with large losses – 60–75% system efficiency, predominantly with no heating distribution	- solid fuel, steam or fuel oil heating, gas and hot water network development – rising number of connected buildings, 60–75% system efficiency, central DHW generation and heating development	- solid fuel, steam or fuel oil heating, further gas and hot water network development, liquid fuel consumption still dominant, 65–90% system efficiency, heating distribution, central DHW generation	- solid fuel, steam or fuel oil heating, rapid gas network and consumer number increase with hot water and steam network expansion – uneven growth, liquid fuel consumption dominates, 80–95% system efficiency, heating distribution, central DHW generation	- natural gas or LNG heating, HVAC system automation, efficient heating (low-temperature, condensation, heat pump etc.) systems, 95–108% efficiency, efficient heating distribution (fan coils etc.)	- natural gas or LNG heating, HVAC system automation, efficient heating (low-temperature, condensation, heat pump etc.) systems, 95–108% efficiency, efficient heating distribution (fan coils etc.)
Non-residential commercial buildings**	- solid fuel (wood, coal) heating, 60–75% system efficiency, no heating distribution	- solid fuel, steam or fuel oil heating, inefficient systems with large losses – 60–75% system efficiency, predominantly with no heating distribution	- solid fuel, steam or fuel oil heating, gas and hot water network development – rising number of connected buildings, 60–75% system efficiency, central DHW generation and heating development	- solid fuel, steam or fuel oil heating, further gas and hot water network development, liquid fuel consumption still dominant, 65–90% system efficiency, heating distribution, central DHW generation	- solid fuel, steam or fuel oil heating, rapid gas network and consumer number increase with hot water and steam network expansion – uneven growth, liquid fuel consumption dominates, 80–95% system efficiency, heating distribution, central DHW generation	- natural gas or LNG heating, HVAC system automation, efficient heating (low-temperature, condensation, heat pump etc.) systems, 95–108% efficiency, efficient heating distribution (fan coils etc.)	- natural gas or LNG heating, HVAC system automation, efficient heating (low-temperature, condensation, heat pump etc.) systems, 95–108% efficiency, efficient heating distribution (fan coils etc.)

Building purpose	Coastal Croatia						
	prior to 1940	1941–1970	1971–1980	1981–1987	1988–2005	2006–2009	2010–2011
Apartment buildings*	- solid fuel (wood, coal) heating, 60–75% system efficiency, no heating distribution	- solid fuel, electrical and fuel oil heating, inefficient systems with large losses – 60–75% system efficiency, predominantly with no heating distribution	- solid fuel, electrical and fuel oil heating, gas, no gas or hot water network development, 60–75% system efficiency, central DHW generation and heating development	- solid fuel, electrical, LPG and fuel oil heating, gas, no gas or hot water network development, 65–90% system efficiency, heating distribution, central DHW generation	- solid fuel, electrical, LPG and fuel oil heating, gas, no gas or hot water network development, 80–95% system efficiency, heating distribution, central DHW generation	- electrical heating and cooling, LPG use, efficient (low-temperature, condensation, heat pump etc.) heating systems, 95–108% efficiency, efficient heating distribution (fan coils etc.)	- electrical heating and cooling, LPG use, efficient (low-temperature, condensation, heat pump etc.) heating systems, 95–108% efficiency, efficient heating distribution (fan coils etc.)
Family houses*	- solid fuel (wood, coal) heating, 60–75% system efficiency, no heating distribution	- solid fuel, electrical and fuel oil heating, inefficient systems with large losses – 60–75% system efficiency, predominantly with no heating distribution	- solid fuel, electrical and fuel oil heating, gas, no gas or hot water network development, 60–75% system efficiency, central DHW generation and heating development	- solid fuel, electrical, LPG and fuel oil heating, gas, no gas or hot water network development, 65–90% system efficiency, heating distribution, central DHW generation	- solid fuel, electrical, LPG and fuel oil heating, gas, no gas or hot water network development, 80–95% system efficiency, heating distribution, central DHW generation	- electrical heating and cooling, LPG use, efficient (low-temperature, condensation, heat pump etc.) heating systems, 95–108% efficiency, efficient heating distribution (fan coils etc.)	- electrical heating and cooling, LPG use, efficient (low-temperature, condensation, heat pump etc.) heating systems, 95–108% efficiency, efficient heating distribution (fan coils etc.)
Non-residential public buildings***	- solid fuel (wood, coal) heating, 60–75% system efficiency, no heating distribution	- solid fuel, electrical and fuel oil heating, inefficient systems with large losses – 60–75% system efficiency, predominantly with no heating distribution	- solid fuel, electrical and fuel oil heating, gas, no gas or hot water network development, 60–75% system efficiency, central DHW generation and heating development	- solid fuel, electrical, LPG and fuel oil heating, gas, no gas or hot water network development, 65–90% system efficiency, heating distribution, central DHW generation	- solid fuel, electrical, LPG and fuel oil heating, gas, no gas or hot water network development, 80–95% system efficiency, heating distribution, central DHW generation	- electrical heating and cooling, LPG use, HVAC system automation, efficient (low-temperature, condensation, heat pump etc.) heating systems, 95–108% efficiency, efficient heating distribution (fan coils etc.)	- electrical heating and cooling, LPG use, HVAC system automation, efficient (low-temperature, condensation, heat pump etc.) heating systems, 95–108% efficiency, efficient heating distribution (fan coils etc.)
Non-residential commercial buildings**	- solid fuel (wood, coal) heating, 60–75% system efficiency, no heating distribution	- solid fuel, electrical and fuel oil heating, inefficient systems with large losses – 60–75% system efficiency, predominantly with no heating distribution	- solid fuel, electrical and fuel oil heating, gas, no gas or hot water network development, 60–75% system efficiency, central DHW generation and heating development	- solid fuel, electrical, LPG and fuel oil heating, gas, no gas or hot water network development, 65–90% system efficiency, heating distribution, central DHW generation	- solid fuel, electrical, LPG and fuel oil heating, gas, no gas or hot water network development, 80–95% system efficiency, heating distribution, central DHW generation	- electrical heating and cooling, LPG use, HVAC system automation, efficient (low-temperature, condensation, heat pump etc.) heating systems, 95–108% efficiency, efficient heating distribution (fan coils etc.)	- electrical heating and cooling, LPG use, HVAC system automation, efficient (low-temperature, condensation, heat pump etc.) heating systems, 95–108% efficiency, efficient heating distribution (fan coils etc.)

The most important factors affecting the selection of heating systems are the following[52]:

- climate conditions(geographic location);
- location and type of building (residential, non-residential commercial, school etc.)
- daily regime of building use (24-hour, 8-hour etc.)
- availability of energy sources (electricity, fossil fuels, biomass and other renewable energy sources);
- investment and operating costs;
- laws, regulations, standards, recommendations;
- environmental impact.

Currently, there is a large selection of boilers on the market but, since fuel resources are limited, it is important to choose a heating system of maximum efficiency; their overview is given in the following table.

Table 2.21 Overview of various boilers and their efficiency[53]

Fuel	Type of device	Efficiency
Solid fuels	Heating and cooking stoves	60 to 75%
	Boilers – older makes	60 to 75%
	Boilers – newer makes	80 to 90%
	Various biomass-fired boilers	82 to 92 %
	Pellets	87 to 92 %
	Chips	85 to 90 %
	Combined boilers	70 to 78%
Liquid fuels	Combination boilers (solid fuel)	65 to 75 %
	Standard	85 to 90 %
	Low-temperature	90 to 95%
Gas fuels	Standard	92 to 95 %
	Low-temperature	95 to 98 %
	Condensation	up to 108%

Under Article 52 of the Technical regulation (NN Nos 110/08, 89/09), a study of the technical, environmental and economic feasibility of alternative energy supply systems is obligatory for every building larger than 1 000 m^2, particularly in decentralised supply systems using RES, cogeneration systems, heat pumps etc. Article 21 of the Construction Act (NN No 153/13) stipulates that the designer must draw up a study of alternative energy supply systems and submit it to the investor before completing design development of the building, which itself must comply with energy efficiency requirements.

Alternative systems within the meaning of this Article are:

- decentralised supply system based on RES;
- cogeneration;
- district heating and/or cooling, especially if it relies in whole or in part on energy from renewable sources;
- heat pumps.

Thanks to positive experiences and the fact that it is an optimal solution for both environmental and its energy efficiency reasons, district heating and/or cooling based on RES is the right course of future development of heating systems in the Croatian national building stock. Individual systems also using RES, such as biomass boilers and heat pumps, should be installed in the areas where the district heating and/or cooling is not practicable. Considering that large biomass energy potential, as well as the economic benefits arising from its exploitation, a greater use of biomass-fired district heating systems is in the national interest.

[52] Balen I., *Grijanje-kratka povijest, podjela sustava grijanja* [Heating: a short history, classification of heating systems]. Faculty of Mechanical Engineering and Naval Architecture, Zagreb

[53] Group of authors, *Priručnik za energetsko certificiranje zgrada* [Energy Certification Manual], UNDP, Zagreb, 2010.

3. Analysis of key elements of the building renovation programme

3.1 Technical options for energy renovation (retrofit) by implementing energy efficiency measures and renewable energy sources for each building category

For the purpose of energy renovation of buildings by implementing energy efficiency (EE) measures and renewable energy sources (RES), attention is devoted to buildings constructed prior to 1987 and their renovation aimed at achieving a low-energy standard and energy class B, A or A+. The said building stock was chosen owing to its greatest savings potential and a significant share in the total area of all buildings, and it complies with the objectives of building renovation measures described in the Third National Energy Efficiency Action Plan for the period through 2017. The implementation of EE and RES measures requires project documentation compliant with the relevant legislation. Another prerequisite for the implementation of these measures is a completed energy audit of the building, including an elaboration of recommended measures and establishment of the energy management system in the building.

Whenever a building is renovated, the prioritised energy efficiency measure is the retrofit of the external envelope of its heated space. The advantage of this measure, in addition to considerable savings resulting from it, is in frequent need for a re-dimensioning of technical systems (primarily heating and cooling systems) after its implementation because of reduced energy requirements. While no major modification of a building's architectural design is possible in the renovation, the following design options regarding the architectural details of the building need to be taken into account separately for each building when renovating it:

- for the purpose of preventing overheating of the indoor space in summer months, glass surface shading needs to be installed on the southern, eastern and western façade; mobile shading elements are recommended to provide invariability in solar gains in the winter, as well as maximising the use of daylight;
- for the purpose of ensuring maximum utilisation of solar gains in winter months, it is necessary to consider the possibility of opening large glass surfaces on southern (south-eastern, south-western) parts of the façade;
- for the purpose of reducing heat losses in winter months, it is necessary to consider reducing glass surfaces on the northern façade;
- for the purpose of eliminating heat losses (especially via thermal bridges), it is necessary to consider thermal protection of unprotected overhangs, penetrations etc.;
- with a view to utilising solar gains in winter months and preventing unwanted solar gains in summer months, it is recommended to consider appropriate positioning of deciduous trees along the southern (south-eastern and south-western) side of the building if the external space permits to function as shading in summer months without preventing insolation of the southern façade in winter months, while also preserving the existing specific building features, such as fire access road etc. It is necessary to form a wind break on all sides of the house, where possible;
- with a view to utilising daylight as much as possible, it is necessary to organise space optimally by installing interior partitions that reflect daylight and contribute to its distribution. Health and bacteriological functions of the building's optimal insolation are to be ensured in this manner. Windows located on opposite sides of the room ensure better dissemination of daylight due to reflection, while horizontal skylights present a source of daylight approximately three times more effective than vertical windows, with uniform lighting of the space an additional advantage;
- with a view to allowing natural ventilation, it is recommended to consider the possibility of constructing vertical ventilation ducts from individual rooms to the roof of the building, with the air supply through the opening in the wall or bottom of the door leaf and discharge from

the room through a hole under the ceiling connected to the ventilation duct; air changes in the rooms must be regulated by means of adjustable duct dampers, with mandatory recovery of heat or cooling energy.

In addition to all the activities listed above, this measure needs to comply with the maximum permitted thermal transmittance of structural parts.

The nZEB construction standard has as yet not been fully defined in Croatia. In some EU Member States, such as Austria or Ireland, the nZEB standard has been defined as a low energy building standard – B- or A-class buildings, covering their total thermal energy requirements for heating or a major part of it from renewable energy sources (biomass, geothermal or solar energy).

In accordance with Directive 2010/31/EU, in the period of public building renovation under the nZEB standard starting from 1 January 2019, and in the period of renovation of all other categories of buildings starting from 1 January 2021, in addition to the previously described measure of retrofitting the external envelope of the heated building space, it is necessary to implement measures to increase EE and install RES listed below.

3.1.1 Measure of heating system centralisation and modernisation by applying renewable energy sources

The measure involves a centralisation of heating systems and a modernisation of existing boiler rooms by replacing them with boilers fuelled by biomass (pyrolysis, pellets etc.) or, where that is not feasible owing to no space for a biomass container in addition to the existing connection to natural gas, with low-temperature condensing boilers fuelled by natural gas, to be used with existing radiator systems. If the building's total energy requirements are small, and the system is suitable for low-temperature heating operation with pronounced cooling requirements, it is recommended to apply geothermal or air heat pump for heating, cooling and additional DHW generation.
For the purpose of defining the most appropriate heating system, it is necessary to consider the following options for each building separately:

- separate (independent) boiler system;
- district heating system – biomass-fired boiler system – chips (contract sale of heat model).

In the case of separate boiler systems, the boiler room is situated within the building at the current location. In the case of district heating system, the boiler room does not need to be situated within the building, but may be part of other facilities connected to the pipeline system. In such case, it is necessary to provide a substation for thermal energy transmission from the district heating to the facility. This measure involves the heating system regulation and balancing (thermostat sets, differential pressure controllers, frequently operated pumps etc.), as well as performing thorough cleaning of the pipeline radiator system and all exchangers. The need for chimney renovation should also be considered for each building separately. When implementing this measure, it is necessary to highlight potential existing barriers in terms of differences among certain Croatian regions (counties) with regard to available biomass quantities and the possibility of its transport which, taking this into account, may result in differences in biomass prices. In addition, there are some barriers in terms of the level of gas supply system development, as well as modest potential for the development of central heating systems in the areas with modest heating requirements, so due attention needs to be paid to them when implementing this measure.

3.1.2 Measure of cooling and ventilation system centralisation and modernisation by applying renewable energy sources

The measure provides for centralisation of the cooling system by using heat pump systems for cooling space. In case of sufficient natural ventilation, it should be noted that brief ventilation through fully-opened windows or balcony doors (e.g. at regular intervals, 5 to 10 minutes every hour) is better than continuous ventilation through half-open door or window leaves, especially in terms of protection against colds, as well as in terms of thermal energy savings for heating and cooling. In case of natural ventilation through vertical ducts, it is necessary to ensure constant supply of fresh air in appropriate amounts and the possibility of regulating air changes in rooms by means of adjustable duct dampers, with mandatory heat or cooling energy recovery.

Where more air changes are necessary (more users or risk of moisture condensation), a local pressure/exhaust ventilation system with the recovery option needs to be planned in certain rooms (corridors and waiting rooms). Automatic ventilation control is preferred, among other things, to allow for air changes at night during the summer (ambient air temperature is lower than the air temperature in the building), resulting in a room-cooling effect. Ventilation devices must meet the requirements set out in Table 3 of Annex C to the *Technical regulation.*

3.1.3 Measure of DHW generation system centralisation and modernisation by applying renewable energy sources

The measure provides for DHW generation in each building via primary and secondary energy sources. Throughout the year, especially in winter months, domestic hot water needs to be generated by using the boiler heating system, representing a *primary source* of thermal energy. The solar collector system or a *secondary source* of thermal energy needs to be envisaged and optimally dimensioned so that all hot water requirements in the period between June and September may be supplied from the solar collector system. This avoids the need for boiler operation to prepare small amounts of hot water while there is no need for heating, thus increasing the annual efficiency and boiler service life. When implementing this measure, attention needs to be paid to the actual DHW requirements, depending on the primary function of the facility.

3.1.4 Lighting system modernisation measure

The measure involving the lighting system modernisation for the purpose of improving lighting comfort of the user must necessarily involve consideration of how to make better use of natural (day) lighting, as a preparatory action. For optimal utilisation of natural lighting, it is necessary to consider reorganising space and installing internal partitions that reflect daylight and contribute to its distribution.

Technical characteristics of proposed light technology solutions for the internal lighting in the building must comply with the HRN EN 12464-1:2008 standard, energy class A, with EU's RoHS guidelines 2002/95/EC (restriction of the use of certain hazardous substances in electrical and electronic equipment), the EE guidelines 2005/32/EC (guidelines for establishing a framework for the eco-design of energy-using products), and 2000/55/EC guidelines (guidelines for electronic ballasts). The recommended light sources are T5 fluorescent tubes or CF (energy saving) light bulbs, as well as high energy efficiency LED light sources (min. 75 lm/W), light source colour (4000K or lower) and colour rendering index (CRI) of 85 or higher. Technical characteristics of proposed light technology solutions for the external lighting must also comply with the HRN EN 13201 standard, as well as the *Protection against Light Pollution Act (NN No 114/11).* The recommended light sources are high-pressure sodium (HPS) and LED light sources of high energy efficiency (75 lm/W at minimum) and light source colour (4000K or lower). In addition, light source power needs to be controlled to allow for energy savings and a decrease in light pollution in late-night hours.

3.1.5 Water consumption reduction measure

In order to reduce water consumption, sensor taps and cisterns with a reduced flush volume need to be planned. For the purpose of rain water (rainfall) storage and its use for maintaining grassy areas around the building, it is necessary to envisage rainfall collection container. Where possible, it is recommended to take advantage of the natural slope of the terrain, if any.

3.1.6 Central control and management system installation measure

The measure involves a central control and management system installation to provide for remote reading of the consumption of all energy and water. It is necessary to plan and carry out cabling of all meter points (for electricity, water, gas etc.) and install metering units with pulse output. The installation of a Central Control and Management System (CCMS) allows the operation of the boiler, temperatures in rooms, internal and external lighting, irrigation system and other relevant parameters of energy efficiency to be controlled from a single place. It is necessary to ensure a minimum class C automation and management system under the HRN EN 15232 standard.

3.1.7 Other energy efficiency and renewable energy source measures

With regard to the electricity consumption, it is necessary to install a waste energy compensation device, in accordance with electricity consumption parameters (especially with regard to the lighting system and the cooling system, if planned to be installed). Also, it is recommended to examine the possibility of utilising the roof surface to mount photovoltaic modules for electricity generation.

3.2 Technical possibilities for district heating system (DHS) heating

District heating systems (DHS) or centralised heating systems exist in a large number of cities and larger towns in Croatia, namely: Zagreb, Osijek, Sisak, Velika Gorica, Karlovac, Zaprešić, Samobor, Slavonski Brod, Split, Varaždin, Rijeka, Virovitica, Vinkovci, Vukovar and Požega.

The section below provides an overview of the current central heating supply for the following seven Croatian towns and cities: Zagreb, Osijek, Sisak, Velika Gorica, Karlovac, Zaprešić and Samobor.

In the City of Zagreb, the activities of thermal energy generation, distribution and supply of households and business premises are performed by *HEP-Toplinarstvo d.o.o.* [Ltd], a company which is a member of the HEP Group. The *HEP-Toplinarstvo d.o.o.* heating system consists of a district heating system supplying consumers through a hot water and steam pipeline network, district boiler rooms and heating stations in consumers' facilities. The sources in which thermal energy for customers connected to the DHS of the City of Zagreb is generated together with electricity in cogeneration are thermal power plant and heating plant *Termoelektrana Toplana* (TE-TO), and electricity and heating plant *Elektrana Toplana* (EL-TO). The thermal power and heating plant (TE-TO), with 440 MWe / 850 MWt total power, uses natural gas, extra light fuel oil and heavy fuel oil to generate electricity and thermal energy in a cogeneration process. The electricity and heating plant (EL-TO), with 88.8 MWe / 439 MWt total power, uses natural gas and heavy fuel oil to generate electricity and thermal in cogeneration process. In the City of Zagreb, 89 996 thermal energy customers are supplied through the DHS of *HEP-Toplinarstvo d.o.o*. The total heated area of households connected to the district heating system of the City of Zagreb is 4 731 381 m^2, and their total leased power is 600.33 MWt. In the course of 2011, *HEP-Toplinarstvo d.o.o.* delivered a total of 1 013 121 MWh of thermal energy to household customers connected to the DHS of the City of Zagreb. District heating plants and separate boiler rooms in the City of Zagreb supply thermal energy to 7 031 household customers in 96 residential buildings. The total heated area of households connected to the district heating plants of the City of Zagreb is 362 690 m^2, and their total leased power is 51.32 MW. In the course of 2011, *HEP-Toplinarstvo d.o.o.* delivered a total of 72 995 MWh of thermal energy to household customers connected to the DHS network of the City of Zagreb.[54]

In the town of Velika Gorica the activities of thermal energy generation, distribution and supply of households and business premises are performed by *HEP-Toplinarstvo d.o.o.* The town's heating system consists of district boiler rooms, hot water network and heating stations. *HEP-Toplinarstvo d.o.o.* generates, transmits and distributes thermal energy to the customers from district heating plants and separate boiler rooms. The total number of district heating plants in Velika Gorica is 14, and their total installed power 69.61 MW. The total number of household customers supplied with thermal energy from district heating plants in Velika Gorica is 5 650, in 94 residential buildings with a total heated area of 281 853 m^2, and their total leased power is 39.15 MW. In the course of 2011, *HEP-Toplinarstvo d.o.o.* delivered a total of 59 844 MWh of thermal energy to household customers in Velika Gorica. In addition to household customers, 239 commercial thermal energy customers are also connected to district heating plants in Velika Gorica. The total leased power of these business premises is 7.39 MW, and *HEP-Toplinarstvo d.o.o.* delivered a total of 8 635 MWh of thermal energy to them in 2011.[55]

In the town of Karlovac, the activities of thermal energy generation, distribution and supply of households and business premises are performed by *Toplana d.o.o.* Karlovac. *Švarča,* a separate 1.4 MW boiler room situated at Baščinska Cesta 41, operates as part of the *Toplana* company and it

[54] North-West Croatia Regional Energy Agency (2012), *Analysis of potential use of heat manifold for residential buildings in the City of Zagreb*

[55] North-West Croatia Regional Energy Agency (2012),*Analysis of potential use of heat manifold for residential buildings in the town of Velika Gorica*

supplies thermal energy to 131 residential units. The *Toplana* boiler room includes three hot water boilers (all manufactured by TPK Zagreb), with a total power of 116 MW, which currently more than suffices to supply the existing number of customers, so no more than some 85 MW of the capacity is used at the moment. The boiler types are 29 MW VKLM-25 (2 boilers) and 58 MW VKLM-50 (one boiler). The calculated utilisation level of the boiler plant is 90%. In 2006, the VKLM-50 boiler was gasified, so it can now use both fuels (natural gas and fuel oil). The two smaller boilers can only use fuel oil (MFO). The distribution system of *Toplana* consists of 42.4 km-long hot water pipeline, through which thermal energy customers are supplied. Certain network sections are more than 30 years old, urgently requiring complete replacement. In general, it may be concluded that the general condition of the hot water network is bad, so 3–5 km of the hot water pipeline should be replaced every year over the following 5–8 years. *Toplana* Karlovac currently supplies 8 060 users. Households, i.e. 7 567 flats in Karlovac and 131 at the separate location in Švarča, account for 77% of that number. The total area of flats connected to *Toplana* is 408 438 m^2. The rest of consumers are business entities using joint or separate meters, currently numbering 362. The total heated area of the business premises is 123 757 m^2. [56]

Heating systems in the city of Osijek consist of a central steam and hot water pipeline system, and two closed systems, namely, two block boiler rooms in Jug III and Vijenac V settlements. The existing steam pipeline system supplies steam mostly to factories in the eastern industrial zone (Pivovara, Tvornica Šećera, Žito, Meggle, Karolina, Saponia factories), as well as electricity distributor *Elektroslavonija – Pogon za pomoćne djelatnosti* and the Osijek Clinical Hospital Centre. The hot water pipeline system is used for heating of households and commercial consumers – pre-school and school institutions, faculties, dormitories and old people's homes, shops, hotels, banks, city institutions etc. (no hot water generation available on the hot water pipeline system). Currently, there are several energy units at the existing location of the TE-TO, which have been built in phases. Inside the block there is also a hot water station for the city's heating requirements; it has two hot water heaters with 2 x 45 MW in capacity, to heat water from the fourth (regulated) steam deduction with 1.5 bar pressure and one 49 MW heater with 4-bar steam pressure. In 2012, the Osijek TE-TO generated 188 468 MWh of heat transmitted to the hot water network, and 139 711 tonnes (recalculated as 111 182 MWh) of technological steam for the steam pipeline system. The central hot water system supplies 10 080 household consumers with a total heated area of 582 812 m^{2}and total contracted thermal power of 85.55 MW. Block boiler rooms supply 334 households using thermal energy for room heating (total heated area of 17 106 m^2 and thermal power of 2.15 MW) and 750 households using thermal energy for DHW generation (thermal power of 1.353 MW). The central hot water system supplies a total of 72.29 MW contracted thermal energy to 1 272 commercial consumers (entrepreneurship category).[57]

Thermal energy for the DHS of the town of Sisak is generated at the auxiliary steam boiler room of the Sisak thermal power plant and, as an intervention measure if necessary, at the steam boiler room located at the *HEP-Toplinarstvo* power plant in Caprag. The thermal energy from both these generation facilities is transferred to the main heating stations through steam, using several major steam lines. In its auxiliary steam boiler room, the Sisak thermal power plant has two steam boilers with the capacity of 60 t/h of 300 °C, 16 bar-superheated steam, installed for the purpose of the Sisak DHS. Both boilers are of TPK BKG–300 type, manufactured in 1990, and use natural gas and heavy fuel oil as fuel. On 31 December 2012, the Sisak branch of *HEP Toplinarstvo d.o.o.* supplied a total of 4 136 consumers. Households, i.e. 4 057 flats with a total area of 230 103 m2 account for over 78% of this number. The total installed power at households is 31.17 MW, while the average annual energy consumption is 50 775 MWh. In addition to household customers, 82 commercial

[56] North-West Croatia Regional Energy Agency (2012), *Analysis of potential use of heat manifold for residential buildings in the town of Karlovac*

[57] North-West Croatia Regional Energy Agency (2013), *Analysis of potential use of heat manifold for residential buildings in the city of Osijek*

thermal energy customers are also connected to the DHS system. The total leased power of business premises is 8.49 MW, and *HEP-Toplinarstvo d.o.o.* delivered a total of 10 703 MWh of thermal energy to them in 2012.[58]

In the town of Zaprešić, the activities of thermal energy generation, distribution and supply of households and business premises are performed by *HEP-Toplinarstvo d.o.o.* The heating system consists of district boiler rooms, hot water network and heating stations. In Zaprešić, thermal energy is generated at 8 separate boiler rooms with a total installed power of 20.36 MW. These plants use natural gas, light fuel oil and extra light fuel oil for heat generation. In Zaprešić, district heating plants supply thermal energy to 2 280 household customers with a total heated area of 102 607m^2, and their total leased power is 14.26 MW. In the course of 2011, *HEP-Toplinarstvo d.o.o.* delivered a total of 20 062 MWh of thermal energy. All household customers are connected to a joint heat meter. The heating system of *HEP Toplinarstvo d.o.o.* in Zaprešić supplies 89 commercial customers. The total leased power of these business premises is 0.81 MW, and *HEP-Toplinarstvo d.o.o.* delivered a total of 764 MWh of thermal energy in 2011.[59]

In the town of Samobor, the activities of thermal energy generation, distribution and supply of households and business premises are performed by *HEP-Toplinarstvo d.o.o.* The heating system consists of district boiler rooms, a hot water network and heating stations. In Samobor, thermal energy is generated at 4 separate boiler rooms with a total installed power of 18.75 MW. These plants use natural gas, light fuel oil and extra light fuel oil for heat generation. In Samobor, district heating plants supply thermal energy to 1 352 household customers, with a total heated area of 66 739m^2, and their total leased power is 9.06 MW. In the course of 2011, *HEP-Toplinarstvo d.o.o.* delivered a total of 14 185 MWh of thermal energy. Out of the household category, 1 350 customers are connected to a joint heat meter, while two have separate meters. The total area of housing units with separate heat meters is 299m^2. The heating system of *HEP Toplinarstvo d.o.o.* in Samobor supplies 26 commercial customers. The total leased power of these business premises is 1.95 MW, and *HEP-Toplinarstvo d.o.o.* delivered a total of 1 544 MWh of thermal energy in 2011.[60]

Duties and responsibilities of thermal energy distributors and network customers, including the procedures of thermal energy approval issuing, connection requirements, delivery and supply of thermal energy and the use of the distribution system, metering and calculation terms and other conditions are laid down in the General Terms and Conditions of Thermal Energy Supply (NN No 129/06)[61].

It should be noted that, pursuant to the new Thermal Energy Market Act (NN Nos 80/13, 14/14)[62], *Narodne Novine* also published the following documents, which define the above terms and conditions:

- General Terms and Conditions of Thermal Energy Supply (NN No 35/14)[63], entering into force on 1 September 2014. This regulation governs relations between thermal energy producers, distributors and suppliers, duties and responsibilities of thermal energy producers, distributors and suppliers, as well as the criteria of thermal energy supply

[58] North-West Croatia Regional Energy Agency (2013), *Analysis of potential use of heat manifold for residential buildings in the town of Sisak*

North-West Croatia Regional Energy Agency (2012), *Analysis of potential use of heat manifold for residential buildings in the town of Zaprešić*

[60] North-West Croatia Regional Energy Agency (2012), *Analysis of potential use of heat manifold for residential buildings in the town of Samobor*

[61] General Terms and Conditions of Thermal Energy Supply (NN No 129/06). Available at: http://narodne-novine.nn.r/clanci/sluzbeni/128597.tml

[62] Thermal Energy Market Act (NN Nos 80/13, 14/14). Available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2013 06 80 1655.html

[63] General Terms and Conditions of Thermal Energy Supply (NN No 35/14). Available at: http://narodne- novine.nn.hr/clanci/sluzbeni/2014 03 35 628.html

quality and safety, criteria of thermal energy supply restrictions and suspension, criteria governing the accounting and collection of thermal energy charges, the procedure of switching between thermal energy suppliers, measures to protect end customers and legal protection.

- General Terms and Conditions of Thermal Energy Delivery (NN No 35/14)[64], entering into force on 1 September 2014. This regulation governs relations between thermal energy suppliers and thermal energy customers, relations between thermal energy customers and end customers, duties and responsibilities of thermal energy suppliers and thermal energy customers, duties and responsibilities of thermal energy customers and end customers, criteria governing the accounting and collection of thermal energy charges, criteria of restrictions and suspension of thermal energy deliveries, investment, reconstruction and maintenance of generation facilities and internal installations, access to heat meters and connection installations, procedure in the event of unauthorised use of thermal energy, procedure in the event of technical and other disruptions in thermal energy supply, procedure in the event of thermal energy redistribution to the end customer, procedure in the event that an entire building is disconnected from the heating system, measures to protect end customers, the procedure of thermal energy customer change, manner of informing end customers about thermal energy consumption and cost, thermal energy customers' obligation to inform end customers of each change in the final price of thermal energy, the right to access consumption data, including the right to forward data to another thermal energy customer and the conditions thereof, as well as legal protection.
- Network Rules of Thermal Energy Distribution (NN No 35/14)[65], (hereinafter: the Network Rules), entering into force on 1 September 2014. This regulation governs the distribution network description, development, construction and maintenance, the management and supervision of the distribution network, conditions of connecting to the distribution network, the connection construction and connecting to the distribution network, the rights and duties of thermal energy distributors and distribution network users, metering criteria in respect of delivered heat, the publication of data and exchange of information, the quality of service and safety of thermal energy supply, measures to protect distribution network users, unauthorised use of thermal energy, indemnification and legal protection. In addition, the Network Rules stipulate that they are to be adhered to by the investor in or owner of a building to be connected to the distribution network, thermal energy consumer, end customer connected to the distribution network, thermal energy suppliers, distributors and producers.

In view of the above, technical possibilities and requirements for connecting a building to the central heating system are described in detail in the Network Rules, but there is no difference in the technical possibilities and requirements depending on the building categories considered within the scope of this Strategy.

In accordance with Art. 17 of the Network Rules, Preliminary thermal energy approval establishes the possibility and requirements of connection of the building to the distribution network, technical requirements for the connection and terms of use of the distribution network. In addition, it is noted that the Preliminary thermal energy approval is issued at the request of the building investor or a third party authorised by the building investor/owner, and prior to the drafting of the main project of the building or the main project of mechanical installations and heating substation.

[64] General Terms and Conditions of Thermal Energy Delivery (NN No 35/14). Available at: http://narodne-novine.nn.r/clanci/sluzbeni/2014 03 35 629.html

[65] Network Rules of Thermal Energy Distribution (NN No 35/14). Available at: http://narodne- novine.nn.hr/clanci/sluzbeni/2014 03 35 630.html

In accordance with Art. 18 of the Network Rules, the Preliminary thermal energy approval contains:

- information on the building investor/owner,
- name, type, address and the number of cadastral unit of the building to be connected to the distribution network,
- point of connection of the building to the distribution network,
- planned connected load,
- estimated economic requirements for the connection of the building to the distribution network,
- connection construction method,
- tariff group, tariff model and the consumption purpose,
- parameters of the distribution network to which the building is to be connected,
- technical requirements for meter points,
- terms of use of the distribution network,
- validity period,
- terms of expiry,
- instruction on the right to appeal.

In accordance with Art. 22 of the Network Rules, after obtaining the Preliminary thermal energy approval, any of the concerned parties may request to enter into a preliminary agreement on the connection to the distribution network, while Article 23 stipulates that the Thermal energy approval is issued at the request of the building investor or a third party authorised by the building investor/owner, after concluding an agreement on the connection, and prior to entering into an agreement on the thermal energy supply to the customer, or agreement on the thermal energy supply.

In accordance with Art. 24 of the Network Rules, a Thermal energy approval includes:

- information on the building investor/owner,
- name, type, address and number of the cadastral unit of the building to be connected to the distribution network,
- number of the Preliminary thermal energy approval,
- building permit number and the date of its issuance,
- project number and the designer's name,
- connected load,
- tariff group, tariff model and consumption purpose,
- technical data for meter points,
- terms of expiry,
- instruction on the right to appeal.

Furthermore, under the provisions of Article 25, a thermal energy customer must notify the thermal energy distributor and supplier of planned changes to be made on internal installations, concerning any:

- change in connected load;
- change on the connection;
- merger of several meter points into a single one in the same location;
- division of a single meter point to several meter points in the same location;
- change in tariff group and tariff model at the meter point.

Article 26 of the Network Rules stipulates that, in the event of building renovation by which the thermal energy requirement for heating is reduced, making the building is more energy efficient, the thermal energy customer has the right to require a reduction in connected load at the meter point, as well as the issuance of a new Thermal energy approval by the distributor.

It also needs to be emphasised that Article 7 of the Energy Act (NN Nos 120/12, 14/14)[66]stipulates an obligation of local self-government and local (regional) government units to plan the needs and the method of energy supply in their development documents, and harmonise such documents with the Energy Development Strategy and the Energy Development Strategy Implementation Programme. This obligation also includes planning of district heating system development.

Systems using a centralised thermal supply have certain advantages over separate heat generation systems, including the exploitation of waste heat from cogeneration plants (which significantly increases the overall efficiency of such plants compared to the case in which waste heat is not used) and possible interpolation to other systems (waste management, exploitation of waste heat from industry etc.). In the event that renewable energy sources (primarily biomass energy) are used in the DHS, when setting the optimum plant variant in terms of thermal energy generation only (heating plant) or thermal energy and electricity cogeneration, it is necessary to consider limitations related to energy efficiency laid down in the Tariff system for electricity generation from renewable energy sources and cogeneration (NN No 133/13)[67]. If a biomass-fired cogeneration plant is built, the financial effectiveness of the investment increases by a great number of peak hours a year and these values, typically, range from 6 000 up. However, thermal energy requirements of buildings do not depend solely on the energy performance of buildings, but also on climate characteristics, namely, the number of heating degree days. In continental Croatia, typical amounts of heat generation system peak working hours a year range between 1 500 and 2 000 in well-planned systems (in the sense that they are not overly large). Taking into account what has been stated above, in case of DHS heat generation from biomass-fired cogeneration plants, around a maximum of 30% of the generated thermal energy would be used for buildings' heating requirements, so the overall energy efficiency of such plants (defined according to the Tariff system for electricity generation from renewable energy sources and cogeneration (NN No 133/13) , as well as the efficiency of the fuel primary energy conversion into generated electricity and useful generated heat) would range from 50% down. Considerably higher efficiency of up to 80% is achieved in the event that thermal energy from biomass-fired cogeneration plants is used within industrial plants (such as wood-processing industry), which have thermal energy requirements throughout the year, so the peak number of working hours is typically 6 000 or higher.

It needs to be pointed out that, when planning the connection of existing buildings to existing or future DHS, it is necessary to consider possible hindrances, primarily the fact that a certain number of building has no internal or central heating installations (all buildings with storey-based heating systems). Connecting such buildings to DHS requires significantly higher financial resources than the buildings heated, for example, from joint separate boiler room with central heating installations. The said problem needs to be examined in more detail when analysing the possibilities of connecting each individual building to the DHS.

3.3 Possible sustainable building renovation models

For the purpose of selecting the optimum renovation model for each building category, in accordance with cost-effectiveness of EE and RES measures and in view of currently applicable technical and financial parameters, the following models of sustainable building renovation have been considered:

- retrofit of the external heated space envelope under the *Technical Regulation;*
- retrofit of the external heated space envelope under the *Technical Regulation Proposal;*
- integral building renovation to the nZEB standard;

[66] Energy Act (NN Nos 120/12, 14/14). Available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2012 10 120 2583.html

[67] Tariff system for electricity generation from renewable energy sources and cogeneration (NN No 133/13). Available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2013 11 133 2888.html

- integral building renovation to the passive house standard;
- integral building renovation to the active house standard;

Since all the five listed models include retrofitting the external heated space envelope, target heat transmittance coefficients of various envelope elements included in the said renovation models are shown below (Table 3.1).

Table 3.1 Overview of target thermal transmittance coefficients of structural building elements in possible sustainable building renovation models

Thermal transmittance coefficient of the structural element [W/(m^{2}K)]	**Technical Regulation***		**Technical Regulation Proposal/nZEB****		**Passive house/active house*****
	Continental Croatia	**Coastal Croatia**	**Continental Croatia**	**Coastal Croatia**	**Continental and coastal Croatia**
External walls, walls bordering garage or attic	0.45	0.60	0.30	0.45	0.13
Windows, balcony doors, skylights, transparent elements of the building envelope	1.80	1.80	1.40	1.80	0.80
Flat and inclined roofs above heated space, ceilings bordering attic	0.30	0.40	0.25	0.30	0.10
Ceilings above outdoor space, ceilings above garage	0.30	0.40	0.25	0.30	0.10
Walls bordering ground, floors on	0.50	0.50	0.30	0.50	0.15
Ceilings and walls between flats or between various heated separate parts of buildings (business premises etc.)	1.40	1.40	0.60	0.80	0.15

Source: **Technical Regulation, **Technical Regulation Proposal, ***ISOVER Saint-Gobain Planner – catalogues and brochures, passive house standard*

In view of technical possibilities of implementing various EE and RES measures for each building category shown in the previous chapter, an outline of the measure package scope for the five proposed models of sustainable renovation for each of the four building categories is provided below (Table 3.2 and Annex 1). It is necessary to point out that there are differences in the parameters of identical measures applicable to a certain renovation level to achieve energy and cost savings in percentage terms, as well as specific investment amount.

Table 3.2 EE and RES measures in respect of building categories to be considered for possible building renovation models

	Measure number													
Building category	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Public buildings														
Retrofit of the external heated space envelope under the *Technical Regulation*	x	x	x	x	x									
Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	x	x	x	x	x									
Building renovation to the nZEB standard	x	x	x	x	x		x	x	x	x	x	x	x	
Building renovation to the passive house standard	x	x	x	x	x	x	x	x	x	x	x	x	x	
Building renovation to the active house standard	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Commercial buildings														
Retrofit of the external heated space envelope under the *Technical Regulation*	x	x	x	x	x									
Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	x	x	x	x	x									
Building renovation to the nZEB standard	x	x	x	x	x		x	x	x	x	x	x	x	
Building renovation to the passive house standard	x	x	x	x	x	x	x	x	x	x	x	x	x	
Building renovation to the active house standard	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Apartment buildings														
Retrofit of the external heated space envelope under the *Technical Regulation*	x	x	x	x	x									
Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	x	x	x	x	x									
Building renovation to the nZEB standard	x	x	x	x	x		x	x						
Building renovation to the passive house standard	x	x	x	x	x	x	x	x						
Building renovation to the active house standard	x	x	x	x	x	x	x	x						
Family houses														
Retrofit of the external heated space envelope under the *Technical Regulation*	x	x	x	x	x									
Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	x	x	x	x	x									
Building renovation to the nZEB standard	x	x	x	x	x		x	x	x	x	x			
Building renovation to the passive house standard	x	x	x	x	x	x	x	x	x	x	x			
Building renovation to the active house standard	x	x	x	x	x	x	x	x	x	x	x			x
Measure 0: Energy audit of the building and establishment of systematic energy management														
Measure 1: Outer window and door frame replacement														
Measure 2: Thermal insulation retrofitting to external walls														
Measure 3: Thermal insulation retrofitting to the roof/ceiling bordering unheated attic														
Measure 4: Thermal insulation retrofitting to the ceiling bordering unheated basement (if any)														
Measure 5: Thermal insulation retrofitting to the floor on ground level														
Measure 6: Heating system centralisation and modernisation by applying RES, if possible														
Measure 7: Cooling and ventilation system centralisation and modernisation by applying RES														
Measure 8: DHW system centralisation and modernisation by applying RES														
Measure 9: Lighting system modernisation														
Measure 10: Water consumption reduction														
Measure 11: Central control and management system installation														
Measure 12: Installation of waste energy compensation devices														
Measure 13: Installation of photovoltaic modules for RES electricity generation														

Source: *REGEA,* 2014

3.4 Identification of a cost-effective approach to renovation, depending on building category and climate zone

With regard to the total area, condition of the heated space envelope and energy requirements, a group of buildings constructed prior to 1987 has been selected as the target building group. The measure of retrofitting the external heated space envelope of buildings is to be applied under the Technical Regulation Proposal in the period of renovation up to 2018 in respect of public buildings and up to 2020 in respect of all other buildings, while the requirements of the Directive 2010/31/EU will need to be met by implementing an integrated energy renovation to the nZEB standard after 2018 in respect of public buildings and after 2020 in respect of all other buildings. With regard to the obligations laid down in Directive 2010/31/EU, measures or measure packages to meet the energy saving targets referred to in the 2nd NEEAP are specified for two renovation periods:

- Renovation period up to 2018 in respect of public buildings, and up to 2020 in respect of all other buildings;
- Renovation period after 2018 in respect of public buildings, and after 2020 in respect of all other buildings;

The reason for the scope of measures not being identical for all building categories lies in differences among measure effectiveness in certain building categories, depending on the estimated fuel spending and regime of individual technical system use. Input parameters for identifying a cost-effective approach to the renovation of each building category are the specific amounts of energy and cost savings per m^2 of the building area, and are shown separately for buildings in continental and coastal Croatia in the tables below (Table 3.3 and Table 3.4). These input parameters have been calculated with regard to initial assumption provided in Chapter 2 (Table 2.1, Table 2.2, Table 2.3, Table 2.4, Table 2.9, Table 2.10, Table 2.11, Table 2.12, Table 2.13, Table 2.20 and Table 2.21).

The amounts of investment into energy renovation have been calculated from available cost specifications of the projects implemented by the North-West Croatia Regional Energy Agency for the past five years; for the purpose of drafting the Strategy, they have been reduced to the area of buildings under renovation (investment amount in HRK divided by m^2 of the building area)[68]. VAT is not included in the investment amounts. In the case of renovation under the *Technical Regulation,* the cost of investment in retrofitting an envelope of heated space is HRK 860.00/m^2, while in the case of an envelope retrofit under the *Technical Regulation Proposal* it stands at HRK 1 000.00/m^2 (in the case of passive/active house, it is HRK 1 750.00/m^2). For the renovation period after 2020, the overall investment cost into the energy renovation of individual buildings grows because, in addition to retrofitting the external heated space envelope, the renovation also includes replacing inefficient technical systems with more efficient ones and, where possible, with the systems using renewable energy sources. The investment cost of heating system replacement by new ones, presuming the replacement of 70% of the existing systems with gas systems and 30% of the existing systems with biomass-fired boilers, along with system balancing and installation of thermostat sets on radiator units, is HRK 157.00/m^2. The investment cost of cooling system centralisation and new cooling system installation using a heat pump stands at HRK 210.00/m^2 (in the case of passive/active house, it is HRK 350.00/m^2). The installation of solar collector systems for DHW generation is a measure with a cost investment amounting to HRK 95.70/m^2, while the replacement of existing lighting systems with more efficient ones is an EE measure with a cost investment of HRK 135/m^2 of the building area.

[68] North-West Croatia Regional Energy Agency (2013), *Project Guidelines for Sustainable Building,* Zagreb; City Office for Energy, Environment Protection and Sustainable Development of the City of Zagreb and North-West Croatia Regional Energy Agency (2013), *Zagreb – Energy Efficient City Project,* Zagreb; North-West Croatia Regional Energy Agency (2013), *Report on the Energy Audit of the Dubovac Primary School Building in Karlovac;* North-West Croatia Regional Energy Agency (2013), *Report on the Energy Audit of the Karlovac Hostel Building,* Karlovac; North-West Croatia Regional Energy Agency (2013), *Analysis of the internal lighting system in the Velika Gorica Grammar School building,* Zagreb, North-West Croatia Regional Energy Agency (2013), *City of Zagreb Energy Sustainable Development Action Plan,* Zagreb

Financial savings have been calculated in accordance with the percentage distribution of fuels and energy sources in direct consumption for each building category[69] and their respective prices in December 2013[70]. VAT is not included in the amounts of financial savings.
The specific amount of total costs has been discussed as a basic parameter in the comparison of various building renovation models, depending on the climate zone (Annex 2, Annex 4, Annex 6, Annex 8, Annex 10, Annex 12, Annex 14 and Annex 16) and used as a basis for a chart, drawn for each building category to illustrate global cost dependence on the primary energy level after renovation according to a certain renovation model (Annex 3, Annex 5, Annex 7, Annex 9, Annex 11, Annex 13, Annex 15 and Annex 17). Total costs include initial investment costs, energy costs, taking into account the rise in energy source prices at an annual level[71]. From each of the presented graphs it may be concluded which of the five proposed renovation models is currently the most cost-effective (minimum total costs) and which level of primary energy is achieved with the said model. The parameters also depend on the calculation period, so a graph showing a 30-, 50-, and 70-year calculation period has been provided for each building category for the purpose of comparing the impact of input parameters.

Based on the presented graphs, the active house model is found to be the most cost-effective; however, it also includes the procedure of acquiring the status of preferential RES and cogeneration producer. The key stakeholder in this is the Croatian Energy Market Operator (Cr. abbreviation: HROTE)[72], which enters into an Agreement with a potential preferential energy producer with regard to the permitted installed capacity for generation from such energy sources to be connected to the network at an annual level. In view of the above, the said active house model may only be selected for a small portion of buildings.

[69] International Energy Agency (2013), Online Report for Croatia [online]. Available at: http://www.iea.org/statistics/statisticssearc/report/?&country=CROATIA&year=2011&product=Balances [31. prosinca, 2013.]

[70] Narodne Novine (2008), Decision on tariff item amounts in the Tariff system for heat generation, distribution and supply activities, Zagreb: Narodne Novine d.d., 2008 (154);

[70] Narodne Novine (2012) *Decision on tariff item amounts in the Tariff system for electricity supply, with the exception of preferential customers, without tariff item amounts*, Zagreb: Narodne Novine d.d., 2012 (49);

[70] Narodne Novine (2012) *Decision on tariff item amounts in the Tariff system for electricity distribution, without tariff item amounts,* Zagreb: Narodne Novine d.d., 2012 (49);

[70] Narodne Novine (2012), *Decision on tariff item amounts in the Tariff system for electricity transmission, without tariff item amounts,* Zagreb: Narodne Novine d.d., 2012 (49);

[70] Narodne Novine (2012), *Decision on tariff item amounts in the Tariff system for natural gas supply, with the exception ofpreferential customers, without tariff item amounts, NN No 49/12,*Zagreb: Narodne Novine d.d., 2012 (49);

[70] Narodne Novine (2012), *Decision on tariff item amounts in the Tariff system for natural gas supply, with the exception ofpreferential customers, without tariff item amounts, NN No 49/12,*Zagreb: Narodne Novine d.d., 2012 (49);

[70] Narodne Novine (2012), *Decision on tariff item amounts in the Tariff system for natural gas distribution, without tariff itemamounts, NN No 49/12, NN No 99/12,*Zagreb: Narodne Novine d.d., 2012 (99);

[70] Narodne Novine (2012), Decision on tariff item amounts in the Tariff system for the services of thermal energy generation, distribution and supply for the energy entity *EP-Toplinarstvo d.o.o.*, Zagreb: Narodne Novine d.d., 2012 (134);

[70] INA-Industrija Nafte, d.d. (2013), http://ina.hr/default.aspx?id=4788 i http://www.ina.hr/default.aspx?id=203 [31 December 2013];

[70] Gradska Plinara Zagreb d.o.o. (2013), http://www.gpz-opskrba.hr/default.aspx?id=28 [31 December 2013]

[71] European Commission (2010), EU Energy Trends to 2030; update 2009. European Union, 2010. [online]. Available at: http://ec.europa.eu/energy/observatory/trends 2030/doc/trends to 2030 update 2009.pdf [4 August 2010]

[72] www.hrote.hr

Table 3.3 Overview of EE and RES measures under possible building renovation models in continental Croatia, depending on building category

Building category, continental Croatia	Measure packages	Specific energy savings by useful building area (kWh/m^2 per year)	Specific cost savings by useful building area (HRK/m^2 per year)	Comment
Public buildings				
Retrofit of the external heated space envelope under the *Technical Regulation*	Measures 0, 1, 2, 3 and 4	124.34	74.56	–
Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	Measures 0, 1, 2, 3 and 4	155.26	93.10	–
Building renovation to the nZEB standard	Measures 0, 1, 2, 3, 4, 6, 7, 8, 9, 10, 11 and 12	196.02	131.71	Mandatory implementation from 1 January 2019
Building renovation to the passive house standard	Measures 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12	230.51	153.67	–
Building renovation to the active house standard	Measures 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 and 13	303.45	230.40	–
Commercial buildings				
Retrofit of the external heated space envelope under the *Technical Regulation*	Measures 0, 1, 2, 3 and 4	165.16	99.04	–
Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	Measures 0, 1, 2, 3 and 4	206.24	123.67	–
Building renovation to the nZEB standard	Measures 0, 1, 2, 3, 4, 6, 7, 8, 9, 10, 11 and 12	261.49	176.08	Mandatory implementation from 01 January 2021
Building renovation to the passive house standard	Measures 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12	311.11	207.49	–
Building renovation to the active house standard	Measures 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 and 13	409.92	311.65	–
Apartment buildings				
Retrofit of the external heated space envelope under the *Technical Regulation*	Measures 0, 1, 2, 3 and 4	122.67	63.55	–
Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	Measures 0, 1, 2, 3 and 4	153.19	79.35	–
Building renovation to the nZEB standard	Measures 0, 1, 2, 3, 4, 6 and 7	197.19	119.36	Mandatory implementation from 01 January 2021
Building renovation to the passive house standard	Measures 0, 1, 2, 3, 4, 5, 6 and 7	236.58	143.57	–
Family houses				
Retrofit of the external heated space envelope under the *Technical Regulation*	Measures 0, 1, 2, 3 and 4	184.75	95.70	–
Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	Measures 0, 1, 2, 3 and 4	230.70	119.50	–
Building renovation to the nZEB standard	Measures 0, 1, 2, 3, 4, 6, 7, 8, 9 and 10	372.99	238.40	Mandatory implementation from 01 January 2021
Building renovation to the passive house standard	Measures 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10	438.01	277.65	–
Building renovation to the active house standard	Measures 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 and 13	528.81	373.21	–
Measure 0: Energy audit of the building and establishment of systematic energy management				
Measure 1: Outer window and door frame replacement				
Measure 2: Thermal insulation retrofitting to external walls				
Measure 3: Thermal insulation retrofitting to the roof/ceiling bordering unheated attic				
Measure 4: Thermal insulation retrofitting to the ceiling bordering unheated basement (if any)				
Measure 5: Thermal insulation retrofitting to the floor on ground level				
Measure 6: Heating system centralisation and modernisation by applying RES, if possible				
Measure 7: Cooling and ventilation system centralisation and modernisation by applying RES				
Measure 8: DHW system centralisation and modernisation by applying RES				
Measure 9: Lighting system modernisation				
Measure 10: Water consumption reduction				
Measure 11: Central control and management system installation				
Measure 12: Installation of waste energy compensation devices				
Measure 13: Installation of photovoltaic modules for RES electricity generation				

Source: *REGEA,* 2014

Table 3.4 Overview of EE and RES measures under possible building renovation models in coastal Croatia, depending on building category

Building category, coastal Croatia	Measure packages	Specific energy savings by useful building area (kWh/m^2 per year)	Specific cost savings by useful building area (HRK/m^2 per year)	Comment
Public buildings				
Retrofit of the external heated space envelope under the *Technical Regulation*	Measures 0, 1, 2, 3 and 4	59.51	35.68	–
Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	Measures 0, 1, 2, 3 and 4	76.53	45.89	–
Building renovation to the nZEB standard	Measures 0, 1, 2, 3, 4, 6, 7, 8, 9, 10, 11 and 12	117.84	86.73	Mandatory implementation from 1 January 2019
Building renovation to the passive house standard	Measures 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12	133.78	98.04	–
Building renovation to the active house standard	Measures 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 and 13	183.63	150.30	–
Commercial buildings				
Retrofit of the external heated space envelope under the *Technical Regulation*	Measures 0, 1, 2, 3 and 4	78.68	47.18	–
Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	Measures 0, 1, 2, 3 and 4	101.18	60.67	–
Building renovation to the nZEB standard	Measures 0, 1, 2, 3, 4, 6, 7, 8, 9, 10, 11 and 12	158.24	117.17	Mandatory implementation from 01 January 2021
Building renovation to the passive house standard	Measures 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12	183.20	134.49	–
Building renovation to the active house standard	Measures 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 and 13	281.83	206.66	–
Apartment buildings				
Retrofit of the external heated space envelope under the *Technical Regulation*	Measures 0, 1, 2, 3 and 4	52.23	27.06	–
Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	Measures 0, 1, 2, 3 and 4	67.17	34.79	–
Building renovation to the nZEB standard	Measures 0, 1, 2, 3, 4, 6 and 7	105.12	70.46	Mandatory implementation from 01 January 2021
Building renovation to the passive house standard	Measures 0, 1, 2, 3, 4, 5, 6 and 7	119.93	80.73	–
Family houses				
Retrofit of the external heated space envelope under the *Technical Regulation*	Measures 0, 1, 2, 3 and 4	81.86	42.40	–
Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	Measures 0, 1, 2, 3 and 4	105.27	54.53	–
Building renovation to the nZEB standard	Measures 0, 1, 2, 3, 4, 6, 7, 8, 9 and 10	200.26	138.34	Mandatory implementation from 01 January 2021
Building renovation to the passive house standard	Measures 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10	229.86	157.58	–
Building renovation to the active house standard	Measures 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 and 13	280.39	210.45	–
Measure 0: Energy audit of the building and establishment of systematic energy management				
Measure 1: Outer window and door frame replacement				
Measure 2: Thermal insulation retrofitting to external walls				
Measure 3: Thermal insulation retrofitting to the roof/ceiling bordering unheated attic				
Measure 4: Thermal insulation retrofitting to the ceiling bordering unheated basement (if any)				
Measure 5: Thermal insulation retrofitting to the floor on ground level				
Measure 6: Heating system centralisation and modernisation by applying RES, if possible				
Measure 7: Cooling and ventilation system centralisation and modernisation by applying RES				
Measure 8: DHW system centralisation and modernisation by applying RES				
Measure 9: Lighting system modernisation				
Measure 10: Water consumption reduction				
Measure 11: Central control and management system installation				
Measure 12: Installation of waste energy compensation devices				
Measure 13: Installation of photovoltaic modules for RES electricity generation				

Source: *REGEA,* 2014

3.5 Description of the method used in cost-effectiveness analysis

Cost-effectiveness analysis is based on the optimum cost method, in compliance with the HRN EN 15459/2008 standard (in accordance with the requirements of the European Directive on the energy performance of buildings *EPBD (2002/91/EC)),* as well as Commission Delegated Regulation (EU) No 244/2012[73]. The said standard defines the method used in the calculation of energy performance of buildings with regard to the functionality of energy systems in the building, with an emphasis on the method of economic heating system parametrisation.

The method defines the calculation of cost-effectiveness of individual energy saving methods, thus comparing different energy saving methods. It also enables assessment of an economic parameter or building performance as a whole, with parametrisation of individual energy saving measures applied to the existing system, with regard to the calculation of its initial and final condition.

Based on the standard, in view of the guidelines provided for the definition and structure of cost types in the economic or financial calculation of energy savings, parameters required for cost definition, the very method of economic or financial calculation, the method of presenting the results of economic or financial calculation and service life parameters of different technical system components, it is possible to select cost-optimal measures to increase energy efficiency in individual building categories.

Although the standard is based on the European Energy Performance of Buildings Directive, *EPBD (2002/91/EC),* considering that the said directive has been replaced by a new directive of the same name, *EPBD (2010/31/EU), Commission Delegated Regulation (EU) No 244/2012* is also taken into account in selecting the method used in the cost-effectiveness analysis, since it describes in more detail a part of European Directive *EPBD II (2010/31/EU)*[74]on energy performance of buildings, namely, the development of a comparative method of calculating a cost-optimal level of energy performance of a building and its elements. The Directive obliges EU Member States to decide which one of the two methods of calculating overall cost they will select (macroeconomic, observed through the building's entire service life, or financial, taking into account only the initial investment). Croatia has not selected any of the said calculation methods to date, so its method of calculating individual measures or a combination of several measures is based on the financial model.
In selecting measures to increase energy efficiency, simultaneous consideration has been given to the introduction of systems using RES to the possible greatest extent, in order to meet the requirements of Section 9 of *European Directive EPBD 2010/31/EU,* as well as the 2nd NEEAP, which prescribe approximation to the Nearly Zero Energy Building (En. abbreviation nZEB) standard in building construction/renovation. The term 'nearly zero energy building' is defined in the *Technical Regulation Proposal* (Article 4(44)), provided late in 2013, and which defines it as a building with very high energy performance and in which a very significant portion of its energy requirements is covered by renewable sources, including RES energy generated on the building or in its proximity.
The package of measures to increase energy efficiency (hereinafter: the EE) and the use of renewable energy sources (hereinafter: RES) is selected by optimising the measures, or by selecting among several existing measure packages that have the greatest impact on primary energy savings for a certain building with regard to total costs. For the purpose of cost optimisation, it is necessary to take into account a number of parameters adjusted to national conditions, such as service life of the building, all types of costs throughout the building's service life (energy sources, materials, systems,

[73] European Commission (2012), Commission Delegated Regulation (EU) No 244/2012. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:081:0018:0036:EN:PDF [16 January 2012] European Commission, Guidelines Accompanying Commission Delegated Regulation (EU) No 244/2012. Available at: http://eur- lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52012XC0419%2802%29 [19 April 2012]

[74] European Commisson (2013), *Directive 2010/31/EU on energy performance of buildings, recast of EPBD 2002/32/EC.* Available at: http://ec.europa.eu/enerey/efficiency/buildines/buildines en.htm [14 December 2013]

maintenance, operating and labour costs), factors of end-use (final) energy conversion into primary energy, fluctuations in energy prices etc. In addition to the European legislation mentioned above, the selection and parametrisation of various packages of the measures to increase EE and RES use of each building category also takes into account the national legislation. With regard to the proposed building renovation models, the following measures to increase EE and RES have been developed in accordance with the *HRN EN 15459/2008* standard:

1. Retrofit of the building's external envelope aimed at achieving energy class B, A or A+, using realistic models in the calculation for each building category[75];
2. Introduction of central heating systems using a wood biomass-fired (pellets, wood chips) boiler or, where impossible, a condensation boiler using natural gas as fuel;
3. Introduction of the central DHW generation system with a solar collector system;
4. Introduction of the central cooling system using heat pumps;
5. Existing lighting system replacement by a more energy efficient one.

Since the EPBD Directive 2010/31/EU prescribes the introduction of the nZEB standard in construction/renovation starting from 1 January 2019 in respect of public buildings and from 1 January 2021 in respect of all buildings, comprehensive measure packages including EE and RES measures are to be implemented in respect of the said building categories starting from the said dates.

The calculation of savings in CO_2 emissions, as well as the amount of primary energy is based on the *Building energy audit methodology*[76]in accordance with European legislation, while the calculation of required investment and appropriate cost savings is based on existing price catalogues or realistic cost specifications.[77]

Guidelines related to the Commission Delegated Regulation (EU) No 244/2012, Article 6(3), two data sources were taken into account when calculating required investment, with regard to renovation under the existing Technical Proposal and with regard to renovation under low energy standards that correspond to the Technical Regulation Proposal. Calculations for both renovation methods are derived from instructions in Annex 1 to the said regulation (Article 2(4)), which lay down an obligation of calculation in compliance with the current legal requirements, as well as compliance with the standard prescribed as a prerequisite for co-financing by national institutions, such as the Environmental Protection and Energy Efficiency Fund (EPEEF). Based on the parameters resulting from both types of calculation, the cost-optimal parametrisation is that of renovation compliant with the *Technical Regulation Proposal,* so it needs to be used in analysing energy savings and other relevant parameters.

In the parametrisation of measures to increase energy efficiency, 2013 is taken as the reference year for the calculation, where the current condition model is based on data provided by the Croatian Bureau of Statistics, the 2011 census and the records on total building permits issued and buildings completed, as well as the division of final energy for the purposes of different technical systems in buildings based on the *International Energy Agency - IEA Statistics* database in Croatia.[78]

---

[75] North-West Croatia Regional Energy Agency (2013), *Final report on the energy audit of Alstom Hrvatska d.o.o. buildings*; *Final report on the energy audit of SPAR HRVATSKA Osijek building; Final report on the energy audit of SPAR HRVATSKA Sisak building; Final report on the energy audit of SPAR HRVATSKA Zadar building; Final report on the energy audit of Terme Tuhelj-Tuheljske Toplice spa complex,* Zagreb; *Final report on the energy audit of Dubovac Primary School, Karlovac*; *Final report on the energy audit of Gaza Kindergarten*, Karlovac; North-West Croatia Regional Energy Agency (2014), *Final report on the energy audit of the Krapina-Zagorje County's Community Health Centre, Pregrada Outpatient Clinic*, Zagreb; *Final report on the energy audit of residential building at Šipački breg 22, Samobor*; *Final report on the energy audit of a family house in Punat*; Final report on the energy audit of the City Office for Energy, Environmental Protection and Sustainable Development of the City of Zagreb and North-West Croatia Regional Energy Agency (2013), *Zagreb – Energy Efficient City Project*, Zagreb.

[76] Ministry of Construction and Physical Planning (2012), *Metodologija provođenja energetskog pregleda zgrada*[online], http://www.meipu.r/doc/EnergetskaUcinkovitost/Metodologiia provodenja EPG.pdf [31 December 2013]

[77] North-West Croatia Regional Energy Agency (2013), *Project guidelines for sustainable construction,* Zagreb; City Office for Energy, Environmental Protection and Sustainable Development of the City of Zagreb and North-West Croatia Regional Energy Agency (2013), Zagreb – Energy Efficient City Project, *Zagreb*

[78] International Energy Agency (2013), Online Report for Croatia [online]. Available at: http://www.iea.org/statistics/statisticssearc/report/?&country=CR0ATIA&year=2011&product=Balances [31 December 2013]

4. Policies and measures to stimulate cost-effective integral building renovation

4.1 Overview of existing measures to stimulate building renovation in Croatia

An overview of existing measures to stimulate building renovation in the Republic of Croatia will include the following:

- National and international projects and programmes of building renovation;
- Implementation of Croatia's operational programmes for different types of buildings.

Programmes of financial institutions intended for integral building renovation are described in detail in Chapter 5.2.

4.1.1 Overview of national and international building renovation projects and programmes

A large number of building renovation projects in Croatia have been implemented within the scope of the following programmes and initiatives:

- Cross-border cooperation under the Instrument for Pre-Accession Assistance – IPA;
- European Commission's CONCERTO initiative under the European Research Framework Programme (FP7);
- Competitiveness and Innovation Framework Programme – CIP;
- *KUENzgrada* National Programme to Increase Energy Efficiency in Buildings;
- UNDP programme: Increasing Energy Efficiency in the Republic of Croatia;
- Technology Research and Development Promotion Programme – TEST[79];
- Programme to Stimulate Entrepreneurship Based on Innovation and New Technologies
- Under the Ministry of the Economy's 2013–2015 Strategy Plan[80];
- Science and Research Investment Action Plan of the Ministry of Science, Education and Sports;
- Entrepreneurial Impulse[81] of the Ministry of Entrepreneurship and Crafts.

Croatian Ministry of Construction and Physical Planning (MoCPP) continuously stimulates and supports research and development of new energy and environmentally friendly construction materials and technologies by providing support to a number of national and international research and development projects, of which the 2011 CIP-EIP-Eco-Innovation Project entitled Energy Efficient, Recycled Concrete Sandwich Façade Panel – ECO-SANDWICH is certainly worth mentioning. The ECO-SANDWICH project is to stimulate recycling and reuse of construction and demolition waste, promoting the substitution of conventional thermal insulation materials, promoting the application of prefabricated energy efficient products and reducing energy consumption in production, greenhouse gas emissions and production waste by-products and product use.

In the period up to 2020, a number of building renovation projects within the scope of EU's HORIZON 2020 programme are expected to be implemented,[82] specifically, in operational areas EE1, EE2, EC4, EE16, EE18, LCE18, LCE19, EIE1 and others. One of the important HORIZON 2020 programme

---

[79] Business and Innovation Croatian Agency (2013). Available at: http://cirtt.unizg.hr/media/uploads/mj inovacija 2013/test - mjesec inovacija 03 2013.pdf [31 December 2013]

[80] Ministry of the Economy (2012). Available at: http://www.mingo.hr/userdocsimages/STRATE%C5%A0KI%20PLAN%20MING0%202013-2015%20kona%C4%8Dno.doc [31 December 2013]

[81] Ministry of Entrepreneurship and Crafts (2013). Available at: http://www.minpo.hr/default.aspx?id=288 [31 December 2013]

[82] European Union. Available at: http://ec.europa.eu/programmes/orizon2020/ [31 December 2013]

objectives is the acquisition of necessary knowledge and skills by all stakeholders in the process of energy-efficient building renovation (building owners, designers, contractors and end-users). On 14 December 2013, the European Union published a first tender for the award of grants under the HORIZON 2020 programme named *Energy efficient research and development (H2020-EE-2014 and H2020-EE-2015),* with a the total indicated budget of EUR 140.35 million. Eligible applicants include state administration bodies, with the exception of governments and ministries, as well as local and regional self-government unit, large enterprises, small and medium enterprises, institutes and faculties.

4.1.2 Implementation of Croatia's operational programmes for different types of buildings

Croatia's Second National Energy Efficiency Action Plan for the period through 2013 was adopted pursuant to Article 6(3) of the End-Use Energy Efficiency Act, in accordance with the requirements of Article 14.1 of Directive 2006/32/EC on energy end-use efficiency and energy services (hereinafter: the ESD) under which EU Member States are required every three years to prepare and submit to the European Commission (EC) their plans, including measures which, once implemented, will achieve the set end-use energy savings targets by 2016. The NEEAP defines preparation and implementation of national programmes of integral renovation of residential and [commercial? word missing] buildings which may generate savings of 10.4 PJ, or 53% of the national target by 2016.
According to the main determinants of the operational Programme of energy renovation of residential buildings,[83] measures to stimulate the renovation of apartment buildings include:

1. Energy audits and energy certification of buildings;
2. Aid to support the preparation of project documents for building renovation;
3. Stimulating integral renovation of apartment buildings;
    a. Increasing thermal protection of the external envelope;
    b. Window replacement;
    c. Heating system upgrading or substitution;
4. Introduction of individual thermal energy consumption metering.

The organisational charts of Programme implementation for measures 1, 2 and 3, as well as measure 4 are provided in Annex 18 A and B.

The programme of energy renovation of family houses[84] groups measures of energy renovation of existing family houses, according to the coverage, as follows:

1. Stimulating external envelope renovation:
    a. Increasing thermal protection of the external envelope;
    b. Window replacement;
2. Stimulating heating systems substitution:
    a. Substitution of existing heating systems that use electricity or fossil fuels by new condensation gas boiler systems;
3. Stimulating RES use:
    a. Solar thermal collector installation;
    b. Heat pump installation;
    c. Installation of small biomass stoves.

Operational implementation of all these measures is presumed to begin in 2014, starting from which their effects will also be monitored. The organisational chart of Programme implementation is

[83] Programme of energy renovation of residential buildings for the period between 2013 and 2020 with a detailed plan for the 2014–2016 period, Ministry of Construction and Physical Planning, November 2013;

[84] Programme of energy renovation of family houses for the period between 2013 and 2020 with a detailed plan of energy renovation of residential buildings for the 2014–2016 period, Ministry of Construction and Physical Planning, January 2014

provided in Annex 19.

Cost-effective integral renovation of public buildings will be stimulated by implementing the Operational programme of energy renovation of public buildings,[85] which is to achieve the following specific objectives by the end of 2015:

1. contract and implement a comprehensive renovation of 200 public buildings with approx. 420 000.00 m^2 in useful area;
2. reduce energy consumption in renovated buildings by 30–60%, or by around 150 kWh/m^2 per year;
3. reduce CO2 emissions by approximately 20 500 t per year;
4. mobilise investments of approximately HRK 400 000 000.00.

Public buildings are selected for the purpose of minimising additional costs, under the following criteria:

1. average energy consumption for heating in excess of 200 kWh/m^2;
2. the building is not part of a complex and is a separate energy consumer;
3. the building has no defects in terms of other criteria relevant for built structures;
4. the building is not subject to a cultural heritage preservation programme, preventing cost-effective energy regeneration.

The main stages of Programme implementation are as follows:

- Preparation of a form for the owner;
- Energy audit, preparation of the energy certificate and/or project task (terms of reference);
- Verification of data in the EMIS system;
- Analysis of the energy audit data;
- Drafting and preparation of bidding documents;
- Preparation and implementation of a public procurement procedure for contracting energy renovation under the Energy Performance Contract model;
- Selection of the most advantageous bid;
- Energy service contracting;
- Project documentation preparation;
- Expert committee and project approval;
- Lending – Croatian Reconstruction and Development Bank (CRDB)/commercial banks;
- Works on the building (renovation);
- Programme co-financing by the EPEEF;
- Obtaining an energy certificate on renovation completion;
- Delivery of works.

A flowchart of project implementation of the energy renovation of public buildings is provided in Annex 20.

In full compliance with the provisions of relevant EU directives,[86] the Programme of energy renovation of commercial buildings[87] provides a detailed list of all parameters required for the implementation of integral renovation of commercial buildings to the nZEB standard by 2050 (Table 4.1).

---

[85] Programme of energy renovation of public buildings, Ministry of Construction and Physical Planning, October 2010

[86] Directive 2010/31/EU on the energy performance of buildings, Directive 2012/27/EC on energy efficiency,

[87] Programme of energy renovation of commercial buildings for the period between 2013 and 2020 with a detailed plan for the 2014–2016 period, Ministry of Construction and Physical Planning, December 2013

Table 4.1 Overview of all parameters required for the implementation of integral renovation of commercial buildings to the nZEB standard by 2050

Measure		**Integral commercial building renovation to the nZEB standard;**	
Measure index according to the		C5.b	
Description	Time frame	beginning: 2020 ending: 2050 (with a 2030 interim target)	
	Objective / brief description	Detailed plan of existing commercial building renovation, targeting buildings constructed prior to 1987, in the form of integral building renovation to the nZEB standard.	
	Target end-use consumption	Existing commercial buildings (privately owned)	
	Target group	Owners of [word missing] commercial buildings	
	Application level	National	
Information on implemen-tation	List and description of activities to implement measure	<u>Future activities:</u> Motivate commercial banks to open credit lines. The plan implementation needs to be monitored on an annual basis in terms of resources spent, expected energy and financial savings and reductions in CO_2 emissions.	
	Financial resources in the period up to 2030	External envelope of heated space	HRK 2 893.00 million (HRK 6 104.85 million cumulatively for envelope from 2013 on)
		Heating system	HRK 454.20 million
		Cooling system	HRK 2 198.68 million
		Domestic hot water generation system	HRK 21.79 million
		Lighting system	HRK 390.55 million
		Total	HRK 5 958.22 million (HRK 9 170.07 million cumulatively from 2013 on)
	Financial resources in the period up to 2050	External envelope of heated space	HRK 8 679.00 million (HRK 11 890.85 million cumulatively for envelope from 2013 on)
		Heating system	HRK 1 362.60 million
		Cooling system	HRK 6 596.04 million
		Domestic hot water generation system	HRK 65.38 million
		Lighting system	HRK 1 171.66 million
		Total	HRK 17 874.68 million (HRK 21 086.53 million cumulatively from 2013
	Implementing	Ministry of Construction and Physical Planning (MoCPP) (programme implementation)	
	Monitoring authority	Ministry of Construction and Physical Planning (MoCPP) and Ministry of Tourism (MoT)	

Energy Savings	Energy savings monitoring / measuring method	Apply methods of savings measurement and verification, in accordance with the *Rules of the methodology to monitor, measure and verify energy savings in end-use consumption (NN 71/12)*[88]	
	Expected energy savings in 2030 (excl. cumulative impact of previous renovation on an annual basis)	External envelope of heated space	2.49 PJ (691.11 GWh) (5.16 PJ, or 1 434.51 GWh cumulatively from 2013 on)
		Heating system	97.63 TJ (27.12 GWh)
		Cooling system	80.86 TJ (22.46 GWh)
		Domestic hot water generation system	69.41 TJ (19.28 GWh)
		Lighting system	237.71 TJ (66.03 GWh)
		Total	2.97 PJ (826.00 GWh) (5.65 PJ, or 1 569.40 GWh cumulatively from 2013 on)
	Expected energy savings in 2050 (excl. cumulative impact of previous renovation on an annual basis)	External envelope of heated space	7.46 PJ (2 073.33 GWh) (10.14 PJ, or 2 816.73 GWh cumulatively from 2013 on)
		Heating system	292.93 TJ (81.37 GWh)
		Cooling system	242.53 TJ (67.37 GWh)
		Domestic hot water generation system	208.19 TJ (57.83 GWh)
		Lighting system	713.12 TJ (198.09 GWh)
		Total	8.92 PJ (2 477.99 GWh) (11.60 PJ, or 3 221.39 GWh cumulatively from 2013 on)
	Overlaps, multiplication effect, synergy	In order to achieve the multiplication effect and get commercial building owners interested in the renovation of their buildings, it is necessary to regularly present completed projects and resulting benefits for their owners to the public. The measure also provides for energy audits and energy certification of buildings.	

4.2 Analysis of measures to stimulate integral building renovation in European Union Member States

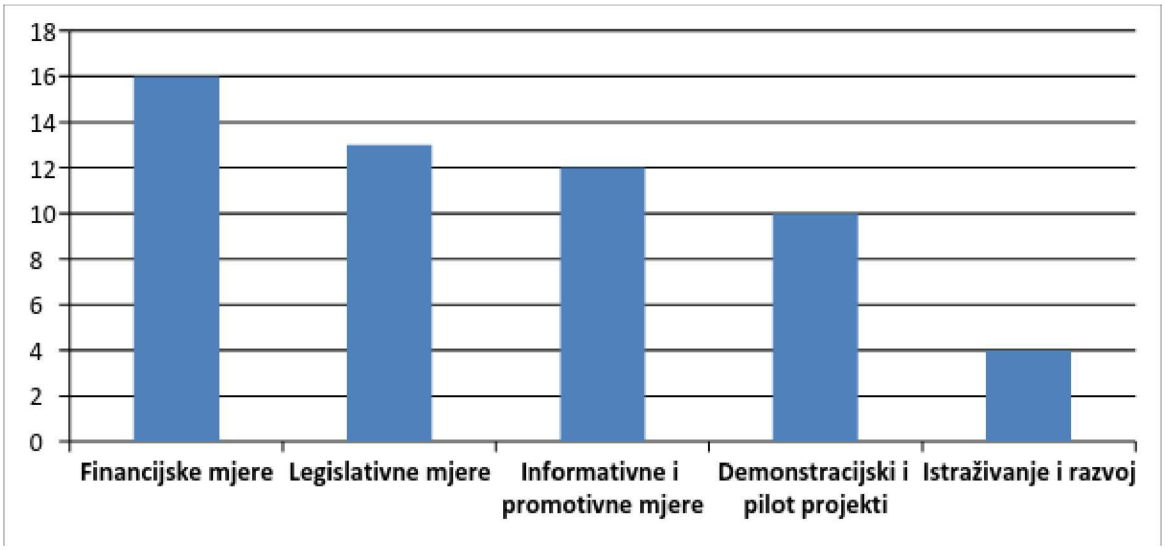
Policies and measures to stimulate the integral renovation of the national building stock of European Union Member States, conditioned by specific characteristics of each country, are very different and difficult to summarise under a common denominator.

According to the European Commission Report on the progress by Member States,[89] the most common incentive measures are divided into five main categories (Figure 4.1):

- Financial measures;
- legislative measures;
- information and publicity measures;
- demonstration and pilot projects;
- research and development.

[88] Rules of the methodology to monitor, measure and verify energy savings in end-use consumption, NN 152/ 08 and 55/12, available at http://narodne-novine.nn.hr/clanci/sluzbeni/2012 07 77 1816.html

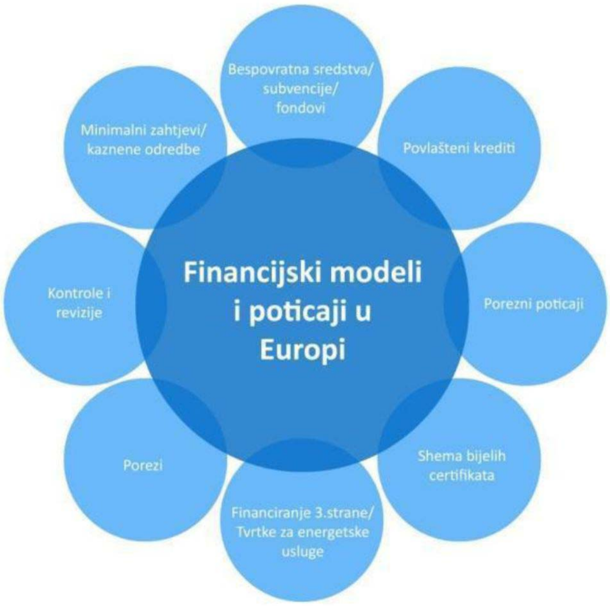
[89] Report from the Commission to the European Parliament and the Council: Progress by Member States towards nearly Zero-Energy Buildings COM(2013)483



Financijske mjere	Financial measures;
Legislativne mjere	Legislative measures;
Informativne i promotivne mjere	Information and publicity measures;
Demonstracijski i pilot projekti	Demonstration and pilot projects;
Istraživanje i razvoj	Research and development.

Figure 4.1 Share of various stimulating measures in EU Member States

Financial models and measures used in EU Member States, which might equally successfully be applied in Croatia, are shown in Figure 4.2.



Financijski modeli i poticaji u Europi	Financial models and incentives in Europe
Bespovratna sredstva/subvencije/fondovi	Grants/subsidies/funds
Povlašteni krediti	Preferential loans
Porezni poticaji	Tax allowances
Shema bijelih certifikata	White certificate scheme
Financiranje 3. strane/Tvrtke za energetske usluge	3rd party financing/Energy services companies
Porezi	Taxes
Kontrole i revizije	Controlling and audits

Minimalni zahtjevi/kaznene odredbe	Minimum requirements/criminal provisions

Figure 4.2 Overview of available financial models and incentives in European Union Member States

Overview of successful policies and measures to stimulate investment in energy renovation of various building types in EU Member States includes the following programmes and initiatives[90]:

- The Green Deal, Great Britain[91];
- Energy renovation of Bulgarian homes, Bulgaria[92];
- Berlin: Energy Savings Partnership, Germany[93];
- Energies Posit'if, France[94];
- BgEEF: Bulgarian Energy Efficiency Fund, Bulgaria[95] ;
- Bulgarian Energetics and Energy Savings Fund (FEEI or EESF), Bulgaria[96];
- Italian Tax Credit Programme)[97], Italy;
- The Green Funds Scheme[98], Netherlands.

The examples of financial and legislative policies of Germany and Estonia, which are applicable to Croatia with minor adjustment to the current situation, are described in more detail below. It is important to note that a low interest rate is the main prerequisite of successful lending for integral building renovation. A high interest rate of 5–7% drastically increases total investment expenditures, which resulting in the fact that the only economically optimal buildings for renovation are those of extremely poor energy performance. In order to be successfully applied in Croatia, the interest rates payable on financial mechanisms described below must not exceed 3%.

KfW's Green Loans, Germany

State-owned German bank KfW, as the main financial tool for channelling public and private resources to investments in energy efficiency, has financed projects of integral energy renovation of buildings since 2002. Germany has very successfully implemented the energy renovation of its national building stock, and has so far renovated 9 000 000 of buildings to the low-energy building and/or passive house standard. Existing, primarily residential buildings in Germany are consuming three times more energy for heating than new ones, built under the current German legislation. Germany is particularly successful in the implementation of building energy renovation projects through public-private partnership. By investing EUR 3.8 billion in public subsidies between 2001 and 2006, the German Federation of Labour and Environmental Protection spurred total investment of EUR 15.4 [billion?] into integral building renovation. In the period between 2006 and 2009, KfW granted EUR 27 billion in loans and grants through various financial programmes and models, resulting in a total investment of EUR 54 billion.
Among the most successful financial models of residential building sector renovation in Europe[99] is the Energy-Efficient Construction and Reconstruction Programme, through which KfW has funded energy-efficient construction and renovation of the German residential sector via favourable loans and grants. Under the programme, financial resources are available on equal terms to all private

[90] Assistance Documents for EU Member States in developing long-term strategies for mobilising investment in building energy renovation, November 2013, Joint working group of CA EED, CA EPBD and CA RES

[91] https://www.gov.uk/green-deal-energy-saving-measures

[92] http://www.eib.org/epec/ee/documents/sofia_03_10_2013_2_stoickova_energy_renovatio_of_bulgarian_omes.pdf

[93] http://www.berliner-e-agentur.de/

[94] http://ec.europa.eu/energy/intelligent/projects/?/page/Page.jsp?op=project_detail&prid=2652

[95] http://www.bgeef.com/display.aspx

[96] http://enemona.bg/englis/index.ppP97

[97] http://www.efficienzaenergetica.enea.it/doc/pubblicazioni/rapporto-55-2011-WEB.pdf

[98] http://www.agentscapnl.nl/sites/default/files/biilagen/SEN040%20DQW%20A4%20Greenfunds_tcm24-119449.pdf

[99] Technical Guidance: Financing the energy renovation of buildings with Coesion Policy funding, EC DG Energy, 2014

investors and housing companies in the territory of Germany.

The main prerequisite for obtaining funds is the application of energy standards that are higher than those currently applicable, in accordance with the German energy savings rules,[100] according to two key parameters:

- annual primary energy requirement in comparison to the energy requirement of a "reference building";
- specific thermal transmittance losses in comparison to the losses of a "reference building".

Achieved energy savings are determined under the provisions of the KfW's Efficiency House Standard,[101] which has become the term for high energy efficiency in buildings, and promotional interest rates are granted for three levels of primary energy savings achieved in the construction of new buildings and five levels in the renovation of existing buildings.

- ***New building construction***

The expected levels of primary energy consumption in new buildings are 40%, 55% and 70% of the annual primary energy requirement of the "reference building" under the current rules.[102]
The initial level of promotional interest rates is the same for all three levels of anticipated savings, but the loan principal may also be reduced, depending on actual energy savings certified by a qualified specialist; for example, the loan principal for a building that will consume only 40% of primary energy requirement of the "reference building" will be reduced by 10%. The maximum loan amount is EUR 50 000.

- ***Integral renovation of existing buildings***

The levels of expected primary energy consumption for integral renovation of existing buildings are 55%, 70%, 85%, 100% and 115% of the annual primary energy requirement of the "reference building" under the current rules[103], and the loan principal reduction ranges from 2.5% for buildings whose primary energy consumption after renovation will be 115% of primary energy consumption of a "reference building", to 17.5% for a highly energy-efficient building that consumes 55% less primary energy than does the "reference building".

In addition to integral building renovation, loans are also granted for implementing individual energy efficiency measures, such as window replacement, heating system improvements etc. Within the scope of the programme, in addition to the loan and grants ranging between 10% and 25% of the maximum loan amount of EUR 75 000 (between EUR 5 000 and EUR 18 750), based on equal levels of primary energy savings as those applied for loan approval. It should be noted that, the participation of an energy consultant, who is responsible for project monitoring and verification of achieved energy savings, is essential for the application.

Credit-Guarantee Fund – KredEx, Estonia

The Credit-Guarantee Fund – KredEx[104] is an Estonian revolving fund established in 2001 by the Ministry of the Economy and Communication for the main purpose of financing energy efficiency measures, primarily the energy renovation by households in Estonia through loans, grants and bank guarantees. The sources of financing of the fund consist of 80% national and 20% European resources.

[100] German Energy Savings Ordinance (EnEV 2014), available at: www.dena.de
[101] KfW-Efficiency House Standard
[102] German Energy Savings Ordinance (EnEV 2014), available at: www.dena.de
[103] German Energy Savings Ordinance (EnEV 2014), available at: www.dena.de
[104] Website: ttp://www. kredex.ee/

In its offering the fund has 3 mechanisms to finance energy efficiency:

- bank guarantees for the purchase or renovation of an apartment or family home;
- loans at favourable interest rates for renovation of apartments in apartment buildings;
- grants intended primarily for tenant associations for integral renovation of apartment buildings.

The fund's goal is to development of Estonian companies through energy renovation of the household sector, as well as financing of a strong promotional and education campaign: "Energy-saving way of thinking!" The fund's activities have gone beyond the borders of Estonia and spread to the Baltic network energy efficiency.

New Energy Saving Ordinance (EnEV 2014), Germany

Germany's federal government adopted a new Energy Savings Ordinance (EnEV 2014) in October 2013, entering into force in May 2014, is characterised by much stricter and higher energy standards for new buildings, and strict provisions for the owners of existing buildings.

- ***New buildings***

Between 1 January 2016 and 1 January 2021, new residential and [commercial? word missing] buildings are to meet higher energy efficiency standards, which will reduce annual primary energy requirements by 25%. After 1 January 2021, all new buildings will be subject to the nZEB standard.

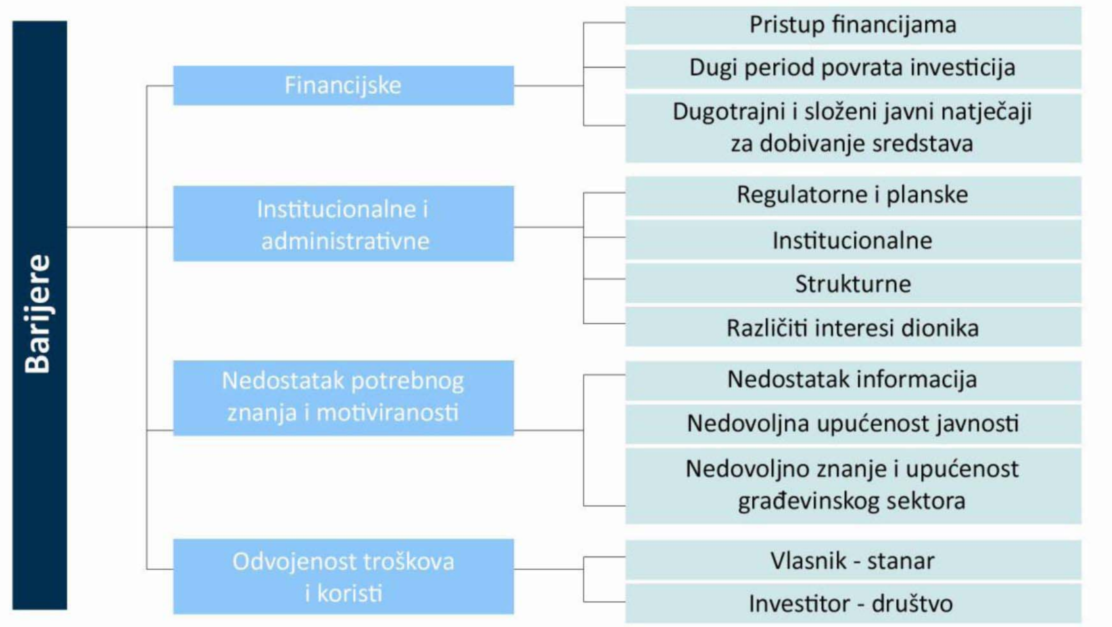
- ***Existing buildings***

In addition to all the provisions of the currently applicable Rules, the owners of existing buildings will have to implement the following:

1. All fuel oil or gas-fired boilers installed prior to 1985 need to be replaced by the end of 2015;
2. All heating systems installed after 1 January 1985 need to be replaced after a maximum of 30 years;
3. Top-floor ceilings which not meeting minimum thermal insulation requirements have to be insulated by the end of 2015;
4. Sellers and lessors of flats need to produce an energy certificate as early as the property viewing stage, and its key parameters (e.g. average energy consumption) must be stated in advertisements for the property sale or lease;
5. On concluding a contract of sale or lease of the property, the energy certificate must be delivered to the buyer or lessee.

4.3 Analysis of existing barriers to integral energy renovation of buildings

Existing barriers to an integral energy renovation of buildings are numerous, and may generally be divided into 4 main categories shown in Figure 4.3.



Barijere	Barriers
Financijske	Financial
Institucionalne i administrativne	Institutional and administrative
Nedostatak potrebnog znanja i motiviranosti	Lack of necessary knowledge and motivation
Odvojenost troškova i koristi	Separation of costs and benefits
Pristup financijama	Access to financing
Dugi period povrata investicija	Long period of return on investment
Dugotrajni i složeni javni natječaji za dobivanje sredstava	Lengthy and complex public tenders for funding
Regulatorne i planske	Regulatory and planning
Institucionalne	Institutional
Strukturne	Structural
Različiti interesi dionika	Different interests of stakeholders
Nedostatak informacija	Lack of information
Nedovoljna upućenost javnosti	Insufficient public awareness
Nedovoljno znanje i upućenost građevinskog sektora	Insufficient construction sector knowledge and awareness
Vlasnik - stanar	Owner – tenant
Investitor - društvo	Investor – company

Figure 4.3 Main categories of existing barriers to integral energy renovation of the Croatian national building stock[105]

Overall, it can be concluded that the main obstacles to the national building stock renovation are not only of legislative and financial nature[106], but that the integral energy renovation of buildings is also largely hampered by lack of information and motivation on the part of investors, the public and stakeholders.

[105] Building Performance Institute Europe – BPIE: Europe's Buildings under the Microscope, October 2011

[106] For more information on financial barriers and limits see subsection 5.2.2.

On accession to the EU, Croatia has assumed an obligation of full harmonisation of relevant national legislation with EU directives, but considering the complexity of the task, it is clear that full harmonisation may take time and expert knowledge. Until such time as the Croatian legislation is fully harmonised with the EU legislation, investing in integral renovation of the national building stock represents a risk to all stakeholders: ranging from investors to financial institutions to building owners and users.

The existing Croatian legislation is satisfactory insofar as it relates to the technical guidelines and requirements for the energy renovation of buildings and is not a barrier in the technical sense, but what is missing is regulation introducing an obligation of energy renovation of existing buildings with the mandatory use of an optimal renewable energy source for heating and cooling. At this point, only the obligation to perform energy audits and prepare and present energy certificates is regulated.[107]

Major economic crisis in Croatia has led to a considerable reduction of the capacity for investment into all economic sectors, including the construction sector in the part relating to the renovation of existing buildings which largely depends on the economic indicators at the national level. As the Croatian economy has declined steadily since the onset of the economic crisis in 2009, the renovation of all types of buildings has been on a constant decline to. An important indicator of construction sector trends is the index of the physical volume of construction works based on the number of hours worked on sites, according to the Methodology used for short-term business statistics[108]. According to the Central Bureau of Statistics, the physical volume of construction works index recorded constant growth up to 2008 only to fall since then, thus confirming a continued downward trend in the Croatian construction sector. In 2011, the average annual decline in the volume of construction works amounted to 9.7% before moving to double-digit territory at 11.6% in the first three months of 2012, indicating a strong negative trend. Since the recovery of the construction sector in Croatia should precede recovery of the entire real sector (and consequently of the labour market), it is quite unrealistic to expect positive developments any time soon to have a significant contribution to his recovery, especially in the absence of capital investments.

If quite a long period of return on investment into renovation, as well as insufficient financial incentives and lack of successful financial models are added to the generally poor financial situation in Croatia, financial barriers are gaining strength. The absence of strong incentives and insufficient preparedness of financial institutions to lend for the energy renovation of buildings slow the whole process further. Largely "socially determined" energy prices in Croatia are not stimulating for the implementation of energy efficiency measures, primarily those with relatively long period of return. Expected growth in energy prices will make energy reconstruction financially more viable, so this barrier will eventually diminish.

The current situation in the Croatian banking sector, which recorded losses and whose profitability has shrunk significantly, is another important barrier. In the real sector crisis environment, as the number of non-recoverable and non-performing loans increases , and the number of Croatian banking sector employees falls, rapid development of the construction and energy market can hardly be expected.

The next barrier, which has definitely not been taken into account sufficiently, is the level of information, education and participation of the public in taking important decisions on building renovation. Lack of information on positive effects for each individual and society as a whole, that will certainly emerge from the integral renovation of the entire national building stock,

[107] Rules of energy audits and energy certification of buildings (NN No 81/12 and NN 29/13)

[108] European Commission (2006), Methodology of short-term business statistics – Guidelines in the industry, trade and services, ISSN 1725-0099

results in insufficient motivation and frequently unfounded increase in the risks that block potential investors further.

Furthermore, unlike [word missing] buildings with relatively simple ownership, owner relations in apartment buildings are extremely complex since, depending on the amount of investment, the consent of at least 51% to 100% of tenants is required for decision-making about investment into renovation. Given the low living standard of an average Croatian citizen, obtaining required approvals for investment into energy renovation of buildings is an extremely difficult task to accomplish.

Solid development of the market in construction and energy services, as well as a sufficient number of experienced companies specialising in the implementation of the integrated energy renovation to include mechanical, energy and construction elements of buildings, is a prerequisite of successful initiation and implementation of the integrated energy renewal of the national building stock and requires an interdisciplinary approach. The crisis affecting Croatia's construction and energy sectors and resulting in the closure or bankruptcy of a large number of companies has exacerbated the existing barrier involving insufficient capacity, knowledge, competences and skills to a successful accomplishment of the complex task of integral building renovation. For as long as Croatia sees no substantial strengthening of the entrepreneurial business sector or regains investor confidence, the programme of integral building renovation will face an insurmountable barrier.

An important barrier to a successful implementation of integral building renovation also consists of demographic and migration trends, as well as changes in the culture of living and lifestyle.

The integral building renovation is a complex process with a large number of participants, mutually linked by different interests and goals representing another in a series of barriers to successful implementation. Unresolved property relations and property ownership status are the next barrier to decision-making on energy renovation.

A typical barrier, slowing down the process of energy renovation of non-commercial public buildings, is the public procurement procedure that always time-consuming and in a large number of cases produces unsatisfactory results.

A category of buildings involving an even more complex process of energy renovation are the buildings entered in the Ministry of Culture's Register of Cultural Goods. In Croatia, there are 6 207 such individual immovable cultural properties and a group cultural properties under permanent or preventive protection, entered in the Register of Cultural Goods. Assuming an average area of 1 000 m^2, currently there is around 6.2 million m^2 of protected building area in Croatia, accounting for nearly 3% of the total national building stock area.

The impact of various barriers to the process of integral renovation of the Croatian national building stock is not the same so, in order to determine potential risks and depending on their impact, certain identified barriers are to be divided into the barriers of large, medium or small impact.

Barriers with a large impact on the process of integral building renovation are the following:
- lack of strong financial incentives for the energy renovation of buildings;
- lack of developed financial models of investing in the energy renovation of buildings;
- insufficient preparedness of financial institutions to lend;
- lack of regulation imposing an obligation to implement energy efficiency and RES use in buildings.

The following barriers have a medium impact on the process of integral building renovation:

- large number of participants with frequently conflicting goals and interests;
- insufficient development of the energy services market, primarily on account of an insufficient number of companies specialising in the provision of services of integral building restoration and their lack of financial resources;
- insufficient information, education and participation of the public in taking important decisions on building renovation;
- socially-dictated energy and fuel prices.

The following barriers have a small, but by no means negligible impact on the process of integral building renovation:

complexity of the process initiation and implementation;

- necessity of taking an individual and multidisciplinary approach to each individual building;
- unresolved property relations;
- lengthy and uncertain public procurement procedures in respect of public buildings;
- additional complexity of the process of energy renovation of buildings entered in the Ministry of Culture's Register of Cultural Goods.

4.4 Proposed solutions and new measures to overcome existing barriers

An identification of efficient measures to stimulate a cost-effective integrated renovation of the Croatian national building stock will be based on a plan of possible targets and indicators for the period up to 2050, according to the Energy Roadmap 2050, adopted by the European Parliament in January 2013.[109]

Table 4.2 Long-term plan of integral national building stock renovation by 2050[110]

Target year	Target
2050	**Reducing greenhouse gasses in buildings by 80%** **All nearly zero-energy or high energy efficiency buildings**
2040	65% nearly zero-energy or high energy efficiency buildings; around 3.5% of buildings undergoing integral renovation each year 4% of historic or buildings of cultural significance renovated each year; 95% of users aware of positive effects of integral building renovation
2030	30% buildings renovated to the nearly zero-energy and high energy-performance level; around 3.5% of buildings undergoing integral renovation each year Prepared regulations for requirements for a high energy-performance level of all buildings as a condition of sale or lease. Completely developed integral renovation with optimised costs Contracting companies certified for renovation and employing the workers trained to perform energy renovation works. 50% of users aware of the benefits of renovation Developed renovation techniques of historic and buildings of cultural significance
2025	15% buildings renovated to the nearly zero-energy and high energy-performance level. Around 3.5% of buildings undergoing integral renovation each year. Developed renovation techniques of all types of buildings; 20% of users aware of the benefits of renovation Renovation techniques of historic and buildings of cultural significance being developed 50% of contracting companies certified for the energy renovation of zero-energy buildings and employing 50% of workers trained to perform such works The Government supports banks in lending for the integral renovation by socially vulnerable groups; Users undergoing education on the benefits of renovation
2020	5% of buildings renovated to the nearly zero-energy and high energy-performance level. Around 1% of buildings undergoing integral renovation to the nearly zero-energy building level each year; Renovation techniques for most types of buildings developed. Integral renovation techniques developed 20% of contracting companies certified for the energy renovation of zero-energy buildings and employing 20% of workers trained to perform such works The Government provides budget funding for public building renovation and incentives to renovate the buildings of a social character. User education conducted by energy agencies etc. Training materials prepared for the education in schools and universities
2017	Integral renovation techniques for most types of buildings developed 5% of contracting companies certified for the energy renovation of zero-energy buildings and 5% of employees trained to perform such works Universities and schools have introduced energy renovation in their curriculum The Government has prepared plans of financing the renovation of public buildings and council flats The Government supports energy renovation research and presentations The Government supports worker training to perform renovation

[109] http://ec.europa.eu/energy/publications/doc/2012 energy roadmap 2050 en.pdf

[110] Planned targets of energy renovation under the operational Programmes of energy renovation of various building types, Ministry of Construction and Physical Planning, according to the EC's European Roadmap 2050

2015	Materials on the renovation of existing building stock fully prepared Agreement on the level of required energy performance to be achieved by renovated buildings in 2050 and strategies to accomplish it Overview of integral renovation techniques, including applicability to different types of buildings; Integral renovation techniques for most types of buildings developed; Training materials prepared; Government support to renovation research
2014	Preparation for the work plan with the national course of renovation

Croatia's national policy of integral renovation of the national building stock aimed at achieving the targets set in accordance with the provisions of EU directives needs to including 6 categories of measures:[111]

- strategic;
- legislative;
- technical;
- financial;
- communication measures and measures aimed at enhancing capacity;
- research and development measures.

Strategic measures of integral renovation of the national building stock include:

- establish support of the entire Croatian political spectrum for integral renovation of the national building stock;
- put in place a wide stakeholder network as a basis for a successful implementation of the plan of integral building renovation;
- establish an independent commission to monitor and report on the progress on a permanent basis, including timely constructive improvement proposals;
- conduct a systematic assessment of barriers to successful implementation of integral renovation of the national building stock and developing individual solutions to remove each one of them;
- set a target to reduce energy poverty of Croatia's population by improving the energy efficiency measures in the housing sector;
- set integration objectives for various sectors; sustainable urban planning, sustainable construction, local energy resources etc.;
- by successfully renovating non-commercial public buildings, set a good example and stimulate the renovation of other types of national stock buildings.

Legislative measures for successful integral renovation of the national building stock include the following:

- identify the most effective legislative mechanism applied to result in improved energy efficiency of buildings (energy certification, boiler room inspections, stricter technical standards etc.);
- legislative acts introducing an obligation to use renewable energy resources and apply energy efficiency measures in existing buildings;
- amend or repeal restrictive legislative acts destimulating energy efficiency improvements in buildings (Building maintenance regulation[112] etc.);
- legislation introducing an obligation to upgrade buildings of poor energy performance (e.g. introduce various limits and restrictions on the sale and lease of buildings of the energy class below D).

Technical measures need to include the following:

[111] A guide to developing strategies for building energy renovation, BPIE, February 2013

[112] Building maintenance regulation, NN 64/97, available at http://www.mgipu.hr/

- continually harmonise technical norms and standards with new technological solutions available in the market;
- analyse and apply centralised thermal systems for building heating and cooling to the greatest extent possible;
- build gas-fired district heating systems;
- ensure adequate control of compliance with construction regulations and enforcement of criminal provisions in the event of non-compliance;
- develop typical solutions for easy implementation in same-purpose buildings;
- introduce mandatory quality certification of installation service and products.

Financial measures to implement integral building renovation are described in subsection 5.2.3.

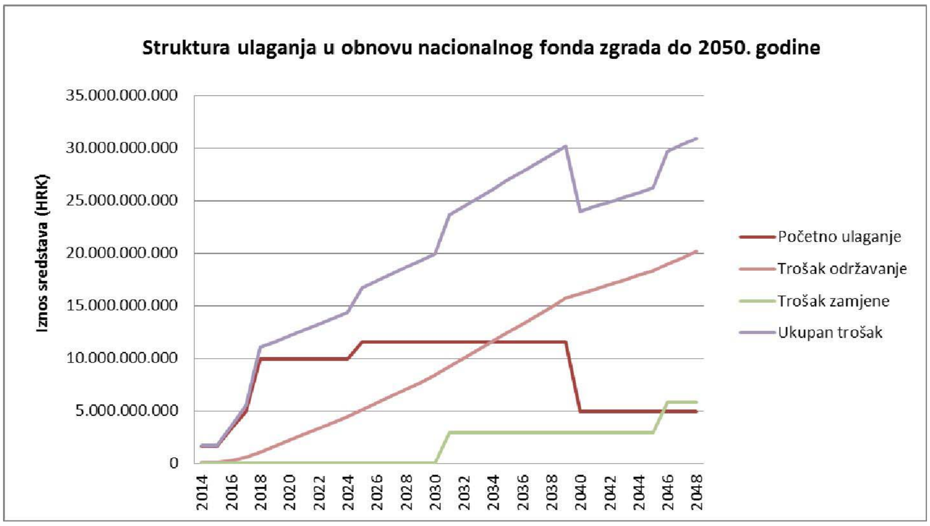
Communication measures and measures aimed at enhancing capacity include the following:
- establish publicly available databases with examples of good practices and all requisite data to initiate and implement building energy renovation projects;
- initiate and continually implement training programmes for all categories of workers in the building segment;
- establish good communication channels for exchanging expertise and experiences among different levels of administration (national, regional, county, local);
- continually conduct promotional and educational activities for various target groups with an emphasis on positive effects of the energy renovation of buildings;
- continually inform stakeholders and the public of the Strategy implementation.

Research and development measures are based on support to research and development of new technologies techniques, materials and elements of a cost-optimal integral building renovation.

5. Long-term perspective to guide investment decisions by individuals, construction industry and financial institutions by the year 2050

5.1 Estimates of required investments

Meeting the set targets of the national building stock energy renovation requires a mobilisation of sizeable financial resources. An estimate of total investments for the period between 2014 and 2049, including initial investment expenditures, maintenance and replacement of worn-out equipment, has been made in accordance with the selected nZEB building renovation standard (Fig 5.1).



Struktura ulaganja u obnovu nacionalnog fonda zgrada do 2050. godine	Structure of investments into the national building stock renovation by 2050
Iznos sredstava (HRK)	Amount of funding (HRK)
Početno ulaganje	Initial investment
Trošak održavanje	Maintenance costs
Trošak zamjene	Replacement costs
Ukupan trošak	Total expenditure

Figure 5.1 Structure of investments into the national building stock renovation

Source: North-West Croatia Regional Energy Agency [Cr. abbreviation: REGEA]

Total expenditures for initial investment and exploitation costs in that period are estimated at HRK 727 billion. The investment has been estimated on the basis of specific costs of construction (renovation) to the nZEB standard and a total area of buildings to undergo energy renovation. A detailed breakdown of investments by the type of expenditure for the 2014–2049 period is provided in Annex 21.

The pace of implementation of the national building stock renovation is aimed at meeting the energy savings targets set by Croatia's Second National Energy Efficiency Action Plan and the EU Energy Roadmap 2050[113]. The pace of renovation across the years represents a presumed framework and is not even through the entire period under observation, so [the renovation] is to take place in several distinct phases:

- In the initial 2014–2015 period, the rate of national building stock renovation is presumed to be somewhat low at 0.5% per year, on account of expected running-in of the process of renovation to the nZEB standard;

[113] Energy Roadmap 2050, available at: http://ec.europa.eu/energy/publications/doc/2012_energy_roadmap_2050_en.pdf

- In the 2016–2017 period, growth of renovated buildings is expected to be 1% and 1.5% per year, respectively;
- Between 2018 and 2024, renovation will take place at a rate of 3% per year;
- Between 2025 and 2039, the renovation rate will be 3.5 % per year;
- Between 2040 and 2049, the renovation pace will slow down to 1.5 % per year.

Planned energy savings of 19 501 PJ as referred to in Croatia's Second National Energy Efficiency Action Plan for the 2014–2020 period are to be achieved in full at that rate of implementation.

Targeted reductions in CO2 emissions set by the Energy Roadmap 2050 are also to be met at the proposed pace of renovation and amount to 87.22% (80% as a minimum). As that target is achieved, a total of 92% of the total national building stock area will have been renovated.

5.2 Identification of funding sources

The Strategy of energy renovation of the Croatian national building stock requires an integral and systematic approach to provide the most suitable financing mechanisms for private and public sector investors over the long term. The primary role of the Government is not in providing financial resources for energy renovation, but in creating and improving conditions in order to create a favourable investment climate among investors for the implementation of required investments defined within the scope of the Strategy. Favourable conditions include macroeconomic stability, efficient state administration, a competitive level of the tax burden, legal certainty, protection of competition and existence of appropriate financial incentives to investing. An overview of existing sources of financing, limits and barriers to their implementation and a long-term strategy of financing renovation projects in buildings sector is provided below.

5.2.1 Existing sources of financing

Energy renovation projects in the building segment are a demanding type capital investment whose successful implementation largely depends on the sources of financing. To date, a number of different financial instruments and models have emerged, with the most significant ones including grants, preferential loans, guarantees, tax instruments and the ESCO model.

Investors in Croatia have so far relied on public grants and various forms of subsidised financial instruments. Length periods of return and very high amounts of investment in the increase of energy efficiency are the reason why this form of financial aid has been introduced in most EU Member States, increasing the profitability level of such investments for investors. Although financial institutions have developed market models involving more favourable lending conditions for energy efficiency projects, the Government’s role in this sector remains crucial for the success of their implementation. That is why the Ministry of Construction and Physical Planning has initiated drafting of energy renovation programmes for four identified building purposes (public, commercial, apartment buildings and family houses). These programmes also envisage special financing models, combined with existing instruments presented in an overview below (Table 5.1).

Table 5.1 Overview of existing programmes and financial instruments

National programmes and funds	
Programme of energy renovation of public buildings for the period between 2014 and 2015	The Government's programme governs the process of energy service provision in the public sector by entrusting the role energy services provider (ESP) to the private sector, while supporting the profitability of investment by grants from the Environmental Protection and Energy Efficiency Fund, preferential loans of the Croatian Bank for Reconstruction and Development and guarantees of the Croatian Agency for Small Business.
Programme of energy renovation of family houses for the period between 2014 and 2020	The Government's programme envisages co-financing of the energy renovation of family houses with resources of the Environmental Protection and Energy Efficiency Fund, EU structural instruments and local and regional self-government budgets.
Programme of energy renovation of apartment buildings between 2013 and 2020	The Government's programme envisages co-financing of the energy renovation of residential buildings with resources of the Environmental Protection and Energy Efficiency Fund, EU structural instruments and local and regional self-government budgets.
Environmental Protection and Energy Efficiency Fund (EPEEF)	The Fund enables grants in all project phases (preparation of documents and implementation co-financing) for public and private sector beneficiaries.
Development banks and credit facilities	
Croatian Bank for Reconstruction and Development (CBRD)	Preferential loans are offered under several programmes to increase energy efficiency aimed at public and private sector investors. Grants are available through grant programmes of the European Commission.
European development banks and funds (EIB, EBRD, EEE-F)	Direct preferential loans are offered to public and private sector investors for large projects.
Western Balkans Sustainable Energy Financing Facility (WeBSEFF)	EBRD loan and grant programme intended for public sector beneficiaries and enterprises.
Croatian Private Sector Support Facility (CroPSSF Sustainable Energy)	EBRD loan and grant programme intended for enterprises and citizens.
Technical assistance programmes	
Western Balkans Investment Framework (WBIF)	Initiative of the European Commission and European development banks provides grants for technical assistance in the preparation of priority infrastructure projects of the public sector.
European technical assistance programmes (ELENA, JASPERS, Horizon2020)	Programmes of co-financing and technical assistance for the preparation of large innovative public sector projects.

Source: REGEA

An overview of currently available sources of financing shows that the majority of instruments is intended for public sector investors. Reasons for it lie in the obligations arising from European Union directives, requiring that the public sector take a leading role in the implementation of activities to improve energy efficiency in buildings sector. In addition to compliance with the obligations assumed by accession to the European Union, the public sector leads by example in the energy renovation of its buildings, contributing to the introduction of new financial instruments and application of new technologies and knowledge in the construction sector.

5.2.2 Financial barriers and limits

Directive 2012/27/EU on energy efficiency dictates support for development of the energy services market, development of new financial mechanisms and incentives, as well as institutional, financial and legal frameworks to remove existing market barriers and shortcomings preventing efficient end-use energy consumption. Barriers of a financial nature which currently hinder the development of energy renovation projects and are to be removed with the help of the Strategy include:

- Very limited and unstable public aid funding;
- High degree of public sector indebtedness;
- Lack of adequate, long-term financial instruments;
- High cost of capital due to a perceived risk of energy renovation projects;
- Lack of support instruments for large enterprises;
- Absence of tax breaks for energy renovation projects;
- Undeveloped ESCo market;
- Energy prices not determined by the market reduce cost-effectiveness of energy efficiency projects;
- High minimum projects size to qualify for the use of the EU technical assistance programmes for Croatian investors.

Existing institutions and associated sources of financing in Croatia currently lack sufficient financial strength to carry through the total investment envisaged under this Strategy. This is particularly true for limited budget funds of the central government and regional and local self-government units, which must be relieved by new and innovative financing mechanisms.

The commercial sector is driven by the principle of profit maximisation and constant operating cost reduction; hence it finds its interest in energy efficiency in the cases where investments result in a significant reduction in expenditures, enabling a return on investment over a short horizon. Most incentives intended for the private sector are aimed at apartment buildings and family houses, leading to a conclusion that the commercial sector is not equally supported in the segment energy renovation of buildings. Reasons for this lie in limits on the use of state aid imposed on EU Member States by the European Commission to prevent distortions of competition in the market by placing certain economic operators into a more favourable position.[114] Existing financial mechanisms are insufficient to implement national energy targets; this is particularly true in respect of large enterprises since the *de minimis* limit of EUR 200 000 on state aid is typically not a sufficiently high incentive for launching investments into the renovation of own buildings.

Citizens are particularly vulnerable groups of end-consumers, so not only special financial models but also promotional campaigns are necessary raise their awareness and level of information on the need for and benefits of investing in the energy renovation of their homes. The energy renovation in the sector of family houses and apartment buildings can be used to efficiently combat a growing danger of energy poverty among citizens.

[114] Official Journal of the European Union (OJ C 83, 30.03.2010). *Consolidated version of the Treaty on the Functioning of the European Union.* Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2010:083:0047:0200:en:PDF [31 December 2013]

5.2.3 Long-term energy renovation financing model

Lack of favourable and constantly available sources of financing leads to the implementation of only commercially viable projects to increase energy efficiency in the buildings sector. By establishing special programmes, funds and credit facilities in cooperation with European development banks, Croatia has recognised the importance of financial support investors. Lack of financial resources in the public sector due to unfavourable macroeconomic developments has been a key impediment to a wider implementation of energy efficiency projects. In the implementation of programmes to stimulate energy renovation to date, Croatia has had no access to Cohesion Policy Funds or European Structural and Investment Funds[115], which greatly limited its possibilities of support to investors in this sector. The European Union requires and at the same time allows Member States to use these instruments to finance the implementation of their energy renovation programmes in the building segment. This is particularly emphasised in Article 20 of Directive 2012/27/EU on energy efficiency, which calls on Member States to set up energy efficiency national funds to support national energy efficiency initiatives if there are no sufficiently strong market-based instruments to implement planned targets. In the previous Multiannual Financial Framework (2007–2013), ESI Funds were the primary source for the majority of national energy renovation programmes, and their role in the new financial framework has been further strengthened. The European Commission has set a minimum allocation of funds from the European Regional Development Fund to achieve Thematic Objective 4 – Support to a shift towards an economy based on low-level CO2 emissions, for less developed members such as Croatia, of 12%[116] in all sectors. Through operational programmes, funding must be used to mobilise investment in the energy renovation of public and private sector building stock, stimulate the use of renewable energy sources, advanced energy networks and urban mobility. This funding represents a major step forward and an opportunity to support the integral energy renovation of the national building stock, so long-term strategy financial mechanisms are mostly based on European funds.

In the course of the previous financial framework for the use of ESI funds, a departure from the usual grant instruments has made in order to achieve the three objectives, missing under previous programmes. These objectives also form the basis of long-term funding sources for the Strategy of renovation of the Croatian national building stock, and their key features are the following:

- financial sustainability;
- rationality in the allocation of grants aimed at encouraging integral energy renovation projects, resulting in ambitious energy savings;
- inclusion of the private sector and market mechanisms in project financing.

In addition to compliance with the requirements for the introduction of innovative and sustainable financial instruments, and taking into account the barriers identified in Chapter 5.2.2., an overview of financial measures to facilitate the implementation of the national building stock renovation in the period up to 2050 has also been prepared (Table 5.2).

[115] Cohesion Policy Funds consist of the European Regional Development Fund (ERDF), the European Social Fund (ESF) and the Cohesion Fund (CF). European Structural and Investment Funds (ESI Funds) include the three above-mentioned funds, the European Agricultural Fund for Rural Development (EAFRD) and the European Maritime and Fisheries Fund (EMFF).

[116] Funding from the Cohesion Fund can also be used for Thematic Objective 4, allowing for 15% fund allocation

Table 5.2 Long-term financial and fiscal measures to stimulate energy renovation of buildings

Financial measures	Effects on identified barriers
Establishment of a national revolving fund for energy efficiency financed by ESI funds and development banks to enable the use of long-term financing instruments, grants and guarantees for public and private sector beneficiaries	– Securing permanent availability of funding, irrespective of budgetary resources of the central government and regional and local government units – Inclusion of other financial institutions in the capacity of investors – Possibility of obtaining grants to increase the cost-effectiveness of ambitious projects – Providing low-cost financing for ESCo projects – Providing for small and micro enterprises lacking their equity capital provided
Further implementation of the Programme of energy renovation of public buildings	– Stimulating the ESCo market development – Reducing the burden on the budget of public sector beneficiaries by avoiding additional borrowing – Lower initial project costs – Engaging financial resources and capacities of the private sector
Setting up a special instrument to co-finance the technical preparation of projects	– Avoiding high costs of project development –Creating a database of projects ready for financing and implementation
Introducing a legislative provision transferring the obligation to implement energy efficiency projects for large enterprises to energy suppliers by using a system of contributions	– Providing sources of grants for large enterprises where the amount of state aid does not suffice – Relief for financial and human resources of public institutions
Establishing a system of tax allowances for investments into energy renovation and higher real estate tax rates on particularly energy inefficient buildings	– Promoting investment in the renovation of inefficient buildings

An optimal financial model to be used for supporting the implementation of Strategy objectives is a complex package of financial and fiscal mechanisms combining market and public instruments. Meanwhile, the Government must ensure maximum efficiency of public funds by taking due care that the use of grants does not crowd out private investments in the projects of commercial nature.

5.3 Ways to make investing in energy renovation more attractive to banks and private investors

The Strategy is aimed at ensuring a long-term removal of barriers to private investments in the energy sector by providing instructions to create a clear, unambiguous and stable legal and administrative framework, which will be stimulating to undertaking investments in the energy renovation of buildings in order to reduce the degree of uncertainty faced by private investors. Because of high investment amounts, their long-term nature and sensitivity when it comes to the outcome amid considerable movements in the market prices of energy, investments in the energy sector need to be stimulated further to make them more attractive to investors. This may include timely information provision to all relevant stakeholders about the financial and legal framework and an extensive exchange of best practices at all levels.

Financial institutions are a key stakeholder in the strategic renovation of the national building stock because the public sector lacks financial strength to support the implementation all planned measures on its own. The involvement of private investors and banks in energy efficiency projects was minimal in the past and limited to commercial projects. Energy renovation project do not generate direct cash receipts, but contribute to a reduction of existing costs. Such financial benefits are more susceptible to technical risk and customer behaviour, so banks have been reluctant to finance this type of projects or demanded higher interest rates and high guarantees. Removing and bridging such risks, as well as distrust of the ESCo model of financing is a key prerequisite of a more intensive involvement of financial institutions, but the Government has mechanisms to provide for it. Some progress has been achieved to date nevertheless thanks to the intervention of European development banks (EBRD and EIB) which, in cooperation with local commercial banks, have established financing facilities for sustainable energy projects and strengthening the capacity of financial institutions for project evaluation and structuring.

The greatest barrier for private investors and energy services providers is a limited access to affordable sources of financing. Lack of support by financial institutions in the form of long-term preferential loans has led to a very high price of ESCo projects, and consequent investor reluctance to opt for that model.

The new package of EU Cohesion Policy measures requires that most investments in sustainable energy projects be implemented by involving private investors. Public aid must meanwhile assume the role of complementary financial resources to leverage the engagement of private investor funding by raising the attraction of their involvement in renovation financing. This goal may be achieved by introducing the following financial and regulatory mechanisms:

- Establishment of a national revolving fund by reallocating resources from ESI funds to enable access by energy services providers to long-term source of financing under more favourable market terms, while providing an opportunity to banks to invest in the fund;
- Introduction of special guarantee instruments to reduce the risk of investment by private investors;
- Subsidising interest rates on commercial loans to enable the placement of commercial banks' resources into the energy renovation of buildings;
- Promotion of the energy services market by implementing the Programme of public buildings renovation;
- Development of standardised methods to measure and verify energy savings, thereby increasing the confidence of beneficiaries and financial institutions into the ESCo model.

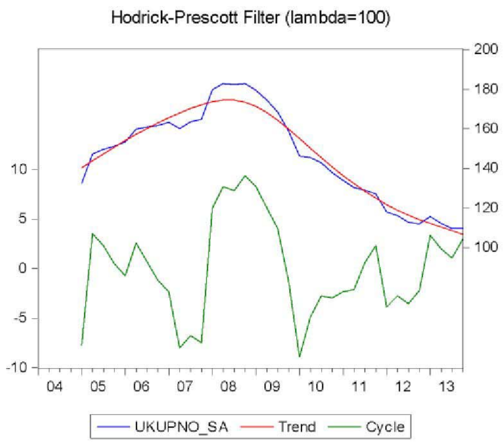
Apart from intervening on the supply side, it is important to make efforts to increase demand for financing services in energy efficiency projects through promotional and information campaigns to increase awareness of beneficiaries of the existence of favourable sources of financing. Many banks in Croatia have recognised the importance of this element, which not only enables them to engage their resources, but also to build an image of socially and environmentally responsible institutions.

6. Estimate of the expected savings and wider benefits based on calculation and model data

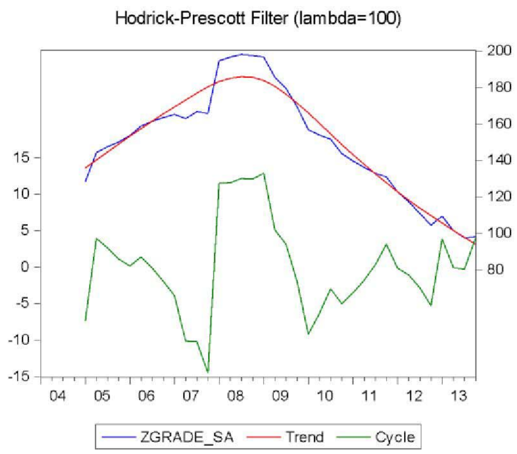
6.1 Economic modelling of integral building renovation

Investments in sustainable building renovation generate wider economic benefits, exceeding the effects of energy savings alone. Some of these benefits can be estimated as the impact of increased construction activity on gross domestic product, employment and state budget revenues.
Also, there are some side benefits which are more difficult to measure: effects on human health, energy poverty decrease and real estate value growth. Wider non-quantifiable benefits, such as positive effects on tourism, quality of life and financial stability, are also present.
This chapter presents links among wider economic benefits. The three measurable economic benefits, the impact of increased construction activity on gross domestic product, employment and state budget revenues have been estimated. Some of the less easily quantifiable measures have also been examined to the extent allowed by statistical data.
The first section contains an overview of the situation in the construction sector, with an emphasis on the building segment. Introductory description of the approach to the economic modelling concludes the introduction. Section 2 describes wider public benefits of integral building renovation. Tax and other incentives to sustainable building renovation, its correlation to property prices and impact on energy poverty are also examined.
Sections presenting the results of economic analysis show that the energy renovation programme may have major effects on economic activity (GDP), job creation and state budget revenues. Depending on the power of multiplicative effects, the renovation programme might contribute to between 23 and 39 thousand new jobs in the period up to 2020 (through 2019), while the overall effect might climb to 62–102 thousand new jobs created in the entire renovation period up to 2050 (through 2049), depending on the power of multiplicative investment effects of investment.
The construction sector in Croatia has seen a major decline after its activity peaked in 2008. Direct dependence of the construction sector on investments is the main cause of an almost 40% decrease in the physical volume of activity between the last quarter of 2008 and the last quarter of 2013. (Figure 6.1). It is the greatest decrease in activity to have been recorded by key economic sectors.
The activity decline in building-related construction activities has been greater than in other construction activities (Figure 6.1). The physical volume of activities in the building segment almost doubled between 2000 and their pre-crisis peak (in 2008), only to almost halve by the end of 2013. A long-term oscillation in other construction activities (Figure 6.1, bottom chart) is almost half that in the building segment.
Trend analysis shows continued presence of a major difference in oscillations among sector activities: a long-term trend in the building segment continues to point sharply downwards, while showing signs of stabilisation in other construction activities.

OVERALL CONSTRUCTION VOLUME INDEX 2004–2013, 2000=100

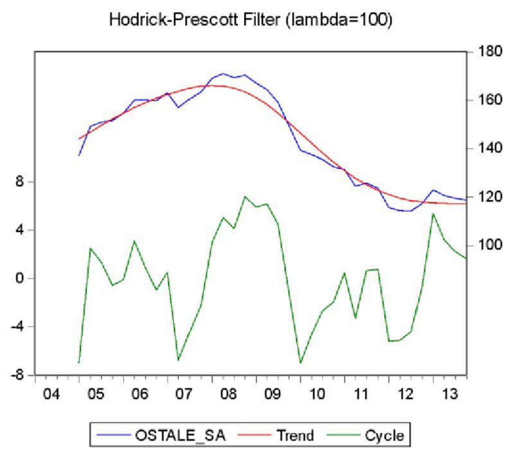


CONSTRUCTION VOLUME INDEX, BUILDINGS, 2004–2013, 2000=100



UKUPNO_SA	TOTAL_SA
Trend	Trend
Cycle	Cycle
ZGRADE_SA	BUILDINGS_SA

CONSTRUCTION VOLUME INDEX, OTHER, 2004–2013, 2000=100



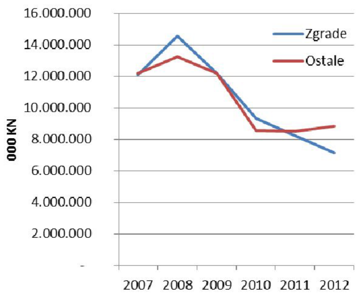
OSTALE_SA	OTHER_SA
Trend	Trend
Cycle	Cycle

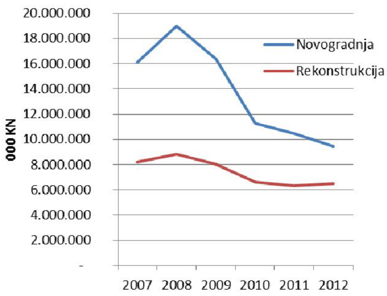
Figure 6.1 Physical volume of economic activity in the construction sector, 2004–2013
Seasonally adjusted indices, data for companies with 20 or more employees[117]
Source: own analysis based on various construction industry releases, Croatian Bureau of Statistics www.dzs.hr

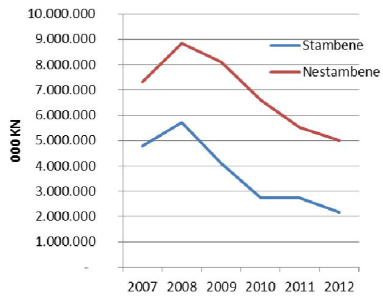
Statistical data in the chart above refer to reporting units with 20 or more employees. They submit monthly and quarterly data. Statistical data including data for enterprises and trades or crafts with five or more employees is available on an annual basis with a time delay. The latest available data at the time this study was being drafted was that for 2012 (Figure 6.2). They confirm a greater oscillation and downward trend in the building segment compared to other activities. The oscillation is smaller in other activities, showing stabilisation and modest growth.

[117] As of 2013, data on trades or crafts are also included in data on legal persons.

However, a stable pace of renovation activities may be observed within the building segment. They are much less pronounced than in new-builds, which were still on a decline in 2012. A smaller share of construction activities related to residential properties is also evident. They have seen a greater relative decline from the 2008 peak, in comparison to the activities related to other buildings. It may be concluded that excessive oscillations and a continued negative trend in the building segment are a result of neglected renovations and over-dependence of the building segment on new-builds, which have been hit by structural crisis due to accumulation of a stock of unsold flats and commercial premises, as well as adverse demographic trends.







000 KN	HRK 000
Zgrade	Buildings
Ostale	Other
Novogradnja	New-build
Rekonstrukcija	Renovation

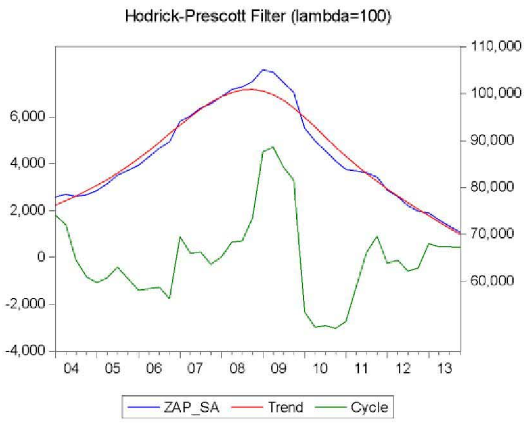
Figure 6.2 Value of completed construction works, 2007–2012

Annual data for companies with five employees or more

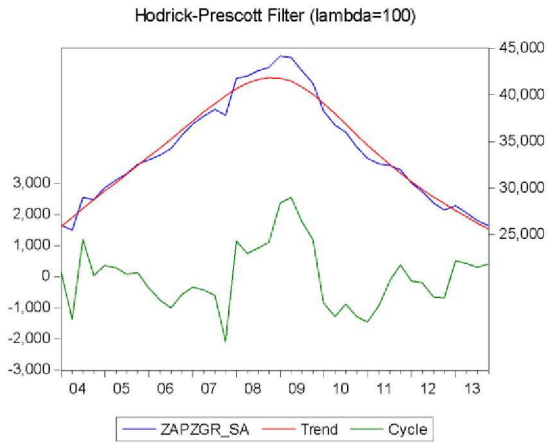
Source: Annual report on construction works in the Republic of Croatia, Croatian Bureau of Statistics, www.dzs.hr

Between the end of 2008 and the end of 2013, the number of construction industry jobs shrank by almost 31 000 (around 30%). Of the total decrease in the number of employees at legal persons in the entire economy (by 118 000 from end-2008 to end-2013), construction companies account for 26%. Even though strong, such decline in the number of construction jobs was slower than that in the psychical volume of activities. It implies labour reserves within the sector. Therefore, potential stabilisation and increase in activities will not immediately lead to a noticeable increase in employment, but rather, activities will be performed by current workers. This is also confirmed by data in Figure 6.3: all employment trends continue to be decidedly downward.

CONSTRUCTION SECTOR EMPLOYEES, 2004–2013 TOTAL

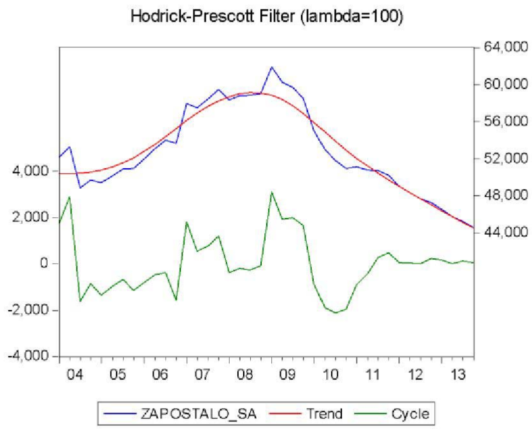


CONSTRUCTION SECTOR EMPLOYEES, BUILDINGS 2004–2013



ZAP_SA	EMP_SA
Trend	Trend
Cycle	Cycle
ZAPZGR_SA	EMPBUI_SA

EMPLOYEES IN OTHER CONSTRUCTION ACTIVITIES, 2004–2013



ZAPOSTALO_SA	EMPOTHR_SA
Trend	Trend
Cycle	Cycle

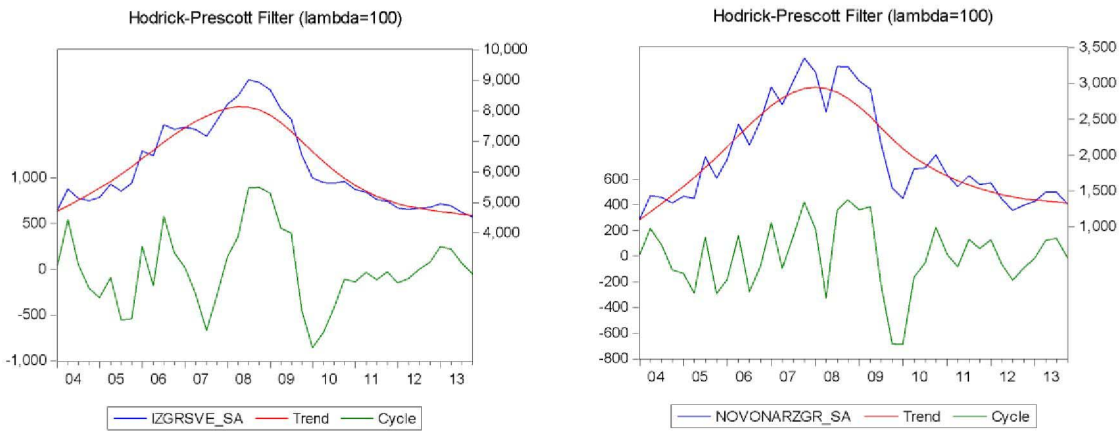
Figure 6.3 Construction sector employees, 2004–2013
Seasonally adjusted data
Source: own analysis based on various construction industry releases, Croatian Bureau of Statistics www.dzs.hr

Any recovery will depend on new investments. When it comes to new building orders, a significantly different trend than the one identified with employment may be observed. Both trends in Figure 4 below show most of the investment decline shock to have been absorbed by 2010. Even though a declining pace of investment has persisted beyond 2010, it has been relatively modest compared to the power of 2009–2010 shock (in terms of the value of completed construction works). The value of new orders[118] in the building segment even points to trend stabilisation. This is explained by

[118] New orders are defined as the value of newly-contracted works Completed works include value without VAT, costs of land purchase, design and supervision, irrespective of the works have been paid or not.

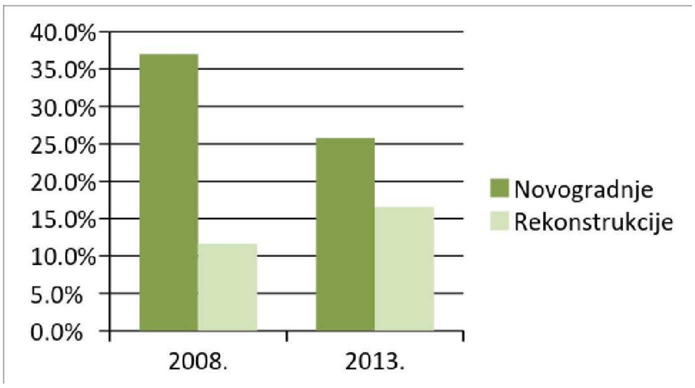
structural substitution of activities in the new-build segment by the renovation activities. Figure 6.5 shows a significant increase in the share of working hours spent on renovations and a relatively greater decrease in the share of working hours in the new-build segment, which proves the aforementioned stabilisation potential of the activities related to building renovation.

VALUE OF COMPLETED CONSTRUCTION WORKS, TOTAL **VALUE OF NEW ORDERS, BUILDINGS**



IZGRSVE_SA	COMPLALL_SA
Trend	Trend
Cycle	Cycle
NOVONARZGR_SA	NEWBUILDORD_SA

Figure 6.4 Value of new orders and completed constructions, 2004–2013, quarterly data
Seasonally adjusted data in HRK mil.
Source: own analysis based on various construction industry releases, Croatian Bureau of Statistics www.dzs.hr



Novogradnje	New-builds
Rekonstrukcije	Reconstruction works

Figure 6.5 Share of working hours spent in building segment in total working hours in the construction sector, December 2008 and December 2013.[119]

The introductory analysis showed three important results:

- the construction sector was hit hard by the crisis and experienced a job loss in excess of 25% of total jobs lost at legal persons in the entire economy during crisis;
- employment trend in all construction segments remains on a pronounced decline, so any programme aimed at halting such trend might produce a very positive effect on the sector

[119] Own analysis based on various construction industry releases, Croatian Bureau of Statistics, www.dzs.hr

and economy as a whole;
- the building segment was hit harder by the crisis than other construction activities; activities in the new-build segment declined much more strongly than the total building segment and construction sector, with the renovation activity decline much less strong than all averages, showing a pronounced stabilisation potential.

Despite an evident need (buildings in Croatia are poorly maintained) and its obvious stabilisation potential, construction activities related to building renovation have been neglected so far. If long-term limitations due to unsold apartment stock and demographic restrictions in the new-build segment, which has been dominant, are added, building renovation activities present the key strategic determinant of the construction sector development over the next long-term horizon.

Different models of investment in sustainable building renovation yield different results with regard to the investment amount, structure and dynamics, but they all produce direct effects on the following:
- stabilisation and increase in economic activity,
- employment,
- public (budget) revenues,
- improved human health,
- reduction of energy poverty, and
- increase in real estate value.

Estimates of individual effects have been calculated using an economic model that measures the main expected economic effects of investment in the renovation of the Croatian national building stock. The main expected effects are the effects on the stabilisation and increase in economic activity, employment and public (budget) revenues. Effects on improved health, poverty reduction and increase in real estate value have only been mentioned in the document and accompanied by an overview of a further course of research necessary to obtain relevant estimates.

The economic model for measuring the main effects of investment in the renovation of the national building stock has been developed in three steps. Step 1 (subsection 6.2.3) establishes a correlation between investment in building renovation and construction sector employment. Step 2 (subsection 6.2.5) establishes a correlation between construction sector investment and value added (Gross Domestic Product – GDP), quantifying multiplicative effects of investment in the construction sector on the economy as a whole. Step 3 (subsection 6.2.5) – calculation of the effects on the public (budget) revenue, derives from it. A result overview follows an overview of total public benefits of integral building renovation and a discussion of some benefits of integral building renovation which are more difficult to measure.

6.2 Public benefits of integral building renovation

Public benefits of integral building renovation can be divided into direct and indirect. Direct benefits in quantity terms can be estimated with more or less success (estimates for the first three benefits are given below). Direct public benefits include:
- stabilisation and increase in the economic activity;
- employment;
- increase in public (budget) revenues;
- improved human health;
- reduced energy poverty;
- increase in real estate value.

Indirect public benefits of integral building renovation can be divided into complex correlations (which are very difficult to estimate, hence they are only mentioned here), and other or indirect benefits.

Here are some examples of complex correlations and feedback loops:
- *effects of employment on poverty reduction:* programmes of investment in sustainable

building renovation are associated with a reduction of energy poverty due to reduced energy costs, but will also entail an effect on reducing energy and general poverty which is associated with the employment of younger and less educated people (who are relatively more susceptible to poverty risk) in construction and other economic activities;

- *effect of improved human health on reducing budget expenditures:* stay in the rooms of inadequate temperature and humidity has a negative effect on human health and increases expenditures of the public health system to be reduced by renovation;[120]
- *effect of budget revenue increase on fiscal stability:* a correlation of decreased budget expenditures due to improved human health and increased budget revenues due to GDP and employment growth creates conditions for reducing the fiscal deficit and/or tax burden and/or increasing other productive government expenditures; all these methods of using increased fiscal stability create an additional positive effect on the economic activity, employment and budget revenues;
- *impact of an increase in real estate value on consumption, GDP and employment growth:* better known as the "wealth effect", it occurs because people are proven to be more relaxed and prone to spending, and even borrowing, when the prices of assets in their possession grow;[121]
- *reduced grey economy:* since grey economy evades tax authorities and statisticians, changes in its volume are difficult to estimate, but it can safely be predicted that the introduction of fiscal incentives and special funding programmes for building renovation will reduce a relative importance and size of the grey economy, thus contributing to fiscal stabilisation and improving worker protection.

Some of the other or indirect benefits are the following:

- *positive effects on tourism development:* renovated buildings, especially their façades, can have a positive effect on attracting and a return of tourists to bigger towns and cities, especially those along the Adriatic coast, where building renovation in tourist centres also involve remodelling, leading to increased attractiveness and/or objective quality growth of any buildings in which some form of tourism or catering activity takes place;
- *quality of life:* beauty and good condition and/or maintenance of the architecture is an important factor of subjective satisfaction with life in cities and towns, positively affecting people's behaviour;
- *increased financial stability*: a higher share of renovations in construction activities reduces fluctuations of the construction and overall business cycle and of real estate prices, thus directly contributing to financial stability; favourable financial incentive schemes associated with funding programmes for building renovation increase the protection of consumers of financial products and services, and prevent misunderstanding of financial contracts, excessive financial fluctuations etc.

[120] These effects could be roughly estimated by means of research, combining available statistical data and expanded to include a field collection of additional data in cooperation with the public health service;

[121] Ahec-Šonje, Čeh-Časni and Vizek, 2014: „The Effect of Housing and Stock Market Wealth on Consumption in Emerging and Developed Countries". Economic Systems, forthcoming).

A consolidated scheme of public benefits of integral building renovation is shown in Figure 6.6:

IZRAVNI UČINCI	DIRECT EFFECTS
Stabilizacija i povećanje ekonomske aktivnosti	Stabilisation and increase in economic activity,
Zapošljavanje	Employment
Povećanje prihoda proračuna	Increase in budget revenues
Poboljšano zdravlje ljudi	Improved human health
Smanjenje energetskog siromaštva	Reduced energy poverty
Povećanje vrijednosti nekretnina	Increase in real estate value
KOMPLEKSNE VEZE	COMPLEX CORRELATIONS
Smanjenje siromaštva zbog zapošljavanja	Reduced poverty thanks to employment
Smanjenje troškova zdravstva zbog boljeg zdravlja ljudi	Reduced health care expenditures thanks to improved human health
Povećanje fiskalne stabilnosti	Increased fiscal stability
Učinak bogatstva: veća potrošnja zbog rasta vrijednosti nekretnina	Wealth effect: greater consumption due to an increase in real estate value
Smanjenje sive ekonomije	Reduced grey economy
NEIZRAVNI UČINCI	INDIRECT EFFECTS
Razvoj turizma	Tourism development
Povećanje kvalitete života	Improved quality of life
Jačanje financijske stabilnosti	Strengthened financial stability

Figure 6.6 Public benefits of integral building renovation

6.2.1 Tax and other incentives

Public benefits described above justify a consideration of tax and other fiscal incentives to facilitate the financing of integral building renovation. Four complementary instruments have been considered: tax allowances, reduction or abolition of the real estate transfer tax, housing saving subsidies and special financing programmes, including the use of grants from EU funds. It should be noted that financing programmes cannot rely solely on EU funds in the long run since the amount of necessary grants and the project time horizon will exceed their financial capacity.

Tax allowances. Tax allowances for investment are usually introduced as part of the income tax system. However, the system of income taxation in a debt-ridden country such as Croatia should be as clear and simple as possible, with any allowances preferably omitted or made exceptional or, if any, they should be associated with other, more important social goals. But a real estate tax could be a useful source of new incentives. The introduction of a real estate tax inevitably falls in the time horizon set for renovation of the national residential building stock until 2050. In view of multiple public benefits of integral building renovation, the real estate tax structure should be designed to provide for tax allowances for property owners investing in renovation and achieve targeted construction and energy standards. Such allowances could multiply back through reciprocal effects of induced economic activities on public revenues (subsection 6.2.5).

Real estate transfer tax. The real estate transfer tax, payable at a rate of 5% in Croatia, is an archaic form of taxation. It places real estate into a less favourable position compared to other forms of assets, the trading in or the acquisition of which is not taxed. In addition, this form of taxation does not represent a major source of budget revenues. The principle of tax system simplicity, neutrality, generosity and equity therefore call for a review, and possibly to abolishment of this tax form. However, these general principles are not the main reason to reconsider the use of real estate transfer tax in order to encourage building renovation in Croatia. The reason is deeper and more important: the population ageing trend, as well as inability to provide financial adequacy of the vast majority of state pensions and a long-term downward trend in the value of poorly maintained real estate, represent a combination of factors making both necessary and mutually beneficial a real estate transfer from the hands of the elderly who cannot maintain them, to younger people who will be able to invest in their renovation. By moving into cheaper properties, the elderly receive money – equal to a difference in the prices of respective properties – thereby markedly improving their living standard in the third age or enabling a renovation of some less valuable property, while younger people would acquire real estate in better locations under relatively favourable terms and could invest in its renovation to increase in its value. Therefore, real estate transfer tax abolishment represents an important instrument of enhancing optimal allocation of the real estate stock to people who will be able to maintain it and increase its value, reaping substantial benefits for the persons selling them in the process.

Subsidised housing saving system. Even though housing saving subsidies were abolished in 2014 because of excessive deficit and public debt, building societies [Cr. term: housing savings bank] are still trying to find modalities of survival. Housing savings depositors still believe that some form of incentives again be possible one day, as evidenced by more than 700 000 opened housing savings accounts. The fact that almost a half of all loans granted by building societies have been for remodelling and renovations[122] is also important, testifying to a dire need for renovation financing among citizen. It can be concluded that a subsidised housing saving scheme is an extremely adaptable financial instrument, suitable for conducting sectoral policy in the construction industry. The introduction of differentiated incentives may encourage a preferred saving purpose and borrowing, which in this case refers to certain types of integral renovation of housing units. As long as such savings are Government-subsidised, building societies are the only credit institutions able to offer long-term loans at a favourable interest rate, which remains fixed through the loan repayment period. This largely contributes to achieving the indirect goal of financial stability and stress-free loan repayment. It is therefore necessary to consider a reintroduction of purpose-differentiated housing saving subsidies, linked to the financing of integral building renovation.

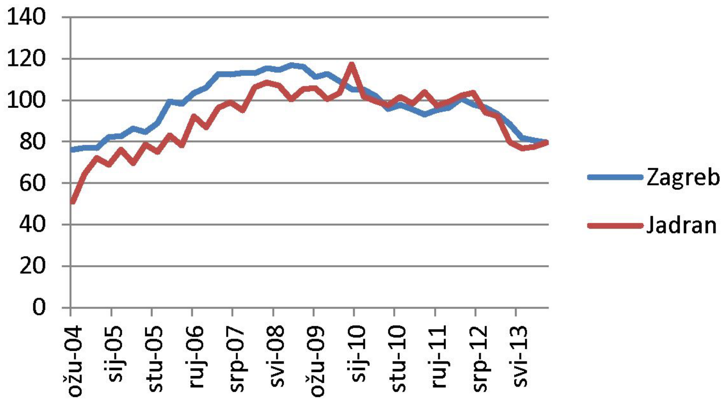
Special financing programmes that include the possibility of grants from EU funds. The three forms of incentives are unlikely to suffice for mobilising integral building renovation of the scope and

[122] Institute of Public Finance (2013): *Analysis of the system of subsidised housing savings in the Republic of Croatia.* Zagreb: Institute of Public Finance .

dynamics required by the current situation, and planned under this Strategy. It is thus necessary to arrange for special loan-warranty financial schemes that include the distribution of risk and subsidies to some costs of preparation, development, supervision and implementation, which cannot be done without engaging resources from EU funds and budgetary resources. Macroeconomic aspects of the role of budgetary resources are described in detail in subsection 6.2.5.

6.2.2 Increase in real estate value

A strongly pronounced long-term construction and business cycle has had an impact on real estate prices in Croatia. The price peak occurring in Zagreb in 2008 and on the Adriatic in 2009 was followed by a downward price correction. By the end of 2013, prices had fallen by 32% compared to their maximum level. According to an international real estate price database for 54 countries of the Basel-based Bank for International Settlements, similar declines in prices occurred in Slovenia, Romania, Latvia, Greece, Estonia and Bulgaria, and for certain types of real estate in Denmark and Japan, in that same period.



ožu-04	Mar-04
sij-05	Jan-05
stu-05	Nov-05
ruj-06	Sept-06
srp-07	July-07
svi-08	May-08
ožu-09	Mar-09
sij-10	Jan-10
stu-10	Nov-10
ruj-11	Sept-11
srp-12	July-12
svi-13	May-13
Jadran	Adriatic

Figure 6.7 Hedonic real estate price index 2004–2013, 2010 average=100

Source: Croatian National Bank, Statistical Review, www.hnb.hr

The described price cycle cannot be explained merely by the overall economic situation or by the price bubble which preceded the crisis. Countries of similar macroeconomic dynamics have seen very different price amplitudes. Some differences in price amplitudes may be explained by the real estate market regulation and institutional organisation, as well as preferences and habits of property owners and tenants. Therefore, price amplitudes have been more pronounced in Croatia than in some other countries of similar macroeconomic characteristics: the phenomenon of greater preference for property ownership exhibited by younger generations with non-utilised credit potential has led to a relatively higher demand for new-builds than for maintaining old ones.

The structure of the economic activity in the construction sector is related to real estate price fluctuations. Overemphasising new-builds while neglecting renovations and remodelling has led to more pronounced price oscillations in Croatia. When demand for and investment in new-builds stopped – accompanied by a major allocation error reflected in the stock of unsold apartments and buildings – prices slumped. This was even more pronounced with older properties that have been undermaintained. The allocation error due to neglected renovations also affects the labour market, where know-how and efforts have been channelled into new-builds, while some specific remodelling and renovation know-how and skills, especially with regard to the energy renovation, have also been neglected. This dynamics error can be corrected, mitigating construction and business cycles, by encouraging renovation activities. Hence, it is necessary to ensure a stable flow of these activities through policy measures. In that case, a favourable effect of investment into building renovation will also occur on account of smaller price fluctuations and a higher value of renovated properties in the future.

The effect of increase in the value of renovated properties can be estimated, but it requires more complex modelling than it has been possible to develop within the scope of this project. It is necessary to collect data on transactions in certain properties, as well as data on the quality and investment in the properties in question in order to estimate, along with controlling for the effects of macroeconomic factors such as GDP and interest rates, the extent to which investment affects the market price achieved by it.

6.2.3 New job creation

There is a narrow, positive correlation among investment, economic activity and employment in the construction sector. There is also a wider circle of induced, so-called multiplicative effects. This means that (labour and capital) income, generated in the activities related to a construction investment, are spent in the second, third and further consumption "circles", stimulating the overall economic activity (subsection 6.2.5). The impact of the programme of integral building renovation on new job creation may be observed through two effects:

- *direct job creation in the construction sector,* which depends on the employment response to new investment in the construction sector;
- *indirect multiplication,* enabling further job creation in the economy as a whole, which depends on induced GDP growth and the employment response in the construction sector as a whole.

<u>Direct job creation in the construction sector</u>

An estimate of the employment response to investment in the construction sector depends on the technological character of investment, labour price and labour market characteristics. The more complex the technology, the higher the price of labour and the more rigid the labour market, the weaker the direct effect on employment. Owing to the effect of different external factors, the estimates of the number of jobs created [123] per EUR million invested in the energy renovation of buildings range widely, from 5.5 in Ireland[124] to 26 in Hungary.[125] [126]

The estimated direct effect for Croatia is based on regression analysis that links the values of new building orders to the number of employee (Box 1 and Annex 22). Employment elasticity, i.e. change in the number of construction sector employees in relation to investments (new orders) has been estimated to stand at 0.4. It means that a 10% nominal increase in investment in the building segment leads to an increase in the number of jobs by 4%. The result needs to be interpreted with caution because of being derived from a simple regression equation, but in the absence of a better model, even that may serve as a basis for the purpose of long-term estimation.

Box 1 Econometric estimation of the investment to employment ratio in the building segment

The estimation has been done by using the error correction model (ECM). Both the dependent and the independent variable have been transformed into the In form, so that regression coefficients can be interpreted as elasticities. These are quarterly data: the value of new building orders by quarter in HRK mil. and the mid-quarter number of employees in the building segment. The partial adjustment model (PAM) was evaluated first, with the short-term coefficient = 0.11 and the long-term coefficient = 0.61. The problem is that the variables are not stationary I(0), but rather integrated first-grade I(1) variables, so any consideration of long-term effects might be susceptible to high estimation risks. Long-term parameters draw to them a number of extra-model impacts (such as the inverse effect of real estate price growth, as well as sectoral and growth of the economy). Such a reservation with regard to long-term specifications has been confirmed by the EMC estimation. It estimated the long-term coefficient to be 0.4. More details on the estimation may be found in the annex at the end of the document.

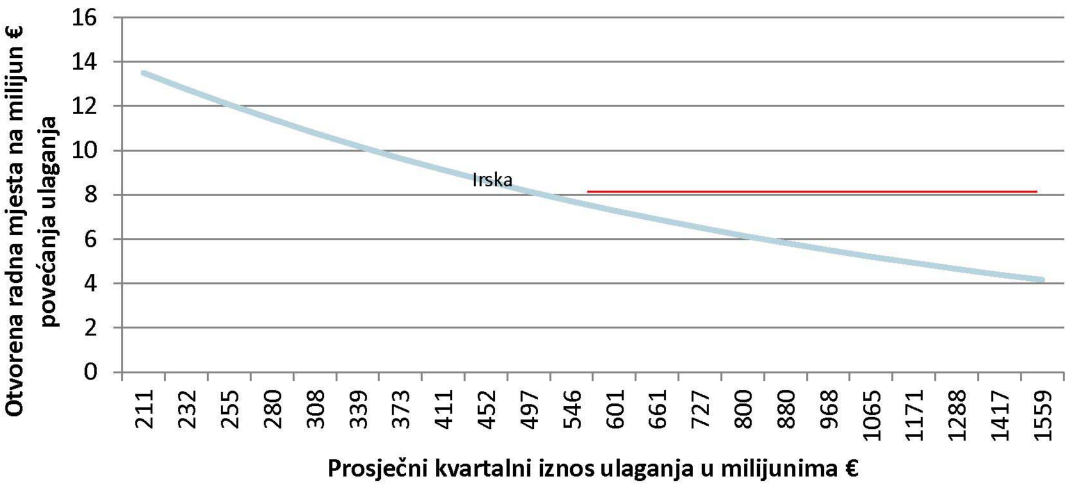
[123] This refers directly to the construction sector, as well as to the energy sector and related professional activities.

[124] http://www.seai.ie/News Events/End of Year Statement 2012.pdf Both incentives and stimulated private investment have been taken into account.

[125] http://3csep.ceu.u/projects/employment-impacts-of-a-large-scale-deep-building-energy-retrofit-programme-in-hungary

[126] The Hungarian study, for example, also includes all the effects of energy savings, including the effects on the savings in disposable income, which – apart from reducing poverty – also induce new circles of additional consumption, thus increasing employment in the entire economy. Hungarians used a dynamic input-output analysis, but their figures are hypothetical. The figure for Ireland refers only to direct job creation in construction and energy sectors (direct effect only), but their figures are based on the implementation of an actual programme.

If a 10%-nominal increase in investment in the building segment leads to an increase in the number of jobs by 4%, then the correlation between investment and employment is not linear. Each additional million invested leads to a steadily diminishing number of new jobs. Non-linearity occurs because more new investment is to create an additional job is necessary at higher investment levels. The reasons for it are logical: as investment grows over time, business is better organised (organisations amalgamate, economies of scale appear), competition gets stronger, new skills (routines) are acquired, labour productivity grows, the labour price and other input parameters also increase and, thanks to technological advances in materials, the real material cost ratio to total investment expenditure also grows. Therefore, among other things, the effect of the same nominal amount of investment on employment is much smaller in Ireland than in Hungary, where all prices (apart from imported equipment) are considerably lower.
Figure 6.8 shows the result of simulation using the estimated 0.4 elasticity ratio for Croatia and starting from the value of new orders and the employment situation in the building segment late in 2013. The X axis shows quarterly flows of the value of new orders in EUR million, growing at a rate of 10% from one quarter to another. The Y axis shows the number of new jobs per EUR million of additional investment in the quarter (equivalent to EUR 4 million of investment a year, since these are quarterly millions). The effect on employment is high early on, but it subsides fast with investment growth.



Otvorena radna mjesta na milijun € povećanja ulaganja	Jobs created per EUR mil. of increased investment
Prosječni kvartalni iznos ulaganja u milijunima €	Average quarterly investment amount in EUR mil.
Irska	Ireland

Figure 6.8 Simulation of new employment per EUR million of additional investment in the circumstances of growth in the value of new building orders, with the elasticity ratio of employment to investment of 0.4[127]

Table 6.1 shows direct effects of the programme on the construction sector. Croatia's total building stock has an area of 192.5 mil. m^2. The presumed renovation pace has grown steadily early at the onset of the renovation programme (since 2014) and is to reach 3% of the building stock per year by 2018. Between 2025 and 2039, the rate of renovation is to rise to 3.5% a year, only to fall to 1.5% in the last decade of the programme. Data in Table 6.1 show that the average annual investment in the initial phase up to 2020 (through 2019) might be around 1.8% of the 2013 GDP and that the building

[127] Hungary includes all indirect effects and figures are hypothetical, taken from a model. Figures for Ireland are actual and only include direct effects of employment. It is thus reasonable to expect the Croatian figures to be closer to the Irish ones. However, one should keep in mind that direct comparisons to other studies are tentative only, since these studies usually state no period to which the investment refers – hence, it has been emphasised that the figure refers to a quarterly million, with the number of induced jobs divided by 4 to obtain the annual, sustainable number of jobs.

segment, which currently employs around 25 000 workers, might directly create around 15.5 thousand new jobs in that period, or 31 thousand new jobs over the entire programme horizon up to 2050.

Table 6.1 Investment and direct new employment in the building segment under the integral renovation programme

	2014–2019	2020–2024	2025–2029	2030–2039	2040–2049	TOTAL 2014–2049
% of renovated building stock (cumulative)	9.50%	24.50%	42.00%	77.00%	92.00%	92.00%
investment amount – total HRK	35 232 196 521	66 359 539 484	89 986 505 135	262 284 335 213	273 281 444 805	727 144 021 230
of which: initial investment	31 415 539 199	49 603 482 945	57 870 730 103	115 741 460 205	49 603 482 945	304 234 695 397
of which: maintenance	3 816 657 323	16 756 056 539	31 115 775 033	120 448 849 748	183 087 255 900	355 224 594 543
of which: substitutions	0	0	0	26 094 025 260	40 590 705 960	66 684 731 220
investment amount – total HRK, yearly average	5 872 032 754	13 271 907 897	17 997 301 027	26 228 433 521	27 328 144 480	20 198 445 032
investment amount – total EUR, yearly average	772 635 889	1 746 303 671	2 368 065 925	3 451 109 674	3 595 808 484	2 657 690 136
Average annual investment amount in % of 2013 GDP	1.80%	4.00%	5.5%	8.0%	8.3%	6.2%
New jobs	15 507	2 585	4 116	7 654	1 166	31 029
New jobs per EUR mil. and investment**	10.5	7.0	6.2	5.2	5.1	6.3

*All calculations are based on a fixed exchange rate: 1 EUR=HRK 7.6.

<u>Multiplicative effects</u>

(Labour and capital) income generated by direct involvement in an investment activity concentrically creates new demand and value added in the economy. These are multiplicative effects. In subsection 6.2.5, multiplicative effects on GDP were estimated using three scenarios:

- low multiplier = 1.2 (total effect on GDP exceeds investment value by 20%)
- medium multiplier = 1.5 (total effect on GDP exceeds investment value by 50%)
- high multiplier = 2.0 (total effect on GDP exceeds investment value by 100%)

Table 6.2 shows effects on employment for three multiplication scenarios. Depending on the multiplier size, between 23 and 39 thousand new jobs may be expected by 2020. The total effect (initial investment + multiplication) on the new job creation by 2050 has been estimated at between 62 and 102 thousand jobs, depending on the strength of the effect of multiplication.

Table 6.2 Total effect on employment, multiplicative effect included

	2014–2019	2020–2024	2025–2029	2030–2039	2040–2049	TOTAL 2014–2049
Total employment increase						
1.2	23 333	5 516	9 633	21 018	2 697	62 197
1.5	29 104	6 850	11 942	25 964	3 349	77 208
2	36 668	9 035	15 710	33 962	4 416	101 790
Of which: multiplicative effect						
1.2	7 826	2 931	5 517	13 363	1 530	31 168
1.5	13 597	4 265	7 826	18 309	2 182	46 180
2	23 160	6 450	11 593	26 308	3 250	70 762

6.2.4 Reduced energy poverty

According to the household consumption survey (last published data for 2011), a total of 16.2% of Croatian households spends significantly more than 10% of the total personal consumption expenditure on energy (electricity, gas and solid fuels) This represents 3.5% of the total number of households with expenditure of less than 40% of medial personal consumption expenditure per equivalent adult, and 12.7% of the total number of households with expenditure per equivalent adult household member between 40% and 60% of medial expenditure of an equivalent adult member (Table 6.3). This problem is especially pronounced in 3.5% of households with expenditures of less than 40% of the medial expenditure. On average, they spend around 16.4% of the total expenditures on energy.

These are households with an above average share of older members (share of members over 65 three times higher than in households of the highest consumer class). Such households usually live in family houses (more than 90%). Approximately the same percentage have no heating installations, which means that they predominantly use solid fuels for heating.

Published survey data, unfortunately, do not allow more accurate calculations. However, the social and economic image and the living conditions of these households point to the possibility of energy savings with a substantial impact on reducing energy poverty. The implementation of the programme of integral renovation of the national building stock needs to include special measures and models to encourage energy renovation of smaller undermaintained family houses, accommodating persons and families with a lower disposable income, as an especially important part of the social policy if relative energy price growth is expected over a long-term horizon.

Table 6.3 Preliminary energy poverty indicators

	Less than 40%	40%–60%	60%–80%	80%–120%	120%–160%	More than 160%
Household distribution	3.5%	12.7%	20.1%	36.7%	17.6%	9.4%
Share of persons over 65	33.7%	26.5%	23.1%	20.0%	14.1%	11.2%
Share of energy cost	16.4%	13.3%	10.9%	9.3%	7.4%	6.1%
House	96.9%	91.6%	84.0%	70.2%	69.7%	61.9%
Flat	3.1%	8.4%	16.0%	29.8%	30.3%	38.1%
Heating – installations	7.4%	10.7%	22.8%	39.0%	52.2%	57.7%

* According to available consumption expenditure per equivalent adult household member.

Source: Results of the 2011 Household Consumption Survey, Croatian Bureau of Statistics, Statistical reports No 1484.

6.2.5 Impact of integral building renovation measures on economic activities

The effects of integral renovation of the national building stock on economic activities may be divided into three groups, in addition to the already presented effect on new job creation:

- effect on value added, that is, on gross domestic product (GDP),
- effect on public (budget) revenues,
- structural effect.

Effect on GDP

The effect on GDP consists of a direct effect of investment, which is equal to the amount of investment increased by the multiplicative effect achieved by income generation and its spending in the second, third and further concentric circles of consumption, spurred by initial investment. The multiplicative effect was estimated on the basis of multipliers specified in earlier similar studies related to the construction sector (Arhivanalitika, 2009[128] and Institute of Public Finance, 2013).

Concentric expansion of multiplicative effects through the economic system is very difficult to monitor. It depends on thousands of autonomous economic decisions on which there are no statistical data. However, the principles of expansion are well-known: the investment multiplier is higher where marginal propensity to consume is greater, and lower where the marginal tax rate on production factors and marginal propensity to import is higher (this is additional taxation or additional imports related to an added income unit). Due to the high marginal propensity to import, the investment multiplier is lower in smaller and more open national economies, especially those with a high tax burden. These are Croatia's characteristics, so one should not expect a particularly high multiplier in Croatia.

One should also bear in mind that the multiplier depends on the type of investment. Investments with a higher share of more expensive (more taxable) labour and a high import component will have

[128] Arhivanalitika (2009): Ocjena učinaka i perspektiva stambene štednje u Hrvatskoj [Evaluation of the effects of housing savings and their perspective in Croatia]. Zagreb, Arhivanalitika.

a lower multiplier, and vice versa. Unfortunately, there is no methodologically well-conducted research of investment multipliers depending on the types of investments in Croatia.[129]

Therefore, a direct estimate of the investment multiplier in Croatian construction industry – for the type of investment referred to here, exceeds the objectives and possibilities of this study by far. However, expert estimates enable defining a likely multiplier range. Generally, the multipliers of construction investments normally assume a value from around 1.5 (implying an additional effect of up to 50% in excess of the initial investment value), where the import component is relatively high, to above 2 (additional effect of more than 100% of the initial investment value), where the import component is small. In the United States, multipliers can even stand around 3. Arhivanalitika (2009) prepared estimates with a multiplier of 1.5, but reduced that multiplier to 1.2 in the sensitivity analysis. The Institute of Public Finance (2013) worked with a multiplier of 2, after examining a number of international studies about multipliers induced by construction investments.[130]

The problem with the multiplier of 2 is that it relies on optimistic assumptions when it comes to the structure of the Croatian economy: for example, the multiplier of 2 might be achieved if the marginal propensity to consume was 75% (average is around 60%), the marginal tax burden of the labour and capital factor were to fall to 20% and the marginal propensity to import only 10% (average is around 40%). Although the said assumptions are unrealistic at the moment, new activities and suppliers might appear in the country over time, and fiscal healing, growth and smaller tax burden may be achieved, which will lead to an increase in the multiplier. This could also occur due to shrinkage in the share of new-builds and an increase in the share of specialist activities in the construction industry structure. As the range of possible multipliers is very wide, below are the results for three versions of the multiplier: low multiplier = 1.2; medium multiplier = 1.5; and high multiplier = 2.

The calculation is simple: the amount of total investment referred to in Table 6.1 is increased by 20% with the low, 50% with the medium, and 100% with the high multiplier. Thus, we obtain the total effect on GDP growth, shown in Table 6.4, along with the effect on budget revenues.[131]

Effect on public (budget) revenues and overview of results

The share of current general government revenues in GDP in Croatia over a long number of years has varied between 37.5% and 40% of GDP (according to the national fiscal statistics methodology). The estimate of fiscal effects is based on the assumption that total GDP growth associated with the programme of integral building renovation will induce general government revenues in constant proportion to the historically stable 38%.

Table 6.4 shows that the *programme of integral building renovation in the initial period up to 2020 will lead to an increase in GDP of between 2.1% and 3.6%,* depending on the achieved investment

[129] The investment multiplier shows how much GDP will increase if investments are increased by a unit: where *c* is marginal propensity to consume (which shows how much consumption will change if income changes by a unit, *t* is the tax rate on production factors, and *m* is the marginal propensity to import (which shows how much imports will change if GDP changes by a unit). The multiplier is a highly problematic concept in analytical terms, since a simple mathematical structure is used to calculate an extremely complex phenomenon. Mathematics is as a metaphor here, not an accurate description of the actual process. This is evident in the fact that the multiplier "collapses" (becomes smaller than 1) if $m > c(1-t)$. Geoff Riley (2006) points out in "Multiplier and Accelerator Effects" http://tutor2u.net/economics/revision-notes/as-macro-multiplier-_accelerator.tml that a lower threshold of the real multiplier is about 1.4, but due to the extreme openness of the Croatian economy (propensity to import) and a high tax burden, the possibility that the multiplier might be even lower cannot be ruled out. In fact, even if imports are excluded (even though the marginal propensity to import is high), the marginal propensity to consume in Croatia is around 60% (approximated by the average propensity to consume), and the marginal rate of income taxation and paid out profits ranges between 30% and 35%, so assuming $c = 0.6$ and $t = 0.3$, we get a multiplier of 1.7, without imports. With an assumed $m = 0.4$, which is very conservative for Croatia, a multiplier only slightly higher than 1 is obtained.

[130] According to the Institute of Public Finance (2013: 60), estimated multipliers range from 2 in Scotland to 3.5 in the U.S., but pointed out that multipliers are very different for construction (lower) and specialised activities (higher).

[131] Estimates are provided in nominal amounts. There is no point to calculating real changes since the prices of goods on which the expenditure induced by this programme are spent cannot be anticipated (for that purpose, one should be familiar with the input market structure and anticipate technological changes, and that is impossible). However, in macroeconomic terms, growth induced by the integrated building renovation programme is probably not large enough to bring about a particular inflation of demand (see Table 4 for the strength of effects). However, the effect on prices cannot be completely ignored, so the reader must bear in mind that price growth may reduce translation of nominal values into real ones.

multiplier (1.2 or 2): this refers to an increase in the level of economic activity by the 2014–2019 period average compared to 2013. Such increased activity could lead to growth in general government revenues of between 0.8% and 1.4%, measured as the period average compared to the 2013 GDP, and depending on the investment multiplier achieved. By the last period of programme implementation (2040–2049), GDP for the period average could increase by between 10% and 17% from the 2013 GDP, depending on the size of the investment multiplier achieved. A corresponding increase in state budget revenues could range between 3.8% and 6.3% of the 2013 GDP.

Table 6.4 Effect of the programme of integral building renovation on GDP and general government revenues

	2014–2019	2020–2024	2025–2029	2030–2039	2040–2049
Effect on GDP – total HRK					
1.2	42 278 635 825	79 631 447 381	107 983 806 162	310 494 336 354	327 937 733 766
1.5	52 848 294 782	99 539 309 226	134 979 757 703	382 809 338 065	409 922 167 207
2	70 464 393 042	132 719 078 968	179 973 010 270	503 334 340 917	546 562 889 609
Effect on GDP – period average in % of 2013 GDP					
1.2	2.1%	4.9%	6.6%	9.5%	10.0%
1.5	2.7%	6.1%	8.2%	11.7%	12.5%
2	3.6%	8.1%	11.0%	15.3%	16.7%
Effect on budget revenue – total HRK					
1.2	160 658 816	30 259 950 005	41 033 846 342	117 987 847 814	124 616 338 831
1.5	20 082 352 017	37 824 937 506	51 292 307 927	145 467 548 465	155 770 423 539
2	26 776 469 356	50 433 250 008	68 389 743 903	191 267 049 548	207 693 898 052
Effect on budget revenue – period average in % of 2013 GDP *					
1.2	0.8%	1.8%	2.5%	3.6%	3.8%
1.5	1.0%	2.3%	3.1%	4.4%	4.7%
2	1.4%	3.1%	4.2%	5.8%	6.3%

When it comes to budget revenue resulting from implementation of the programme of integral building renovation, it should be noted that it may be possible to use only a small portion of these funds – if any at all – for new public expenditures or deficit reduction. Required investments in the programme of integral building renovation will not be possible without incentives. A part of incentives in the initial years of the programme may be co-financed from EU funds, while growth of the relative price of energy over a long term will trigger market incentives to private investments by energy end-users. However, meanwhile, it may be possible to complete the planned investment programme only if most or all the funding raised through increases in budget revenues find their way back into financial programmes to encourage investment in sustainable building renovation. Given the ambitious nature of the programme of integral renovation in terms of its dynamics and targeted investment amounts, embarking on further development of financial programmes and establishment of a system of continuous monitoring of direct and induced effects of investments is advisable, so that, with the use of EU funds, the amounts required for the functioning of incentive schemes to finance integral building renovation in Croatia by 2050 may be planned with greater precision.

Structural effects

The programme of integral building renovation will also have three important structural effects:

- *Predictable demand independent of government investment projects* will redirect resources into more stable remodelling and renovation activities, thus reducing the amplitude of the construction and overall business cycle.
- *The effect on productivity* will be immediately positive thanks to energy savings, which is usually not the case in government investment whose returns and effects on productivity are very long-term and hard to predict.

- *Steady market growth* will stimulate stronger competition and amalgamations in the construction sector, as well as the acquisition of specific routines and skills related to the energy renovation, and that in turn will affect sectoral productivity and efficiency of the use of resources with positive end-benefits for consumers.

Annex 1. Overview of energy efficiency measures and renewable energy resources for each building category

Building category	EE/RES measures
Public buildings	**Measure 0:** Energy audit of the building and establishment of systematic energy management **Measure 1:** Renovation of external envelope of the building's heated space, including the replacement of external carpentry and increasing heat retention of external walls, roof or ceiling bordering unheated attic and ceiling bordering unheated basement. The goal of renovation is to achieve energy class B, A or A+ of the building as a whole. The existence of project documentation required in accordance with construction legislation is a prerequisite for the implementation of this measure. Energy renovation means design, performance of works under the main or detailed construction project documentation, issuance of an energy certificate after the renovation, public display of the certificate and proving renovation results. **Measure 2:** Replacement of existing heating systems using electricity or fossil fuels by new systems using condensation gas boilers or biomass-fired boilers to improve heating system efficiency, along with heating system balancing and thermostat set installation. If the building's total energy requirements are small, and the system is suitable for low-temperature heating operation with pronounced cooling requirements, it is recommended to apply a geothermal or air heat pump for heating, cooling and DHW generation. In accordance with par. 28 of the preamble to Directive 2012/27/EE, the use of individual meters or heating cost splitters to measure individual heating consumption in apartment buildings with centralised heating or common central heating is useful when end-consumers may monitor their individual consumption. Therefore, their use makes sense only in the buildings in which radiators are fitted with thermostatic valves. **Measure 3:** Installation of a solar collector system for DWH generation in special-purpose facilities – health care facilities and educational institutions active during summer months. **Measure 4:** Existing cooling system replacement by a more energy-efficient one (unless implemented under Measure 2) **Measure 5:** Existing lighting system replacement by a more efficient one **Measure 6:** Water consumption reduction **Measure 7:** Central control and management system installation measure In accordance with par. 31 of the preamble to Directive 2012/27/EE, Directives 2009/72/EC and 2009/73/EC, Member States are required to ensure the implementation of intelligent metering systems which contribute to active consumer participation in electricity and gas supply markets. In relation to electricity, if the introduction of smart meters is deemed cost-efficient, at least 80% of consumers must be equipped with intelligent metering systems by 2020. In relation to natural gas, no time limit has been set by a timeline must be prepared. Those directives also state that end customers must be duly and sufficiently frequently informed of their actual electricity/natural gas consumption and cost in order to regulate their own consumption. **Measure 8:** Installation of waste energy compensation devices, if necessary **Measure 9:** Where possible, consider the installation of photovoltaic modules for RES electricity generation
Commercial buildings	**Measure 0:** Energy audit of the building and establishment of systematic energy management **Measure 1:** Renovation of external envelope of the building's heated space, including the replacement of external carpentry and increasing heat retention of external walls, roof or ceiling bordering unheated attic and ceiling bordering unheated basement. The goal of renovation is to achieve energy class B, A or A+ of the building as a whole. The existence of project documentation required in accordance with construction legislation is a prerequisite for the implementation of this measure. **Measure 2:** Replacement of existing heating systems using electricity or fossil fuels by new central systems using condensation gas boilers or biomass-fired (pellet and chips) boilers to improve heating system efficiency, along with heating system balancing and thermostat set installation. If the building's total energy requirements are small, and the system is suitable for low-temperature heating operation with pronounced cooling requirements, it is recommended to apply geothermal or air heat pump for heating, cooling and DHW generation. In accordance with par. 28 of the preamble to Directive 2012/27/EE, the use of individual meters or heating cost splitters to measure individual heating consumption in apartment buildings with centralised heating or common central heating is useful when end-consumers may monitor their individual consumption. Therefore, their use makes sense only in the buildings in which radiators are fitted with thermostatic valves. **Measure 3:** Installation of a solar collector system of DHW generation in catering facilities.

	Measure 4: Existing cooling system replacement by a more energy-efficient one (unless implemented under Measure 2) The measure includes a cooling system centralisation in large facilities (e.g. hotels) where not yet implemented, the use of heat pumps and the environment as a thermal container (for sea water in coastal Croatia). In addition to electricity savings, peak load reductions in the electrical power system are also achieved. Also, centralisation enables the use of condensation heat for DHW generation. A centralised space heating system is also made available. The use of condensation heat for DHW generation, in combination with solar collectors and insulated containers, may be a complete substitute for other fuels in DHW generation. **Measure 5:** Existing lighting system replacement by a more efficient one **Measure 6:** Water consumption reduction **Measure 7:** Central control and management system installation measure In accordance with par. 31 of the preamble to Directive 2012/27/EE, Directives 2009/72/EC and 2009/73/EC, Member States are required to ensure the implementation of intelligent metering systems which contribute to active consumer participation in electricity and gas supply markets. In relation to electricity, if the introduction of smart meters is deemed cost-efficient, at least 80% of consumers must be equipped with intelligent metering systems by 2020. In relation to natural gas, no time limit has been set by a timeline must be prepared. Those directives also state that end customers must be duly and sufficiently frequently informed of their actual electricity/natural gas consumption and cost in order to regulate their own consumption. **Measure 8:** Installation of waste energy compensation devices, if necessary **Measure 9:** Where possible, consider the installation of photovoltaic modules for RES electricity generation
Apartment buildings	**Measure 0:** Energy audit of the building and establishment of systematic energy management **Measure 1:** Renovation of external envelope of the building's heated space, including the replacement of external carpentry and increasing heat retention of external walls, roof or ceiling bordering unheated attic and ceiling bordering unheated basement. The goal of renovation is to achieve energy class B, A or A+ of the building as a whole. The existence of project documentation required in accordance with construction legislation is a prerequisite for the implementation of this measure. Measures to reduce energy consumption for non-thermal requirements, in accordance with energy audit recommendations, is a constituent part of the project of integral renovation. **Measure 2:** Upgrading or replacement of a central heating system, along with heating system balancing and installation of thermostat sets, as well as introduction of a system of individual thermal energy consumption metering. Under the new Thermal Energy Market Act, the installation of a system of individual thermal energy consumption metering as a measure for apartment buildings connected to a district heating systems becomes obligatory for thermal energy consumers, eliminating the need to obtain consent of all co-owners. The current practice of energy consumption accounting and collection in buildings connected to district heating systems does not foster energy-efficient behaviour by thermal energy consumers, nor does it encourage them to implement energy efficiency measures in their homes as the effects of such measure would not ultimately be evident in their energy bills. The introduction of individual energy consumption metering therefore represents a prerequisite of all future energy efficiency activities in such buildings. In addition, under the new Thermal Energy Market Act proposal, the obligation of installing an individual metering system becomes binding on all co-owners and will certainly be a financial burden for them. Financial aid will serve as support to the implementation of this legal obligation. The Ministry of the Economy invites all thermal energy suppliers to prepare their programmes of individual metering system installation, in cooperation with building managers. In accordance with par. 28 of the preamble to Directive 2012/27/EE, the use of individual meters or heating cost splitters to measure individual heating consumption in apartment buildings with centralised heating or common central heating is useful when end-consumers may monitor their individual consumption. Therefore, their use makes sense only in the buildings in which radiators are fitted with thermostatic valves. Also, under par. 29 of the preamble to Directive 2012/27/EU, the use of precise individual thermal energy meters in some apartment buildings with multiple apartments supplied by centralised heating or common district heating would be technically more complex and expensive since the hot water used for heating enters and exits apartments in several places. However, individual heat consumption metering may be presumed to be technically possible in apartment buildings if the installation of individual meters did not require a replacement of the existing internal hot water pipeline used for heating in the building. In such buildings, individual heat consumption may be metered by means of individual cost splitters fitted to each radiator. **Measure 3:** Centralisation of existing cooling system to increase the system's energy efficiency

Family houses	**Measure 0:** Energy audit of the building and establishment of systematic energy management **Measure 1:** Renovation of external envelope of the building's heated space, including the replacement of external carpentry and increasing heat retention of external walls, roof or ceiling bordering unheated attic and ceiling bordering unheated basement. Performing any newly planned works to improve the energy efficiency of a residential building requires a project, at least at the level of design development, including a snapshot of the situation as-is. It is to be enclosed as mandatory documentation to exercise the right to a subsidy. **Measure 2:** Replacement of existing heating systems using electricity or fossil fuels by new systems using condensation gas boilers or installing small biomass-fired boilers to improve heating system efficiency, along with heating system balancing and thermostat set installation. If the building's total energy requirements are small, and the system is suitable for low-temperature heating operation with pronounced cooling requirements, it is recommended to apply geothermal or air heat pump for heating, cooling and DHW generation. The tender procedure for the grant of funding must give priority to the household which have had their envelope thermally insulated. Also, priority should be given to the households with older existing heating systems, nearing the end of their service life. **Measure 3:** Installation of a solar collector system of DHW generation and additional heating. Minimum criteria for the grant of incentives include replacing the current DHW generation system using electricity, fuel oil, coal or gas by a new system using renewable energy sources – solar thermal collector system. Priority should be given to the households with older existing DHW generation systems, nearing the end of their service life. **Measure 4:** Existing cooling system replacement by a more energy-efficient one (unless implemented under Measure 2) The measure include the use of heat pumps and the environment as a thermal container (for sea water in coastal Croatia). In addition to electricity savings, peak load reductions in the electrical power system are also achieved. A centralised space heating system is also made available. **Measure 5:** Existing lighting system replacement by a more efficient one **Measure 6:** Water consumption reduction **Measure 7:** Where possible, consider the installation of photovoltaic modules for RES electricity generation

Source: *REGEA,* 2014

Annex 2. Overview of specific parameters of EE and RES measures under possible models of public building renovation in continental Croatia

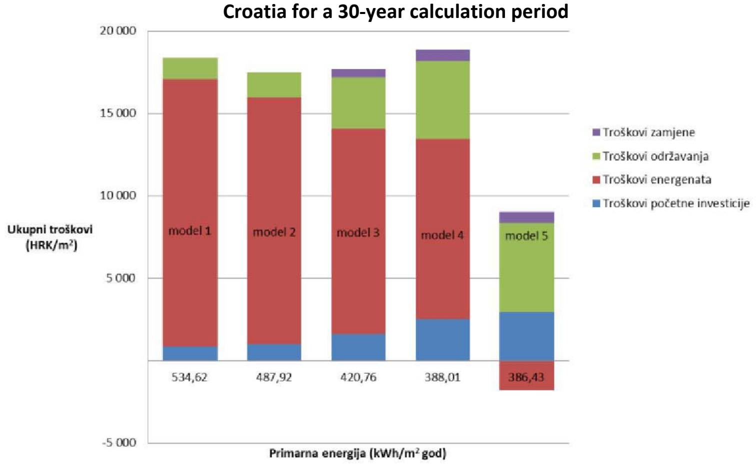
Public buildings in continental Croatia															
Measure number	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Specific energy savings (kWh/m²)															
Retrofit of the external heated space envelope under the *Technical Regulation*		124.34													124.34
Retrofit of the external heated space envelope under the *Technical Regulation Proposal*		155.26													155.26
Building renovation to the nZEB standard		155.26					8.22	14.00	6.67	11.87					196.02
Building renovation to the passive house standard		190.72					3.75	17.50	6.67	11.87					230.51
Building renovation to the active house standard		190.72					5.25	17.50	6.67	11.87				71.44	303.45
Specific cost savings (HRK/m²)															
Retrofit of the external heated space envelope under the *Technical Regulation*		74.56													74.56
Retrofit of the external heated space envelope under the *Technical Regulation Proposal*		93.10													93.10
Building renovation to the nZEB standard		93.10					5.54	14.84	5.64	12.58					131.71
Building renovation to the passive house standard		114.37					2.53	18.55	5.64	12.58					153.67
Building renovation to the active house standard		114.37					3.54	18.55	5.64	12.58				75.72	230.40
Measure 0: Building's energy management system, energy audit and energy certificate															
Measure 1: Outer window and door frame replacement															
Measure 2: Thermal insulation retrofitting to external walls															
Measure 3: Thermal insulation retrofitting to the roof/ceiling bordering unheated attic															
Measure 4: Thermal insulation retrofitting to the ceiling bordering unheated basement (if any)															
Measure 5: Thermal insulation retrofitting to the floor on ground level															
Measure 6: Heating system centralisation and modernisation by applying RES, if possible															
Measure 7: Cooling and ventilation system centralisation and modernisation by applying RES															
Measure 8: DHW system centralisation and modernisation by applying RES															
Measure 9: Lighting system modernisation															
Measure 10: Water consumption reduction															
Measure 11: Central control and management system installation															
Measure 12: Installation of waste energy compensation devices															
Measure 13: Installation of photovoltaic modules for RES electricity generation															
Measure 14: Combination of all cost justified measures															

Period of calculation	Type of expenditure	Initial investment (HRK/m²)	Energy and fuel costs (HRK/m²)	Maintenance costs (HRK/m²)	Replacement costs (HRK/m²)	Total expenditure (HRK/m²)
30 years	Retrofit of the external heated space envelope under the *Technical Regulation*	860.00	16 212.29	1 290.00	0.00	18 362.29
	Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	1 000.00	14 973.31	1 500.00	0.00	17 473.31
	Building renovation to the nZEB standard	1 597.70	12 434.86	3 149.55	502.00	17 684.11
	Building renovation to the passive house standard	2 502.70	10 945.70	4 739.55	657.00	18 844.95
	Building renovation to the active house standard	2 952.70	-1 797.85	5 414.55	657.00	7 226.40
50 years	Retrofit of the external heated space envelope under the *Technical Regulation*	860.00	46 955.21	3 590.50	576.20	51 981.91
	Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	1 000.00	43 366.80	4 175.00	670.00	49 211.80
	Building renovation to the nZEB standard	1 597.70	36 014.75	8 753.70	1 903.78	48 269.92
	Building renovation to the passive house standard	2 502.70	31 701.72	13 175.32	2 767.43	50 147.17
	Building renovation to the active house standard	2 952.70	-1 161.45	15 054.07	3 068.93	19 914.25
70 years	Retrofit of the external heated space envelope under the *Technical Regulation*	860.00	114 148.48	6 923.00	1 118.00	123 049.48
	Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	1 000.00	105 425.04	8 050.00	1 300.00	115 775.04
	Building renovation to the nZEB standard	1 597.70	87 552.13	17 025.58	3 266.75	109 442.15
	Building renovation to the passive house standard	2 502.70	77 067.13	25 596.55	4 810.60	109 976.98
	Building renovation to the active house standard	2 952.70	1 200.17	29 219.05	5 395.60	38 767.52

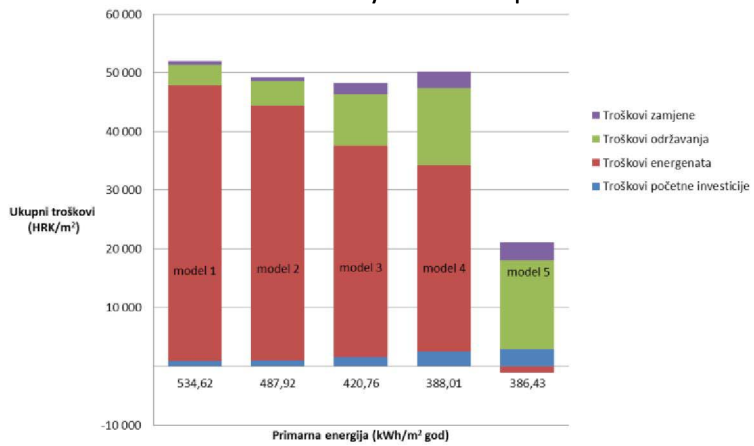
Source: *REGEA*, 2014

Annex 3. Overview of various model parameters of public building renovation in continental Croatia for different calculation periods

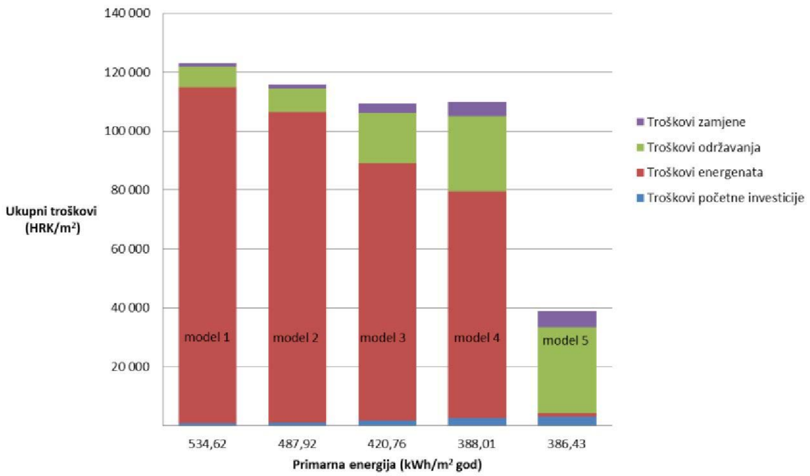
Parameters of various public building renovation models in continental Croatia for a 30-year calculation period



Parameters of various public building renovation models in continental Croatia for a 50-year calculation period



Parameters of various public building renovation models in continental Croatia for a 70-year calculation period



Ukupni troškovi (HRK/m^2)	Total expenditure (HRK/m^2)
Primarna energija (kWh/m^2 god)	Primary energy (kWh/m^2 per year)
Troškovi zamjene	Replacement costs
Troškovi održavanja	Maintenance costs
Troškovi energenata	Energy and fuel costs
Troškovi početne investicije	Initial investment

Model 1	Retrofit of the external heated space envelope under the Technical Regulation
Model 2	Retrofit of the external heated space envelope under the Technical Regulation Proposal
Model 3	Building renovation to the nZEB standard
Model 4	Building renovation to the passive house standard
Model 5	Building renovation to the active house standard

Source: *REGEA*, 2014

Annex 4. Overview of specific parameters of EE and RES measures under possible models of public building renovation in coastal Croatia

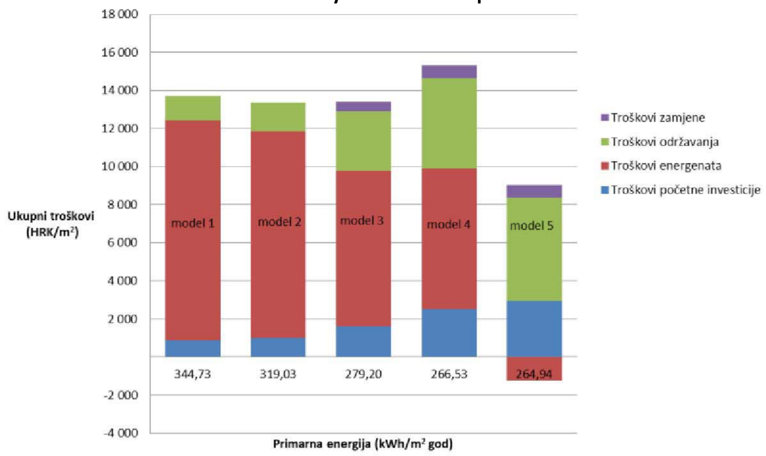
Public buildings in coastal Croatia															
Measure number	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Specific energy savings (kWh/m^2)															
Retrofit of the external heated space envelope under the *Technical Regulation*		59.51													59.51
Retrofit of the external heated space envelope under the *Technical Regulation Proposal*		76.53													76.53
Building renovation to the nZEB standard		76.53					4.53	23.65	5.65	7.49					117.84
Building renovation to the passive house standard		89.30					3.75	27.59	5.65	7.49					133.78
Building renovation to the active house standard		89.30					5.25	27.59	5.65	7.49				48.35	183.63
Specific cost savings (HRK/m^2)															
Retrofit of the external heated space envelope under the *Technical Regulation*		35.68													35.68
Retrofit of the external heated space envelope under the *Technical Regulation Proposal*		45.89													45.89
Building renovation to the nZEB standard		45.89					3.05	25.07	4.78	7.94					86.73
Building renovation to the passive house standard		53.55					2.53	29.25	4.78	7.94					98.04
Building renovation to the active house standard		53.55					3.54	29.25	4.78	7.94				51.25	150.30
Measure 0: Energy audit of the building															
Measure 1: Outer window and door frame replacement															
Measure 2: Thermal insulation retrofitting to external walls															
Measure 3: Thermal insulation retrofitting to the roof/ceiling bordering unheated attic															
Measure 4: Thermal insulation retrofitting to the ceiling bordering unheated basement (if any)															
Measure 5: Thermal insulation retrofitting to the floor on ground level															
Measure 6: Heating system centralisation and modernisation by applying RES, if possible															
Measure 7: Cooling and ventilation system centralisation and modernisation by applying RES															
Measure 8: DHW system centralisation and modernisation by applying RES															
Measure 9: Lighting system modernisation															
Measure 10: Water consumption reduction															
Measure 11: Central control and management system installation															
Measure 12: Installation of waste energy compensation devices															
Measure 13: Installation of photovoltaic modules for RES electricity generation															
Measure 14: Combination of all cost justified measures															

Period of calculation	Type of expenditure	Initial investment (HRK/m^2)	Energy and fuel costs (HRK/m^2)	Maintenance costs (HRK/m^2)	Replacement costs (HRK/m^2)	Total expenditure (HRK/m^2)
30 years	Retrofit of the external heated space envelope under the *Technical Regulation*	860.00	11 552.87	1 290.00	0.00	13 702.87
	Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	1 000.00	10 870.96	1 500.00	0.00	13 370.96
	Building renovation to the nZEB standard	1 597.70	8 165.21	3 149.55	502.00	13 414.46
	Building renovation to the passive house standard	2 502.70	7 405.54	4 739.55	657.00	15 304.79
	Building renovation to the active house standard	2 952.70	-1 239.17	5 414.55	657.00	7 785.08
50 years	Retrofit of the external heated space envelope under the *Technical Regulation*	860.00	33 460.26	3 590.50	576.20	38 486.96
	Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	1 000.00	31 485.26	4 175.00	670.00	37 330.26
	Building renovation to the nZEB standard	1 597.70	23 648.69	8 753.70	1 903.78	35 903.87
	Building renovation to the passive house standard	2 502.70	21 448.46	13 175.32	2 767.43	39 893.91
	Building renovation to the active house standard	2 952.70	-850.76	15 054.07	3 068.93	20 224.94
70 years	Retrofit of the external heated space envelope under the *Technical Regulation*	860.00	81 342.15	6 923.00	1 118.00	90 243.15
	Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	1 000.00	76 540.92	8 050.00	1 300.00	86 890.92
	Building renovation to the nZEB standard	1 597.70	57 490.15	17 025.58	3 266.75	79 380.17
	Building renovation to the passive house standard	2 502.70	52 141.38	25 596.55	4 810.60	85 051.23
	Building renovation to the active house standard	2 952.70	655.16	29 219.05	5 395.60	38 222.51

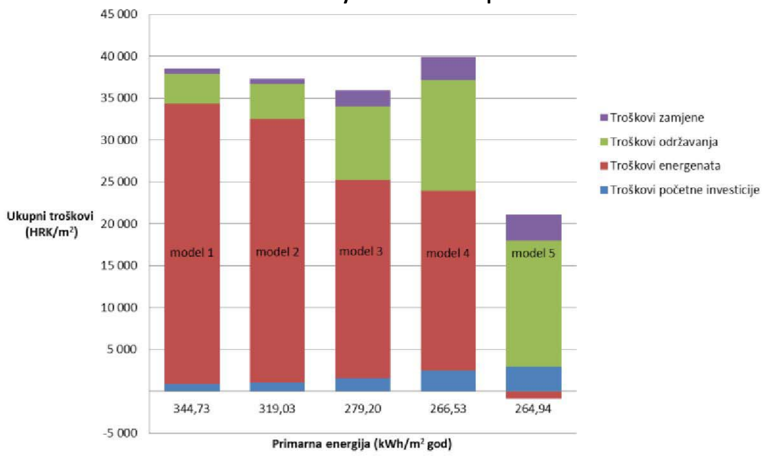
Source: *REGEA,* 2014

Annex 5. Overview of various model parameters of public building renovation in coastal Croatia for different calculation periods

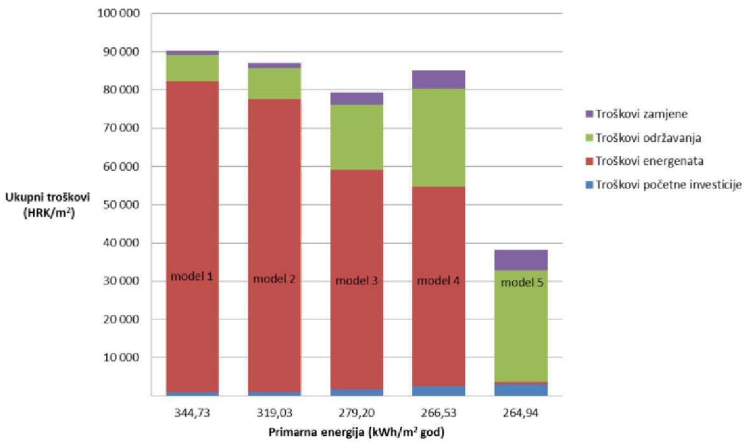
Parameters of various public building renovation models in coastal Croatia for a 30-year calculation period



Parameters of various public building renovation models in coastal Croatia for a 50-year calculation period



Parameters of various public building renovation models in coastal Croatia for a 70-year calculation period



Ukupni troškovi (HRK/m^2)	Total expenditure (HRK/m^2)
Primarna energija (kWh/m^2 god)	Primary energy (kWh/m^2 per year)
Troškovi zamjene	Replacement costs
Troškovi održavanja	Maintenance costs
Troškovi energenata	Energy and fuel costs
Troškovi početne investicije	Initial investment

Model 1	Retrofit of the external heated space envelope under the Technical Regulation
Model 2	Retrofit of the external heated space envelope under the Technical Regulation Proposal
Model 3	Building renovation to the nZEB standard
Model 4	Building renovation to the passive house standard
Model 5	Building renovation to the active house standard

Source: *REGEA,* 2014

Annex 6. Overview of specific parameters of EE and RES measures under possible models of commercial building renovation in continental Croatia

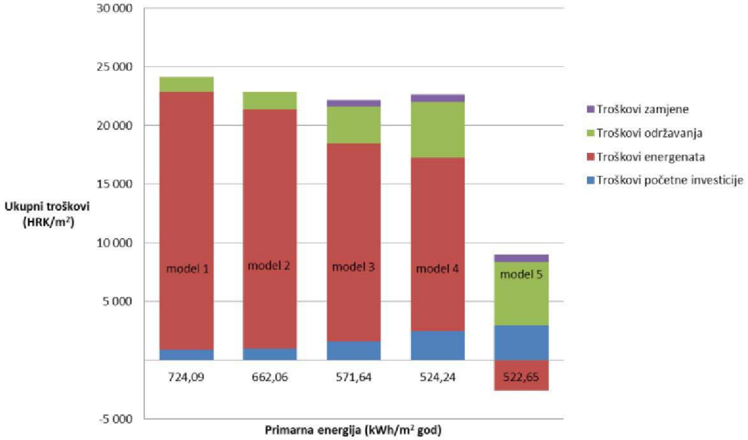
Commercial buildings in continental Croatia															
Measure number	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Specific energy savings (kWh/m^2)															
Retrofit of the external heated space envelope under the *Technical Regulation*		165.16													165.16
Retrofit of the external heated space envelope under the *Technical Regulation Proposal*		206.24													206.24
Building renovation to the nZEB standard		206.24					10.92	19.07	9.08	16.17					261.49
Building renovation to the passive house standard		258.26					3.75	23.84	9.08	16.17					311.11
Building renovation to the active house standard		258.26					5.25	23.84	9.08	16.17				97.31	409.92
Specific cost savings (HRK/m^2)															
Retrofit of the external heated space envelope under the *Technical Regulation*		99.04													99.04
Retrofit of the external heated space envelope under the *Technical Regulation Proposal*		123.67													123.67
Building renovation to the nZEB standard		123.67					7.36	20.22	7.68	17.14					176.08
Building renovation to the passive house standard		154.87					2.53	25.77	7.68	17.14					207.49
Building renovation to the active house standard		154.87					3.54	25.77	7.68	17.14				103.15	311.65
Measure 0: Energy audit of the building															
Measure 1: Outer window and door frame replacement															
Measure 2: Thermal insulation retrofitting to external walls															
Measure 3: Thermal insulation retrofitting to the roof/ceiling bordering unheated attic															
Measure 4: Thermal insulation retrofitting to the ceiling bordering unheated basement (if any)															
Measure 5: Thermal insulation retrofitting to the floor on ground level															
Measure 6: Heating system centralisation and modernisation by applying RES, if possible															
Measure 7: Cooling and ventilation system centralisation and modernisation by applying RES															
Measure 8: DHW system centralisation and modernisation by applying RES															
Measure 9: Lighting system modernisation															
Measure 10: Water consumption reduction															
Measure 11: Central control and management system installation															
Measure 12: Installation of waste energy compensation devices															
Measure 13: Installation of photovoltaic modules for RES electricity generation															
Measure 14: Combination of all cost justified measures															

Period of calculation	Type of expenditure	Initial investment (HRK/m^2)	Energy and fuel costs (HRK/m^2)	Maintenance costs (HRK/m^2)	Replacement costs (HRK/m^2)	Total expenditure (HRK/m^2)
30 years	Retrofit of the external heated space envelope under the *Technical Regulation*	860.00	21 973.77	1 290.00	0.00	24 123.77
	Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	1 000.00	20 327.99	1 500.00	0.00	22 827.99
	Building renovation to the nZEB standard	1 597.70	16 881.30	3 149.55	502.00	22 130.55
	Building renovation to the passive house standard	2 502.70	14 746.80	4 739.55	657.00	22 646.05
	Building renovation to the active house standard	2 952.70	-2 590.48	5 414.55	657.00	6 433.77
50 years	Retrofit of the external heated space envelope under the *Technical Regulation*	860.00	63 642.02	3 590.50	576.20	68 668.72
	Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	1 000.00	58 875.40	4 175.00	670.00	64 720.40
	Building renovation to the nZEB standard	1 597.70	48 892.85	8 753.70	1 903.78	61 148.02
	Building renovation to the passive house standard	2 502.70	42 710.77	13 175.32	2 767.43	61 156.22
	Building renovation to the active house standard	2 952.70	-1 991.86	15 054.07	3 068.93	19 083.84
70 years	Retrofit of the external heated space envelope under the *Technical Regulation*	860.00	154 714.25	6 923.00	1 118.00	163 615.25
	Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	1 000.00	143 126.55	8 050.00	1 300.00	153 476.55
	Building renovation to the nZEB standard	1 597.70	118 858.89	17 025.58	3 266.75	140 748.91
	Building renovation to the passive house standard	2 502.70	103 830.22	25 596.55	4 810.60	136 740.07
	Building renovation to the active house standard	2 952.70	638.75	29 219.05	5 395.60	38 206.10

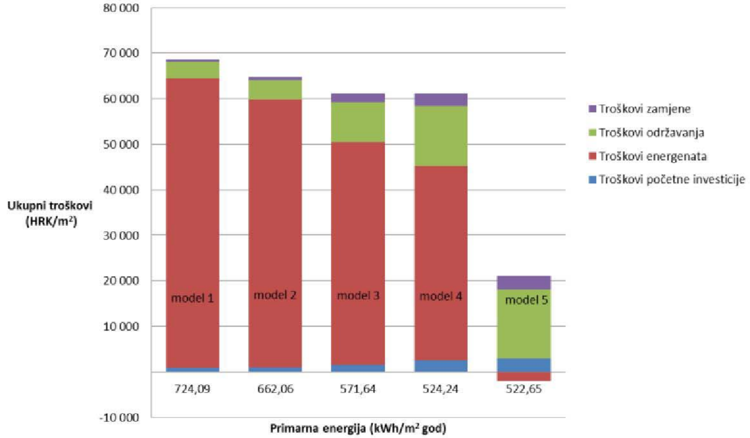
Source: *REGEA,* 2014

Annex 7. Overview of various model parameters of commercial building renovation in continental Croatia for different calculation periods

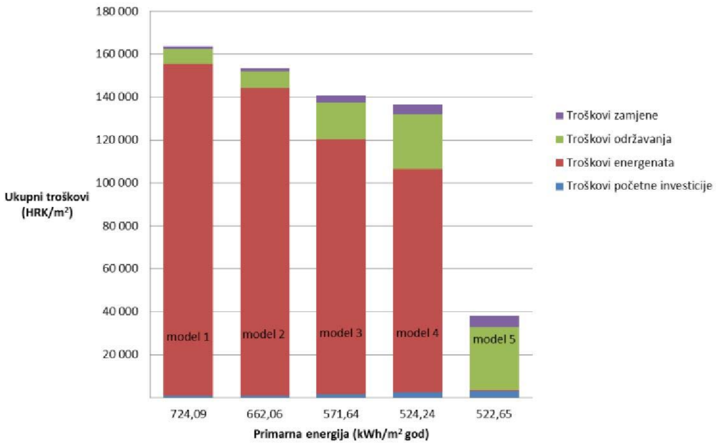
Parameters of various commercial building renovation models in continental Croatia for a 30-year calculation period



Parameters of various commercial building renovation models in continental Croatia for a 50-year calculation period



Parameters of various commercial building renovation models in continental Croatia for a 70-year calculation period



Ukupni troškovi (HRK/m²)	Total expenditure (HRK/m²)
Primarna energija (kWh/m² god)	Primary energy (kWh/m² per year)
Troškovi zamjene	Replacement costs
Troškovi održavanja	Maintenance costs
Troškovi energenata	Energy and fuel costs
Troškovi početne investicije	Initial investment

Model 1	Retrofit of the external heated space envelope under the Technical Regulation
Model 2	Retrofit of the external heated space envelope under the Technical Regulation Proposal
Model 3	Building renovation to the nZEB standard
Model 4	Building renovation to the passive house standard
Model 5	Building renovation to the active house standard

Source: *REGEA,* 2014

Annex 8. Overview of specific parameters of EE and RES measures under possible models of commercial building renovation in coastal Croatia

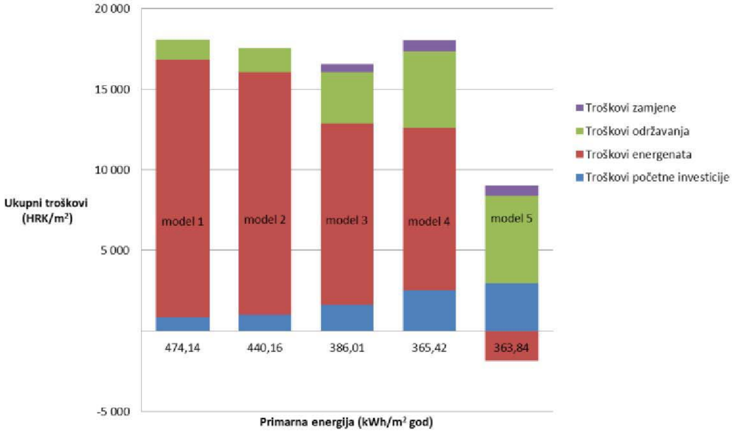
Commercial buildings in coastal Croatia															
Measure number	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Specific energy savings (kWh/m²)															
Retrofit of the external heated space envelope under the *Technical Regulation*		78.68													78.68
Retrofit of the external heated space envelope under the *Technical Regulation Proposal*		101.18													101.18
Building renovation to the nZEB standard		101.18					5.98	32.84	7.85	10.39					158.24
Building renovation to the passive house standard		122.90					3.75	38.31	7.85	10.39					183.20
Building renovation to the active house standard		122.90					5.25	38.31	7.85	10.39				67.13	251.83
Specific cost savings (HRK/m²)															
Retrofit of the external heated space envelope under the *Technical Regulation*		47.18													47.18
Retrofit of the external heated space envelope under the *Technical Regulation Proposal*		60.67													60.67
Building renovation to the nZEB standard		60.67					4.03	34.81	6.63	11.02					117.17
Building renovation to the passive house standard		73.70					2.53	40.61	6.63	11.02					134.49
Building renovation to the active house standard		73.70					3.54	40.61	6.63	11.02				71.16	206.66
Measure 0: Energy audit of the building															
Measure 1: Outer window and door frame replacement															
Measure 2: Thermal insulation retrofitting to external walls															
Measure 3: Thermal insulation retrofitting to the roof/ceiling bordering unheated attic															
Measure 4: Thermal insulation retrofitting to the ceiling bordering unheated basement (if any)															
Measure 5: Thermal insulation retrofitting to the floor on ground level															
Measure 6: Heating system centralisation and modernisation by applying RES, if possible															
Measure 7: Cooling and ventilation system centralisation and modernisation by applying RES															
Measure 8: DHW system centralisation and modernisation by applying RES															
Measure 9: Lighting system modernisation															
Measure 10: Water consumption reduction															
Measure 11: Central control and management system installation															
Measure 12: Installation of waste energy compensation devices															
Measure 13: Installation of photovoltaic modules for RES electricity generation															
Measure 14: Combination of all cost justified measures															

Period of calculation	Type of expenditure	Initial investment (HRK/m²)	Energy and fuel costs (HRK/m²)	Maintenance costs (HRK/m²)	Replacement costs (HRK/m²)	Total expenditure (HRK/m²)
30 years	Retrofit of the external heated space envelope under the *Technical Regulation*	860.00	15 920.97	1 290.00	0.00	18 070.97
	Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	1 000.00	15 019.39	1 500.00	0.00	17 519.39
	Building renovation to the nZEB standard	1 597.70	11 274.78	3 149.55	502.00	16 524.03
	Building renovation to the passive house standard	2 502.70	10 106.70	4 739.55	657.00	18 005.95
	Building renovation to the active house standard	2 952.70	-1 872.16	5 414.55	657.00	7 152.09
50 years	Retrofit of the external heated space envelope under the *Technical Regulation*	860.00	46 111.48	3 590.50	576.20	51 138.18
	Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	1 000.00	43 500.24	4 175.00	670.00	49 345.24
	Building renovation to the nZEB standard	1 597.70	32 654.85	8 753.70	1 903.78	44 910.03
	Building renovation to the passive house standard	2 502.70	29 271.75	13 175.32	2 767.43	47 717.20
	Building renovation to the active house standard	2 952.70	-1 620.57	15 054.07	3 068.93	19 455.13
70 years	Retrofit of the external heated space envelope under the *Technical Regulation*	860.00	112 097.36	6 923.00	1 118.00	120 998.36
	Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	1 000.00	105 749.43	8 050.00	1 300.00	116 099.43
	Building renovation to the nZEB standard	1 597.70	79 384.19	17 025.58	3 266.75	101 274.22
	Building renovation to the passive house standard	2 502.70	71 159.85	25 596.55	4 810.60	104 069.70
	Building renovation to the active house standard	2 952.70	-158.55	29 219.05	5 395.60	37 408.80

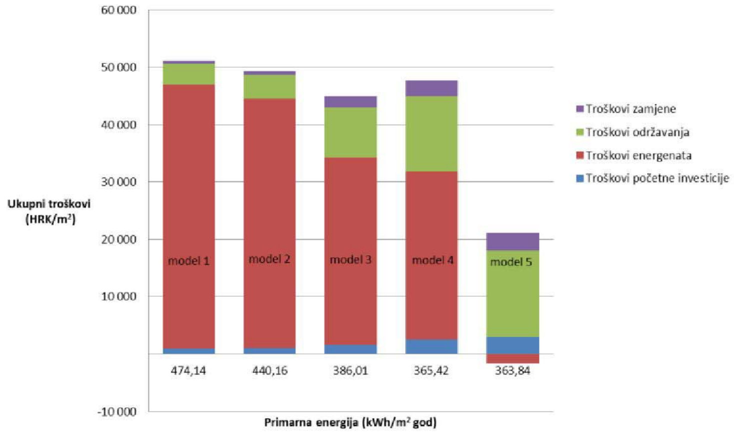
Source: *REGEA*, 2014

Annex 9. Overview of various model parameters of commercial building renovation in coastal Croatia for different calculation periods

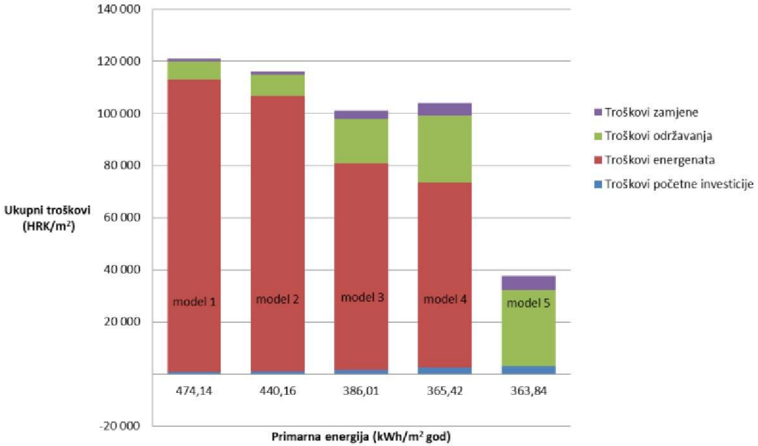
Parameters of various commercial building renovation models in coastal Croatia for a 30-year calculation period



Parameters of various commercial building renovation models in coastal Croatia for a 50-year calculation period



Parameters of various commercial building renovation models in coastal Croatia for a 70-year calculation period



Ukupni troškovi (HRK/m^2)	Total expenditure (HRK/m^2)
Primarna energija (kWh/m^2 god)	Primary energy (kWh/m^2 per year)
Troškovi zamjene	Replacement costs
Troškovi održavanja	Maintenance costs
Troškovi energenata	Energy and fuel costs
Troškovi početne investicije	Initial investment

Model 1	Retrofit of the external heated space envelope under the Technical Regulation
Model 2	Retrofit of the external heated space envelope under the Technical Regulation
Model 3	Building renovation to the nZEB standard
Model 4	Building renovation to the passive house standard
Model 5	Building renovation to the active house standard

Source: *REGEA*, 2014

Annex 10. Overview of specific parameters of EE and RES measures under possible models of apartment building renovation in continental Croatia

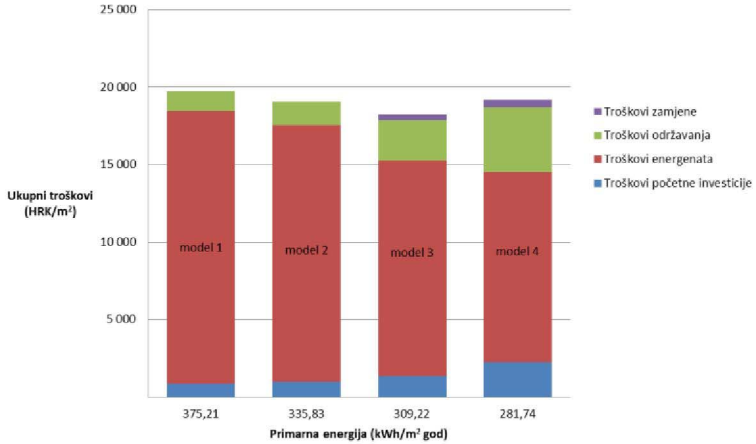
Apartment buildings in continental Croatia															
Measure number	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Specific energy savings (kWh/m^2)															
Retrofit of the external heated space envelope under the *Technical Regulation*		122.67													122.67
Retrofit of the external heated space envelope under the *Technical Regulation Proposal*		15 3.19													153.19
Building renovation to the nZEB standard		15 3.19					8.11	35.89							197.19
Building renovation to the passive house standard		187.97					3.75	44.86							236.58
Specific cost savings (HRK/m^2)															
Retrofit of the external heated space envelope under the *Technical Regulation*		63.55													63.55
Retrofit of the external heated space envelope under the *Technical Regulation Proposal*		79.35													79.35
Building renovation to the nZEB standard		79.35					4.84	35.17							119.36
Building renovation to the passive house standard		97.37					2.24	43.97							143.57
Measure 0: Energy audit of the building and establishment of systematic energy management															
Measure 1: Outer window and door frame replacement															
Measure 2: Thermal insulation retrofitting to external walls															
Measure 3: Thermal insulation retrofitting to the roof/ceiling bordering unheated attic															
Measure 4: Thermal insulation retrofitting to the ceiling bordering unheated basement (if any)															
Measure 5: Thermal insulation retrofitting to the floor on ground level															
Measure 6: Heating system centralisation and modernisation by applying RES, if possible															
Measure 7: Cooling and ventilation system centralisation and modernisation by applying RES															
Measure 8: DHW system centralisation and modernisation by applying RES															
Measure 9: Lighting system modernisation															
Measure 10: Water consumption reduction															
Measure 11: Central control and management system installation															
Measure 12: Installation of waste energy compensation devices															
Measure 13: Installation of photovoltaic modules for RES electricity generation															
Measure 14: Combination of all cost justified measures															

Period of calculation	Type of expenditure	Initial investment (HRK/m^2)	Energy and fuel costs (HRK/m^2)	Maintenance costs (HRK/m^2)	Replacement costs (HRK/m^2)	Total expenditure (HRK/m^2)
30 years	Retrofit of the external heated space envelope under the *Technical Regulation*	860.00	17 593.04	1 290.00	0.00	19 743.04
	Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	1 000.00	16 537.08	1 500.00	0.00	19 037.08
	Building renovation to the nZEB standard	1 367.00	13 906.40	2 601.00	367.00	18 241.40
	Building renovation to the passive house standard	2 257.00	12 266.22	4 146.00	507.00	19 176.22
50 years	Retrofit of the external heated space envelope under the *Technical Regulation*	860.00	50 954.25	2 154.30	576.20	54 544.75
	Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	1 000.00	47 895.89	2 505.00	670.00	52 070.89
	Building renovation to the nZEB standard	1 367.00	40 276.72	4 338.17	1 525.11	47 506.99
	Building renovation to the passive house standard	2 257.00	35 526.31	6 916.22	2 353.81	47 053.33
70 years	Retrofit of the external heated space envelope under the *Technical Regulation*	860.00	123 870.16	2 967.00	1 118.00	128 815.16
	Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	1 000.00	116 435.28	3 450.00	1 300.00	122 185.28
	Building renovation to the nZEB standard	1 367.00	97 913.02	6 020.84	2 646.89	107 947.74
	Building renovation to the passive house standard	2 257.00	86 364.73	9 589.04	4 135.69	102 346.45

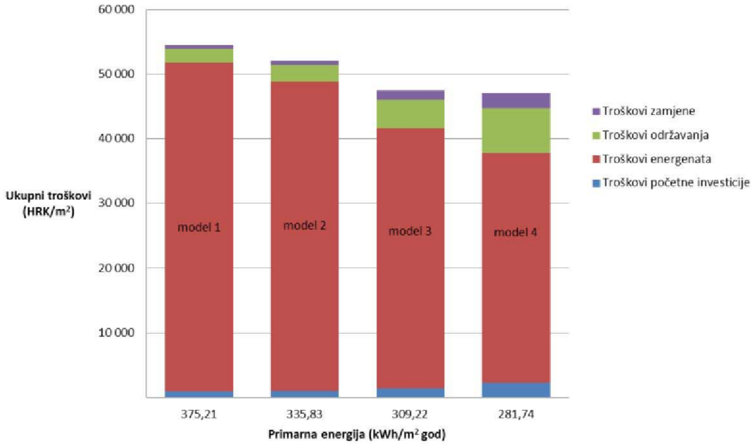
Source: *REGEA*, 2014

Annex 11. Overview of various model parameters of apartment building renovation in continental Croatia for different calculation periods

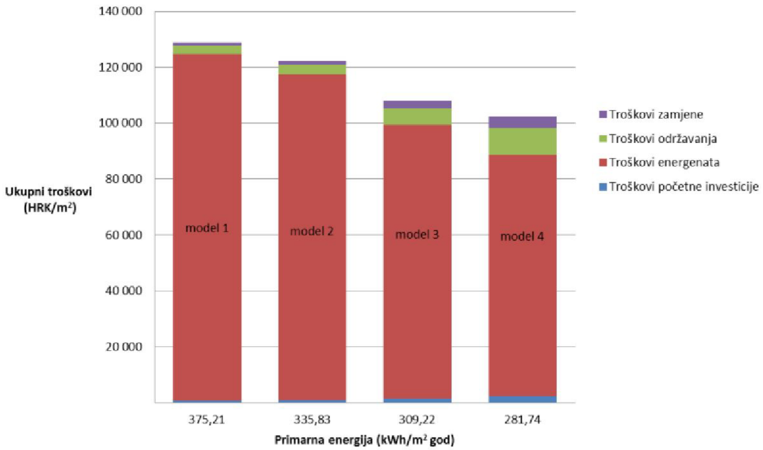
Parameters of various apartment building renovation models in continental Croatia for a 30-year calculation period



Parameters of various apartment building renovation models in continental Croatia for a 50-year calculation period



Parameters of various apartment building renovation models in continental Croatia for a 70-year calculation period



Ukupni troškovi (HRK/m^2)	Total expenditure (HRK/m^2)
Primarna energija (kWh/m^2 god)	Primary energy (kWh/m^2 per year)
Troškovi zamjene	Replacement costs
Troškovi održavanja	Maintenance costs
Troškovi energenata	Energy and fuel costs
Troškovi početne investicije	Initial investment

Model 1	Retrofit of the external heated space envelope under the Technical Regulation
Model 2	Retrofit of the external heated space envelope under the Technical Regulation Proposal
Model 3	Building renovation to the nZEB standard
Model 4	Building renovation to the passive house standard
Model 5	Building renovation to the active house standard

Source: *REGEA*, 2014

Annex 12. Overview of specific parameters of EE and RES measures under possible models of apartment building renovation in coastal Croatia

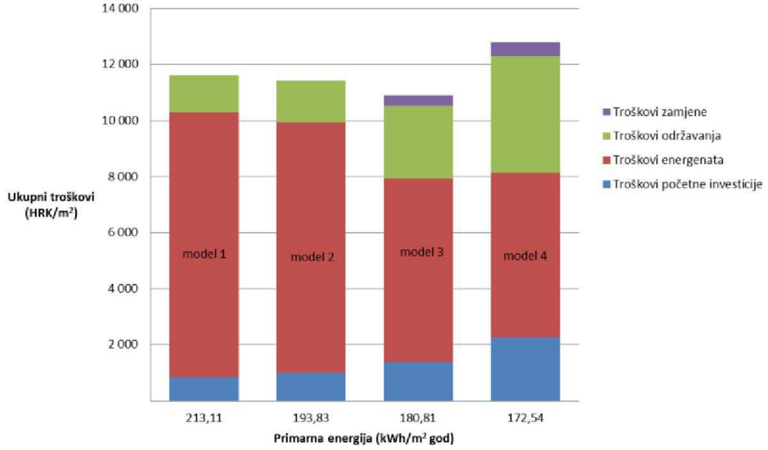
Apartment buildings in coastal Croatia															
Measure number	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Specific energy savings (kWh/m^2)															
Retrofit of the external heated space envelope under the *Technical Regulation*		52.23													52.23
Retrofit of the external heated space envelope under the *Technical Regulation Proposal*		67.17													67.17
Building renovation to the nZEB standard		67.17					3.97	33.98							105.12
Building renovation to the passive house standard		76.54					3.75	39.64							119.93
Specific cost savings (HRK/m^2)															
Retrofit of the external heated space envelope under the *Technical Regulation*		27.06													27.06
Retrofit of the external heated space envelope under the *Technical Regulation Proposal*		34.79													34.79
Building renovation to the nZEB standard		34.79					2.37	33.30							70.46
Building renovation to the passive house standard		39.65					2.24	38.85							80.73
Measure 0: Energy audit of the building and establishment of systematic energy management															
Measure 1: Outer window and door frame replacement															
Measure 2: Thermal insulation retrofitting to external walls															
Measure 3: Thermal insulation retrofitting to the roof/ceiling bordering unheated attic															
Measure 4: Thermal insulation retrofitting to the ceiling bordering unheated basement (if any)															
Measure 5: Thermal insulation retrofitting to the floor on ground level															
Measure 6: Heating system centralisation and modernisation by applying RES, if possible															
Measure 7: Cooling and ventilation system centralisation and modernisation by applying RES															
Measure 8: DHW system centralisation and modernisation by applying RES															
Measure 9: Lighting system modernisation															
Measure 10: Water consumption reduction															
Measure 11: Central control and management system installation															
Measure 12: Installation of waste energy compensation devices															
Measure 13: Installation of photovoltaic modules for RES electricity generation															
Measure 14: Combination of all cost justified measures															

Period of calculation	Type of expenditure	Initial investment (HRK/m^2)	Energy and fuel costs (HRK/m^2)	Maintenance costs (HRK/m^2)	Replacement costs (HRK/m^2)	Total expenditure (HRK/m^2)
30 years	Retrofit of the external heated space envelope under the *Technical Regulation*	860.00	9 449.24	1 290.00	0.00	11 599.24
	Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	1 000.00	8 932.23	1 500.00	0.00	11 432.23
	Building renovation to the nZEB standard	1 367.00	6 570.18	2 601.00	367.00	10 905.18
	Building renovation to the passive house standard	2 257.00	5 882.70	4 146.00	507.00	12 792.70
50 years	Retrofit of the external heated space envelope under the *Technical Regulation*	860.00	27 367.58	2 154.30	576.20	30 958.08
	Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	1 000.00	25 870.17	2 505.00	670.00	30 045.17
	Building renovation to the nZEB standard	1 367.00	19 029.03	4 338.17	1 525.11	26 259.30
	Building renovation to the passive house standard	2 257.00	17 037.91	6 916.22	2 353.81	28 564.94
70 years	Retrofit of the external heated space envelope under the *Technical Regulation*	860.00	66 530.81	2 967.00	1 118.00	71 475.81
	Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	1 000.00	62 890.57	3 450.00	1 300.00	68 640.57
	Building renovation to the nZEB standard	1 367.00	46 259.71	6 020.84	2 646.89	56 294.43
	Building renovation to the passive house standard	2 257.00	41 419.30	9 589.04	4 135.69	57 401.02

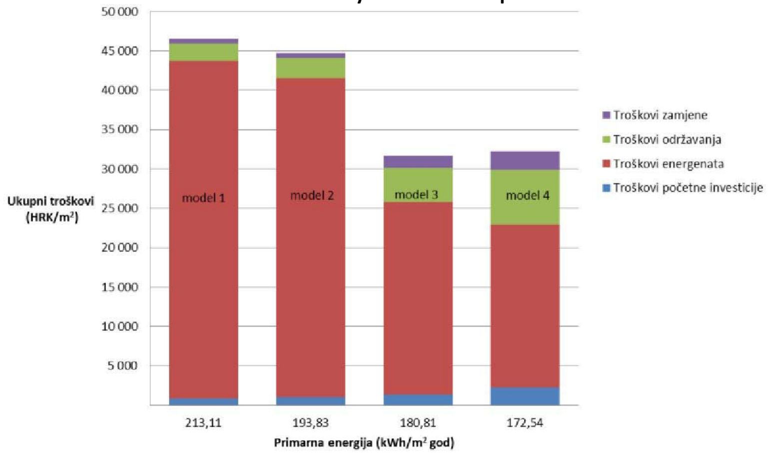
Source: *REGEA*, 2014

Annex 13. Overview of various model parameters of apartment building renovation in coastal Croatia for different calculation periods

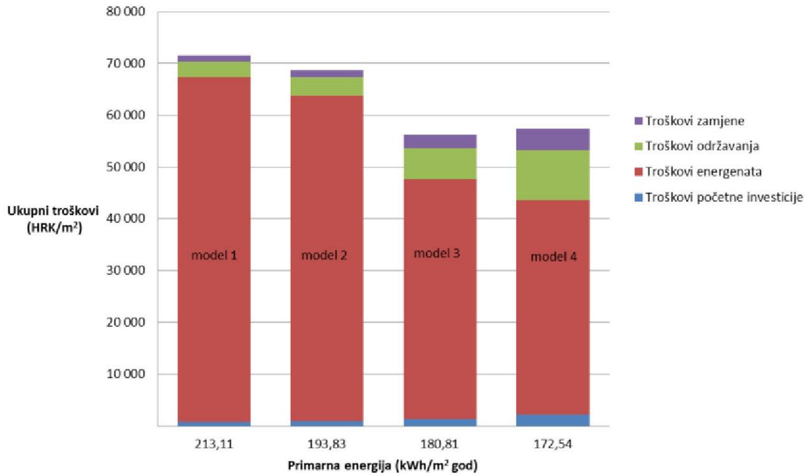
Parameters of various apartment building renovation models in coastal Croatia for a 30-year calculation period



Parameters of various apartment building renovation models in coastal Croatia for a 50-year calculation period



Parameters of various apartment building renovation models in coastal Croatia for a 70-year calculation period



Ukupni troškovi (HRK/m^2)	Total expenditure (HRK/m^2)
Primarna energija (kWh/m^2 god)	Primary energy (kWh/m^2 per year)
Troškovi zamjene	Replacement costs
Troškovi održavanja	Maintenance costs
Troškovi energenata	Energy and fuel costs
Troškovi početne investicije	Initial investment

Model 1	Retrofit of the external heated space envelope under the Technical Regulation
Model 2	Retrofit of the external heated space envelope under the Technical Regulation Proposal
Model 3	Building renovation to the nZEB standard
Model 4	Building renovation to the passive house standard
Model 5	Building renovation to the active house standard

Source: *REGEA*, 2014

Annex 14. Overview of specific parameters of EE and RES measures under possible models of family house renovation in continental Croatia

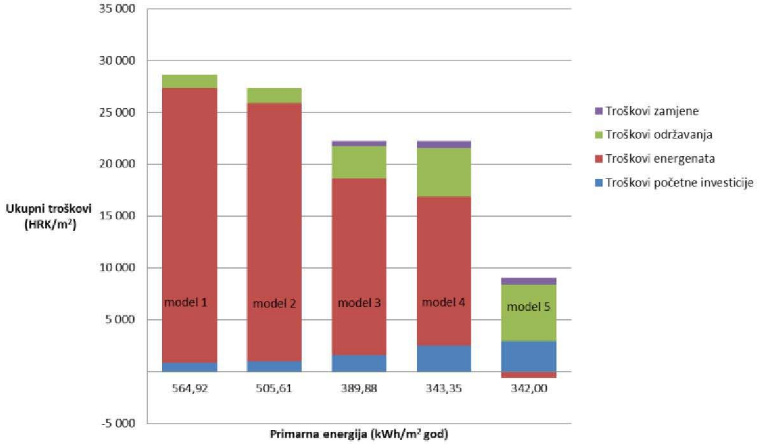
Family houses in continental Croatia															
Measure number	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Specific energy savings (kWh/m^2)															
Retrofit of the external heated space envelope under the *Technical Regulation*		184.75													184.75
Retrofit of the external heated space envelope under the *Technical Regulation Proposal*		230.70													230.70
Building renovation to the nZEB standard		230.70					12.22	54.03	50.82	25.22					372.99
Building renovation to the passive house standard		290.68					3.75	67.54	50.82	25.22					438.01
Building renovation to the active house standard		290.68					5.25	67.54	50.82	25.22				89.30	528.81
Specific cost savings (HRK/m^2)															
Retrofit of the external heated space envelope under the *Technical Regulation*		95.70													95.70
Retrofit of the external heated space envelope under the *Technical Regulation Proposal*		119.50													119.50
Building renovation to the nZEB standard		119.50					7.29	52.95	33.94	24.72					238.40
Building renovation to the passive house standard		150.57					2.24	66.19	33.94	24.72					277.65
Building renovation to the active house standard		150.57					3.13	66.19	33.94	24.72				94.66	373.21
Measure 0: Energy audit of the building															
Measure 1: Outer window and door frame replacement															
Measure 2: Thermal insulation retrofitting to external walls															
Measure 3: Thermal insulation retrofitting to the roof/ceiling bordering unheated attic															
Measure 4: Thermal insulation retrofitting to the ceiling bordering unheated basement (if any)															
Measure 5: Thermal insulation retrofitting to the floor on ground level															
Measure 6: Heating system centralisation and modernisation by applying RES, if possible															
Measure 7: Cooling and ventilation system centralisation and modernisation by applying RES															
Measure 8: DHW system centralisation and modernisation by applying RES															
Measure 9: Lighting system modernisation															
Measure 10: Water consumption reduction															
Measure 11: Central control and management system installation															
Measure 12: Installation of waste energy compensation devices															
Measure 13: Installation of photovoltaic modules for RES electricity generation															
Measure 14: Combination of all cost justified measures															

Period of calculation	Type of expenditure	Initial investment (HRK/m^2)	Energy and fuel costs (HRK/m^2)	Maintenance costs (HRK/m^2)	Replacement costs (HRK/m^2)	Total expenditure (HRK/m^2)
30 years	Retrofit of the external heated space envelope under the *Technical Regulation*	860.00	26 487.05	1 290.00	0.00	28 637.05
	Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	1 000.00	24 896.75	1 500.00	0.00	27 396.75
	Building renovation to the nZEB standard	1 597.70	17 017.34	3 149.55	502.00	22 266.59
	Building renovation to the passive house standard	2 502.70	14 350.S2	4 739.55	657.00	22 249.77
	Building renovation to the active house standard	2 952.70	-601.64	5 414.55	657.00	8 422.61
50 years	Retrofit of the external heated space envelope under the *Technical Regulation*	860.00	76 713.73	3 590.50	576.20	81 740.43
	Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	1 000.00	72 107.77	4 175.00	670.00	77 952.77
	Building renovation to the nZEB standard	1 597.70	49 286.87	8 753.70	1 903.78	61 542.05
	Building renovation to the passive house standard	2 502.70	41 563.01	13 175.32	2 767.43	60 008.46
	Building renovation to the active house standard	2 952.70	3 314.68	15 054.07	3 068.93	24 390.38
70 years	Retrofit of the external heated space envelope under the *Technical Regulation*	860.00	186 491.66	6 923.00	1 118.00	195 392.66
	Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	1 000.00	175 294.55	8 050.00	1 300.00	185 644.55
	Building renovation to the nZEB standard	1 597.70	119 816.77	17 025.58	3 266.75	141 706.80
	Building renovation to the passive house standard	2 502.70	101 040.00	25 596.55	4 810.60	133 949.85
	Building renovation to the active house standard	2 952.70	13 087.76	29 219.05	5 395.60	50 655.11

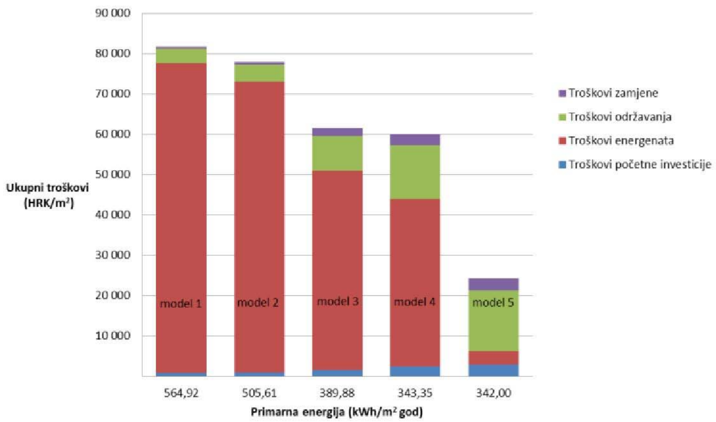
Source: *REGEA*, 2014

Annex 15. Overview of various model parameters of family house renovation in continental Croatia for different calculation periods

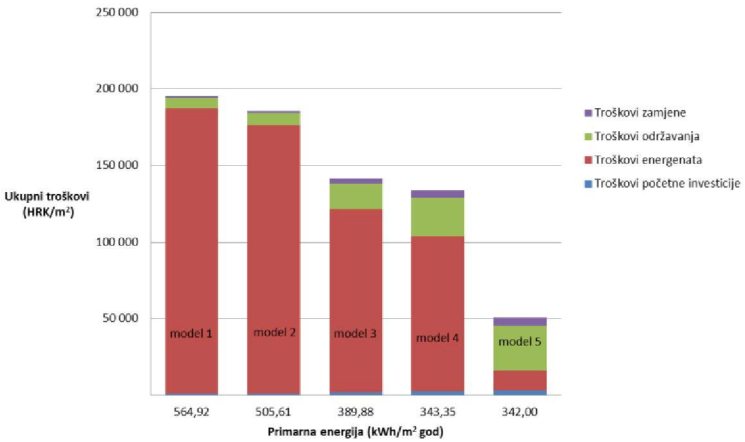
Parameters of various family house renovation models in continental Croatia for a 30-year calculation period



Parameters of various family house renovation models in continental Croatia for a 50-year calculation period



Parameters of various family house renovation models in continental Croatia for a 70-year calculation period



Ukupni troškovi (HRK/m^2)	Total expenditure (HRK/m^2)
Primarna energija (kWh/m^2 god)	Primary energy (kWh/m^2 per year)
Troškovi zamjene	Replacement costs
Troškovi održavanja	Maintenance costs
Troškovi energenata	Energy and fuel costs
Troškovi početne investicije	Initial investment

Model 1	Retrofit of the external heated space envelope under the Technical Regulation
Model 2	Retrofit of the external heated space envelope under the Technical Regulation Proposal
Model 3	Building renovation to the nZEB standard
Model 4	Building renovation to the passive house standard
Model 5	Building renovation to the active house standard

Source: *REGEA*, 2014

Annex 16. Overview of specific parameters of EE and RES measures under possible models of family house renovation in coastal Croatia

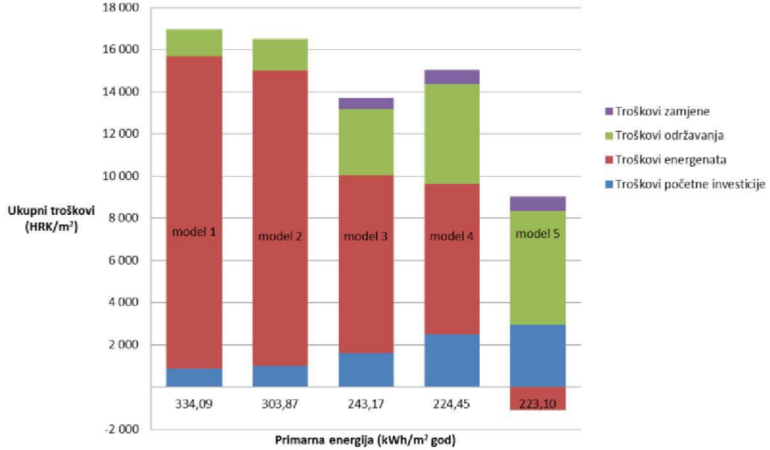
Family houses in coastal Croatia															
Measure number	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Specific energy savings (kWh/m^2)															
Retrofit of the external heated space envelope under the *Technical Regulation*		81.86													81.86
Retrofit of the external heated space envelope under the *Technical Regulation Proposal*		105.27													105.27
Building renovation to the nZEB standard		105.27					6.23	53.27	22.06	13.43					200.26
Building renovation to the passive house standard		128.47					3.75	62.15	22.06	13.43					229.86
Building renovation to the active house standard		128.47					5.25	62.15	22.06	13.43				49.03	280.39
Specific cost savings (HRK/m^2)															
Retrofit of the external heated space envelope under the *Technical Regulation*		42.40													42.40
Retrofit of the external heated space envelope under the *Technical Regulation Proposal*		54.53													54.53
Building renovation to the nZEB standard		54.53					3.71	52.20	14.74	13.16					138.34
Building renovation to the passive house standard		66.55					2.24	60.90	14.74	13.16					157.58
Building renovation to the active house standard		66.55					3.13	60.90	14.74	13.16				51.97	210.45
Measure 0: Energy audit of the building															
Measure 1: Outer window and door frame replacement															
Measure 2: Thermal insulation retrofitting to external walls															
Measure 3: Thermal insulation retrofitting to the roof/ceiling bordering unheated attic															
Measure 4: Thermal insulation retrofitting to the ceiling bordering unheated basement (if any)															
Measure 5: Thermal insulation retrofitting to the floor on ground level															
Measure 6: Heating system centralisation and modernisation by applying RES, if possible															
Measure 7: Cooling and ventilation system centralisation and modernisation by applying RES															
Measure 8: DHW system centralisation and modernisation by applying RES															
Measure 9: Lighting system modernisation															
Measure 10: Water consumption reduction															
Measure 11: Central control and management system installation															
Measure 12: Installation of waste energy compensation devices															
Measure 13: Installation of photovoltaic modules for RES electricity generation															
Measure 14: Combination of all cost justified measures															

Period of calculation	Type of expenditure	Initial investment (HRK/m^2)	Energy and fuel costs (HRK/m^2)	Maintenance costs (HRK/m^2)	Replacement costs (HRK/m^2)	Total expenditure (HRK/m^2)
30 years	Retrofit of the external heated space envelope under the *Technical Regulation*	860.00	14 813.60	1 290.00	0.00	16 963.60
	Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	1 000.00	14 003.32	1 500.00	0.00	16 503.32
	Building renovation to the nZEB standard	1 597.70	8 436.54	3 149.55	502.00	13 685.79
	Building renovation to the passive house standard	2 502.70	7 138.06	4 739.55	657.00	15 037.31
	Building renovation to the active house standard	2 952.70	-1 095.02	5 414.55	657.00	7 929.23
50 years	Retrofit of the external heated space envelope under the *Technical Regulation*	860.00	42 904.23	3 590.50	576.20	47 930.93
	Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	1 000.00	40 557.43	4 175.00	670.00	46 402.43
	Building renovation to the nZEB standard	1 597.70	24 434.53	8 753.70	1 903.78	36 689.70
	Building renovation to the passive house standard	2 502.70	20 673.78	13 175.32	2 767.43	39 119.23
	Building renovation to the active house standard	2 952.70	-394.75	15 054.07	3 068.93	20 680.95
70 years	Retrofit of the external heated space envelope under the *Technical Regulation*	860.00	104 300.51	6 923.00	1 118.00	113 201.51
	Retrofit of the external heated space envelope under the *Technical Regulation Proposal*	1 000.00	98 595.42	8 050.00	1 300.00	108 945.42
	Building renovation to the nZEB standard	1 597.70	59 400.53	17 025.58	3 266.75	81 290.55
	Building renovation to the passive house standard	2 502.70	50 258.12	25 596.55	4 810.60	83 167.97
	Building renovation to the active house standard	2 952.70	1 802.00	29 219.05	5 395.60	39 369.35

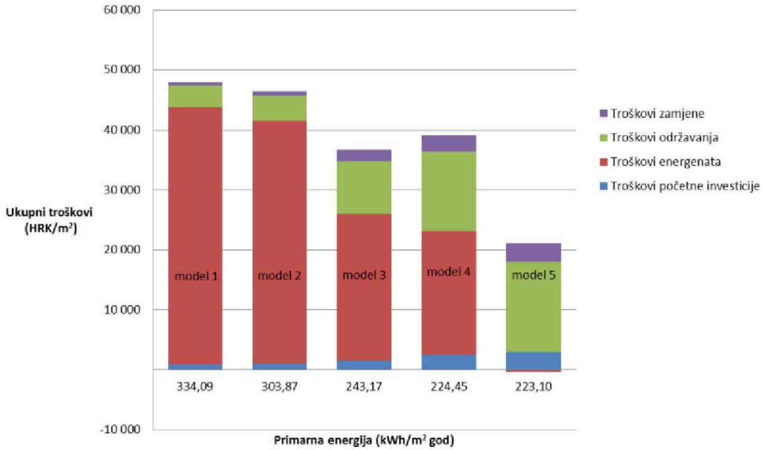
Source: *REGEA*, 2014

Annex 17. Overview of various model parameters of family house renovation in coastal Croatia for different calculation periods

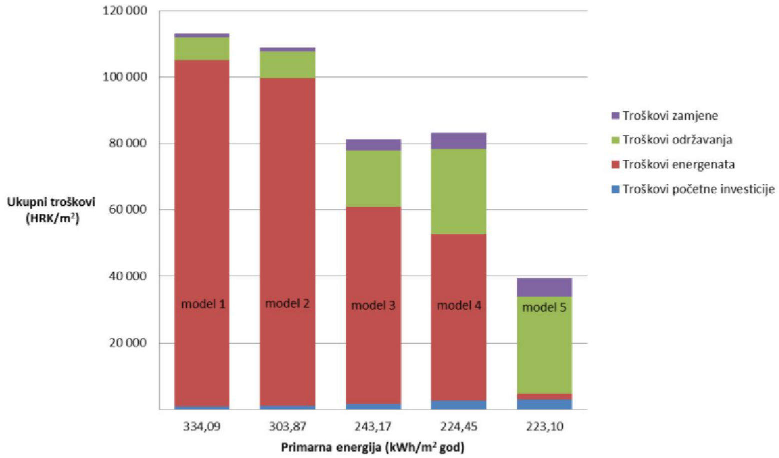
Parameters of various family house renovation models in coastal Croatia for a 30-year calculation period



Parameters of various family house renovation models in coastal Croatia for a 50-year calculation period



Parameters of various family house renovation models in coastal Croatia for a 70-year calculation period

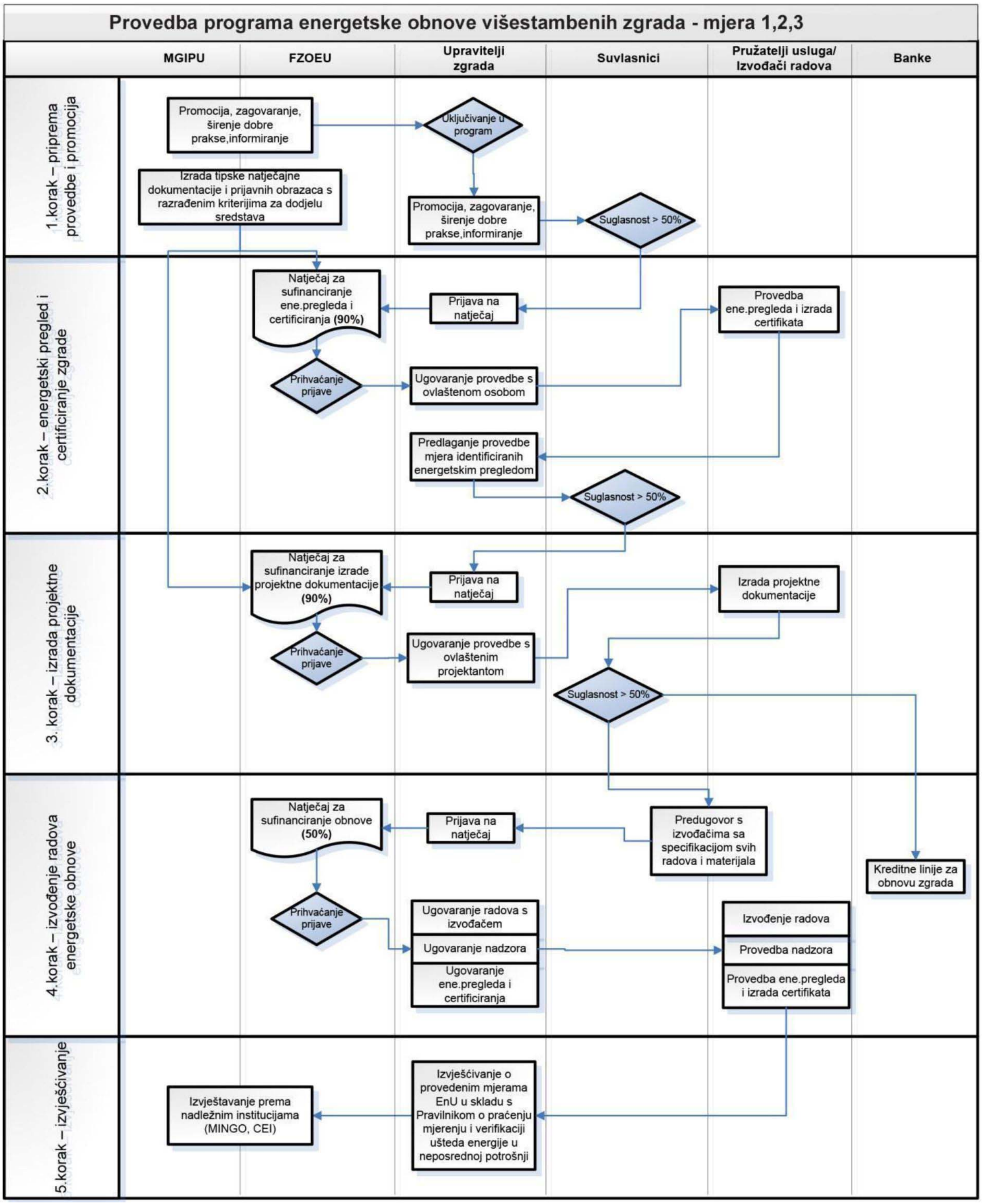


Ukupni troškovi (HRK/m^2)	Total expenditure (HRK/m^2)
Primarna energija (kWh/m^2 god)	Primary energy (kWh/m^2 per year)
Troškovi zamjene	Replacement costs
Troškovi održavanja	Maintenance costs
Troškovi energenata	Energy and fuel costs
Troškovi početne investicije	Initial investment

Model 1	Retrofit of the external heated space envelope under the Technical Regulation
Model 2	Retrofit of the external heated space envelope under the Technical Regulation Proposal
Model 3	Building renovation to the nZEB standard
Model 4	Building renovation to the passive house standard
Model 5	Building renovation to the active house standard

Source: *REGEA*, 2014

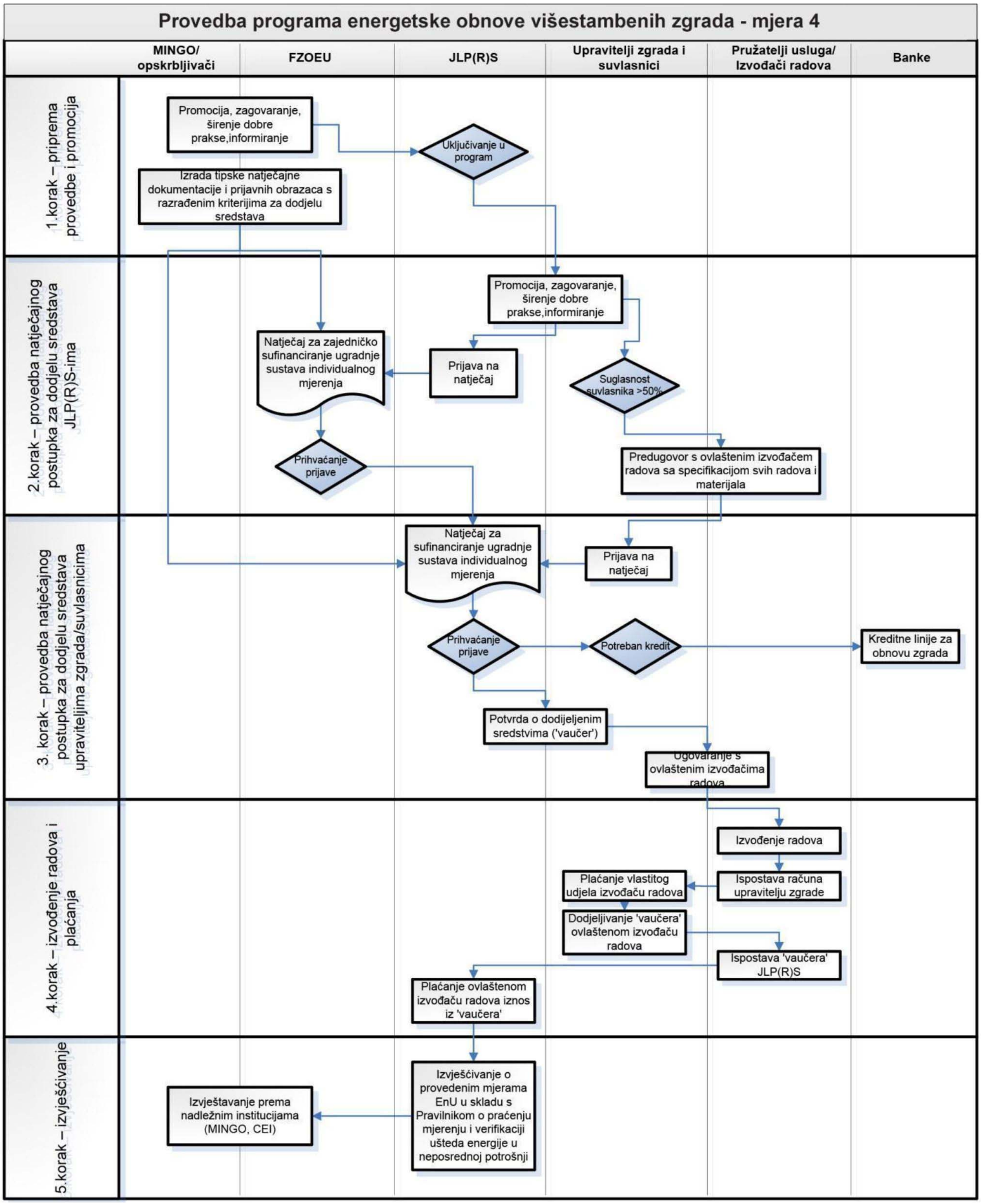
Annex 18A Organisational chart of the implementation of Measures 1, 2 and 3 in apartment buildings



Provedba programa energetske obnove višestambenih zgrada - mjera 1,2,3	Implementation of the programme of energy renovation of apartment buildings – Measures 1,2,3
MGIPU	MCPP
FZOEU	EPEEF
Upravitelji zgrada	Building managers
Suvlasnici	Co-owners
Pružatelji usluga/ Izvođači radova	Service providers / Work contractors

Banke	Banks
1. korak - priprema provedbe i promocija	Step 1 – implementation preparations and promotion
Promocija, zagovaranje, širenje dobre prakse, informiranje	Promotion, advocacy, good practice spreading, information
Izrada tipske natječajne dokumentacije i prijavnih obrazaca s razrađenim kriterijima za dodjelu sredstava	Preparation of typical tender documents and application forms with elaborated criteria for the grant of funding
Uključivanje u program	Inclusion in the programme
Suglasnost > 50%	Consent > 50%
2. korak - energetski pregled i certificiranje zgrade	Step 2 – building's energy audit and certification
Natječaj za sufinanciranje ene.pregleda i certificiranja (90%)	Tender to co-finance ener. audits and certification (90%)
Prihvaćanje prijave	Application acceptance
Prijava na natječaj	Application to tender
Ugovaranje provedbe s ovlaštenom osobom	implementation contracting with authorised person
Predlaganje provedbe mjera identificiranih energetskim pregledom	Implementation proposal of measures identified by en. audit
Provedba ene.pregleda i izrada certifikata	Energy audit and certification
3. korak - izrada projektne dokumentacije	Step 3 – project documentation preparation
Natječaj za sufinanciranje izrade projektne dokumentacije (90%)	Tender to co-finance project document preparation (90%)
Ugovaranje provedbe s ovlaštenim projektantom	Implementation contracting with authorised designer
Izrada projektne dokumentacije	Project documentation preparation;
4. korak - izvođenje radova energetske obnove	Step 4 – energy renovation works
Natječaj za sufinanciranje obnove (50%)	Tender to co-finance renovation (50%)
Ugovaranje radova s izvođačem	Works contracting with contractor
Ugovaranje nadzora	Supervision contracting
Ugovaranje ene.pregleda i certificiranja	Eneg. audit and certification contracting
Predugovor s izvođačima sa specifikacijom svih radova i materijala	Prelim. contract with contractors with a specification of all works and materials
Izvođenje radova	Work performance
Provedba nadzora	Supervision
Provedba ene.pregleda i izrada certifikata	Energy audit and certification
Kreditne linije za obnovu zgrada	Credit facilities for building renovation
5. korak - izvješćivanje	Step 5 – reporting
Izvještavanje prema nadležnim institucijama (MINGO, CEI)	Reporting to competent institutions (MoE, CEI)
Izvješćivanje o provedenim mjerama EnU u skladu s Pravilnikom o praćenju mjerenju i verifikaciji ušteda energije u neposrednoj potrošnji	Reporting on implemented EE measures, in accordance with the Rules of monitoring, measurement and verification of energy savings in end-use consumption

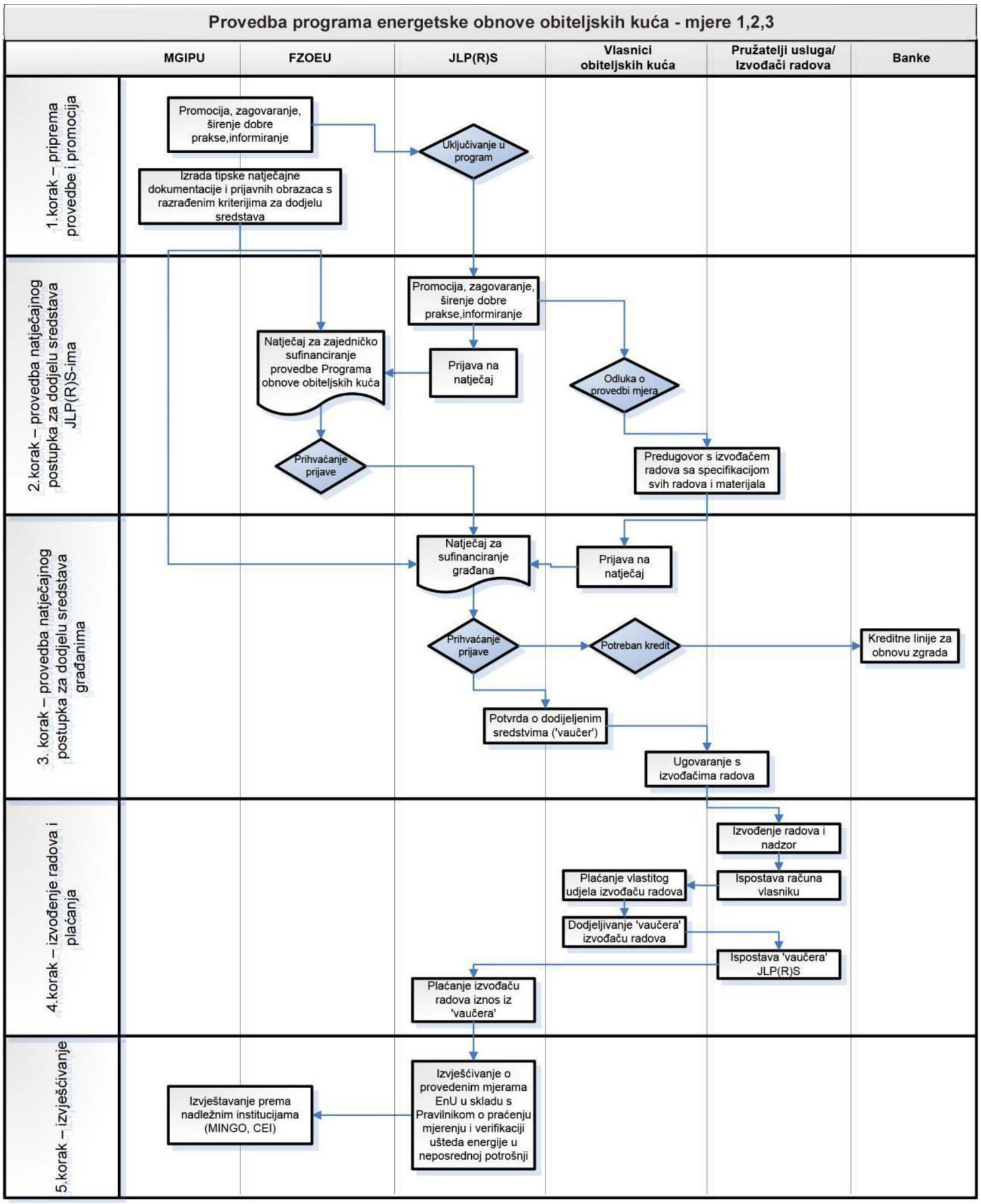
Annex 18B Organisational chart of the implementation of Measure 4 in apartment buildings



Provedba programa energetske obnove višestambenih zgrada - mjera 4	Implementation of the programme of energy renovation of apartment buildings – Measure 4
MINGO/ opskrbljivači	MoE / suppliers
FZOEU	EPEEF
JLP(R)S	LRSGU
Upravitelji zgrada i suvlasnici	Building managers and co-owners

Pružatelji usluga/ Izvođači radova	Service providers / Work contractors
Banke	Banks
1. korak - priprema provedbe i promocija	Step 1 – implementation preparations and promotion
Promocija, zagovaranje, širenje dobre prakse, informiranje	Promotion, advocacy, good practice spreading, information
Izrada tipske natječajne dokumentacije i prijavnih obrazaca s razrađenim kriterijima za dodjelu sredstava	Preparation of typical tender documents and application forms with elaborated criteria for the grant of funding
Uključivanje u program	Inclusion in the programme
2. korak - provedba natječajnog postupka za dodjelu sredstava JLP(R)S-ima	Step 2 – implementation of tender procedure for the grant of funding to local and reg. self-gov. units
Natječaj za zajedničko sufinanciranje ugradnje sustava individualnog mjerenja	Tender for joint co-financing of individual metering system installation
Prihvaćanje prijave	Application acceptance
Prijava na natječaj	Application to tender
Promocija, zagovaranje, širenje dobre prakse, informiranje	Promotion, advocacy, good practice spreading, information
Suglasnost > 50%	Consent > 50%
Predugovor s ovlaštenim izvođačem radova sa specifikacijom svih radova i materijala	Prelim. contract with author. contractor with a specification of all works and materials
3. korak - provedba natječajnog postupka za dodjelu sredstava upraviteljima zgrada/suvlasnicima	Step 3 – implementation of tender procedure for the grant of funding to building managers/co-owners
Natječaj za sufinanciranje ugradnje sustava individualnog mjerenja	Tender for co-financing of individual metering system installation
Potvrda o dodijeljenim sredstvima ("vaučer")	Funding certificate (voucher)
Potreban kredit	Necessary loan
Ugovaranje s ovlaštenim izvođačima radova	Contracting with authorised works contractors
Kreditne linije za obnovu zgrada	Credit facilities for building renovation
4. korak - izvođenje radova i plaćanja	Step 4 – performance of works and payment
Plaćanje ovlaštenom izvođaču radova iznos iz "vaučera"	Voucher payment to authorised works contractor
Plaćanje vlastitog udjela izvođaču radova	Payment of own share to works contractor
Dodjeljivanje "vaučera" ovlaštenom izvođaču radova	Voucher assignment to authorised works contractor
Izvođenje radova	Work performance
Ispostava računa upravitelju zgrade	Invoice issuance to building manager
Ispostava "vaučera" JLP(R)S	Voucher issuance to LRSGU
5. korak - izvješćivanje	Step 5 – reporting
Izvještavanje prema nadležnim institucijama (MINGO, CEI)	Reporting to competent institutions (MoE, CEI)
Izvješćivanje o provedenim mjerama EnU u skladu s Pravilnikom o praćenju mjerenju i verifikaciji ušteda energije u neposrednoj potrošnji	Reporting on implemented EE measures, in accordance with the Rules of monitoring, measurement and verification of energy savings in end-use consumption

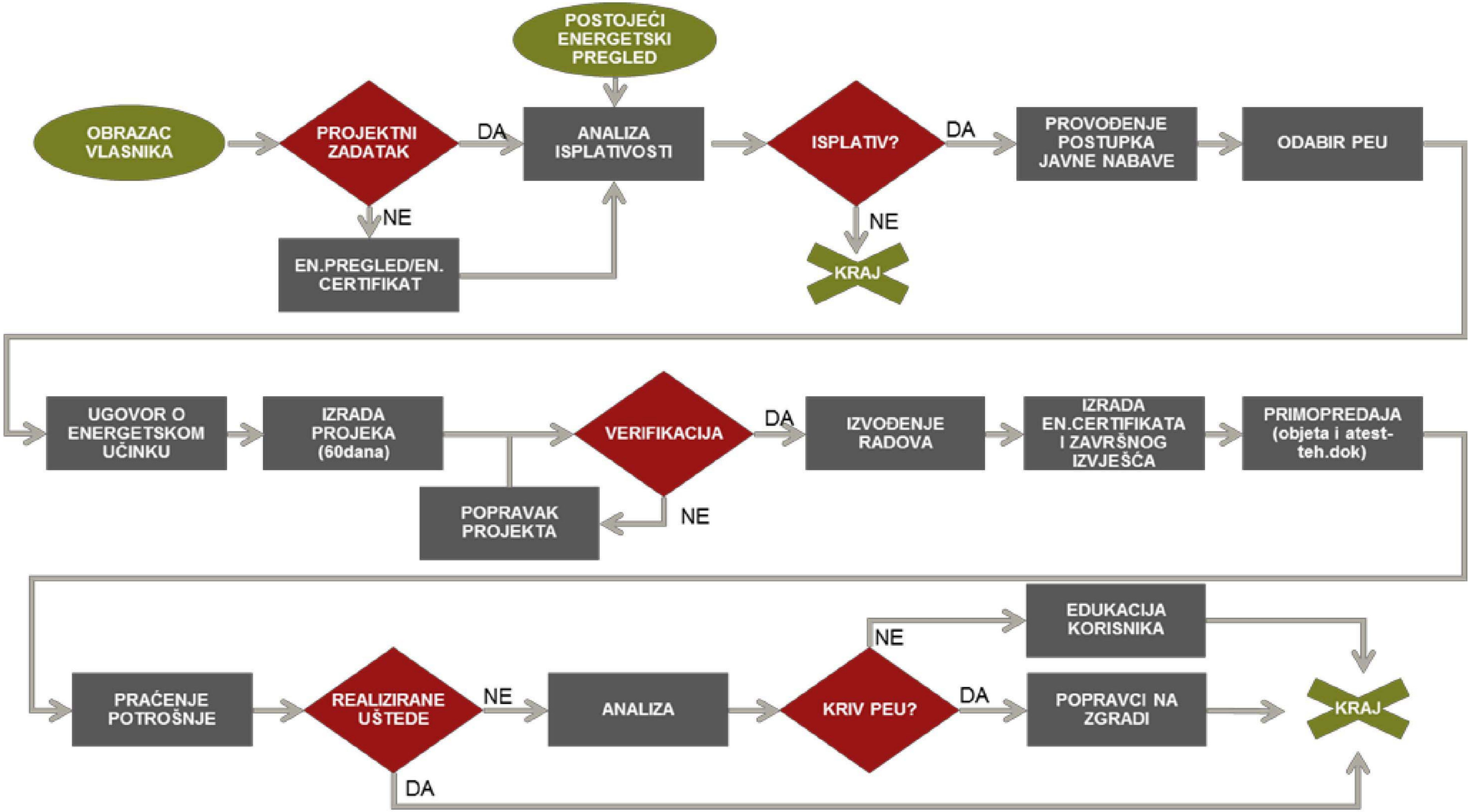
Annex 19 Organisational chart of implementing the family house energy renovation programme



Provedba programa energetske obnove obiteljskih kuća - mjera 1,2,3	Implementation of the programme of energy renovation of family houses – Measures 1,2,3
MGIPU	MCPP
FZOEU	EPEEF
JLP(R)S	LRSGU
Vlasnici obiteljskih kuća	Family house owners
Pružatelji usluga/ Izvođači radova	Service providers / Work contractors
Banke	Banks
1. korak - priprema provedbe i promocija	Step 1 – implementation preparations and promotion
Promocija, zagovaranje, širenje dobre prakse, informiranje	Promotion, advocacy, good practice spreading, information provision
Izrada tipske natječajne dokumentacije i prijavnih	Preparation of typical tender documents and application

obrazaca s razrađenim kriterijima za dodjelu sredstava	forms with elaborated criteria for the grant of funding
Uključivanje u program	Inclusion in the programme
2. korak - provedba natječajnog postupka za dodjelu sredstava JLP(R)S-ima	Step 2 – implementation of tender procedure for the grant of funding to local and reg. self-gov. units
Natječaj za zajedničko sufinanciranje provedbe Programa obnove obiteljskih kuća	Tender for joint co-financing of implementation of the Programme of family house renovation
Prihvaćanje prijave	Application acceptance
Promocija, zagovaranje, širenje dobre prakse, informiranje	Promotion, advocacy, good practice spreading, information
Prijava na natječaj	Application to tender
Odluka o provedbi mjera	Decision on measure implementation
Predugovor s izvođačem radova sa specifikacijom svih radova i materijala	Prelim. contract with contractor with a specification of all works and materials
3. korak - provedba natječajnog postupka za dodjelu sredstava građanima	Step 3 – implementation of tender procedure for the grant of funding to citizens
Natječaj za sufinanciranje građanima	Tender for co-financing of citizens
Potvrda o dodijeljenim sredstvima ("vaučer")	Funding certificate (voucher)
Potreban kredit	Necessary loan
Ugovaranje s izvođačima radova	Contracting with works contractors
Kreditne linije za obnovu zgrada	Credit facilities for building renovation
4. korak - izvođenje radova i plaćanja	Step 4 – performance of works and payment
Plaćanje izvođaču radova iznos iz "vaučera"	Voucher payment to works contractor
Plaćanje vlastitog udjela izvođaču radova	Payment of own share to works contractor
Dodjeljivanje "vaučera" izvođaču radova	Voucher assignment to works contractor
Izvođenje radova i nadzor	Performance of works and supervision
Ispostava računa vlasniku	Invoice issuance to owner
Ispostava "vaučera" JLP(R)S	Voucher issuance to LRSGU
5. korak - izvješćivanje	Step 5 – reporting
Izvještavanje prema nadležnim institucijama (MINGO, CEI)	Reporting to competent institutions (MoE, CEI)
Izvješćivanje o provedenim mjerama EnU u skladu s Pravilnikom o praćenju mjerenju i verifikaciji ušteda energije u neposrednoj potrošnji	Reporting on implemented EE measures, in accordance with the Rules of monitoring, measurement and verification of energy savings in end-use consumption

Annex 20 Flow chart of project implementation of public building energy renovation under the Programme[132]



[132] Programme of energy renovation of public buildings, Ministry of Construction and Physical Planning, October 2010

POSTOJEĆI ENERGETSKI PREGLED	EXISTING ENERGY AUDIT
OBRAZAC VLASNIKA	OWNER FORM
PROJEKTNI ZADATAK	PROJECT TASK
DA	YES
ANALIZA ISPLATIVOSTI	COST-EFFECTIVENESS ANALYSIS
ISPLATIV?	COST-EFFECTIVE?
PROVOĐENJE POSTUPKA JAVNE NABAVE	PUBLIC PROCUREMENT PROCEDURE
ODABIR PEU	ESP SELECTION
NE	NO
EN.PREGLED/EN.CERTIFIKAT	ENER.AUDIT/ENER.CERTIFICATE
KRAJ	END
UGOVOR O ENERGETSKOM UČINKU	ENERGY PERFORMANCE CONTRACT
IZRADA PROJEKA (60 dana)	PROJECT DRAFTING (60 days)
VERIFIKACIJA	VERIFICATION
IZVOĐENJE RADOVA	WORK PERFORMANCE
IZRADA EN.CERTIFIKATA I ZAVRŠNOG IZVJEŠĆA	ENER. CERTIFICATE AND FINAL REPORT DRAFTING
PRIMOPREDAJA (objekta i atest - teh.dok)	HANDOVER (of facility and certificate-tech.doc.)
PRAĆENJE POTROŠNJE	CONSUMPTION MONITORING
REALIZIRANE UŠTEDE	SAVINGS ACHIEVED
ANALIZA	ANALYSIS
KRIV PEU?	ESP AT FAULT?
EDUKACIJA KORISNIKA	USER EDUCATION
POPRAVCI NA ZGRADI	BUILDING REPAIRS

Annex 21 Breakdown of investments in the 2014–2049 national building stock renovation

Items/year	2014	2015	2016	2017	2018	2019	2020	2021	2022
Initial investment (HRK mil.)	1 653	1 653	3 307	4 960	9 921	9 921	9 921	9 921	9 921
Maintenance cost (HRK mil.)	93	93	279	559	1 117	1 676	2 234	2 793	3 351
Replacement cost (HRK mil.)	0	0	0	0	0	0	0	0	0
Total expenditure (HRK mil.)	1 747	1 747	3 586	5 519	11 038	11 596	12 155	12 713	13 272
Cumulative cost (HRK mil.)	1 747	3 493	7 079	12 598	23 636	35 232	47 387	60 100	73 372
Average annual renovation rate (%)	0.5	0.5	1.0	1.5	3.0	3.0	3.0	3.0	3.0
Average renovated area per year (mil. m^2)	0.96	0.96	1.93	2.89	5.78	5.78	5.78	5.78	5.78

Items/year	2023	2024	2025	2026	2027	2028	2029	2030	2031
Initial investment (HRK mil.)	9 921	9 921	11 574	11 574	11 574	11 574	11 574	11 574	11 574
Maintenance cost (HRK mil.)	3 910	4 468	5 120	5 772	6 423	7 075	7 726	8 378	9 193
Replacement cost (HRK mil.)	0	0	0	0	0	0	0	0	2 899
Total expenditure (HRK mil.)	13 830	14 389	16 694	17 346	17 997	18 649	19 301	19 952	23 666
Cumulative cost (HRK mil.)	87 203	101 592	118 286	135 631	153 629	172 278	191 578	211 530	235 197
Average annual renovation rate (%)	3.0	3.0	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Average renovated area per year (mil. m^2)	5.78	5.78	6.74	6.74	6.74	6.74	6.74	6.74	6.74

Items/year	2032	2033	2034	2035	2036	2037	2038	2039	2040
Initial investment (HRK mil.)	11 574	11 574	11 574	11 574	11 574	11 574	11 574	11 574	4 960
Maintenance cost (HRK mil.)	10 008	10 823	11 637	12 452	13 267	14 082	14 897	15 712	16 154
Replacement cost (HRK mil.)	2 899	2 899	2 899	2 899	2 899	2 899	2 899	2 899	2 899
Total expenditure (HRK mil.)	24 481	25 296	26 111	26 926	27 741	28 556	29 370	30 185	24 014
Cumulative cost (HRK mil.)	259 678	284 974	311 085	338 011	365 751	394 307	423 677	453 863	477 877
Average annual renovation rate (%)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	1.5
Average renovated area per year (mil. m^2)	6.74	6.74	6.74	6.74	6.74	6.74	6.74	6.74	2.89

Items/year	2041	2042	2043	2044	2045	2046	2047	2048	2049
Initial investment (HRK mil.)	4 960	4 960	4 960	4 960	4 960	4 960	4 960	4 960	4 960
Maintenance cost (HRK mil.)	16 597	17 039	17 482	17 924	18 367	18 972	19 578	20 184	20 790
Replacement cost (HRK mil.)	2 899	2 899	2 899	2 899	2 899	5 799	5 799	5 799	5 799
Total expenditure (HRK mil.)	24 456	24 899	25 341	25 784	26 226	29 731	30 337	30 943	31 549
Cumulative cost (HRK mil.)	502 333	527 232	552 573	578 357	604 584	634 315	664 652	695 595	727 144
Average annual renovation rate (%)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Average renovated area per year (mil. m2)	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89

Annex 22 Model of partial employment adjustment (ZAPZGRA) for new building segment orders (NOVONARZGR)

The model has been estimated in an ln form, and statistics at the bottom (Breusch–Pagan fourth order LM test) show the residual autocorrelation to have been completely eliminated.

Dependent Variable: LNZAPZGRA
Method: Least Squares
Date: 03/29/14 Time: 14:40
Sample (adjusted): 2004Q2 2013Q4
Included observations: 39 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.109638	0.374923	2.959641	0.0054
LNZAPZGRA(-I)	0.815227	0.046113	17.67898	0.0000
LNNOVONARZGR	0.108222	0.023171	4.670523	0.0000

R-squared	0.963280	Mean dependent var	10.42901
Adjusted R-squared	0.961240	S.D. dependent var	0.161253
S.E. of regression	0.031747	Akaike info criterion	-3.988250
Sum squared resid	0.036283	Schwarz criterion	-3.860284
Log likelihood	80.77088	Hannan-Quinn criter.	-3.942337
F-statistic	472.2005	Durbin-Watson stat	1.978406
Prob(F-statistic)	0.000000		

N*R2=3.25; Pr(hi2(4))=0.52

The short-term coefficient is 0.11, and long-term 0.11/(1-0.82)=0.61. We have reasons to suspect the validity of both coefficients. There is a great possibility of estimate bias, since these are first-order non-stationary variables, and there is a large number of complex extra-model impacts whose effects are probably not normally distributed.

Below are ADF stationarity tests of the variables used, showing that variables I(0) once differentiated:

Null Hypothesis: LNNOVONARZGR has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic based on SIC, MAXLAG=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.725174	0.4111
Test critical	1% level	-3.610453	
	5% level	-2.938987	
	10% level	-2.607932	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNNOVONARZGR) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic based on SIC, MAXLAG=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.230270	0.0000
Test critical	1% level	-3.615588	
	5% level	-2.941145	
	10% level	-2.609066	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNZAPZGRA has a unit root
Exogenous: Constant
Lag Length: 2 (Automatic based on SIC, MAXLAG=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-0.529722	0.8739
Test critical values:	1% level	-3.621023	
	5% level	-2.943427	
	10% level	-2.610263	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNZAPZGRA) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic based on SIC, MAXLAG=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.417475	0.0011
Test critical values:	1% level	-3.615588	
	5% level	-2.941145	
	10% level	-2.609066	

*MacKinnon (1996) one-sided p-values.

Given the possibility that the short-term parameter of the PAM model underestimates the impact of the value of new orders on employment, a long-term cointegration ratio using an error correction model.

The cointegration equation demonstrated long-term elasticity (0.4), and its residuals proved stationary (I(0)), pointing to the existence of a long-term, positive and balanced correlation between orders and employment:

Dependent Variable: LNZAPZGRA
Method: Least Squares
Date: 03/30/14 Time: 15:58
Sample: 2004Q1 2013Q4
Included observations: 40

Variable	Coefficient	Std. Error	t-Statistic	Prob.

C	7.336523	0.355319	20.64770	0 .0000
LNNOVONARZGR	0.409336	0.047089	8.692901	0.0000

R-squared	0.665394	Mean dependent var	10.42243
Adjusted R-squared	0.656589	S.D. dependent var	0.164518
S.E. of regression	0.096410	Akaike info criterion	-1.791709
Sum squared resid	0.353205	Schwarz criterion	-1.707265
Log likelihood	37.83418	Hannan-Quinn criter.	-1.761177
F-statistic	75.56653	Durbin-Watson stat	0.504004
Prob(F-statistic)	0.000000		

ADF TEST OF THE LONG-TERM COINTEGRATION EQUATION RESIDUAL:

Null Hypothesis: R has a unit root
Exogenous: None
Lag Length: 0 (Automatic based on SIC, MAXLAG=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.226008	0.0268
Test critical values:	1% level	-2.625606	
	5% level	-1.949609	
	10% level	-1.611593	

*MacKinnon (1996) one-sided p-values.

The short-term equation yielded no significant short-term reaction parameter, but it yielded a significant parameter of adjustment to a balance whose value (-0.24) points to the system adjustment to the long-term balance through four quarters:

Dependent Variable: DLNZAPZGRA
Method: Least Squares
Date: 03/30/14 Time: 15:45
Sample (adjusted): 2004Q2 2013Q4
Included observations: 39 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DLNNOVONARZGR	0.042138	0.034320	1.227785	0 .2273
R(-1)	-0.237606	0.055243	-4.301095	0.0001

R-squared	0.3 49387	Mean dependent var	-4.43E-05
Adjusted R-squared	0.331802	S.D. dependent var	0.039446
S.E. of regression	0.032244	Akaike info criterion	-3.981042
Sum squared resid	0.038468	Schwarz criterion	-3.895731
Log likelihood	79.63032	Hannan-Quinn criter.	-3.950433
Durbin-Watson stat	1.540174		

Because of an unexpectedly high value of the long-term elasticity coefficient of 0.4 and the absence of short-term (marginal) correlation, it was decided that the simulations would use the average short-term parameter of the PAM model (0.11) and the long-term EMC parameter (0.4), meaning that the shown simulations were obtained by using the elasticity ratio (0.11+0.4)/2=0.26.