MINISTRY OF CONSTRUCTION AND PHYSICAL PLANNING

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

Zagreb, September 2017

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The main objective of the Strategy is to identify effective measures for the long-term mobilisation of cost-efficient integrated renovation of the building stock of the Republic of Croatia (all residential and non-residential buildings) by 2050 on grounds of the established economical and energy-optimal building renovation model.

In accordance with the provisions of Directive 2012/27/EU, the Strategy covers the following topics:

1. **Overview of the Croatian national building stock** includes data on the number, area, and structural and energy characteristics of the national building stock, grouped by purpose into four categories (multi-residential buildings; family houses; public buildings and commercial buildings).

This document provides an overview of the above building categories by construction period, climate zone, ownership and differentiation into rural and urban areas. In order to provide a more precise and accurate overview of the national building stock, the authors have systematically collected, processed and analyzed data in the Statistical Yearbooks, published by the Croatian Bureau of Statistics between 1952 and 2011. According to the results of a systematic research of the Statistical Yearbooks and the expert estimates of missing data, Croatian national residential building stock consists of 762,397 buildings with a total floor area of 142,176,678 m^2, of which 290,689 are multi-residential buildings with a total floor area of 55,438,063 m^2, and 471,708 are family houses with a total floor area of 86,738,615 m^2. Croatian national non-residential building stock consists of 124,924 buildings with a total floor area of 50,342,361 m^2, of which 44,728 are commercial buildings with a total floor area of 36,540,459 m^2, and 80,196 are public buildings with a total floor area of 13,801,902 m^2. On grounds of the analyses performed, it is established that the total current national building stock of the Republic of Croatia comprises 887,321 buildings with a total floor area of 192,519,039 m^2.

Since energy renovation programmes have been implemented within the three years from drafting the Long-Term Strategy up to today, the total floor area of the national building stock to be renewed from 2017 onwards has been updated in accordance with the Annual Report on the Progress towards the National Energy Efficiency Targets under Article 24 (1) in accordance with Part 1 of the of Annex XIV of the Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC (Text with EEA relevance)[3] (hereinafter: the Report). According to the Report providing a review of cumulative savings realized from 2014 to 2016 (1, 72767 PJ), the total floor area of the renovated building stock is estimated at 2,172,440 m^2. Subtracting the area of the renovated building stock from the total national building stock (192.519.000,00 m^2), the updated area of the national building stock subject to renovation amounts to 190,346,560 m^2. It should be noted that buildings which are not currently under the obligation of energy certification or are under some kind of protection are not excluded from the considered building stock due to the long period considered within the Strategy (up to 2050), which implies the possibility of a change in the European and national legislation.

[1]European Commission (2012), *Directive 2012/27/EU of the European Parliament and of the Council of 25th October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC (Texts with EEA relevance)*, available at: http://eur-lex.europa.eu/legal-content/HR/ALL/?uri=celex:32012L0027 [2012]
[2]Energy Efficiency Act, (Official Gazette No. 127/14) (2040), available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2014_10_127_2399.html [30th April 2017]
[3]Draft [10th May 2017]

The part relating to construction and energy characteristics of buildings provides an estimate of the annual heating energy requirements for coastal and continental Croatia, and also presents the buildings' structural characteristics with heat transmittance coefficients of their structural parts and elements, depending on the period, as well as an overview of the heating systems in use in Croatia. According to the analysis conducted, buildings constructed prior to 1987 show the highest annual heating requirements and annual final energy requirements for heating, cooling, domestic hot water (DHW) generation and lighting.

2. **Analysis of key elements of the building renovation programme** involves an analysis of technical options for energy renovation (retrofit) by implementing EE and RES measures, an analysis of the technical capabilities of heating systems, and an identification of possible sustainable building renovation models and the estimates of expected energy savings.

In order to select the optimal renovation method for each building category, with regard to 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 building renovation model compliant to the requirements of the *Technical Regulation on the Rational Use of Energy and Thermal Protection of Buildings (Official Gazette No. 128/15)* (hereinafter: the Technical Regulation), related to large reconstruction, has been selected as the cost-optimal building renovation model. The specific amount of total costs (Annex 2, Annex 4, Annex 6, Annex 8, Annex 10, Annex 12, Annex 14 and Annex 16) has been considered the fundamental parameter in the comparison of various building renovation models and used as a basis for charts drawn for each building category to illustrate the total cost dependence on the primary energy level after renovation under a certain renovation model (Annex 3, Annex 5, Annex 7, Annex 9, Annex 11, Annex 13, Annex 15 and Annex 17). Although the shown charts and parameters in tables (Table 3.6 and Table 3.7) suggest that the active house model is the most commercially viable, it should be noted that viability depends on the status of preferential RES- and cogeneration-based producer which thus covers a small fraction of the national building stock (due to the obligatory administrative procedure to be followed, and due to the obligation to report regularly and to meet the technical conditions of the plant's efficiency), Consequently, building renovation compliant to the *Technical Regulation* requirements related to large reconstruction has been selected as the cost-optimal model.

A group of buildings built up to 1987 was selected as the target group with regard to their total floor area, state of the heated space envelope and energy requirements. The above building stock was selected because of the greatest savings potential and its significant share in the total floor area of all buildings. In addition, the above input parameters in terms of the energy savings potential suggest that, within the buildings stock built up to 1987, the highest priority for integrated renovation should be given to family houses (potential of specific energy savings according to the useful floor area of the building up to 293.48 kWh/m^2 yearly) and commercial buildings (potential of specific energy savings according to the useful floor area of the building up to 274.78 kWh/m^2 yearly). In addition to the great potential for energy savings, family houses are also a priority category of buildings to be renovated in view of combating energy poverty, which is among the objectives of the Draft 4th National Energy Efficiency Action Plan 2017-2019.[4] However, in the category of family houses, deviation from the data obtained is possible due to the high degree of firewood use and the smaller heated floor area of the building than projected, which challenges the financial viability of renovation of family houses with these characteristics, and the implementation largely depends on incentive measures (not only financial).

3. **Policies and measures to stimulate cost-effective integrated building renovation** include an overview of existing measures for and obstacles to an integrated 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 EU Member States.

Overall, it can be concluded that the main obstacles to the renovation of the Croatian national building stock are not only legislative and financial in nature, but that the integrated energy renovation of buildings is also largely hampered by a lack of information and motivation on the part of investors, the public and stake holders.

[4]Draft [10th May 2017]

This chapter gives an overview of successful policies and measures to mobilise investment in the energy renovation of different building types in EU Member States and describes the examples of financial and legislative policies. In order to meet the set targets, the Croatian national policy of integrated renovation of the national building stock shall include the six categories of measures detailed below.

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

Meeting the set energy renovation objectives according to the *Technical Regulation* requirements related to large reconstruction requires a mobilisation of sizeable resources for investment costs as well as maintenance and replacement costs, that are all estimated to reach almost HRK 790 billion by 2050. The proposed pace of renovation will achieve an overall reduction in CO_2 emissions by 81.1% and achieve the objectives set in the EU Energy Roadmap[5]. Since the currently available sources of funding are insufficient to achieve the set objectives, the introduction of new, innovative funding mechanisms which combine 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 of 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. **Estimate of expected energy savings and widespread benefits of the integrated renovation of the national building stock,** based on calculation and model data, takes into account the fact that investing in integrated renovation of the 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 integrated renovation on 91.7% of the national building stock is completed by the end of 2049, the expected impact on employment could produce 56 thousand new jobs in a scenario involving conservatively estimated multiplier effects, or as many as 93 thousand in a scenario involving strong multiplication. Additionally, the expected impact on employment by the year 2020 would be between 25 and 43 thousand new jobs, depending on the estimated multiplier effects, and an additional 5 to 9 thousand more are expected by 2030. The estimated impact of the integrated renovation programme on GDP growth by 2030 ranges between 5.0% and 8.4% and, by 2050, it ranges between 10% and 17%, depending on the estimated multiplier effects. The estimated impact of the integrated renovation programme on achieving energy savings by 2030 is about 67.0 PJ, which is about 82% in terms of achieving the final consumption objectives. Until 2050, it is possible to achieve energy savings of approximately 131.5 PJ, which is about 62% of the overall energy savings objective in the building sector. The effect on CO_2 emission reduction by 2030 will be around 3,197.0 kt, and approximately 6,277.0 kt by 2050.

The wider economic benefits of the integrated renovation of the national building stock do not result only in economic activities, budget revenues, and employment growth. integrated renovation of the national building stock certainly results in improved health and, consequently, in considerable cost reduction in the Croatian healthcare system, reduction of the energy poverty in Croatia and a steady increase of real estate value, while indirect benefits will be visible 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 certainty that the implementation of the integrated renovation programme of the Croatian national building stock will result in improvements of the Croatian economy in almost all its segments in accordance with the elements of this Strategy.

[5]Energy Roadmap 2050. Luxembourg: Publications Office of the European Union, 2012, available at: http://ec.europa.eu/energy/sites/ener/files/documents/2012_energy_roadmap_2050_en_0.pdf [19th May 2017]

1. Introduction

Energy security and climate change prevention largely depend on considerable improvements in building energy efficiency. Individual EU countries have set a 20% energy saving objective by 2020. In accordance with the Proposal for a Directive of the European Parliament and of the Council amending Directive 2010/31/EU on the energy performance of buildings (Text with EEA relevance)[6], within the framework of the climate and energy policy by 2030, EU obligations have been established to further increase energy savings by at least 27%, bearing in mind the EU-wide 30% energy saving target. Furthermore, the European Union[7] has set long-term target of reducing CO_2 emissions from the building sector by 80 to 95% by 2050. In addition, Directive 2010/31/EU of the European Parliament and of the Council of 19th May 2010 on the energy efficiency of buildings (recast)[8] (hereinafter: Directive 2010/31/EU) provides for the encouragement of consideration of the introduction of high-efficiency alternative systems to the extent technically, functionally and economically feasible, while Directive 2009/28/EC of the European Parliament and of the Council of 23rd April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC (Text with EEA relevance)[9] (hereinafter: Directive 2009/28/EU) provides for the obligation to introduce measures to increase the share of energy from renewable sources for all EU Member States.

According to the obligations assumed under Directive 2012/27/EU[10], the Republic of Croatia was required to submit to the European Commission by 30th April 2014 its *Long-Term Strategy for Mobilising Investment in the Renovation of the National Building Stock* (hereinafter: the Strategy) which covers 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 integrated 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 integrated renovation of the national building stock (new job creation, reduction of energy poverty, increase in real estate value etc.)

The Strategy shall be updated every three years and submitted to the European Commission as part of National Energy Efficiency Action Plans. The Strategy review shall be submitted to the European Commission along with 4th National Energy Efficiency Action Plan, the draft of which it is fully aligned with. Croatia's 4th National Energy Efficiency Action Plan up to the end of 2019 (hereinafter: the NEEAP) was adopted in pursuant to Article 8 of the Energy Efficiency Act and, in accordance with the requirements of Directive 2012/27/EU[11], under which EU Member States are required to draft and submit to the European Commission (EC) every three years their plans containing measures which, once implemented, will achieve the set targets for energy end-use savings targets by 2019. NEEAP puts emphasis on the development and implementation of detailed and comprehensive national

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[6]European Commission (2016), *Proposal for a Directive of the European Parliament and of the Council amending Directive 2010/31/EU on the energy performance of buildings (Text with EEA relevance)*, available at http://eur-lex.europa.eu/legal-content/HR/TXT/?uri=COM%3A2016%3A765%3AFIN [30th April 2017]

[7]Energy Roadmap 2050. Luxembourg: Publications Office of the European Union, 2012, available at: http://ec.europa.eu/energy/sites/ener/files/documents/2012_energy_roadmap_2050_en_0.pdf [19th May 2017]

[8]European Commission (2010), *Directive 2010/31/EU of the European Parliament and of the Council of 19th May 2010 on the energy efficiency of buildings (recast)*, available at: http://eur-lex.europa.eu/legal-content/HR/TXT/?uri=CELEX%3A32010L0031 [2010]

[9]European Commission (2009), *Directive 2009/28/EC of the European Parliament and of the Council of 23rd April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC (Text with EEA relevance)*, available at: http://eur-lex.europa.eu/legal-content/HR/TXT/?uri=CELEX%3A32009L0028 [2009]

[10]European Commission (2012), *Directive 2012/27/EU of the European Parliament and of the Council of 25th October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC (Texts with EEA relevance)*, available at: http://eur-lex.europa.eu/legal-content/HR/ALL/?uri=celex:32012L0027 [2012]

[11]European Commission (2012), *Directive 2012/27/EU of the European Parliament and of the Council of 25th October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC (Texts with EEA relevance)*, available at: http://eur-lex.europa.eu/legal-content/HR/ALL/?uri=celex:32012L0027 [2012]

programmes for the complete renovation of residential and non-residential buildings, which can save up to 18.0 PJ by 2019.

While the main objective of Directive 2012/27/EU is to achieve the 2020 20% headline target on energy efficiency, Article 1 prescribes that the directive should "pave the way for further energy efficiency improvements beyond that date". This will be achieved on the basis of the Proposal for a Directive of the European Parliament and of the Council amending Directive 2010/31/EU on the energy performance of buildings (Text with EEA relevance)[12] in terms of energy savings of at least 27% bearing in mind the headline target of 30% of energy savings at EU level. Article 4 goes a step further by obliging EU Member States to draft long-term strategies for mobilising investment in the renovation of the national building stock in order to realise the full potential of energy and financial savings. The main objective 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 non-residential national building stock. It is very important to find measures for mobilising 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 methodology and terminology of the Strategy have been fully harmonised with the following documents and draft documents in force at the national level:

- National Plan for Increasing the Number of Nearly Zero-Energy Buildings 2020[13]
- National Energy Efficiency Programme 2008-2016[14];
- 2nd National Energy Efficiency Action Plan 2011-2013[15];
- 3rd National Energy Efficiency Action Plan 2014-2016[16];
- ~~Draft~~ 4th National Energy Efficiency Action Plan 2017-2019[17];
- Programme of Energy Renovation of Family Houses 2014-2020 with a detailed plan 2014-2016[18];
- Programme of Energy Renovation of Multi-Residential Buildings 2014-2020 with a detailed plan 2014-2016[19]
- Programme of Energy Renovation of Commercial Non-Residential Buildings 2014-2020 with a detailed plan for the energy renovation of commercial non-residential buildings 2014-2016[20],
- Programme of Energy Renovation of Public Buildings 2014-2015[21]

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[12]European Commission (2016), *Proposal for a Directive of the European Parliament and of the Council amending Directive 2010/31/EU on the energy performance of buildings (Text with EEA relevance)*, available at http://eur-lex.europa.eu/legal-content/HR/TXT/?uri=COM%3A2016%3A765%3AFIN [30th April 2017]

[13]National Plan for Increasing the Number of Nearly Zero-Energy Buildings 2020, December 2014, Ministry of Construction and Physical Planning, available at: http://www.mgipu.hr/doc/Propisi/PLAN_PBZ_0_energije_do_2020.pdf [30th April 2017]

[14]National Energy Efficiency Programme 2008-2016. Ministry of Economy, March 2010, available at: http://www.mingo.hr/userdocsimages/energetika/Nacionalni%20program%20energetske%20u%C4%8Dinkovitosti%202008.% 20-% 202010..pdf [30th April 2017]

[15]2nd National Energy Efficiency Action Plan 2011-2013, Ministry of Economy, February 2013, available at: http://www.mingo.hr/userdocsimages/2.20Nacionalni%20akcijski%20plan%20energetske%20ucinkovitosti%20za%%%20razdoblje%20do 20kraja% 202013.pdf [30th April 2017]

[16]3rd National Energy Efficiency Action Plan 2014-2016, Ministry of Economy, July 2014, available at: http://www.mingo.hr/public/3%20Nacionalni_akcijski_plan.pdf [30th April 2017]

[17]Draft [10th May 2017]

[18]Programme of Energy Renovation of Family Houses 2014-2020 with a detailed 2014-2016 plan, March 2014, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/431066.pdf [30th April 2017]

[19]Programme of Energy Renovation for Multi-Residential Buildings 2014-2020 with a detailed 2014-2016 plan, May 2014, Ministry of Construction and Physical Planning, available at: http://www.mgipu.hr/doc/Propisi/Program_EO_VS_ZGRADE.pdf [30th April 2017]

[20]Programme of Energy Renovation of Commercial Non-Residential Buildings 2014-2020 with a detailed plan for the energy renovation of commercial non-residential buildings 2014-2016, July 2014,Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/432768.pdf [30th April 2017]

[21]Programme of Energy Renovation of Public Buildings 2014-2015, October 2013, Ministry of Construction and Physical Planning, available at: http://www.mgipu.hr/doc/EnergetskaUcinkovitost/Program_energetske_obnove_javnih_zgrada_2014-2015.pdf [30th April 2017]

- Programme of Energy Renovation of Public Buildings 2016-2020[22]

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

- Set very high long-term objectives 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 funding mechanisms, as well as the plans and perspectives to ensure a stable investment climate for all market participants.

[22]Programme of Energy Renovation of Public Buildings 2016-2020, March 2017, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2017_03_22_508.html [30th April 2017]

2. Overview of the national building stock of the Republic of Croatia

2.1 National building stock categories by purpose

For the purpose of compliance with strategic documents and programmes of energy renovation of buildings 2013-2020[23] and with the building classification in accordance with Directive 2010/31/EU,[24] for the purpose of drafting this Strategy, the Croatian national building stock is organised into the following categories by purpose:

- Multi-residential buildings;
- Family houses;
- Public buildings;
- Commercial buildings.

In drafting the *Programme of Energy Renovation of Multi-Residential Buildings 2014-2020* and the *Programme of Energy Renovation of Family Houses 2014-2020*[25] the results of the IPA project named *Citizen Participation in Energy Efficiency Planning (CENEP)* classifying residential buildings into family houses and multi-residential buildings, have been used. The above classification of the Croatian residential building stock shall also be used in this Strategy, as well as the definitions within the *Programme of Energy Renovation of Family Houses, Multi-Residential Buildings and Public Buildings*. In the context of the Long-Term Strategy, public buildings are buildings owned by the public sector and used for social activities (education, science, culture, sports, health and social welfare), the activities of state bodies and organizations, as well as those of local and regional government bodies and organizations, the activities of legal entities with public authority, and also residential buildings for communities, buildings of citizens' associations and religious community buildings. A family house is any building in its entirety or in which more than 50% of gross floor area is dedicated to housing, and which has a maximum of two housing units, which is built on a separate building plot and has a building gross floor area of less than or equal to 400 m^2. A multi-residential building is any building wholly or in which more than 50% of gross floor area is dedicated to housing, and which consists of three or more residential units and is managed by a building manager, a legal and natural person, in accordance with the Act on Ownership and Other Real Property Rights.

As commercial buildings are not clearly defined in the relevant Croatian legislative framework, the Strategy will use the definition from the Programme of Energy Renovation of Commercial Non-Residential Buildings 2014-2020 according to which commercial buildings are all majority privately-owned buildings where more than 50% of gross floor area is dedicated to business and/or service activities, compliant to the terms used in the

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[23]Long-Term Strategy for Mobilising Investment in the Renovation of the National Building Stock of the Republic of Croatia, June 2014, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2014_06_74_1397.html [30th April 2017];
Programme of Energy Renovation of Commercial Non-Residential Buildings 2014-2020 with a detailed 2014-2016 plan for the renovation of commercial non-residential buildings, July 2014, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/432768.pdf [30th April 2017];
Programme of Energy Renovation of Public Buildings 2016-2020, March 2017, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2017_03_22_508.html [30th April 2017];
Programme of Energy Renovation of Family Houses 2014-2020 with a detailed 2014-2016 plan, March 2014, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/431066.pdf [30th April 2017];
Programme of Energy Renovation for Multi-Residential Buildings 2014-2020 with a detailed 2014-2016 plan, May 2014, Ministry of Construction and Physical Planning, available at: http://www.mgipu.hr/doc/Propisi/Program_EO_VS_ZGRADE.pdf [30th April 2017]

[24]European Commission (2010), *Directive 2010/31/EU of the European Parliament and of the Council of 19th May 2010 on the energy efficiency of buildings (recast)*, available at: http://eur-lex.europa.eu/legal-content/HR/TXT/?uri=CELEX%3A32010L0031 [2010]

[25]Programme of Energy Renovation of Family Houses 2014-2020 with a detailed 2014-2016 plan, March 2014, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/431066.pdf [30th April 2017]
Programme of Energy Renovation for Multi-Residential Buildings 2014-2020 with a detailed 2014-2016 plan, May 2014, Ministry of Construction and Physical Planning, available at: http://www.mgipu.hr/doc/Propisi/Program_EO_VS_ZGRADE.pdf [30th April 2017]

Construction Act[26], Physical Planning Act[27] and the Technical Regulation on Rational Use of Energy and Thermal Protection in Buildings[28], to the definition of public buildings in the sector of commercial services within the second National Energy Efficiency Action Plan and to the definition of residential and multi-residential buildings in the Programme of Energy Renovation of Multi-Residential Buildings 2014-2020 and the Programme of Energy Renovation of Family Houses 2014-2020.

[26]Construction Act, Zagreb "Official Gazette" Nos 153/2013 and 20/2017 (3221), available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2013_12_153_3221.html [30th April 2017]
[27]Physical Planning Act, Zagreb "Official Gazette" No. 153/2013, (3220), available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2013_12_153_3220.html [30th April 2017]
[28]Technical Regulation on Energy Economy and Heat Retention in Buildings. Zagreb OG128/2015 (2428), available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2015_11_128_2428.html [30th April 2017]

2.2 Overview of the national building stock by construction period

The overview of the national building stock according to the construction period is based on data from the following sources:

- Annual Statistical Yearbook of the Croatian Bureau of Statistics;
- Programme of Energy Renovation of Multi-Residential Buildings 2014-2020[29];
- Programme of Energy Renovation of Family Houses 2014-2020[30];
- Programme of Energy Renovation of Commercial Non-Residential Buildings 2014-2020[31];
- Register of public buildings of the central government and a calculation of targets under Directive 2012/27/EU[32].

The distribution of buildings by construction period is defined by the *Building Energy Audit Methodology*[33] in five time periods:

1. up to 1940;
2. 1941-1970;
3. 1971-1987;
4. 1988-2005;
5. 2006 to present.

In view of a more accurate and detailed overview of the National Building Stock as well as the alignment with the Strategy with the Operational Programme,[34] which distributes the building stock into seven construction periods depending on the manner of construction, the building materials used and the technical regulations in force, the overview of the national building stock by construction period shall be based on the following periods defined in the Programme:

- up to 1940;
- 1941-1970;
- 1971-1980;
- 1981-1987;
- 1988-2005;
- 2006-2009;
- 2010-2011.

The tables below provide an overview of the national residential building stock and an overview of the national non-residential building stock by construction period (Table 2.1 and Table 2.2).

[29]Programme of Energy Renovation for Multi-Residential Buildings 2014-2020 with a detailed 2014-2016 plan, May 2014, Ministry of Construction and Physical Planning, available at: http://www.mgipu.hr/doc/Propisi/Program_EO_VS_ZGRADE.pdf [30th April 2017]

[30]Programme of Energy Renovation of Family Houses 2014-2020 with a detailed 2014-2016 plan, March 2014, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/431066.pdf [30th April 2017]

[31]Programme of Energy Renovation of Commercial Non-Residential Buildings 2014-2020 with a detailed 2014-2016 plan for the renovation of commercial non-residential buildings, July 2014, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/432768.pdf [30th April 2017]

[32]Register of public buildings of the central government and a calculation of targets under Directive 2012/27/EU of 25th October 2012, on energy efficiency, December 2013, Energy Institute Hrvoje Požar, available at http://www.mgipu.hr [30th April 2017]

[33]Building Energy Audit Methodology [online], June 2014, Ministry of Construction and Physical Planning, available at: http://www.mgipu.hr/doc/EnergetskaUcinkovitost/METODOLOGIJA_EPG.pdf [30th April 2017]

[34]Programme of Energy Renovation of Commercial Non-Residential Buildings 2014-2020 with a detailed 2014-2016 plan for the renovation of commercial non-residential buildings, July 2014, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/432768.pdf [30th April 2017]

Table 2.1 Residential building stock of the Republic of Croatia by year of construction

Year of construction	Multi-residential buildings		Family houses	
	No.	Floor area [m^2]	No.	Floor area [m^2]
up 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

Source: *REGEA,* 2017

Table 2.2 Non-residential building stock of the Republic of Croatia by year of construction

Year of construction	Commercial buildings		Public buildings	
	No.	Floor area [m^2]	No.	Floor area [m^2]
up 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

Source: *REGEA,* 2017

Since the first official statistics on construction and floor area of buildings date back to 1952, it was extremely difficult to find credible data on the number and total floor area of the national building stock built up to 1952 which the assessment would be based on. 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[35], the total number and area of Croatia's national building stock from 1941 to 1970 has been established as follows:

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

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 floor area of 142,176,678 m^2, of which 290,689 are multi-residential buildings with a total floor area of 55,438,063 m^2 and 471,708 family houses with a total floor area of 86,738,615 m^2.

Croatian national non-residential building stock consists of 124,924 buildings with a total floor area of 50,342,361 m^2, of which 44,728 are commercial buildings with a total floor area of 36,540,459 m^2, and 80,196 are public buildings with a total floor area of 13,801,902 m^2.

On grounds of the analyses performed, it is established that the current national building stock of the Republic of Croatia comprises 887,321 buildings with a total floor area of 192,519,039 m^2.

Since energy renovation programmes[36] have been implemented within the three years from drafting the Long-Term Strategy[37] up to today, the total floor area of the national building stock to be renewed from 2017 onwards

[35]Croatian Bureau of Statistics (1953-1970), *Statistical Yearbook of the Republic of Croatia* [online], Zagreb, available at: http://www.dzs.hr/ [30th April 2017]

[36]Long-Term Strategy for Mobilising Investment in the Renovation of the National Building Stock of the Republic of Croatia, June 2014, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2014_06_74_1397.html [30th April 2017]

[37]Programme of Energy Renovation of Commercial Non-Residential Buildings 2014-2020 with a detailed 2014-2016 plan for the renovation of commercial non-residential buildings, July 2014, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/432768.pdf [30th April 2017];

has been updated in accordance with the Annual Report on the Progress towards the National Energy Efficiency Targets under Article 24 (1) in accordance with Part 1 of the of Annex XIV of the Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC[38] (hereinafter: the Report). According to the Report which provides an overview of cumulative savings realized from 2014 to 2016, an estimate was made on the total floor area of the renovated building stock (categories.
Table 2.3).

According to the Report, the savings realized through energy renovation programmes from 2014 to 2016 amount to 1.72767 PJ (479.908.333,30 kWh). Since savings data comes from the Energy Savings Measuring, Monitoring and Verification System[39], and the data on the useful floor area of buildings is entered by users only in the case of an integrated renovation, whereas it is not entered in case of renovation involving individual parts of the building envelope, it is necessary to estimate the amount equivalent to the useful floor area of buildings renovated from 2014 to 2016. The documents accompanying the Report state that the integrated renovation of buildings the floor area of which is 84,022.49 m² realized savings of 15,023,645.26 kWh in 2016. By dividing the difference of the total savings in 2016 and the savings realized by integrated renovation with the ratio of the area of buildings subject to integrated renovation and the resulting savings, the amount equivalent to the area of renovated buildings subject to integrated renovation relative to total savings is obtained. The amount equivalent to the area of buildings subject to integrated renovation from 2014 to 2015 is calculated analogously. The calculation results in an estimate of the area of the building stock renovated under energy renovation programmes to the amount of 2,172,440 m². Subtracting the area of the renovated building stock from the total national building stock (192.519.000,00 m²), the updated area of the national building stock subject to renovation amounts to 190,346,560 m². Since this is an estimate, the table below gives the total estimate of the area of renovated buildings, without distributing the buildings into categories.

Table 2.3 Cumulative savings realized and an estimate of the area of the building stock renovated from 2014 to 2016

Measure title	Savings [PJ]	Total investment [HRK]	Estimation of area of the renovated building stock [m²]
Programme of Energy Renovation of Family Houses 2014 -2016	1.10438	778,492,028.45	
Programme of Energy Renovation of Multi-Residential Buildings	0.25131	154,535,990.29	
Programme of Energy Renovation of Public Buildings (2014 -2015)	0.30125	344,258,164.79	
Programme of Energy Renovation of Commercial Non-Residential Buildings	0.07073	49,781,776.24	
TOTAL	1.72767	1,327,067,959.77	2,172,440

Source: *REGEA,* 2017

Programme of Energy Renovation of Public Buildings 2014-2015, October 2013, Ministry of Construction and Physical Planning, available at: http://www.mgipu.hr/doc/EnergetskaUcinkovitost/Program_energetske_obnove_javnih_zgrada_2014-2015.pdf;
Programme of Energy Renovation of Family Houses 2014-2020 with a detailed 2014-2016 plan, March 2014, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/431066.pdf [30th April 2017];
Programme of Energy Renovation for Multi-Residential Buildings 2014-2020 with a detailed 2014-2016 plan, May 2014, Ministry of Construction and Physical Planning, available at: http://www.mgipu.hr/doc/Propisi/Program_EO_VS_ZGRADE.pdf [30th April 2017]
[38]Draft [10th May 2017]
[39]Available at: http://cei.hr/smiv-sustav-mjerenje-pracenje-i-verifikaciju-usteda-energije/

2.3 Overview of the national building Stock by climate zone

According to Article 18 of the Ordinance on Building Energy Audit and Energy Certification,[40] and depending on the average monthly outdoor air temperature in the coldest month at the building location, Croatia is divided into two climatic zones:

- Continental Croatia - cities, towns and villages where the average monthly outdoor air temperature in the coldest month at building location is ≤ 3 °C;
- Coastal Croatia - cities, towns and villages where the average monthly outdoor air temperature in the coldest month at the building location is > 3 °C.

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 Non-Residential Buildings 2014-2020[41];
- Register of public buildings of the central government and a calculation of targets under Directive 2012/27/EU[42].

The following tables provide an overview of the national residential building stock and the national non-residential building stock by climate zone (Table 2.4 and Table 2.5).

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

Climate zones	Multi-residential buildings		Family houses		Total	
	No.	Floor area [m²]	No.	Floor area [m²]	No.	Floor area [m²]
Continental Croatia	186,922	35,648,303	303,322	55,775,475	490,244	91,423,778
Coastal Croatia	103,767	19,789,760	168,386	30,963,140	272,153	50,752,900
TOTAL	290,689	55,438,063	471,708	86,738,615	762,397	142,176,688

Source: *REGEA,* 2017

Table 2.5 Overview of the national non-residential building stock by climate zone

Climate zones	Commercial buildings		Public buildings		Total	
	No.	Floor area [m²]	No.	Floor area [m²]	No.	Floor area [m²]
Continental Croatia	29,968	24,482,108	53,731	9,247,275	83,699	33,729,383
Coastal Croatia	14,760	12,058,351	26,465	4,554,628	41,225	16,612,979
TOTAL	44,728	36,540,459	80,196	13,801,902	124,924	51,342,362

Source: *REGEA,* 2017

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

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

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

[40]Ordinance on Building Energy Audit and Energy Certification, Zagreb OG Nos 48/2014, 150/2014, 133/2015, 22/2016, 49/2016, 87/2016 and 17/2017 (929), available at http://narodne-novine.nn.hr/clanci/sluzbeni/2014_04_48_929.html [30th April 2017]

[41]Programme of Energy Renovation of Commercial Non-Residential Buildings 2014-2020 with a detailed 2014-2016 plan for the renovation of commercial non-residential buildings, July 2014, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/432768.pdf [30th April 2017]

[42]Register of public buildings of the central government and a calculation of targets under Directive 2012/27/EU of 25th October 2012 on energy efficiency, December 2013, Energy Institute Hrvoje Požar, available at: www.mgipu.hr [30th April 2017]

2.4 Overview of the national building stock by ownership

The overview of the national building stock by ownership is based on the data obtained through a systematic search of Statistical Yearbooks, which are published by the Croatian Bureau of Statistics. Since the first statistical data on construction and building floor area date from 1952 and the period considered has seen major social changes, there are significant differences in the categorisation of buildings by ownership. Bearing in mind that almost all buildings (except family houses) were exclusively "socially owned" until 1991 during workers' self-management, as reflected in Statistical Yearbooks, Table 2.6 the data Table 2.7 provide 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 social to private ownership since 1991.

Table 2.6 Overview of the national residential building stock by ownership

Ownership	Multi-residential buildings		Family houses	
	No.	Floor area [m^2]	No.	Floor area [m^2]
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

Source: *REGEA,* 2017

Table 2.7 Overview of the national non-residential building stock by ownership

Ownership	Commercial buildings		Public buildings	
	No.	Floor area [m^2]	No.	Floor area [m^2]
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

Source: *REGEA,* 2017

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

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

The categorisation of the national building stock by type of area (urban/rural) has been conducted according to the Model for the Differentiation of Urban, Rural and Semi-Urban Settlements in the Republic of Croatia[43], which defines the urban area as the local government unit hosting the county seat and any other settlement counting more than 10 000 inhabitants and representing an urban, historical, natural, economic and social entity.
Tables below provide an estimate of the national residential and non-residential building stock, respectively, by type of construction area (Table 2.8 and Table 2.9).

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

Type of area	Multi-residential buildings		Family houses	
	No.	Floor area [m^2]	No.	Floor area [m^2]
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

Source: *REGEA,* 2017

Table 2.9 Overview of the national non-residential building stock by type of area

Type of area	Commercial buildings		Public buildings	
	No.	Floor area [m^2]	No.	Floor area [m^2]
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

Source: *REGEA,* 2017

The overview of the national residential building stock by the type of construction area shows 426,071 buildings with a total floor area of 72,419,263 m^2 being situated in urban areas, and 336,327 buildings with a total floor 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 floor area of 35,436,031 m^2 being situated in urban areas, and 36 990 buildings with a total floor 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 floor area of 107,855,294 m^2 are situated in urban areas, and 373,317 buildings with a total floor area of 84,663,745 m^2 in rural areas.

[43]Model for the Differentiation of Urban, Rural and Semi-Urban Settlements in the Republic of Croatia, Methodological Instructions 67, Croatian Bureau of Statistics, 2011; available at: http://www.dzs.hr/ [30th April 2017]

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[44] (e.g. climate - temperature conditions of the location and climate zone, building shape factor etc.), the construction period mostly provides 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[45].

The essential information in the analysis of energy performance and characteristics of building components and elements is that concerning a building's purpose and energy consumption specifics, that is, the building usage regime according to its purpose[46]. Building categories by 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 2.10 presents the estimated annual thermal energy requirements and annual consumption of energy provided 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.

[44] Programme of Energy Renovation of Family Houses 2014-2020 with a detailed 2014-2016 plan, March 2014, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/431066.pdf [30th April 2017];
Programme of Energy Renovation for Multi-Residential Buildings 2014-2020 with a detailed 2014-2016 plan, May 2014, Ministry of Construction and Physical Planning, available at: http://www.mgipu.hr/doc/Propisi/Program_EO_VS_ZGRADE.pdf [30th April 2017]

[45] United Nations Development Programme - UNDP. (2010) *Energy Certification Manual.* Zelina: Tiskara Zelina

[46] United Nations Development Programme - UNDP. (2010) *Energy Certification Manual.* Zelina: Tiskara Zelina

Table 2.10 Annual thermal energy requirements for heating and annual consumption of energy provided in continental and coastal Croatia [kWh/m²a][47]

Building purpose	Annual thermal energy requirement for heating [kWh/m²a]													
	Continental Croatia							Coastal Croatia						
	up to 1940	1941-1970	1971-1980	1981-1987	1988-2005	2006-2009	2010-2011	up to 1940	1941-1970	1971-1980	1981-1987	1988-2005	2006-2009	2010-2011
Multi-residential 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 consumption of energy provided for heating, cooling, DHW generation and lighting [kWh/m²a]**													
Multi-residential 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

Source: *REGEA,* 2017

[47]Programme of Energy Renovation of Commercial Non-Residential Buildings 2014-2020 with a detailed 2014-2016 plan for the renovation of commercial non-residential buildings, July 2014, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/432768.pdf [30th April 2017];
Programme of Energy Renovation of Family Houses 2014-2020 with a detailed 2014-2016 plan, March 2014, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/431066.pdf [30th April 2017];
Programme of Energy Renovation for Multi-Residential Buildings 2014-2020 with a detailed 2014-2016 plan, May 2014, Ministry of Construction and Physical Planning, available at: http://www.mgipu.hr/doc/Propisi/Program_EO_VS_ZGRADE.pdf [30th April 2017]

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[48]. Buildings were built as a solid or stone masonry construction (primarily in coastal area) structures, with 30–60 cm walls producing satisfactory structure statics. Ceilings are mostly wooden or constructed with brick, stone or concrete elements (ribbed concrete ceiling). Thanks to their large wall thickness and a relatively modest degree of interior space heating, such masonry-walled buildings had rather lower heat losses than more recent light concrete structures without thermal protection. Thermal transmittance coefficient figures shown in the table below (Table 2.11) do not meet the requirements of current 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 2.11 Heat transmittance coefficients for typical structural elements[49]

Typical construction part	Thermal transmittance coefficient, U [W/m²K]		
Typical period	**up 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 solid brick (plastered on both sides).
*[2] 30 cm solid brick (plastered on both sides).
*[3] 60 cm solid 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 aJUS 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.

[48]United Nations Development Programme - UNDP. (2010) *Energy Certification Manual.* Zelina: Tiskara Zelina
[49]Building Energy Audit Methodology, Table 6, Table 7 and Table 8 [online], October 2012, Ministry of Construction and Physical Planning, available at: http://www.mgipu.hr/doc/Propisi/Metodologija_provodenja_epg.pdf [30th April 2017]

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[50]. 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 from 1941 to 1970 had generally poorer thermal performance than the buildings in the previous period - Table 2.11, 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, 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^2K) (currently: U) for individual elements of the external building envelope[51].

This period is characterised by modest application of 2–4 cm thermal insulation such as heraklith, 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 mold 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 the previous table (Table 2.11), and the maximum permitted heat transmittance coefficient k in the table below (Table 2.12).

Table 2.12 Maximum permitted heat transmittance coefficients k [W/m^2K] according to the Regulation on technical measures and requirements for thermal protection of buildings – SL No. 35/70[52]

Construction 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

[50] United Nations Development Programme - UNDP. (2010) *Energy Certification Manual.* Zelina: Tiskara Zelina

[51] Programme of Energy Renovation of Commercial Non-Residential Buildings 2014-2020 with a detailed 2014-2016 plan for the renovation of commercial non-residential buildings, December 2013, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/432768.pdf [30th April 2017]

[52] Programme of Energy Renovation of Family Houses 2014-2020 with a detailed 2014-2016 plan, March 2014, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/431066.pdf [30th April 2017]
Programme of Energy Renovation for Multi-Residential Buildings 2014-2020 with a detailed 2014-2016 plan, May 2014, Ministry of Construction and Physical Planning, available at: http://www.mgipu.hr/doc/Propisi/Program_EO_VS_ZGRADE.pdf [30th April 2017]

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 *IN*(*k*) by approx. 30%[53]. 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[54]. Maximum permitted heat transmittance coefficients, k for structural elements and those for windows and doors are provided in tables below (Table 2.13 and Table 2.14).

Table 2.13 Maximum permitted heat transmittance coefficient k [W/m^2K] according to JUS U.J5.600: Thermal equipment in the construction industry and technical requirements for the design and construction of buildings, 1980[55]

Construction element	Construction climate zones		
	I	II	III
Exterior 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 2.14 Heat transmittance coefficients k [W/m^2K] 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[56].

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	-	-

[53]Programme of Energy Renovation of Commercial Non-Residential Buildings 2014-2020 with a detailed 2014-2016 plan for the renovation of commercial non-residential buildings, July 2014, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/432768.pdf [30th April 2017];

[54]Programme of Energy Renovation of Commercial Non-Residential Buildings 2014-2020 with a detailed 2014-2016 plan for the renovation of commercial non-residential buildings, July 2014, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/432768.pdf [30th April 2017];

[55]Programme of Energy Renovation of Family Houses 2014-2020 with a detailed 2014-2016 plan, March 2014, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/431066.pdf [30th April 2017];

Programme of Energy Renovation for Multi-Residential Buildings 2014-2020 with a detailed 2014-2016 plan, May 2014, Ministry of Construction and Physical Planning, available at: http://www.mgipu.hr/doc/Propisi/Program_EO_VS_ZGRADE.pdf [30th April 2017];

[56]Programme of Energy Renovation of Family Houses 2014-2020 with a detailed 2014-2016 plan, March 2014, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/431066.pdf [30th April 2017];

Programme of Energy Renovation for Multi-Residential Buildings 2014-2020 with a detailed 2014-2016 plan, May 2014, Ministry of Construction and Physical Planning, available at: http://www.mgipu.hr/doc/Propisi/Program_EO_VS_ZGRADE.pdf [30th April 2017];

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 external 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[57]. 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 and for windows and doors are given in tables below (Table 2.15 and Table 2.16).

Table 2.15 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[58]

Construction element	Construction climate zones		
	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 2.16 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, 1987.[59]

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 2x6–8 mm air insulation (three glass layers)	2.4	2.2	2.7	3.0
Double insulating glass with 2x8–10mm air insulation (three glass layers) insulating glass)	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

[57]Programme of Energy Renovation of Commercial Non-Residential Buildings 2014-2020 with a detailed 2014-2016 plan for the renovation of commercial non-residential buildings, July 2014, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/432768.pdf [30th April 2017]

[58]Programme of Energy Renovation of Family Houses 2014-2020 with a detailed 2014-2016 plan, March 2014, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/431066.pdf [30th April 2017]

Programme of Energy Renovation for Multi-Residential Buildings 2014-2020 with a detailed 2014-2016 plan, May 2014, Ministry of Construction and Physical Planning, available at: http://www.mgipu.hr/doc/Propisi/Program_EO_VS_ZGRADE.pdf [30th April 2017]

[59]Programme of Energy Renovation of Family Houses 2014-2020 with a detailed 2014-2016 plan, March 2014, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/431066.pdf [30th April 2017]

Programme of Energy Renovation for Multi-Residential Buildings 2014-2020 with a detailed 2014-2016 plan, May 2014, Ministry of Construction and Physical Planning, available at: http://www.mgipu.hr/doc/Propisi/Program_EO_VS_ZGRADE.pdf [30th April 2017]

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 (OG 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[60]. 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 (OG Nos 79/05, 155/05, 74/06) and for windows and doors are given in tables below (Table 2.17 and Table 2.18).

Table 2.17 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)]**	
	$\Theta_{e, mth, min} > +3$ °C	**$\Theta_{e, mth, min} \leq +3$ ° 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 the 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 2.18 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 useful floor area of the building;
- maximum permitted heat transmittance loss coefficient per unit of external surface of the building's heated part;
- airtightness of the building envelope and ventilation of the building space;
- performance of any heat recovery ventilation systems used.

[60]Programme of Energy Renovation of Commercial Non-Residential Buildings 2014-2020 with a detailed 2014-2016 plan for the renovation of commercial non-residential buildings, July 2014, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/432768.pdf [30th April 2017]

2.6.1.7 Construction typical for the 2010–2011 period

The *Technical regulation on energy economy and heat retention in buildings (OG 110/08, 89/09)* was adopted in 2008 and came into effect on 31 March 2009, superseding the Technical regulation on thermal energy savings and heat retention in buildings (OG Nos 79/05, 155/05, 74/06) from 2005[61]. 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 (OG Nos 110/08, 89/09), and those referring to windows and doors are given in the tables below (Table 2.19 and Table 2.20).

Table 2.19 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)]			
	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, balcony 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 2.20 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 useful floor area of the building;
- maximum permitted heat transmittance loss coefficient per unit of external surface of the building's heated part;
- air tightness of the building envelope and ventilation of the building space;

[61]Programme of Energy Renovation of Commercial Non-Residential Buildings 2014-2020 with a detailed 2014-2016 plan for the renovation of commercial non-residential buildings, July 2014, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/432768.pdf [30th April 2017];

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[62]:

- Heat generator;
- Flue system;
- Thermal energy distribution system;
- Radiators;
- Circulating pumps;
- Closing and regulating valves;
- Expansion system;
- Regulatory and control system.

District heating systems belong to a special group of central heating systems. The heat source is located in the central heating plant supplying heating 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 dedicated for heating of certain rooms, sources such as stoves, fireplaces and tile stoves, were in predominant use in the late 19th and early 20th century. Over the time, fuels changed, depending on their availability and other characteristics, so the following are currently in use:

- Fuel oil;
- Liquified 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[63], with individual gas heaters in the form of regular heaters also in use[64].
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[65]. 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

[62]Group of authors, Priručnik za energetsko certificiranje zgrada (Energy Certification Manual), UNDP, Zagreb, 2010
[63]Programme of Energy Renovation of Commercial Non-Residential Buildings 2014-2020 with a detailed 2014-2016 plan for the energy renovation of commercial non-residential buildings, July 2014 Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/432768.pdf [30th April 2017]
[64]Reknagel, Šprenger, Šramek, Čeperković (2004*), Grejanje i klimatizacija uključujući toplu vodu i teniku lađenja (Heating and airconditioning, including hot water and cooling equipment).* INTERKLIMA-GRAFIKA , Vrnjačka Banja
[65]Programme of Energy Renovation of Commercial Non-Residential Buildings 2014-2020 with a detailed 2014-2016 plan for the renovation of commercial non-residential buildings, July 2014, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/432768.pdf [30th April 2017]

total consumption[66]. 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 also increased, particularly in the industry. Hot water and steam networks were developed in large Croatian towns (Sisak, Karlovac, Varaždin etc.). It is only in the period since 2005 that modern, advanced systems and energy-efficient technologies (condensing boilers, heat pumps, etc.) have been more extensively implemented.

The table below (Table 2.21) provides an overview of used technical systems, energy sources and other data relevant to the energy efficiency of heating systems in coastal and continental Croatia by category of the purpose-relative Croatian national building stock as defined in Chapter 2.1. Such data are the basis for an analysis of key elements of the buildings renovation programme.

[66]Programme of Energy Renovation of Commercial Non-Residential Buildings 2014-2020 with a detailed 2014-2016 plan for the renovation of commercial non-residential buildings, July 2014, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/432768.pdf [30th April 2017]

Table 2.21 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
Multi-residential 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**
Multi-residential 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, 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 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, 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.)

Source: *REGEA,* 2017

The most important factors affecting the selection of heating systems are the following[67]:

- Availability of energy sources (electricity, fossil fuels, biomass, other renewable energy sources);
- Climate conditions (geographic location);
- Investment and operating costs;
- Location and type of building (residential, non-residential, commercial, educational etc.);
- Legislation (laws, regulations, standards, recommendations);
- Daily regime of building use (24-hour, 8-hour etc.);
- 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 2.22).

Table 2.22 Overview of various boilers and their efficiency[68]

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	Combined 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%

Source: *REGEA,* 2017

Article 66 of the Technical regulation[69] prescribes that a study of alternative energy supply systems is obligatory for every building larger than 50 m^2 which has to meet energy performance requirements and which is heated to an indoor temperature larger than 18°C, in particular in RES-based decentralized energy supply systems, cogeneration systems, heat pumps and district heating and cooling systems. The Construction Act stipulates that the designer must draw up a study of alternative energy supply systems and submit it to the investor before completing the building main design which itself must comply with energy efficiency requirements.

Thanks to positive experiences and the fact that it is an optimal solution for both environmental and its energy efficiency reasons, RES-based district heating and/or cooling 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[70].

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

[68]Group of authors, Priručnik za energetsko certificiranje zgrada (Energy Certification Manual), UNDP, Zagreb, 2010

[69]Technical Regulation on Energy Economy and Heat Retention in Buildings. "Official Gazette" No.128/2015 (2428), available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2015_11_128_2428.html [30th April 2017]

[70]Act on Renewable Energy Sources and High Effective Cogeneration. "Official Gazette" Nos100/2015 and 123/2016 (1937), available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2015_09_100_1937.html [30th April 2017]

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 according to the requirements of the *Technical regulation*. The said building stock was chosen owing to its greatest savings potential and a significant share in the total floor area of all buildings, and it complies with the objectives of building renovation measures described in the Draft 4th National Energy Efficiency Action Plan 2019[71]. 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 reconstruction of the external envelope of its heated space. In addition to considerable savings resulting from it, the advantage of this measure 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 design options regarding architectural details of the building as mobile shading elements, implementation of large glass surfaces on southern (south-eastern, south-western) parts of the façade, thermal protection of unprotected overhangs and penetrations to eliminate thermal bridges etc., need to be taken into account separately for each building when renovating it. In addition to all the activities listed above, this measure needs to comply with the maximum permitted thermal transmittance of structural parts.

The standard of constructing a nearly zero-energy building (nZEB standard) in Croatia is fully defined by the Technical regulation on energy economy and heat retention in buildings. Article 9 of Directive 2010/31/EU[72] provides a special objective indicating that, by 31st December 2020, all new buildings must be buildings with nearly zero or very low amount of energy required (nearly zero-energy buildings). Nearly zero or very low amount of energy required should be substantially covered by RES energy. The same provision applies to public buildings to be built after 31st December 2018. In addition to requirements for new buildings, the Directive requires Member States to establish policies to encourage adaptation of buildings which are being renovated into nearly zero-energy buildings. The Croatian legislative framework and plans describing the nZEB standard are as follows:

- Technical regulation on energy economy and heat retention in buildings[73]
- Plan for Increasing the Number of Nearly Zero-Energy Buildings 2020[74]

Properties of nearly zero-energy buildings are established according to stock characteristics provided for the definition of reference buildings, accompanied by optimization of geometric characteristics to achieve as low a level of energy as possible to meet building energy requirements. The definition of nearly zero-energy buildings in Croatia applies to new buildings according to the following uses:

- one-family building;
- multi-residential building;
- office building;
- educational building;
- trade building (retail and wholesale);
- hotel and restaurant building;
- hospital building;

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[71]Draft [10th May 2017]

[72]European Commission (2010), *Directive 2010/31/EU of the European Parliament and of the Council of 19th May 2010 on the energy efficiency of buildings (recast)*, available at: http://eur-lex.europa.eu/legal-content/HR/TXT/?uri=CELEX%3A32010L0031 [2010]

[73]Technical Regulation on Energy Economy and Heat Retention in Buildings. Zagreb OG 128/2015 (2428), available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2015_11_128_2428.html [30th April 2017]

[74]National Plan for Increasing the Number of Nearly Zero-Energy Buildings 2020, December 2014, Ministry of Construction and Physical Planning, available at: http://www.mgipu.hr/doc/Propisi/PLAN_PBZ_0_energije_do_2020.pdf [30th April 2017]

- sports hall building.

The nearly zero-energy building is defined by the consumption of primary energy for heating, cooling, ventilation, DHW generation and lighting, and a minimum RES share of 30% in the primary energy required to meet the building energy requirements. For each type of building according to their purpose, the Technical regulation defines the limitations in the amount of annual heat energy requirements per unit of the useful floor area of the building $Q''_{H,nd}$ [KWh/(m^2·a)], annual delivered energy E_{del} and annual primary energy E_{prim}, which includes energy for heating, cooling, ventilation, DHW generation and, in non-residential buildings, lighting. Plans to increase the number of nearly zero-energy buildings[75] should cover at least 65,000 m² of non-residential buildings annually, provided that buildings are categorized by purpose as shown in the table below (Table 3.1).

Table 3.1 The target floor area of nearly zero-energy buildings by purpose per year

The target floor area of nearly zero-energy buildings by purpose per year	Target floor area per year [m²]	Specific additional cost related to new-builds [HRK/m²]	Total additional cost related to new-builds [HRK]
multi-residential buildings	90,700	1,512	137,138,400
hotels and restaurants	14,630	214	3,133,870
offices	19,736	337	6,660,033
trade buildings	20,879	408	8,528,265
hospital buildings	4,723	691	3,264,192
sports halls	1,428	1,496	2,136,297
educational building	3,612	1,211	4,375,061

Source: *National Plan for Increasing the Number of Nearly Zero-Energy Buildings 2020*[76]

According to Directive 2010/31/EU[77] providing for encouraging the consideration of installing high-efficiency alternative systems to the extent technically, functionally and economically feasible and Directive 2009/28/EU[78] providing for the obligation to introduce measures to increase the share of RES energy, in addition to the previously described reconstruction measure involving the external envelope of the heated building space, measures to increase EE and implement RES as listed below shall be implemented.

3.1.1 Measure of heating system centralisation and modernisation by applying RES

The measure involves centralisation of heating systems and modernisation of existing boiler rooms by replacing them with biomass-fired boilers (pyrolysis, pellets and chips) or, where that is not feasible owing to technical reasons (e.g. no space for a biomass container) and in addition to the existing connection to natural gas, with low-temperature condensing boilers fueled 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 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 a district heating system, the boiler does not have to be located in the building but may within other facilities connected to the pipe system. In this case, it is necessary to provide a substation for heat energy transmittance from the district heating to the facility. This measure involves the heating system regulation and

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[75]National Plan for Increasing the Number of Nearly Zero-Energy Buildings 2020, December 2014, Ministry of Construction and Physical Planning, available at: http://www.mgipu.hr/doc/Propisi/PLAN_PBZ_0_energije_do_2020.pdf [30th April 2017]
[76]National Plan for Increasing the Number of Nearly Zero-Energy Buildings 2020, December 2014, Ministry of Construction and Physical Planning, available at: http://www.mgipu.hr/doc/Propisi/PLAN_PBZ_0_energije_do_2020.pdf [30th April 2017]
[77]European Commission (2010), *Directive 2010/31/EU of the European Parliament and of the Council of 19th May 2010 on the energy efficiency of buildings (recast)*, available at: http://eur-lex.europa.eu/legal-content/HR/TXT/?uri=CELEX%3A32010L0031 [2010]
[78]European Commission (2009), *Directive 2009/28/EC of the European Parliament and of the Council of 23rd April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC (Text with EEA relevance)*, available at: http://eur-lex.europa.eu/legal-content/HR/TXT/?uri=CELEX%3A32009L0028 [2009]

balancing (thermostat sets, differential pressure controllers, frequently operated pumps etc.), as well as performing thorough cleaning of the pipeline radiator system and all exchangers. In separate boiler systems, the need for chimney renovation should also be considered for each building separately.

3.1.2 Measure of cooling and ventilation system centralisation and modernisation by applying RES

The measure provides for centralisation of the cooling system by using heat pump systems to cool 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, 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 inappropriate 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 a recovery option needs to be planned in certain rooms(e.g. corridors and waiting rooms). It is desirable to have automatic ventilation control which would allow air change in summer during the night (ambient air temperature lower than the air temperature in the building), and in turn result in space cooling. Ventilation devices must meet the requirements given in Table 4 of Annex B to the *Technical regulation*.

3.1.3 Measure of DHW generation system centralisation and modernisation by applying RES

The measure provides for DHW generation in each building via primary and secondary energy sources. Throughout the year, especially in winter months, DHW needs to be generated by the boiler heating system, which represents a *primary source* of heating energy. The solar collector system or a *secondary source* of heating energy needs to be implemented 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 eliminates boiler operation for heating small amounts of water when there is no need for heating, and thus increases the annual efficiency and boiler service life. When implementing this measure, actual DHW requirements should be considered depending on the primary function of the facility.

3.1.4 Lighting system modernisation measure

As a preparatory action, the measure involving the lighting system modernisation must necessarily involve consideration of how to make better use of natural(day) lighting for the purpose of improving lighting comfort of the user. For optimal utilisation of natural lighting, space reorganisation and installation of internal partitions reflecting daylight and contributing to its distribution shall be considered.

Technical characteristics of proposed light technology solutions for internal lighting in the building must comply with the HRN EN 12464-1:2008 standard, energy class A, with RoHS guidelines EU 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 setting of eco-design requirements for energy-using products), and 2000/55/EC guidelines (energy efficiency requirements for ballasts). Recommended light sources are high energy-efficient LEDs (min 90 lm/W) and 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 (OG No. 114/11)*. 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, aerators 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 containers. 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 systems contributing to 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 generating electricity for personal purposes since, for the first time in world history, the cost of capital investment for installing 1MW of installed power of a photovoltaic system is lower than 1MW of installed power of a wind generator, which makes photovoltaic systems the most cost-effective sources of RES electricity. Considering the trend of decrease in the price of installed photovoltaic power, it is expected that, by 2025, the price of 1MW will be about USD 0.8 million, i.e. that it will fall by an additional 60% compared to today's price of installed power,[79] which fact will certainly affect the wider application of these systems in the building sector.

[79]IRENA – The power to change: solar and wind ost reduction potential to 2025 [online], available at: http://www.irena.org/menu/index.aspx?mnu=Subcat&PriMenuID=36&CatID=141&SubcatID=2733 [30th April 2017]

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.

Pursuant to the Thermal Energy Market Act[80] the following provisions defining the above conditions apply:

- General Terms and Conditions of Thermal Energy Supply[81]. 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 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[82]. 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[83], hereinafter: the Network Rules). 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 Article 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

[80]Thermal Energy Market Act, Zagreb OG 80/2013, 14/2014, 102/2014 and 95/2015 (1655), available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2013_06_80_1655.html [30th April 2017]
[81]General Conditions for Heat Supply, Zagreb OG No. 35/2014 (628), available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2014_03_35_628.html [30th April 2017]
[82]General Conditions for Heat Delivery, Zagreb OG Nos 35/2014 and 129/15 (629), available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2014_03_35_629.html [30th April 2017]
[83]Network Rules for Heat Distribution, Zagreb OG No. 35/2014 (630), available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2014_03_35_630.html [30th April 2017]

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.

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 should also be emphasized that Article 7 Energy Act[84] 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[85]. 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 EE of such plants (defined according to the Tariff system for electricity generation from RES and cogeneration, 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 as well as when connecting to other heating sources, 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 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.

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[84]Energy Act, Zagreb OG Nos 120/2012, 14/2014, 95/2015 and 102/2015 (2583), available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2012_10_120_2583.html [30th April 2017]

[85]Tariff System for the Production of Electricity from Renewable Energy Sources and Cogeneration, Zagreb OG Nos 133/2013, 151/2013, 20/2014, 107/2014, 100/2015 (2888), available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2013_11_133_2888.html [30th April 2017]

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:

- integrated building renovation according to minimum requirements of the *Technical regulation*
- integrated building renovation according to the *Technical Regulation* requirements related to large reconstruction
- integrated building renovation to the nZEB standard (defined by the *Technical Regulation*[86]);
- integrated building renovation to the passive house standard;
- integrated building renovation to the active house standard;

All five renovation models include renovation of the envelope and replacement and/or installation of efficient technical systems with the utmost level of RES use. Complete building renovation according to minimum requirements of the *Technical Regulation* implies envelope renovation in view of meeting the thermal transmittance coefficients set out in the *Technical Regulation* (Table3.2). Pursuant to Article 45(7), an integrated renovation model according to the *Technical Regulation* requirements related to large reconstruction implies a reconstruction of an existing building, more specifically renovation, partial or complete replacement of envelope parts in the heated building part where the works cover at least 75% of the envelope in the heated building part and, under a restriction related to the value of the thermal transmittance coefficients in building parts and a restriction related to the value of the required heating energy per unit of the useful floor area of the building $Q''_{H,nd}$ [KWh/(m^2·a)], annually delivered energy E_{del} [KWh/(m^2·a)] of annual primary energy E_{prim} [KWh/(m^2·a)], which includes the energy for heating, cooling, ventilation, DHW generation and, in non-residential buildings, for lighting. In the integrated building renovation to the nZEB standard, the same restrictions apply as in the model of building renovation according to *Technical Regulation* requirements related to major reconstruction, provided that criteria for the amounts of annual heating energy required per unit of the useful floor area of the building $Q''_{H,nd}$, annually delivered energy E_{del} and annual primary energy E_{prim} are made stricter.

Since all the five listed renovation models include the renovation of the external envelope of the heated space, target heat transmittance coefficients of various envelope elements included in the said renovation models are shown below (Table3.2).

[86]Technical Regulation on Energy Economy and Heat Retention in Buildings. Zagreb OG 128/2015 (2428), available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2015_11_128_2428.html [30th April 2017]

Table3.2 Overview of target thermal transmittance coefficients of structural building elements impossible sustainable building renovation models

Thermal transmittance coefficient of the structural element [W/(m²K)]	**Technical Regulation/nZEB ***		**Passive house/ active house****
	Continental Croatia	**Coastal Croatia**	**Continental and coastal Croatia**
External walls, walls bordering garage, walls bordering ventilated attic	0.30	0.45	0.13
Windows, balcony doors, skylights, other transparent elements of the building envelope	1.60	1.80	0.80
Glazed parts of windows, balcony doors, skylights, transparent elements of the building envelope	1.10	1.40	0.70
Flat and inclined roofs above heated space, ceilings bordering ventilated attic	0.25	0.30	0.10
Ceilings above outdoor space, ceilings above garage	0.25	0.30	0.10
Walls and ceilings bordering unheated spaces and unheated stairwells at temperatures above 0 °C	0.40	0.60	0.15
Walls to the ground soil, floors on ground level	0.40	0.50	0.15
Exterior door, doors bordering unheated staircase, with non-transparent door wing and glazed partitions bordering unheated and ventilated space	2.00	2.40	-
Roll-up shutter casing rim	0.60	0.80	-
Ceilings and walls between apartments or between various heated separate parts of buildings (business premises etc.)	0.60	0.80	0.15
Domes and light strips	2.50	2.50	-
Windshields, viewed in the direction of the door opening	3.00	3.00	-

Source: **Technical Regulation*, ** *ISOVER Saint-Gobain Planner - catalogs 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 3.3 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 3.3 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														
Building renovation according to minimum requirements of the *Technical Regulation*	x	x	x	x	x		x	x	x	x	x	x	x	
Building renovation according to the *Technical Regulation* requirements related to large reconstruction	x	x	x	x	x		x	x	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														
Building renovation according to minimum requirements of the *Technical Regulation*	x	x	x	x	x		x	x	x	x	x	x	x	
Building renovation according to the *Technical Regulation* requirements related to large reconstruction	x	x	x	x	x		x	x	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
Multi-residential buildings														
Building renovation according to minimum requirements of the *Technical Regulation*	x	x	x	x	x		x	x	x	x	x	x	x	
Building renovation according to the *Technical Regulation* requirements related to large reconstruction	x	x	x	x	x		x	x	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						
Family houses														
Building renovation according to minimum requirements of the *Technical Regulation*	x	x	x	x	x		x	x	x	x	x	x	x	
Building renovation according to the *Technical Regulation* requirements related to large reconstruction	x	x	x	x	x		x	x	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 implementation to external walls														
Measure 3: Thermal insulation implementation to the roof/ceiling bordering unheated attic														
Measure 4: Thermal insulation implementation to the ceiling bordering unheated basement (if any)														
Measure 5: Thermal insulation implementation 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,* 2017

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

A group of buildings built up to 1987 was selected as the target group with regard to their total floor area, state of the heated space envelope and energy requirements. In the renovation period 2020, renovation measures are to be applied in accordance with the existing Programmes of Renovation of Public, Commercial and Multi-Residential Buildings and Family Houses[87] and, after 2020, the application of an integrated energy renovation is assumed in accordance with the *Technical regulation* requirements related to major reconstruction under Directive 2010/31/EU[88] which provides for the encouragement of consideration of the introduction of high-efficiency alternative systems to the extent technically, functionally and economically feasible and Directive 2009/28/EU[89] on the obligation to introduce measures to increase the share of energy from renewable sources. Given the obligations under the Proposal for a Directive of the European Parliament and of the Council amending Directive 2010/31/EU on the energy performance of buildings (Text with EEA relevance)[90], measures or packages of measures to meet the energy savings target from 4th NEEAP are listed for two renovation periods: renovation period up to 2020 and the renovation period after 2020.

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 floor area, and are shown separately for buildings in continental and coastal Croatia in the tables below (Table 3.4 and Table 3.5). These input parameters are calculated based on the initial assumptions given in Chapter 2. The above input parameters in terms of the energy savings potential suggest that, within the buildings stock built up to 1987, the highest priority for integrated renovation should be given to family houses (potential of specific energy savings according to the useful floor area of the building up to 293.48 kWh/m^2 yearly) and commercial buildings (potential of specific energy savings according to the useful floor area of the building up to 274.78 kWh/m^2 yearly) (Table 3.4). In addition to the great potential for energy savings, family houses are also a priority category of buildings to be renovated in view of combating energy poverty, which is among the measures of the Draft 4th National Energy Efficiency Action Plan 2017-2019[91]. The plan provides for the design and launch of a systematic Programme of Energy Poverty Prevention through Implementing Energy Efficiency Measures, and the Programme will establish a list of available measures and co-funding rates for specific measures. The prerequisite for co-funding programme participation is the acquisition of the status of a vulnerable energy customer in accordance with the legal regulations in force at the time of the implementation of an individual measure. The

[87]Programme of Energy Renovation of Family Houses 2014-2020 with a detailed plan 2014-2016, March 2014, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/431066.pdf [30th April 2017]; Programme of Energy Renovation of Multi-Residential Buildings 2014-2020 with a detailed plan 2014-2016, May 2014, Ministry of Construction and Physical Planning, available at: http://www.mgipu.hr/doc/Propisi/Program_EO_VS_ZGRADE.pdf [30th April 2017];
Programme of Energy Renovation of Commercial Non-Residential Buildings 2014-2020 with a detailed 2014-2016 plan for the renovation of commercial non-residential buildings, July 2014, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/432768.pdf [30th April 2017];
Programme of Energy Renovation of Public Buildings 2014-2015, October 2013, Ministry of Construction and Physical Planning, available at: http://www.mgipu.hr/doc/EnergetskaUcinkovitost/Program_energetske_obnove_javnih_zgrada_2014-2015.pdf [30th April 2017];
Programme of Energy Renovation of Public Buildings 2016-2020, March 2017, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2017_03_22_508.html [30th April 2017]

[88]European Commission (2010), *Directive 2010/31/EU of the European Parliament and of the Council of 19th May 2010 on the energy efficiency of buildings (recast)*, available at: http://eur-lex.europa.eu/legal-content/HR/TXT/?uri=CELEX%3A32010L0031 [2010]

[89]European Commission (2009), *Directive 2009/28/EC of the European Parliament and of the Council of 23rd April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC (Text with EEA relevance)*, available at: http://eur-lex.europa.eu/legal-content/HR/TXT/?uri=CELEX%3A32009L0028 [2009]

[90]European Commission (2016), *Proposal for a Directive of the European Parliament and of the Council amending Directive 2010/31/EU on the energy performance of buildings (Text with EEA relevance)*, available at http://eur-lex.europa.eu/legal-content/HR/TXT/?uri=COM%3A2016%3A765%3AFIN [30th April 2017]

[91]Draft [10th May 2017]

specific objective of the measure is the establishment of a system that would allow vulnerable energy consumers to improve energy efficiency at the household level while improving living conditions at the same time.

Table 3.4 Overview of parameters of EE and RES measures involving possible building renovation models in continental Croatia depending on building category

Building category in continental Croatia	**Packages of measures**	**Specific energy savings in delivered energy per useful floor area of the building [kWh/m² annually]**	**Specific cost savings per useful floor area of the building [HRK/m² annually]**
Public buildings			
Building renovation according to minimum requirements of the *Technical Regulation*	Measures 0, 1, 2, 3, 4, 6, 7, 8, 9, 10, 11 and 12	189.41	89.23
Building renovation according to the *Technical Regulation* requirements related to large reconstruction	Measures 0, 1, 2, 3, 4, 6, 7, 8, 9, 10, 11 and 12	218.12	100.37
Building renovation to the nZEB standard	Measures 0, 1, 2, 3, 4, 6, 7, 8, 9, 10, 11 and 12	222.94	102.24
Building renovation to the passive house standard	Measures 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12	237.46	109.26
Building renovation to the active house standard	Measures 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 and 13	308.42	163.38
Commercial buildings			
Building renovation according to minimum requirements of the *Technical Regulation*	Measures 0, 1, 2, 3, 4, 6, 7, 8, 9, 10, 11 and 12	261.13	122.66
Building renovation according to the *Technical Regulation* requirements related to large reconstruction	Measures 0, 1, 2, 3, 4, 6, 7, 8, 9, 10, 11 and 12	274.78	127.95
Building renovation to the nZEB standard	Measures 0, 1, 2, 3, 4, 6, 7, 8, 9, 10, 11 and 12	284.61	131.77
Building renovation to the passive house standard	Measures 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12	319.50	147.17
Building renovation to the active house standard	Measures 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 and 13	415.61	220.66
Multi-residential buildings			
Building renovation according to minimum requirements of the *Technical Regulation*	Measures 0, 1, 2, 3, 4, 6, 7, 8, 9, 10, 11 and 12	161.29	47.51
Building renovation according to the *Technical Regulation* requirements related to large reconstruction	Measures 0, 1, 2, 3, 4, 6, 7, 8, 9, 10, 11 and 12	167.07	49.07
Building renovation to the nZEB standard	Measures 0, 1, 2, 3, 4, 6 and 7	176.41	51,61
Building renovation to the passive house standard	Measures 0, 1, 2, 3, 4, 6 and 7	208.24	61.56
Family houses			
Building renovation according to minimum requirements of the *Technical Regulation*	Measures 0, 1, 2, 3, 4, 6, 7, 8, 9, 10, 11 and 12	278.52	88.78
Building renovation according to the *Technical Regulation* requirements related to large reconstruction	Measures 0, 1, 2, 3, 4, 6, 7, 8, 9, 10, 11 and 12	293.48	92.64
Building renovation to the nZEB standard	Measures 0, 1, 2, 3, 4, 6, 7, 8, 9 and 10	302.68	95.01
Building renovation to the passive house standard	Measures 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10	335.31	105.52
Building renovation to the active house standard	Measures 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 and 13	431.83	179.09
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 implementation to external walls			
Measure 3: Thermal insulation implementation to the roof/ceiling bordering unheated attic			
Measure 4: Thermal insulation implementation to the ceiling bordering unheated basement (if any)			
Measure 5: Thermal insulation implementation 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,* 2017

Table 3.5 Overview of parameters of EE and RES measures involving possible building renovation models in coastal Croatia depending on building category

Building category in coastal Croatia	Packages of measures	Specific energy savings in delivered energy per useful floor area of the building [kWh/m² annually]	Specific cost savings per useful floor area of the building [HRK/m² annually]
Public buildings			
Building renovation according to minimum requirements of the *Technical Regulation*	Measures 0, 1, 2, 3, 4, 6, 7, 8, 9, 10, 11 and 12	114.46	60.35
Building renovation according to the *Technical Regulation* requirements related to large reconstruction	Measures 0, 1, 2, 3, 4, 6, 7, 8, 9, 10, 11 and 12	128.91	66.02
Building renovation to the nZEB standard	Measures 0, 1, 2, 3, 4, 6, 7, 8, 9, 10, 11 and 12	130.08	66.48
Building renovation to the passive house standard	Measures 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12	139.27	71.63
Building renovation to the active house standard	Measures 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 and 13	187.88	108.54
Commercial buildings			
Building renovation according to minimum requirements of the *Technical Regulation*	Measures 0, 1, 2, 3, 4, 6, 7, 8, 9, 10, 11 and 12	156.69	82.82
Building renovation according to the *Technical Regulation* requirements related to large reconstruction	Measures 0, 1, 2, 3, 4, 6, 7, 8, 9, 10, 11 and 12	171.08	88.47
Building renovation to the nZEB standard	Measures 0, 1, 2, 3, 4, 6, 7, 8, 9, 10, 11 and 12	172.83	89.15
Building renovation to the passive house standard	Measures 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12	189.66	97.88
Building renovation to the active house standard	Measures 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 and 13	256.56	148.88
Multi-residential buildings			
Building renovation according to minimum requirements of the *Technical Regulation*	Measures 0, 1, 2, 3, 4, 6, 7, 8, 9, 10, 11 and 12	78.49	29.19
Building renovation according to the *Technical Regulation* requirements related to large reconstruction	Measures 0, 1, 2, 3, 4, 6, 7, 8, 9, 10, 11 and 12	82.67	30,37
Building renovation to the nZEB standard	Measures 0, 1, 2, 3, 4, 6 and 7	84.66	30,93
Building renovation to the passive house standard	Measures 0, 1, 2, 3, 4, 6 and 7	102.01	37.09
Family houses			
Building renovation according to minimum requirements of the *Technical Regulation*	Measures 0, 1, 2, 3, 4, 6, 7, 8, 9, 10, 11 and 12	139.12	54.97
Building renovation according to the *Technical Regulation* requirements related to large reconstruction	Measures 0, 1, 2, 3, 4, 6, 7, 8, 9, 10, 11 and 12	152.55	58.57
Building renovation to the nZEB standard	Measures 0, 1, 2, 3, 4, 6, 7, 8, 9 and 10	154.03	58.97
Building renovation to the passive house standard	Measures 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10	176.21	67.03
Building renovation to the active house standard	Measures 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 and 13	211.38	93.38
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 implementation to external walls			
Measure 3: Thermal insulation implementation to the roof/ceiling bordering unheated attic			
Measure 4: Thermal insulation implementation to the ceiling bordering unheated basement (if any)			
Measure 5: Thermal insulation implementation 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,* 2017

The amounts of investment into energy renovation have been calculated from available bills of quantities of the renovation projects implemented by the North-West Croatia Regional Energy Agency for the past five years, and from the Programme of Energy Renovation of Public Buildings 2016-2020, Tables 7.1, 7.2. and 7.3.[92] and, 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)[93]. In the case of renovation according to minimum requirements of the *Technical regulation*, the cost of investment in the renovation of the heated space envelope is 767.00 HRK/m^2 for continental Croatia, and 671.00 HRK/m^2 for the coastal Croatia and, in the case of building renovation according to *Technical Regulation* requirements related to large reconstruction, it amounts to 800.00 HRK/m^2 for continental Croatia, and 700.00 HRK/m^2 for coastal Croatia. In the case of renovation according to nZEB, the cost of investment in the renovation of the heated space envelope amounts to 1,000.00 HRK/m^2 for continental Croatia, and 874.00 HRK/m^2 for coastal Croatia (in the case of passive/active house 1,750.00 HRK/m^2 for continental Croatia, and 1,530.00 HRK/m^2 for coastal Croatia). In addition to the reconstruction of the external heated space envelope, the overall investment cost into the energy renovation of individual buildings includes the replacement of inefficient technical systems with more efficient ones and, where possible, with the RES-powered systems. The investment cost of heating system replacement by new ones, presuming the replacement of 30% of the existing systems with gas systems, 35% of the existing systems with heat pump systems and 35% of the existing systems with biomass-fired boilers, along with system balancing and installation of thermostat sets on radiator units, is 468.50 HRK/m^2 for continental Croatia, and HRK 413.00/m^2 for coastal Croatia. The above distribution of selected heating systems is in line with the data provided by the Programme of Energy Renovation of Public Buildings 2016-2020 (Chapter 11.2), where the analysis of three possible public building renovation models uses a standard system based on fossil fuel for 30% energy requirements and a RES-powered system for 70% of requirements as the standard heating power generation system. The investment cost of cooling system centralisation and new cooling system installation using a heat pump stands at 233,00 HRK/m^2 for continental Croatia, AND 223.00 HRK/m^2 for coastal Croatia (in the case of passive/active house 350,00 HRK/m^2 for continental Croatia, and 335.00 HRK/m^2 for coastal Croatia). The installation of solar collector systems for DHW generation is a measure with a cost investment amounting to 20.20 HRK/m^2 for continental Croatia, and HRK 14.00/m^2 for coastal Croatia, while the replacement of existing lighting systems with more efficient ones is an EE measure with a cost investment of 61.00 HRK/m^2 of the building floor area. Financial savings have been calculated in accordance with the percentage distribution of fuels and energy sources in direct consumption for each building category[94] and their respective prices in April 2017[95]. The financial savings amount does not include VAT.

[92] Programme of Energy Renovation of Public Buildings 2016-2020, March 2017, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2017_03_22_508.html [30th April 2017]

[93] North-West Croatia Regional Energy Agency (2013), *Design 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; North-West Croatia Regional Energy Agency (2013), *Report on the Energy Audit of the Dubovac Primary School Building, 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

[94] International Energy Agency (2017), Online Report for Croatia [online], available at: http://www.iea.org/statistics/statisticssearch/report/?country=CROATIA&product=Balances&year=2014 [30th April 2017]

[95] Decision on the Tariff Line Amount for Electricity Supply within the Universal Service, Zagreb OG No. 63/2015 (1219), available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2015_06_63_1219.html [30th April 2017];

[95] Decision on the Tariff Line Amount for Electricity Supply, Zagreb OG No. 134/2015 (2533), available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2015_12_134_2533.html [30th April 2017]

[95] Decision on the Tariff Line Amount for Electricity Transmission, Zagreb OG No. 134/2015 (2532), available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2015_12_134_2532.html [30th April 2017]

[95] Decision on Tariff Line Amounts in the Tariff System for Natural Gas Supply, with the Exception of Preferential Customers, without Tariff Line Amounts, Zagreb OG Nos 49/2012 and 99/2012 (2199), available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2012_08_99_2199.html [30th April 2017]

[95] Methodology for Setting the Tariff Line Amounts for the Public Service of Gas Supply and Guaranteed Supply, Zagreb OG No. 26/2017 (585), available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2017_03_26_585.html [30th April 2017]

[95] Decision on Tariff Line Amounts in the Tariff System for Heat Distribution in District Heating Systems of Zagreb, Osijek and Sisak for HEP - Toplinarstvo d.o.o., Miševečka 15/a, Zagreb OG No. 105/2014 (2040), available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2014_08_105_2040.html [30th April 2017]; Decision on Tariff Line Amounts in the Tariff System for Heat Distribution in District Heating Systems of Dubrava, Velika Gorica and Samobor for HEP - Toplinarstvo d.o.o., Miševečka 15/a, Zagreb OG No. 105/2014 (2039), available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2014_08_105_2039.html ; Decision on Tariff Line Amounts in the Tariff System for Heat

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 overall 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). Overall costs include initial investment costs, energy costs while taking into account the rise in energy source prices at an annual level[96], maintenance costs and replacement costs. 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. A summary of the above parameters is shown in the tables below (Table 3.6 and Table 3.7)

Distribution in District Heating Systems of Dubrava, Velika Gorica and Samobor for energy company HEP - Toplinarstvo d.o.o., Miševečka 15/a, Zagreb NN 105/2014 (2039), available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2014_08_105_2038.html ; Decision on Tariff Line Amounts in the Tariff System for Heat Distribution in District Heating Systems of Zagreb, Osijek and Sisak, for HEP - Proizvodnja d.o.o., Ulica grada Vukovara 37, Zagreb OG No. 105/2014 (2037), available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2014_08_105_2037.html ; Decision on Tariff Line Amounts in the Tariff System for Heat Distribution in District Heating Systems of Karlovac, for Gradska toplana d.o.o., Tina Ujevića 7, Karlovac OG No. 105/2014 (2036), available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2014_08_105_2036.html ; Decision on Tariff Line Amounts in the Tariff System for Heat Distribution in District Heating Systems of Karlovac, for Gradska toplana d.o.o., Tina Ujevića 7, Karlovac OG No. 105/2014 (2035), available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2014_08_105_2035.html ; Decision on Tariff Line Amounts in the Tariff System for Heat Distribution in District Heating Systems of Gornja Vežica, Vojak and Krnjevo for Energo d.o.o., Dolac 14, Rijeka OG No. 105/2014 (2034), available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2014_08_105_2034.html ; Decision on Tariff Line Amounts in the Tariff System for Heat Distribution in District Heating Systems of Gornja Vežica, Vojak and Krnjevo for Energo d.o.o., Dolac 14, Rijeka OG No. 105/2014 (2033), available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2014_08_105_2033.html ; Decision on Tariff Line Amounts in the Tariff System for Heat Distribution in District Heating Systems of Borovo Naselje and Olajnica for Tehnostan d.o.o., Dr. Franje Tuđmana 23, Vukovar OG No. 105/2014 (2032), available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2014_08_105_2032.html ; Decision on Tariff Line Amounts in the Tariff System for Heat Distribution in District Heating Systems of Borovo Naselje and Olajnica for Tehnostan d.o.o., Dr. Franje Tuđmana 23, Vukovar OG No. 105/2014 (2031), available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2014_08_105_2031.html ; Decision on Tariff Line Amounts in the Tariff System for Heat Distribution in District Heating Systems of Slavonija, for Brod-plin d.o.o., Tome Skalice 4, Slavonski Brod OG No. 105/2014 (2030), available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2014_08_105_2030.html ; Decision on Tariff Line Amounts in the Tariff System for Heat Distribution in District Heating Systems of Slavonija, for Brod-plin d.o.o., Tome Skalice 4, Slavonski Brod OG No. 105/2014 (2029), available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2014_08_105_2029.html

[95]Available at: http://www.hak.hr/info/cijene-goriva/ [10th May 2017]

[96]European Commission (2010), EU Energy Trends to 2030; update 2009. European Union, 2010. [online], available at: https://ec.europa.eu/energy/sites/ener/files/documents/trends_to_2030_update_2009.pdf [30th April 2017]

Table 3.6 Overview of total costs of possible building renovation models in continental Croatia, depending on building category and calculation period

Building category in continental Croatia	Public buildings	Commercial buildings	Multi-residential buildings	Family houses
Total cost of five analyzed renovation models for a 30-year calculation period [HRK/m²]				
Building renovation according to minimum requirements of the *Technical Regulation*	14,169.65	17,057.25	13,632.75	16,889.45
Building renovation according to the *Technical Regulation* requirements related to large reconstruction	13,824.11	16,935.75	13,629.33	16,747.64
Building renovation to the nZEB standard	14,252.60	17,289.76	13,992.43	17,110.48
Building renovation to the passive house standard	16,737.42	19,425.46	16,255.05	19,303.83
Building renovation to the active house standard	9,124.55	8,701.24	9,621.82	8,529.33
Total cost of five analyzed renovation models for a 50-year calculation period [HRK/m²]				
Building renovation according to minimum requirements of the *Technical Regulation*	37,784.09	46,147.37	36,229.10	45,661.37
Building renovation according to the *Technical Regulation* requirements related to large reconstruction	36,737.91	45,750.08	36,173.80	45,205.28
Building renovation to the nZEB standard	37,699.72	46,496.17	36,946.23	45,976.94
Building renovation to the passive house standard	43,310.55	51,095.87	41,913.48	50,743.60
Building renovation to the active house standard	22,478.97	21,896.04	23,716.77	21,408.53
Total cost of five analyzed renovation models for a 70-year calculation period [HRK/m²]				
Building renovation according to minimum requirements of the *Technical Regulation*	83,231.72	103,562.90	79,451.52	102,381.45
Building renovation according to the *Technical Regulation* requirements related to large reconstruction	80,562.91	102,471.56	79,191.55	101,147.13
Building renovation to the nZEB standard	82,129.02	103,513.25	80,297.26	102,250.99
Building renovation to the passive house standard	91,478.58	110,404.73	88,082.27	109,548.36
Building renovation to the active house standard	41,774.55	41,256.15	44,500.76	40,085.50

Source: *REGEA,* 2017

Table 3.7 Overview of total costs of possible building renovation models in coastal Croatia, depending on building category and calculation period

Building category in coastal Croatia	Public buildings	Commercial buildings	Multi-residential buildings	Family houses
Total cost of five analyzed renovation models for a 30-year calculation period [HRK/m²]				
Building renovation according to minimum requirements of the *Technical Regulation*	10,755.70	12,845.49	8,133.70	9,549.82
Building renovation according to the *Technical Regulation* requirements related to large reconstruction	10,612.01	12,702.63	8,143.51	9,420.61
Building renovation to the nZEB standard	11,031.86	13,113.85	8,551.47	9,835.70
Building renovation to the passive house standard	13,321.62	15,234.09	10,769.36	11,922.29
Building renovation to the active house standard	8,473.63	8,123.49	9,469.13	8,735.78
Total cost of five analyzed renovation models for a 50-year calculation period [HRK/m²]				
Building renovation according to minimum requirements of the *Technical Regulation*	28,226.34	34,278.93	20,632.33	24,733.79
Building renovation according to the *Technical Regulation* requirements related to large reconstruction	27,770.48	33,825.49	20,621.03	24,319.86
Building renovation to the nZEB standard	28,742.39	34,772.41	21,558.50	25,277.98
Building renovation to the passive house standard	33,932.53	39,471.58	26,540.50	29,879.69
Building renovation to the active house standard	20,537.31	19,990.89	22,687.29	20,953.12
Total cost of five analyzed renovation models for a 70-year calculation period [HRK/m²]				
Building renovation according to minimum requirements of the *Technical Regulation*	60,876.34	75,590.25	42,415.24	52,385.93
Building renovation according to the *Technical Regulation* requirements related to large reconstruction	59,658.41	74,378.19	42,278.03	51,269.92
Building renovation to the nZEB standard	61,346.14	76,005.17	43,882.05	52,924.13
Building renovation to the passive house standard	70,069.71	83,535.18	52,099.62	60,217.23
Building renovation to the active house standard	37,644.90	36,970.09	41,846.82	38,175.78

Source: *REGEA,* 2017

Based on the charts shown in the Annexes (Annex 3, Annex 5, Annex 7, Annex 9, Annex 11, Annex 13, Annex 15 and Annex 17) and the data presented in tables (Table 3.6 and Table 3.7), the active house model is most cost-effective, but it also includes the process of obtaining the status of eligible RES- and cogeneration-based producers and the status of preferential energy purchase price (as defined in Article 44 of the Act on Renewable Energy Sources and High Effective Cogeneration[97]). Given the above, the stated active house model can be chosen for a low percentage of buildings. In the above tables, the optimal model in terms of cost is marked in dark green, while the next most cost-effective model is marked in light green. The model of building renovation according to *Technical Regulation* requirements related to large reconstruction (in the previous tables marked with a darker green tint) was selected as optimal in terms of cost. However, it should be noted that its realization in terms of public building renovation in continental Croatia is almost impossible, given the limitations for the annual delivered energy E_{del} and the annual primary energy E_{prim}. This model does not prove optimal only in the multi-residential building category of coastal Croatia where, as a cost-optimal model, it results in a renovation model according to minimum requirements of the *Technical Regulation*. The realization of the renovation model to the nZEB standard is impossible due to the restrictions in the annually delivered energy E_{del} for public buildings in continental Croatia and the annual primary energy E_{prim} for almost all building categories (exceptions involve commercial buildings in continental Croatia and coastal Croatia). However, if reduced criteria could result in its realization, its cost-effectiveness would increase with the length of the calculation period for the buildings in continental Croatia. Building renovation model according to minimum requirements of the *Technical Regulation* is less cost-effective than the building renovation model according to *Technical Regulation* requirements related to large reconstruction, specifically to a greater extent in continental Croatia and with the extension of the calculation period.

[97]Act on Renewable Energy Sources and High Effective Cogeneration. Zagreb OG Nos 100/2015 and 123/2016 (1937), available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2015_09_100_1937.html [30th April 2017]

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: Energy performance of buildings evaluation procedure for energy systems in buildings (in accordance with the requirements of Directive 2002/91/EC of the European Parliament and of the Council of 16th December 2002 on the energy performance of buildings[98] (hereinafter: Directive 2002/91/EC)), as well as the Commission Delegated Regulation (EU) No. 244/2012 of 16th January 2012 supplementing Directive 2010/31/EU of the European Parliament and of the Council on the energy performance of buildings by establishing a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements (Text with EEA relevance) and respective guidelines[99] (hereafter: Commission Delegated Regulation (EU) No. 244/2012). 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 Directive 2002/91/EC, considering that the said Directive has been replaced by the new Directive 2010/31/EU[100], the 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 Directive 2010/31/EU, more specifically 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 RES-based systems to the greatest possible extent, in order to meet the requirements of Directive 2010/31/EU[101] and Directive 2009/28/EU[102], as well as the Draft 4th National Energy Efficiency Action Plan 2017-

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[98]European Commission (2002), *Directive 2002/91/EC of the European Parliament and of the Council of 16th December 2002 on the energy performance of buildings*, available at: http://eur-lex.europa.eu/eli/dir/2002/91/oj [2002]

[99]European Commission (2012), Commission Delegated Regulation (EU) No. 244/2012 of 16th January 2012 supplementing Directive 2010/31/EU of the European Parliament and of the Council on energy performance of buildings by establishing a comparative methodological framework for calculating cost-optimal levels for minimum energy performance requirements for buildings and building elements (Text with EEA relevance), available at: http://eur-lex.europa.eu/legal-content/HR/TXT/?uri=celex%3A32012R0244 [16th January 2012] European Commission (2012), 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 [19th April 2012]

[100]European Commission (2010), *Directive 2010/31/EU of the European Parliament and of the Council of 19th May 2010 on the energy efficiency of buildings (recast)*, available at: http://eur-lex.europa.eu/legal-content/HR/TXT/?uri=CELEX%3A32010L0031 [2010]

[101]European Commission (2010), *Directive 2010/31/EU of the European Parliament and of the Council of 19th May 2010 on the energy efficiency of buildings (recast)*, available at: http://eur-lex.europa.eu/legal-content/HR/TXT/?uri=CELEX%3A32010L0031 [2010]

[102]European Commission (2009), *Directive 2009/28/EC of the European Parliament and of the Council of 23rd April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC (Text with EEA relevance)*, available at: http://eur-lex.europa.eu/legal-content/HR/TXT/?uri=CELEX%3A32009L0028 [2009]

2019,[103] which, in the case of implementing a significant renovation of an existing building, prescribe the obligation to take measures in the consideration of installing high-efficiency alternative systems to the extent technically, functionally and economically feasible.

The package of measures to increase energy efficiency (hereinafter: 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, maintenance, operating and labor costs), factors of delivered energy conversion into primary energy, fluctuations in energy prices etc. In addition to the European legislation mentioned above, the selection and parameterization 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. Renovation of the external building envelope according to the *Technical Regulation* requirements, using realistic models in the calculation for each building category[104];
2. Introduction of central heating systems using a wood biomass-fired (pellets, wood chips) boiler, heat pumps using ambient air temperature 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.

As the Programmes of Renovation of Public, Commercial and Multi-Residential Buildings and Family Houses[105] cover the building renovation period up to 2020, the application of an integrated energy renovation according to *Technical Regulation* requirements related to large reconstruction is assumed after 2020. In the case of a significant building renovation, Directive 2010/31/EU[106] provides for encouraging the consideration of installing high-efficiency alternative systems to the extent technically, functionally and economically feasible, while Directive 2009/28/EU[107] stipulates the obligation to introduce measures to increase the share of RES energy. For

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[103]Draft [10th May 2017]

[104]North-West Croatia Regional Energy Agency (2013), *Final Report on the Energy Audit of the Terme Tuhelj-Tuheljske Spa Complex,* Zagreb; *Final Report on the Energy Audit of the 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 the 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 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.

[105]Programme of Energy Renovation of Family Houses 2014-2020 with a detailed 2014-2016 plan, March 2014, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/431066.pdf [30th April 2017];
Programme of Energy Renovation for Multi-Residential Buildings 2014-2020 with a detailed 2014-2016 plan, May 2014, Ministry of Construction and Physical Planning, available at: http://www.mgipu.hr/doc/Propisi/Program_EO_VS_ZGRADE.pdf [30th April 2017];
Programme of Energy Renovation of Commercial Non-Residential Buildings 2014-2020 with a detailed 2014-2016 plan for the renovation of commercial non-residential buildings, July 2014, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/432768.pdf [30th April 2017];
Programme of Energy Renovation of Public Buildings 2014-2015, October 2013, Ministry of Construction and Physical Planning, available at: http://www.mgipu.hr/doc/EnergetskaUcinkovitost/Program_energetske_obnove_javnih_zgrada_2014-2015.pdf [30th April 2017];
Programme of Energy Renovation of Public Buildings 2016-2020, March 2017, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2017_03_22_508.html [30th April 2017]

[106]European Commission (2010), *Directive 2010/31/EU of the European Parliament and of the Council of 19th May 2010 on the energy efficiency of buildings (recast)*, available at: http://eur-lex.europa.eu/legal-content/HR/TXT/?uri=CELEX%3A32010L0031 [2010]

[107]European Commission (2009), *Directive 2009/28/EC of the European Parliament and of the Council of 23rd April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC*

these reasons, comprehensive measure packages including EE and RES measures are to be implemented in respect of the said building categories.

The calculation of savings in CO_2 emissions as well as the amount of primary energy is based on the Building Energy Audit Methodology[108], more specifically the conversion factors related to delivered energy into primary energy and CO_2[109] emissions published on the official site of the Ministry of Construction and Physical Planning, in which the overall component of the primary energy factor taken from the official site of the Ministry of Construction and Physical Planning[110]. is used for the purpose of calculating the building energy performance in accordance with the instructions of the Ministry. To calculate savings in CO_2 emissions, specific CO_2 emission factors were used per energy unit of fuel (kgCO_2/KWh). The data obtained correspond to the energy savings of individual building categories and are in line with the energy source distribution in energy consumption based on data from the *International Energy Agency - IEA Statistics* database in Croatia[111]. Calculation of required investment and appropriate cost savings is based on existing price catalogues or realistic cost specifications[112].

Given the guidelines related to Article 6(3) of the Commission Delegated Regulation (EU) No. 244/2012[113], a data source related to reconstruction under low-energy standards was taken into account when calculating required investment. The calculation derives from instructions in Annex 1 to the said regulation (Article 2(4)), which lay down an obligation of calculation in compliance with the standard prescribed as a prerequisite for co-funding by national institutions, such as the Environmental Protection and Energy Efficiency Fund (EPEEF).

In the parameterization of measures to increase energy efficiency, 2016 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 delivered energy for the purposes of different technical systems in buildings based on the *International Energy Agency - IEA Statistics* database in Croatia[114].

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and 2003/30/EC (Text with EEA relevance), available at: http://eur-lex.europa.eu/legal-content/HR/TXT/?uri=CELEX%3A32009L0028 [2009]

[108]Metodologija provođenja energetskog pregleda građevina (Energy Audit Methodology) [online], June 2014, Ministry of Construction and Physical Planning, available at: http://www.mgipu.hr/doc/EnergetskaUcinkovitost/METODOLOGIJA_EPG.pdf [30th April 2017]

[109]Factors of Primary Energy and CO_2 Emissions [online], October 2014, Ministry of Construction and Physical Planning, available at: http://www.mgipu.hr/doc/EnergetskaUcinkovitost/FAKTORI_primarne_energije-do.29.9.2017.pdf[30th April 2017]

[110]Available at: http://www.mgipu.hr/doc/EnergetskaUcinkovitost/FAKTORI_primarne_energije-do.29.9.2017.pdf[30th April 2017];

[111]International Energy Agency (2017), Online Report for Croatia [online], available at: http://www.iea.org/statistics/statisticssearch/report/?country=CROATIA&product=Balances&year=2014 [30th April 2017];

[112]North-West Croatia Regional Energy Agency (2013), *Design 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.

[113]European Commission (2012), Commission Delegated Regulation (EU) No. 244/2012 of 16th January 2012 supplementing Directive 2010/31/EU of the European Parliament and of the Council on energy performance of buildings by establishing a comparative methodological framework for calculating cost-optimal levels for minimum energy performance requirements for buildings and building elements (Text with EEA relevance), available at: http://eur-lex.europa.eu/legal-content/HR/TXT/?uri=celex%3A32012R0244 [16th January 2012] European Commission (2012), 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 [19th April 2012]

[114]International Energy Agency (2017), Online Report for Croatia [online], available at: http://www.iea.org/statistics/statisticssearch/report/?country=CROATIA&product=Balances&year=2014 [30th April 2017]

4. Policies and measures to stimulate cost-effective integrated 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 dedicated to integrated 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*[115];
- European Commission's CONCERTO initiative under the European Research Framework Programme (FP7)[116];
- Competitiveness and Innovation Framework Programme – *CIP*)[117];
- European Union's Horizon 2020 for research and innovation 2014-2020 [118];
- Programmes and projects of the Environmental Protection and Energy Efficiency Fund (EPEEF)[119];
- Loan programmes involving projects of environmental protection, EE and RES, and Loan programmes of the Croatian Bank for Reconstruction and Development (HBOR) involving environmental protection projects[120];
- European Bank for Reconstruction and Development (EBRD) technical assistance programmes[121];
- UNDP project: Increasing Energy Efficiency in the Republic of Croatia[122];
- Technology Research and Development Promotion Programme – TEST[123];
- Strategy Plan of the Ministry of Economy 2013-2015[124];
- Science and Research Investment Action Plan of the Ministry of Science, Education and Sports[125];
- Entrepreneurial Impulse[126] of the Ministry of Economy, Entrepreneurship and Crafts

[115]Ministry of Regional Development and EU Funds (2017), available at: http://www.strukturnifondovi.hr/UserDocsImages/Publikacije/Instrument_pretpristupne_pomoci_IPA.pdf [30th April 2017]
[116]European Commission (2014), available at: http://www.concertoplus.eu/ [30th April 2017]
[117]European Commission (2014), available at: http://ec.europa.eu/cip/ [30th April 2017]
[118]Agency for Mobility and EU Programmes (2017), available at: http://www.obzor2020.hr/ [2017]
[119]Environmental Protection and Energy Efficiency Fund (2017), available at: http://www.fzoeu.hr/hr/energetska_ucinkovitost/enu_u_zgradarstvu/ [2017]
[120]Croatian Bank for Reconstruction and Development (2017), available at: https://www.hbor.hr/wp-content/uploads/2017/05/Za%C5%A1tita-okoli%C5%A1a-Pk-projekata-za%C5%A1tite-okoli%C5%A1a-energetske-u%C4%8Dinkovitosti -1612-1704.pdf [2017]
[121]European Bank for Reconstruction and Development (2017), available at: http://www.wb-reep.org/ [2017]
[122]UNDP Energy Efficiency Promotion Project in Croatia (2012), available at: http://www.enu.fzoeu.hr/ [2012]
[123]Business Innovation Agency of the Republic of Croatia (2013), available at: http://www.hamagbicro.hr/inovacije/javni-sektor/test/ [31st December 2013]
[124]Ministry of Economy (2012), available at: http://www.mingo.hr/userdocsimages/STRATE%C5%A0KI%20PLAN%20MINGO%202013-2015%20kona%C4%8Dno.doc [30th April 2017]
[125]Ministry of Science, Education and Sports (2008), available at: http://novebojeznanja.hr/UserDocsImages/Dokumenti%20i%20publikacije/Dokumenti%20i%20publikacije%20referirani%20u%20SOZT-u%20(popis%201)/146%20Akcijski%20plan%20za%20poticanje%20ulaganja%20u%20znanost%20i%20istra%C5%BEivanje.pdf [30th April 2008]
[126]Ministry of Entrepreneurship and Crafts (2016), available at: http://www.strukturnifondovi.hr/natjecaji/1276 [30th September 2016]

Croatian Ministry of Construction and Physical Planning (MCPP) continuously stimulates and supports research and development of new energy-related and environmentally friendly construction materials and technologies through a number of national and international research and development projects, and the following stand out: 2011 CIP-EIP-Eco-Innovation project entitled Energy Efficient, Recycled Concrete Sandwich Façade Panel – ECO-SANDWICH[127]. The objective of the ECO-SANDWICH project is to stimulate recycling and reuse of construction and demolition waste, promote the substitution of conventional thermal insulation materials, promote the application of prefabricated energy efficient products and reduce energy consumption introduction, greenhouse gas emissions and production waste by-products and product use. The Horizon 2020[128] BUILD UPON project[129] is the world's largest co-operation project in the field of energy building renovation and has connected more than 1,000 organizations from 13 countries in 80 events held in 2016 and 2017. It aims to launch a revolution in renovation across Europe, helping states to deliver energy renovation strategies of existing buildings by 30th April 2017. These strategies are critical to reducing energy consumption in Europe, reducing climate change impacts and constructing buildings that ensure high quality of life. 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[130]. One of the important HORIZON 2020 programme 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).

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

Since its establishment on 1st January 2004, the Environmental Protection and Energy Efficiency Fund (EPEEF) has been continuously and systematically promoting energy building renovation through numerous programmes of sustainable development co-funding. Table 4.1 shows the cumulative savings of the alternative policy measures that have been realized from 2014 to 2016, that is after taking and adopting the Long-Term Strategy for Mobilising Investment in the Renovation of the National Building Stock, through tenders of the Environmental Protection and Energy Efficiency Fund. Collected data on all measures implemented are contained in the System for measuring and verifying energy savings (SMiV) which contains the savings calculated according to the bottom-up methodology.

[127]University of Zagreb, Faculty of Civil Engineering (2015), available at: http://www.eco-sandwich.hr/hr/
[128]European Union, available at: https://ec.europa.eu/info/funding-tenders_en [30th April 2017]
[129]Available at: http://buildupon.eu/hr/
[130]European Union, available at: http://ec.europa.eu/programmes/horizon2020/ [30th April 2017]

Table 4.1 Cumulative savings of alternative policy measures realized from 2014 to 2016

Measure title	Savings [PJ]	Savings [tCO_2]	Total investment [HRK]	Total Fund resources issued [HRK]
RESIDENTIAL BUILDINGS				
Programme of Energy Renovation of Family Houses 2014 -2016	1.10438	53,709.00	778,492,028.45	487,329,822.20
Programme of Energy Renovation of Multi-Residential Buildings	0.25131	19,825.03	154,535,990.29	61,997,642.77
Introduction of an individual measurement system involving heat energy consumption	0.51337	42,331.63	116,930,071.23	46,313,643.72
PUBLIC BUILDINGS				
Programme of Energy Renovation of Public Buildings (2014 -2015)	0.30125	22,388.49	344,258,164.79	155,309,742.45
Programme of Energy Renovation of Public Buildings (2016 -2020)	0	0.00	0.00	0
COMMERCIAL NON-RESIDENTIAL BUILDINGS				
Programme of Energy Renovation of Commercial Non-Residential Buildings	0.07073	5,388.05	49,781,776.24	20,279,641.08
PUBLIC LIGHTING				
Energy-efficient public lighting programme	0.19776	19,783.05	160,986,313.89	84,028,721.96
TRANSPORT				
Financial incentives for energy-efficient vehicles	0.083556	7,706.02	207,250,726.57	39,996,341.06
Encouraging eco-driving	0.09159	6,784.91	2,986,214.63	977,649.24
Establishment of a special tax on motor vehicles based on CO2 emissions	0	0.00	0.00	0
TOTAL	2.61395	177,916.18	1,815,221,286.09	896,233,204.48

Source: Annual progress report on the achievement of national energy efficiency targets pursuant to Article 24(1) in accordance with Part 1 of Annex XIV of the Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC, CEI

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

Article 5 of Directive 2012/27/EU[131] defines the obligation of all MSs to renovate public buildings owned by the central government. For this purpose, national plans and policies were drafted as a framework for the implementation of the renovation programme. Each MS has a different approach regarding implementation as well as financial mechanisms. Implementation of Article 5 Directive 2012/27/EC is possible with the so called standard approach, more specifically by renovating 3% of the total floor area of heated and/or cooled buildings owned and used by the central government every year, and the alternative approach implementing other cost-effective measures taken in eligible buildings owned and used by the central government, provided that they achieve at least equal savings as the standard approach. In alternative approaches, each MS defines various energy efficiency measures for achieving the required savings. One of the key factors for a successful renovation programme are the funding methods, i.e. financial instruments. Briefly, the following can be noted at the EU level:

- Almost all MSs have programmes encouraging building renovation by means of classic or innovative funding models, of or external funding;
- Most of the financial instruments target existing buildings;
- The most commonly used funding methods are subsidies, more specifically non-refundable co-funding. Loans or fiscal instruments are used to a lesser extent;
- There is no systematic way of monitoring, using standardized indicators and there are no reports on the final objectives achieved;
- A small part of financial instruments is directed at comprehensive building renovation;
- More active involvement of private funding is not addressed in many MSs.

Energy building renovation activities being carried out in most EU Member States are regional or local initiatives, specifically projects that have the option of using co-funding from development funds in view of sustainable development. The data available on the implemented energy renovation programmes is related to benefiting from EU Operational Programmes (ERDF) and development programmes (Jessica and Elena) and a partial share in the national budget, subsidies or funding the building occupant himself. Programmes focused on a specific group of buildings or territorial unit are larger in number than the integrated national programmes. Only several programmes are listed below for the purpose of presenting different approaches to solving the problem of encouraging building stock renovation and construction to the nZEB principles of sustainable construction:

- Portugal - Energy Efficiency Programme in Public Administration (Eco.AP) was initiated in 2011 in view of increasing energy efficiency by 30% by 2020 in public services and public administration bodies (all institutions under the authority of the central government). The Energy Efficiency Fund financed the programme activities, yet a detailed overview is not available.
- City of Berlin - the Berlin Energy Agency manages the project (Berlin Energy Saving Partnership) in which the partners are the City of Berlin and several ESCOs. The service is procured through a public tender. Funding is provided through ESCOs which guarantee savings. Payback period with regard to the measures is 8 to 12 years, and 80% of the savings serves as a compensation for the ESCO, and the remaining 20% is direct profit for the City of Berlin. Throughout the term of the energy saving contract, technical systems are maintained by an ESCO, and the building by the City of Berlin.
- Province of Milan - a centrally coordinated and joint preparation of the project for the energy renovation of 30-40 school buildings in several municipalities. Standardized energy performance contracts were drafted, and the projects were carried out as an ESCO service with guaranteed savings of 20% and payment through the realized savings in energy costs. The project was implemented through local banks and was financed by a EIB loan of EUR 65 m (EIB-ELENA instrument).
- City of Prague - energy renovation of 15 schools through three stakeholders: according to the energy performance contract, modernization/replacement of technical systems is implemented, and the external envelope is financed by a subsidy from the Operational Programme EU Cohesion 2007-2013 and the resources of building owners (about 28%).

[131] European Commission (2012), *Directive 2012/27/EU of the European Parliament and of the Council of 25th October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC (Texts with EEA relevance)*, available at: http://eur-lex.europa.eu/legal-content/HR/ALL/?uri=celex:32012L0027 [2012]

- Poland - TM programme (Thermo-Modernization) provides a subsidy of 20% for commercial loans. Subsidies are provided from the state budget and managed by the state commercial bank (BGK). The programme is designed for all sectors, but 90% of projects were completed in the housing sector. Commercial loans are disbursed through 16 banks in which the client submits an energy overview showing the project's feasibility and a unique application for a loan and subsidies;
- Graz, Austria - integrated energy contracting included the application of 3 ESCO service mechanisms: energy savings contract on replacing cogeneration plant boilers; energy performance contracting for mechanical ventilation equipment and system with heat recovery; energy savings contract based on renewable energy sources for solar thermal systems. ESCO services provided 75% of the co-funding. The model was implemented to a public building under the architectural heritage protection. Delivered energy savings amounted to 15% and savings in emissions of CO_2 to 35%.

We have already mentioned that the majority of MSs attempt to involve private funding in the energy renovation of public buildings. Past experience shows the lack of profitability of integrated building reconstruction projects, notably by investing in the external building envelope, which discourages potential private investors. In very rare cases it shall be possible to carry out integrated building renovation using only one funding source - energy service providers . Due to a possible market expansion, the energy service providers have been presented with additional financing methods such as co-funding and subsidies with a view to ensuring project cost-effectiveness. According to available data, only Croatia, Lithuania and Slovenia opted for a programme of public building renovation based exclusively or predominantly on the ESCO model. In other MMs, the ESCO model is one of the instruments most commonly implemented at the local or regional level, although it is considered to become introduced as the dominant model. For this reason, as well as the aforementioned unprofitability, sample programmes of integrated renovation are smaller in volume and in number. From EU practices, the following can be concluded[132]:

- The ESCO model is used in partial renovation of buildings. The stated is left to the owners, regional or local government units, to develop or choose. In high-quality contract development and transfer of necessary risks onto the service provider, the model is not considered a debt. The vast majority concerns individual projects carried out in most MSs (Germany, Poland, Czech Republic, Slovenia, Slovakia, etc.). The experience of the ESCO model in developed markets such as Italy showed a significant penetration of energy services in public buildings in partial renovation (HVAC systems, energy source change);
- In a complete renovation of residential buildings, sources of funding without subsidies such as ESCO models, classic debt or revolving funds are implemented relatively successfully. It turns out that, primarily because of high energy consumption, market profitability is found in integrated renovation of residential buildings, which includes private capital. These models were noted in countries with exceptionally high heating energy consumption, especially due to climatic specifics (e.g. Latvia);
- In a complete renovation of public non-residential buildings, there are rare cases where funding was covered by the ESCO model without co-funding. First of all, this depends on the prices of energy, type of energy consumed, how the building is used and the existing technology (including the external envelope). The examples include individual buildings, without the possibility of replication onto a larger sample. In order to expand the model, subsidies ensuring profitability to private investors were introduced.

The saving of heating and cooling energy in the residential building stock of the Republic of Croatia is of great importance for the following reasons:

- reduction of carbon dioxide emissions (CO_2) in the atmosphere;
- security of supply - reduction of a country's dependence on imported energy;
- saving money for the supply of energy-generating products on the side of the supplier (country, company);
- prevention of energy poverty - reduction of energy costs on the user/consumer side (households, population).

This importance has been recognized in the EU, where there are already significant experiences with the energy renovation of residential buildings. Table 4.2 shows energy renovation measures for multi-residential buildings

[132]Source: Programme of Energy Renovation of Public Buildings 2016 -2020

in the EU region, which includes the Czech Republic, Hungary, Slovakia, and Slovenia. This region's climate is the most similar to Croatia, albeit with significant climatic differences compared to Croatia (Adriatic region). In these countries, there are about 3 million apartments in multi-residential buildings, or around 27% of apartments in the region, which in theory represents about 50,000 buildings. The possibility of saving heat energy with construction measures was estimated at about 64%, or about 75%, if the effect of installing thermostatic valves on the heating elements is included. The simple time of recovering the invested funds is 8.6 years. The total potential for energy savings in multi-residential buildings is about 39%, or 2.5% of the direct energy demand in the region, or 4 Mt of CO_2. The particularity of the mentioned region of the EU is the greatest possibility of saving energy compared to other regions. The buildings are predominantly made of prefabricated large concrete walls, with flat concrete roofs and floors and double-glazed windows in wooden frames. The buildings are mainly connected to the district heating network, with the possibility of installing thermostatic valves and balancing.

Table 4.2 Energy Renovation of Multi-residential Buildings, International Energy Agency - IEA/AIE, Table no. 10, from the publication "High rise refurbishment"

Size / Element	U – value before renovation (W/m²°C)	U – value after renovation (W/m²°C)	Energy saved annually (kWh/m²)		Annual investment cost (€/m²)	Cost of conserved energy (€cent/kWh)	Simple payback time (years)
Walls	1.20	0.30	50.1	33.1%	0.92	1.5	8.7
Roof	2.17	0.24	21.7	12.0%	0.15	0.7	3.8
Floor	1.10	0.45	7.3	4.0%	0.13	1.7	9.9
Windows	2.90	1.70	26.7	14.7%	0.71	2.7	15.2
Package	1.63	0.59	115.8	63.8%	1.91	1.6	9.3
Thermostatic valves			54.5	30.0%	0.19	0.3	1.6
All of the above combined			135.5	74.7%	2.10	1.5	8.6

Source: Programme of Renovation of Multi-Residential Buildings

At the EU level, where residential buildings represent 75% of the total building stock, several structure scenarios and intensity of the implementation of the energy renovation of the total residential and other building stock are elaborated. In the event of a complete energy renovation, annual energy savings in 2020 are estimated at 527 TWh, or 13% in relation to direct energy consumption in 2011. Building energy renovation investments would amount to € 477 billion under this plan, while cash savings would amount to € 487 billion. Annual CO_2 emission reduction would amount to 161 Mt. in 2020. By implementing the energy renovation programme, a total of 1.2 million jobs would be created by the EU-wide complete renovation scenario annually. By launching the Programme of Renovation of Multi-Residential Buildings and Family Houses, buildings will fall into two groups - renovated and non-renovated. The first of these will have a higher market price, which means a rise in real estate prices. But even though the Programme of Renovation implies an initial rise in real estate prices, according to the microeconomic theory, as the supply of renovated real estate increases, their price will decrease, but in any case will always be higher than the price of non-renovated real estate. Experience from EU countries, for example Ireland, shows that the difference in the price of real estate with energy grade A/B and F/G is 16%[133]. This is an additional effect of the Programme of Renovation, as it is an incentive for building owners to invest in renovation, because they will be able to achieve a better price by selling/renting.

~~*Text taken from the Programme of Renovation of Public Buildings, Multi-Residential Buildings and Family Houses*~~

[133]The survey was conducted in Ireland in 2012 on a sample of 20,000 real-estate properties, available at: http://www.arhitekti-hka.hr/fi les/fi le/pdf/2013/ZET/PLANETARIS-HKA-2013-05-14.pdf This link is not available online any more !!!

4.3 Analysis of existing obstacles for integrated energy renovation of buildings

The existing obstacles to integrated energy renovation of buildings are numerous and can generally be divided into 4 main categories shown in the following figure (Figure 4.1).

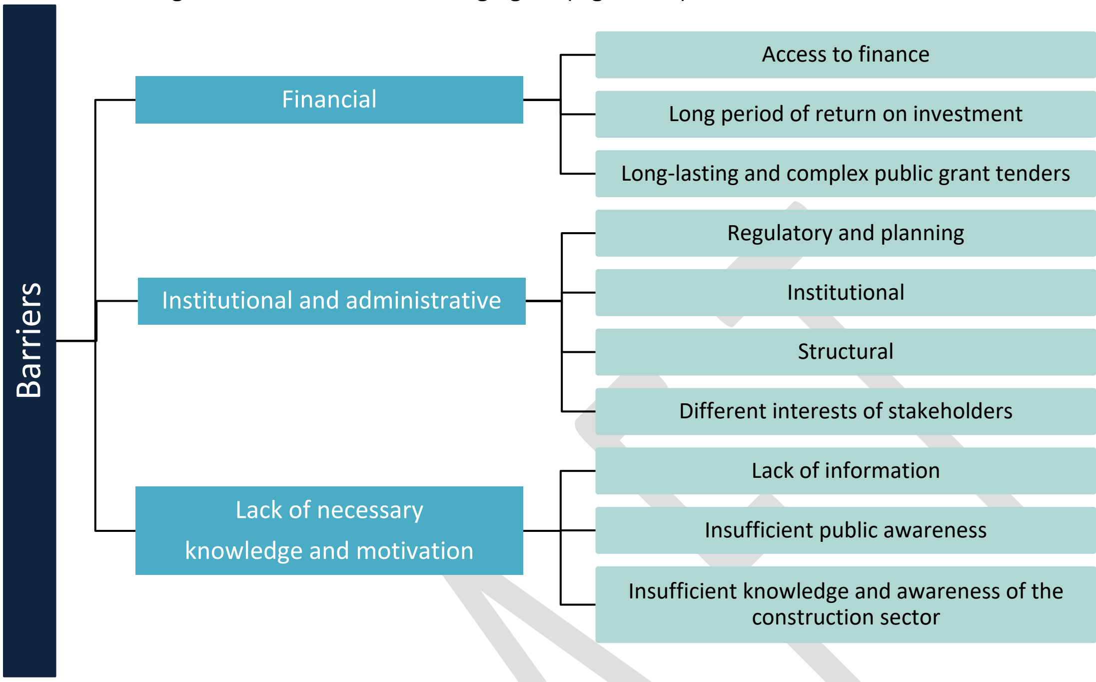

Figure 4.1 The main categories of existing obstacles to integrated energy renovation of the national building stock of the Republic of Croatia[134]

Overall, it can be concluded that the main obstacles to the renovation of the Croatian national building stock are financial in nature,[135] but also that the integrated energy renovation of buildings is also largely hampered by a lack of information and motivation on the part of investors, the public and stakeholders. Directive 2012/27/EU[136] requires support in developing the energy services market, development of new financial mechanisms and incentives as well as institutional, financial and legal frameworks to remove existing market obstacles and shortcomings preventing efficient end-use of energy. Consequently, this chapter identifies the legal, financial, and organizational obstacles to wider implementation of energy efficiency improvement measures.

By joining the European Union, Croatia has assumed the obligation to fully align the relevant national legislation with EU directives, but given the complexity of the task, it is clear that full harmonization will require time and professional knowledge. Until the moment of full Croatian compliance with the EU legislation, investing in the integrated renovation of the national building stock represents a risk for all interested parties: from investors, through financial institutions, to owners or users of buildings.

Existing Croatian legislation is satisfactory in the part related to technical guidelines and requirements for energy renovation of buildings and does not constitute an obstacle in the technical sense, but there is a lack of regulation that would commit to the energy renovation of existing buildings with the mandatory use of the optimal renewable energy source for heating and cooling where it is technically feasible and economically viable. At this point, only the obligation to carry out energy audits and the production and presentation of energy certificates is regulated.

The major economic crisis in Croatia has resulted in a significant reduction in investment capacity for investment in all branches of the economy, as well as in the construction sector in the section related to the renovation of

[134] Building Performance Institute Europe - BPIE: Europe's Buildings under the Microscope, October 2011
[135] More on financial barriers and limitations in Chapter 5.2.2
[136] European Commission (2012), *Directive 2012/27/EU of the European Parliament and of the Council of 25th October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC (Texts with EEA relevance)*, available at: http://eur-lex.europa.eu/legal-content/HR/ALL/?uri=celex:32012L0027 [2012]

existing buildings, which is largely dependent on economic indicators at the national level. Since the beginning of the economic crisis in 2009, the Croatian economy recorded a steady decline and renovation of all types of buildings has been steadily declining. An important indicator of movement in the construction sector is the index of the physical volume of construction works based on the working hours of construction workers according to the Methodology for short-term business statistics. According to the data of the Croatian Bureau of Statistics, the index of the physical volume of construction works recorded a steady growth until 2008 and declined until 2014. Since the recovery of the construction sector in Croatia was preceded by the recovery of the entire real sector (consequently the labour market as well), it is realistic to expect a continuation of the trend of positive moves that will significantly contribute to its further recovery, especially in the light of capital investment.

If a rather long period of investment return on renovation, insufficient financial incentives, and a lack of successful financial models are added to the generally bad financial situation in Croatia, the financial barriers are even stronger. Lack of strong incentive systems and insufficient preparation of financial institutions for lending for energy renovation of buildings further slow down the whole process. And to a large extent, the socially-determined price of energy-generating products in Croatia is destimulating the implementation of energy efficiency measures, primarily those with a relatively long investment return period. The expected increase in energy prices will make energy renovation more financially viable, and this barrier will decrease over time.

The next barrier which is taken into account is partially information, education, and participation of the public in making important decisions on the renovation of buildings. Insufficient awareness of the positive effects for every individual and the society as a whole which the integrated renovation of the entire national building stocks certainly brings results in insufficient motivation and often undesirable increase in risk that further blocks potential investors. Furthermore, unlike public buildings, where ownership relationships are relatively simple, the ownership relations of multi-residential buildings are extremely complex, because renovation investment decisions related to the amount of investment require a minimum of 51% of tenants.

The precondition for a successful start and implementation of the integrated energy renovation of the National buildings stock is a good development of the market for construction and energy services, and a sufficient number of experienced companies specializing in the implementation of integrated energy renovation involving mechanical, energetic, and construction elements of a building and requires an interdisciplinary approach. The crisis in the Croatian construction and energy sector resulting in the shutdown or bankruptcy of a large number of companies has further strengthened the existing barrier of inadequate capacity, knowledge, abilities, and skills to successfully implement the complex task of integrated building renovation.

An important barrier to successful implementation of integrated renovation of buildings are also the demographic and migration trends, as well as changes in housing culture and living habits. Integrated building renovation is a complex process with a large number of participants interrelated by different interests and objectives that make another in a series of barriers to successful implementation. Unresolved property and legal relations and property ownership status are the next obstacle in deciding on energy renovation.

A typical obstacle to the process of energy renovation of public buildings is the public procurement process, which is always time consuming, and in many cases unsatisfactory. The procurement processes that have been implemented so far based on the most financially favourable selection criteria for the contractor simply did not yield good results. Such contractual relationships do not guarantee the quality, respecting the construction deadlines or the long-term guarantee for the works carried out. Over the next few years, in the field of contracting public works, the application of the most economically advantageous tender model should also apply criteria such as the so-called " Design and Build[137] or ESCO or JPP model[138] of realization with mandatory bid

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[137]The Design and Build (D&B) Contract requires the most economically viable offer, which will also guarantee a functional construction and reduce the overall cost of living through its design. This model implies a "turnkey" project. The public partner announces the tender, and the money is issued to the private partner only upon the project completion at the completed stages and the largest part. The cost risk and quality risk is transferred to the private partner, while funding and funding costs are defrayed by the public partner.

[138]In the Energy Performance Contract, the public partner announces a tender, the private partner applies to it and wins it in the case (as with the D&B model) it guarantees the most economically viable conditions in terms of reducing overall living costs based on planned energy savings. However, in this model, the private partner receives the first payment only after the reconstruction project has been carried out, more specifically on a monthly basis during the next ten years (depending on how amount of the contract signed), only if the project demonstrates the realization of planned energy savings or if the

selection criteria such as the Whole Life Cycle Cost , achieving guaranteed savings and guarantees for the performed works.

In the Programme of Energy Renovation of Public Buildings 2014-2015, according to the ESCO model, value added tax calculation has not been clearly resolved. Namely, the provisions of Article 26, paragraph 7 of the Energy Efficiency Act stipulates that for services, works, and goods under the energy performance contract, the value added tax liability is repaid over a period of ten years after energy renovation has been completed. However, Article 30 Paragraph 1 of the Value Added Tax Act stipulates that the taxable event and obligation to calculate value added tax arises when the goods are delivered or services performed. It is apparent from the above-mentioned that the provisions of the Energy Efficiency Act stipulating payment of value added tax obligations over a period of ten years are not in accordance with the provisions of the Value Added Tax Act, but the fact is that the provisions of these laws are simultaneously in force.

Pursuant to the Budget Act, units of local and regional government may be borrowed by taking out loans and issuing securities. The total annual commitment of the units of local and regional government can amount to up to 20% of the realized income in the year preceding the year in which they are debited. However, this provision does not apply to projects co-financed by pre-accession programmes and EU funds, and energy efficiency improvement projects involving local and regional government units, as well as tax and accounting treatment of energy performance contracts that is not transparent enough in the Republic of Croatia. From the previously analyzed obstacles, there is a need to finalize the standard energy performance contract, which is the basis for establishing a sustainable model and removing important barriers to implementation. As the terms of the agreement in the implementation of the public procurement procedure are defined by the bidding documents, the drafting of the standard contract facilitates the implementation of the public procurement procedure itself and reduces the administrative burden. Public procurement documentation should include, in addition to the usual parts and the technical background described above, the standard energy performance contract and the rules for action on verification of savings and/or building energy renovation project, and the selection criteria must be predictable, transparent, and non-discriminatory.

In practice, there is a problem of different interpretations of the scope of public-private partnerships in relation to the energy performance contract. The clear delineation of these two institutes is a prerequisite for public sector security, which has often received contradictory instructions regarding the contracting or application of these two models. Although there are different types of partnerships between public and private entities, there is no doubt that a great deal of influence in this area lies with an understanding of some important general terms and their proper use in practice. The term public-private partnership is understood in the broadest possible sense, i.e. as any "contractual or legally regulated relationship between public and private entities aimed at enhancing and/or expanding infrastructure services." In such a definition, a PPP in the sense of the Public Private Partnership Act (Official Gazette, nos 78/12 and 152/14) is only one of the emerging forms of public-private partnership, specific to Croatian legislation.

Starting from such a definition, energy services could be characterised as a public-private partnership solely in the situation when maintenance services are provided during the implementation of the energy service. The distinction between the public-private partnership and energy services models in accordance with the Public Private Partnership Act is most clearly manifested in three elements that define it:

I. Definition of a Public Private Partnership Project
II. Obligation to establish a special purpose company
III. The right of construction or concession as a mandatory part of the public-private partnership contract.

Pursuant to the applicable public debt and deficit rules, i.e. the European Accounting Standard, a key feature of a PPP is that, in the case of renovation of an existing building, the private partner investment must amount to more than 50% of the final market value of the building after renovation. If such level of investment is not achieved, such a contract is not a PPP contract. As the energy performance contract never achieves such amounts for existing buildings, this rule sets out a clear delimitation of energy performance contracts and public-private partnership contracts.

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energy service delivered and other standards are in accordance with agreed terms. In the event that this does not occur, the private partner bears the risk and receives a lower fee than agreed, since obviously the job was not performed as contracted.

The following analysis shows the following:

- A public-private partnership agreement deals with investments in which new real estate is created for the purpose of providing public services, or investments exceed 50% of the final value of the building after renovation;
- The energy performance contract shall renovate buildings for which no change in use and/or intensity of use is planned, in view of achieving energy savings at least equal to the value of the payment of the fee payable to the energy service provider under such contract.

The economic crisis that has affected Croatia since 2008 has been a significant impact on the emergence of a greater number of financial constraints for the implementation of energy efficiency measures in public buildings. It has caused general market uncertainty, postponing many projects and investments, and discouraging potential customers.

According to the Ministry of Finance data on Budget Execution of LRGUs for the period 2010 - 2014, interest payments on received loans at the level of all considered LRGUs increased by 64% over the four-year period. The above data shows one of the main obstacles to the implementation of energy renovation of public buildings, which is a lack of financial resources and creditworthiness. This problem arises especially when the building is not suitable for renovation using the ESCO model. Despite the share of grants in public building energy renovation projects, some LRGUs are unable to secure the remaining part of the required investment. Potential providers of energy services are companies in the construction sector, and they are already overburdened by indebtedness and inadequate revenues due to unfavorable economic trends in recent years. Both factors limit their credit standing, especially for the need to raise recurrent long-term loans. On the other hand, a low-income level ensures a limited amount of own resources. Banks in the Republic of Croatia do not show sufficient interest in funding projects on the principle of contracting energy performance. There are several reasons for this:

- credit insolvency of a large number of potential energy service providers;
- insufficient number of guarantees;
- high cost of capital in the Republic of Croatia.

Due to the low credit rating of the Republic of Croatia, the cost of capital is extremely high. In addition, the bank assess the level of risk separately for the energy service provider or client. Banks are not ready for long-term funding of a client who fully takes on the risk in the project. Therefore, banks seek additional guarantees such as pledged rights related to real estate. Interest rates are high, both because of country risk as well as client risk. According to the experiences from the Programme of Energy Renovation of Public Buildings 2014 - 2015, the guarantee system issued by HAMAG BICRO did not survive. There are no financial instruments available on the Croatian market for energy renovation of the entire public building potential. That is why this Strategy, along with the already prepared Programme documents of building energy renovation, aims to define the necessary financial instruments to achieve the renovation objective.

The category of buildings for which the implementation of energy renovation is an even more complex process are buildings are entered in the Register of Cultural Goods of the Ministry of Culture. In the Republic of Croatia, there are 6,207 individual real estate cultural goods and groups of cultural goods registered in the Register of Cultural Goods, which are permanently and preventively protected. With an assumed average floor area of 1000 ^{m2}, there is currently about 6.2 million m^2 of protected building areas in Croatia, which makes up almost 3% of the total floor area of the national building stock.

The impact of various obstacles to the integrated renovation process of the national stock of public buildings of the Republic of Croatia is not identical, and in view of determining the potential risks, some identified obstacles depending on impact will be divided into obstacles of great, medium, and small impact. The obstacles which have an impact on the process of integrated building renovation are the following:

- lack of strong financial incentives for energy renovation of buildings;
- lack of developed and tested financial models for investing in energy renovation of buildings;
- insufficient preparation of financial institutions for loans (e.g. on project funding) for the purpose of stimulating ESCO markets;
- the lack of regulation which obliges the application of the selection criteria based on the lowest total cost of living for the building, the achievement of guaranteed savings by means of renovation measures and guarantees on performed works and contracted standards.

The following barriers have a mid-range impact on the integrated building renovation process:

- insufficient development of the energy services market, primarily through the insufficient number of companies specializing in providing complete building renovation services and a lack of financial resources;
- insufficient information, education, and participation of the public in making important decisions on the renovation of buildings;
- socially dictated energy prices.

The following obstacles have a small, but not negligible impact on the implementation of integrated building renovation:

- the complexity of the process of initiating and implementing the process;
- the necessity of an individual and multidisciplinary approach to each building;
- unresolved property and legal relations;
- additional complexity of the procedure for renovation of buildings entered in the Register of Cultural Goods of the Ministry of Culture.

In existing multi-residential buildings and family houses, the existing Programmes focus exclusively on the heating needs of buildings, i.e. energy efficiency measures aimed at reducing energy consumption for heating and DHW preparation. Regarding other energy needs, especially household appliances and interior lighting, further development of standards and regulations in this area (e.g. prohibition of the sale of light sources with wire filament, stricter regulations for energy efficiency classes etc.) is already yielding visible results on the market and usually require smaller investment costs than the renovation measures proposed by the Programmes and are a prerequisite for integrated renovation.

4.4 Proposals for solutions and new measures to overcome the existing obstacles

Identification of effective measures to encourage cost-effective integrated renovation of the national stock of the Republic of Croatia will be based on a plan of possible targets and indicators for the period up to 2050 according to the Energy Roadmap 2050 of the European Parliament passed in January 2013[139] (Table 4.3).

Table 4.3 Long-term Plan for the Integrated Renovation of the National Building Stock by 2050[140](Energy Roadmap 2050)

Target year	Target
2050	Reduction of greenhouse gas emissions in buildings by 80% All buildings are almost zero energy buildings or with a high level of energy efficiency
2040	65% of buildings are nearly zero energy buildings or with a high level of energy efficiency Around 3.5% of the buildings is renovated annually 4% of historical buildings or buildings of cultural significance are renovated annually 95% of users are aware of the positive effects of integrated building renovation
2030	30% of the building has been renovated to the level of nearly zero-energy and high energy efficiency properties Around 3.5% of the buildings is renovated annually Prepared regulations for requirements that all building properties be at a high energy efficient level as a condition for sale or lease. Full renovation fully developed with optimized costs Construction companies with a certificate for renovation and with workers educated for carrying out works in the energy renovation of buildings. 50% of users are aware of the benefits of renovation Developed techniques for renovation of historic and buildings of cultural significance
2025	15% of the building has been renovated to the level of nearly zero-energy and with high energy efficiency properties Around 3% of the buildings is renovated annually Developed renovation techniques for all types of buildings 20% of users are aware of the benefits of renovation Techniques for renovation of historic and buildings of cultural significance are being developed 50% of contractors have a certificate for energy renovation of zero energy buildings and 50% of workers that are trained for performing such works The government provides support to banks in lending the full renovation for socially vulnerable groups User education on the benefits of renovation is provided
2020	5% of the building has been renovated to the level of nearly zero-energy and high energy efficiency properties About 1% of the building is renovated annually to the level of zero-energy buildings Renovation techniques for most types of buildings are developed Complete renovation technique developed 20% of contractors have a certificate for energy renovation of zero energy buildings and 20% of workers that are trained for performing such works The government provides a budget for the renovation of public buildings and provides incentives for the renovation of buildings of social character. User education is carried out by energy agencies etc. Prepared educational materials for the implementation of training in schools and faculties
2017	Renovation techniques for most types of buildings are developed 5% of contractors have been certified for energy renovation of zero energy buildings and 5% of employees are trained for performing such works Universities and schools have introduced energy renovation into the curriculum The government prepared funding plans for the renovation of public buildings and social housing The government supports research and presentation of energy renovation The government supports the education of workers in carrying out renovation
2015	Materials for renovation of the existing building stock completely prepared Agreement on the level of required building properties that the renovated buildings should reach in 2050 and the strategy of how to achieve it Overview of the complete renovation techniques including application to different types of buildings A complete renovation technique has been developed for most types of buildings Materials for education prepared Government support for renovation research

Croatia's national policy on the integrated renovation of the national building stock to achieve the objectives set in accordance with the provisions of the EU directive should cover six categories of measures[141]:

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

[139]Energy Roadmap 2050. Luxembourg: Publications Office of the European Union, 2012, available at: http://ec.europa.eu/energy/sites/ener/files/documents/2012_energy_roadmap_2050_en_0.pdf [19th May 2017]
[140]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
[141]A guide to developing strategies for building energy renovation, BPIE, February 2013

In accordance with the conclusions and recommendations of the EU Build Upon project,[142] this Strategy is harmonized in the part of the recommendations for improving the legislative framework (legislation), a part related to innovative funding mechanisms, a part related to ensuring the necessary knowledge and skills, and communication aspects for promotion and informing the wider public.

Strategic measures of integrated renovation of the national building stock include:
- establishing the support of the entire political spectrum of the Republic of Croatia for the integrated renovation of the national building stock;
- establishing a broad network of stakeholders as a basis for the successful implementation of the building renovation plan;
- establishing an independent commission to monitor and report on progress on a permanent basis, including timely constructive suggestions for improvement;
- carrying out a systematic assessment of the obstacles to successful implementation of the integrated renovation of the national building stock and to develop individual solutions for the removal of each of them;
- setting the target for reducing energy poverty of the Croatian population by improving energy efficiency of the housing sector;
- setting objectives for integration of various sectors: sustainable urbanism, sustainable construction, local energy resources etc.;
- providing a good example through successful renovation of non-commercial public buildings and encouraging the renovation of other types of buildings from the national stock.

Legislative measures for successful renovation of the national building stock are the following:
- identifying the most effective legislative mechanisms that would result in the improvement of energy efficiency of buildings (energy certification, boiler room inspection, stricter technical standards etc.);
- using legislature to mandate the use of renewable energy sources and implementing energy efficiency measures in existing buildings;
- amending or abolishing restrictive legislative acts that will discourage the improvement of energy efficiency in buildings (Decree on building maintenance[143], etc.);
- using legislation to mandate improving buildings with poor energy characteristics (e.g. introducing various restrictions and restrictions on the sale and renting of buildings with an energy class worse than D).

Technical measures should include the following:
- continuously aligning technical standards with the new technological solutions available on the market;
- analyzing and applying centralized heating systems for heating and cooling buildings to the fullest extent;
- building regional biomass heating systems;
- ensuring adequate control of compliance with construction regulations and the implementation of penal provisions in case of non-compliance;
- developing standard solutions for easy application in buildings of the same purpose;
- introducing mandatory certification of the quality of installation services and products.

Financial measures for the integrated renovation of buildings include the following:
- Development of financial instruments;
- Granting method;

In order for the financial institutions to keep track of energy service providers, it is necessary to develop financial instruments in accordance with the rules for the use of ESI Funds with a specific purpose for energy service providers. The development of financial instruments in the context of this Strategy should also create conditions for the development of the energy services market, including via the PPP model, i.e. the development of markets among private entities wishing to operate on the principles of providing energy services. In the case of financial instruments, it is possible to offer products that will first and foremost facilitate access to funding to all entities implementing projects following the energy service model and then stimulate market development by removing

[142]EU project BUILD UPON, available at: http://buildupon.eu/hr/
[143]Regulation on Building Maintenance, Zagreb OG 64/1997 (1002), available on http://narodne-novine.nn.hr/clanci/sluzbeni/1997_06_64_1002.html

specific obstacles stemming from the energy service model itself and reducing the problem of undercapitalization (which is the systemic problem of the economy as a whole, and especially expressed by ESCO companies due to capital intensity and the specific problem of the model as such). Given the specifics of the financial instruments, it is possible to achieve the following objectives: to provide access to funding of EE projects to encourage the development of ESCO markets through specific products to reduce the cost of funding for EE projects. There are three basic instruments:

a) a guarantee instrument;
b) equity instrument;
c) credit line.

The co-funding model should be adjusted in such a way as to grant the aid directly to the service provider without the intermediary role of e.g. APN, so that the risk of subsidizing is borne by the energy service provider, which does not affect the obligations under the energy performance contract.

Communication and capacity building measures include the following:

- Establishing publicly accessible databases with examples of good practice and all necessary data for launching and implementing energy renovation projects;
- initiating and continuously implementing educational programmes for all categories of workers in the building sector;
- Establishing good communication channels for the exchange of knowledge and experience between different levels of administration (national, regional, county, local);
- continuously carrying out promotional-educational activities for different target groups with emphasis on the positive effects of energy renovation of buildings;
- continuously informing stakeholders and the public about the implementation of this Strategy.

Research and development measures are based on the support for research and development of new technologies, techniques, materials, and components for cost-optimal integrated renovation of buildings.

Concrete examples of possible measures are described in more detail below.

Models and incentives

The Description of Social Benefits (Chapter 6) defines the framework for modeling and incentives that will mobilize investors on the demand side, and the construction industry on the supply side. The gap between what was planned and what was realized in the first years of implementation of the Strategy shows that incentive models were not aligned in ways that would contribute to the targeted mobilization of investment demand and supply.

Conceiving optimum incentives goes beyond the scope of this document, which briefly describes the principles and possible tools for designing the incentive model. Among the funding sources of the model are the EU funds (whose allocation for the purpose of meeting the objectives of the Strategy should be increased if possible), expected benefits for general government budgets, which justify the use of publicly financed incentives and new financial instruments. Concrete incentive models must be pre-tested on microeconomic models in order to achieve the maximum impact ratio in the form of new investments towards resource reallocation in construction.

Grant Scheme

By using a grant scheme, it is possible (and necessary) to achieve the following objectives:

- encourage end recipients to develop technical backgrounds necessary for the implementation of energy renovation projects with the aim of developing energy efficiency renovation projects ready for execution;
- Encourage investment in energy efficiency technologies that have not yet been proven on the domestic market, with the aim of early exploitation of numerous innovations in the market;
- subsidize projects whose cost-effectiveness is below the margin level of market interest;
- encourage the market to invest in energy efficiency measures which achieve a technical standard higher than the minimum required;
- subsidizing ESCO projects by co-funding the fee (PPP or EPC) over the duration of the contractual relationship.

Bearing in mind the above objectives, as well as the practical needs and disadvantages set out in this Strategy, the grant scheme should be formed in such a way as to encourage:

- investing in technical documentation;
- investing in innovative technologies;
- investing in projects below marketable levels of profitability, but that achieve high economic benefits for the community;
- investing in measures that achieve higher levels of technical standards.

The grant scheme, under (a), would finance the development of technical and economic documentation which will clearly show the feasibility of investing in a possible energy renovation project. Given that the implementation of the Energy renovation project depends on findings and conclusions from the relevant documentation, in this case a high proportion of co-funding is recommended in order to encourage end-beneficiaries to take risks and invest their own co-funding. For private sector projects, this may be co-funding of an investment study, a main and a performance project, detailed energy audits, PPP cost comparators, cost and benefit analysis, etc.

Grant schemes under (b), would approve grants exclusively to the private sector for the use of equipment not previously used in the market. This would encourage end-users to take the risk of investing in equipment that is not widely applied in the market, which indirectly promotes technical innovation in the area of energy efficiency.

Grant schemes under (c) would approve grants for measures or projects aimed at achieving a higher level of technical standard. Given a number of external factors, an investment above a certain level of a technical standard has no economic justification, but what is actually paid is the price of achieving a non-economic objective (e.g. the development of the energy services market, employment, reduction of CO_2 emissions). This kind of grant scheme would encourage those end recipients who are willing to pay that price.

Finally, the grant scheme under (d) promotes investment in non-marketable projects. Within the context of this Strategy, non-marketable projects are those projects which, under available funding conditions, offer the investor a Return on Equity (ROE) which below the level available on the market. The logic is, that in case of insufficient return to own investment into an energy efficiency project, a rational entity will engage their own capital somewhere else, therefore this investment should be encouraged in such a way that projects that are below acceptable levels of return on own investment under this scheme of allocation of grants be granted aid that will compensate for the necessary difference.

Tax incentives

Investment tax incentives are most commonly introduced within the income tax system. However, the system of taxation of income in an indebted country such as Croatia must be as clear and simple as possible, and the incentives must be, if possible, omitted or exceptional and, if any, associated with more important social objectives. However, real estate tax could be a useful source for new incentives. Considering the multiple public benefits of sustainable renovation of buildings, real estate taxation should provide for tax incentives for property owners who invest in renovation and achieve targeted building and energy standards. Such incentives can be returned several times over through the shown return effects of boosted economic activity on public revenue. Another important source of potential incentives is real estate sales tax. In the tax reform of 2017, the real estate sales tax has been symbolically reduced from 5% to 4%, which still makes it a potentially generous source of incentives. Because of the aging population, energy poverty of the elderly and their inability to ensure necessary investments, there is a threat of further long-term decline in the value of poorly maintained real estate. Therefore, the transfer of real estate from the hands of older people, who cannot maintain them, into the hands of younger people who will be able to invest in renovation makes it necessary and mutually and socially useful. By moving into cheaper real estate, older people obtain funds equal to the difference in real estate prices, which can significantly improve the standard of living in old age or allow for renovation of some less valuable real estate, while younger people can relatively cheaply obtain real estate at better locations in whose renovation they can invest and whose values will therefore increase. Therefore, the abolition of real estate sales tax or its return when the new owner invests in the renovation of the building according to the target standard is an important instrument in encouraging the optimal allocation of the real estate fund to people who will be able to maintain it and increase its value.

Stimulated housing savings system

Although incentives for housing savings were abolished in 2014 due to excessive deficit and public debt, they were subsequently returned. Housing savings institutions are trying to find survival modalities. People investing in housing saving still believe in the possibility of return on some form of incentive, as evidenced by some 500 000 open savings accounts. An important fact is that almost half of all loans granted in housing savings institutions are intended for adaptations and renovations[144], which speaks of the great need for citizens to finance the renovation of apartments and buildings. Incentivized housing savings is a highly customizable financial instrument, suitable for conducting sector policy in construction. By introducing differentiated incentives, the preferred purpose of savings or raising loans can be encouraged, which in this case refers to certain types of sustainable renovation of housing units. Housing savings institutions are the only credit institutions that, while savings are government-sponsored, can offer long-term loans with a fixed interest rate fixed over the entire lifetime of the loan repayment. This manner achieves a major contribution to the realization of the indirect objective of financial stability and stress-free repayment. Therefore, it is necessary to consider the return of differentiated incentives for housing savings, related to the funding of sustainable renovation of buildings. Dedicated differentiated incentives need to be followed by regulatory reform that would allow collective bargaining of owners' savings in multi-residential buildings.

Special funding programmes that include the possibility of using EU non-refundable funds

[144]Institute of Public Finance (2013): *Analysis of the System of Subsidised Housing Savings in the Republic of Croatia.* Zagreb: Institute of Public Finance, available at: http://www.ijf.hr/upload/files/file/projekti/Analiza_sustava_poticanja_stambene_stednje_u_Republici_Hrvatskoj.pdf [10th May 2017]

These incentives are unlikely to be sufficient to initiate sustainable building renovation in the volume and the dynamics required by the as-is state and envisaged herein. Therefore, it is necessary to arrange special credit-guarantee financial schemes that include risk sharing and subsidizing part of the costs of preparation, design, supervision and performance, which cannot be done without engaging EU funds and budget funds. This is to examine the possibility of using innovative financial schemes such as securitization of loan portfolios and revolving funds.

5. Long-term perspective for guiding decisions of individuals, construction industry and financial institutions on investments by 2050

5.1 Estimates of required investments

Achievement of the set objectives of energy renovation of the national stock of the Republic of Croatia will require the mobilization of significant financial resources. Estimated total investment for the period 2014-2049 which includes the costs of initial investment, maintenance, and replacement of outdated equipment was made according to the selected building renovation model according to the *Technical Regulation* requirements related to large reconstruction. (Figure 5.1).

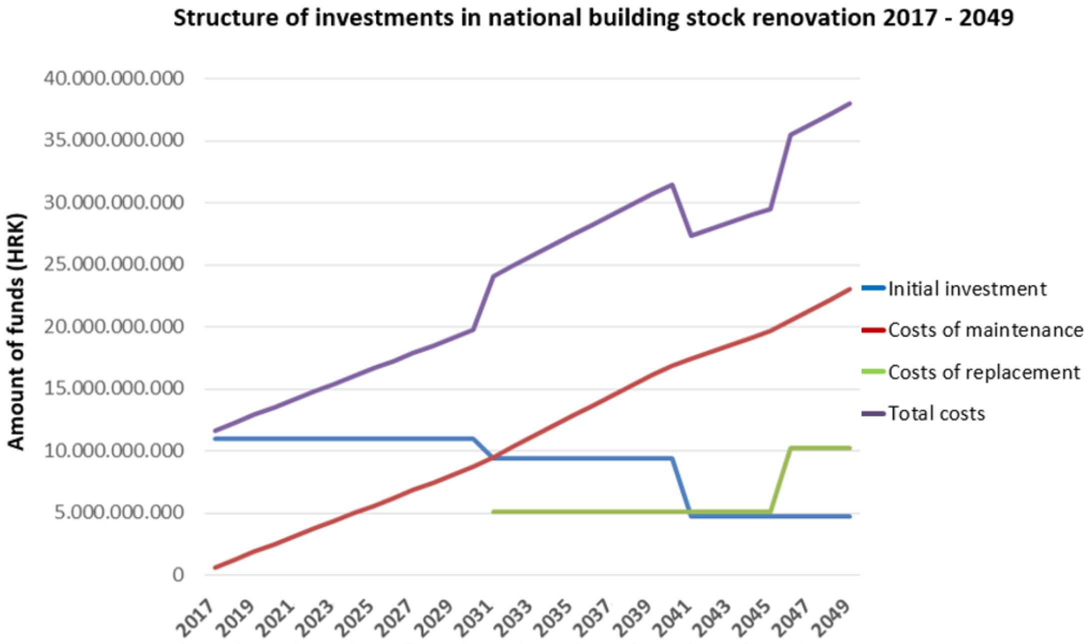


Figure 5.1 Structure of investments in the renovation of the National Stock of the Republic of Croatia

Source: *REGEA,* 2017

The total cost of initial investment and exploitation cost in the considered period are estimated at HRK 790 billion. Investment is estimated based on specific construction (reconstruction) costs according to *Technical Regulation* requirements related to large reconstruction and the total building floor area to be subjected to energy renovation. Detailed overview of investment structure by expenditure type 2017-2049 is provided in Annex 18.

The renovation dynamics of the national building stock has been developed to meet the energy saving targets set by the 4th National Energy Efficiency Action Plan of the Republic of Croatia[145] and the Energy Roadmap 2050[146]. The renovation dynamics by year is roughly assumed and not uniform throughout the period considered, and it involves several different phases:

- From 2017 to 2029, renovation will take place at 3.5% per year;
- From 2030 to 2039, the renovation rate will take place at 3.0% per year;
- From 2040 to 2049, renovation rate will be reduced to 1.5% per year;

Planned energy savings of 14,124 PJ set out in the Draft 4th National Energy Efficiency Action Plan of the Republic of Croatia 2017-2019 are achieved with this realization dynamic in practice.

[145] Draft [10th May 2017]

[146] Energy Roadmap 2050. Luxembourg: Publications Office of the European Union, 2012, available at: http://ec.europa.eu/energy/sites/ener/files/documents/2012_energy_roadmap_2050_en_0.pdf [19th May 2017]

CO_2 emission reduction targets set out in the Energy Roadmap 2050 will also be achieved with the proposed dynamics and they amount to 81.1% (min 80%). By achieving this target, a total of 91,6% of the national building stock will be renovated.

5.2 Funding source identification

Long-Term Strategy for the Energy Renovation of the National Building Stock of the Republic of Croatia requires a comprehensive and systematic approach that will provide the most appropriate funding mechanisms to public and private investors in the long run. The primary role of the state is not to provide financial resources for energy renovation, but to create and improve conditions in order to create a favourable investment climate between investors for realizing the required investments defined in the Strategy. Favourable conditions include macroeconomic stability, efficient state administration, competitive tax burden, legal certainty, market competition and the existence of appropriate financial incentives for investments. An overview of existing funding sources, limits and barriers in their implementation, and the long-term strategy for funding renovation projects in the building sector is given below.

5.2.1 Existing funding sources

Energy renovation projects in the building sector are demanding capital investments the successful implementation of which largely depends on funding sources. In the present practice, a number of different financial instruments and models have emerged, and the most significant include grants, soft loans, guarantees, tax instruments and the ESCO model.

So far, investors in Croatia have relied largely on public grants and various types of subsidized financial instruments. Longer return periods and very high investments to increase energy efficiency are the reasons why most of the EU member states introduced this form of financial aid and provided investors with a higher level of cost-effectiveness regarding the investment. Although financial institutions have developed market models with more favorable conditions to provide loans for energy efficiency projects, the role of the state in this sector remains crucial to the success of project implementation. For this reason, Ministry of Construction and Physical Planning has developed energy renovation programmes for the four building types (public, commercial, multi-residential buildings and family houses). These programmes also provide for specific funding models accompanied by existing instruments listed below (Table 5.1).

Table 5.1 Overview of existing programmes and funding instruments

National programmes and funds	
Programme of Energy Renovation of Public Buildings 2016-2020	The government programme provides for renovation implementation through MODEL III, which provides partial co-funding grants from ESI Funds, while the beneficiary, depending on their own payment possibilities, selects the optimal type of implementation from the following models: • Contracting energy services, within which ESCO undertakes to implement energy saving measures in exchange for a remuneration paid by the client from the realized savings; • Financial instrument in the form of a specialized line of credit with a favorable interest rate and delayed payment until the completion of renovation; • Funds of the EU Project Implementation Co-Funding Fund, which funds are provided by MRRFEU to co-finance the implementation of EU projects at the regional and local level; • Own funds provided in the budget of the applicant.
Programme of Energy Renovation of Family Houses 2014-2020;	• The government programme provides for co-funding of energy renovation of family houses through state budget grants (2014-2015) and the European Regional Development Fund (2016-2020).
Programme of Energy Renovation of Multi-Residential Buildings 2014-2020;	• The programme provides for co-funding of energy renovation of multi-residential buildings through grants of the European Regional Development Fund.
Programme of Energy Renovation of Commercial Non-Residential Buildings 2014-2020 with a detailed 2014-2016 plan for the energy renovation of commercial non-residential buildings	The programme provides for co-funding of energy renovation of commercial buildings from the state budget (2014-2015) and the European Regional Development Fund (2016-2020) through the following financial mechanisms: • Establishing special financial instruments by the aid of the European Regional Development Fund; • By introducing legal obligations to energy suppliers to achieve energy savings for their clients; • Continuous implementation of Environmental Protection and Energy Efficiency Fund programmes and projects.
Environmental Protection and Energy Efficiency Fund	• The Fund provides systematic technical and administrative support to the implementation of the energy renovation programme and conducts educational activities for public and private beneficiaries.
Development banks, funds and lines of credit	
Croatian Bank for Reconstruction and Development (HBOR)	• Soft loans and guarantees are offered as part of several energy efficiency improvement programmes to public and private investors.
Croatian Agency for SMEs, Innovation and Investment (HAMAG-BICRO)	• Financial instruments provide investment support through loans, guarantees with the possibility of combine them with interest rate subsidies and energy renovation of business facilities.
European development banks and funds (EIB Group, EBRD, European Energy Efficiency Fund, European Fund for Strategic Investments)	• Direct and indirect soft loans and guarantees are offered to public and private investors for large energy renovation projects.
EBRD Programme for Croatian Private Sector Support (REENOVA+)	• EBRD lending programme dedicated to citizens and entrepreneurs.
Technical Assistance Programmes	
European Technical Assistance Programmes (ELENA, JASPERS, Horizon 2020)	• Co-funding and technical support programmes for developing large projects of the public sector.

Source: *REGEA,* 2017

Looking at the currently available sources of funding, it is clear that most instruments are dedicated to public investors. The reasons thereof are provided in the obligations deriving from EU directives, which require the public sector to take a leading role in implementing energy efficiency improvement activities in the building sector. In addition to meeting the obligations undertaken by accession to the EU, the public sector serves as an example for the private sector by implementing energy building renovation and also contributes to the establishment of new financial models and the application of new technology and knowledge in the construction sector.

5.2.2 Financial barriers and restrictions

Directive 2012/27/EU[147] requires support in developing 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 of energy. Financial barriers currently hindering the development of energy renovation projects, the removal of which barriers the Strategy is to contribute to, include:

- Very limited public aid funds available;
- Lack of financial capacity and high level of public sector indebtedness;
- Tax (VAT) and statistical (EUROSTAT) treatment of energy performance contracts;
- Lack of appropriate, renewable financial instruments;
- High cost of capital due to risky perception of energy renovation projects, and lack of financial products for project funding;
- Lack of special aid programmes for energy renovation of cultural heritage buildings;
- Lack of aid instruments for large enterprises;
- A lack of tax incentives for energy renovation programmes;
- Underdeveloped ESCO market;
- Non-market-based energy prices reduce the profitability of energy efficiency projects;
- High minimum size of projects for benefiting from EU technical assistance programmes for investors from Croatia.

Currently, the existing institutions and related sources of funding in Croatia do not have sufficient financial strength to provide for the entire investment set out herein. This especially applies to limited budgetary resources of the state as well as of regional and local government units, which should be relieved by means of new and innovative funding mechanisms.

The commercial sector is guided by the principle of maximizing profits and a steady reduction in operating costs, which is why it is interested in energy efficiency in cases where investments result in significant expenditure cuts and allow the return of invested funds in a short time frame. In the context of public financial incentives, enterprises are subject to restrictions on the use of state aid, which restrictions are imposed upon EU MSs by the European Commission to prevent distortion of competition on the market by placing certain economic operators in a more favorable position[148]. To enable this sector to use public aid beyond the level of low-value aid, the Ministry of Environmental Protection and Energy plans to develop a state aid model for energy renovation of commercial buildings, which model would be consistent with state aid rules, assuming that the applicable *general block exemption regulations apply (GBER*).

Citizens are a particularly vulnerable group of end-consumers, who require the consideration of special financial models as well as promotional campaigns to raise awareness and provide information on the need and benefits of investing in the energy renovation of their homes. Energy renovation in the family house and multi-residential building sector can effectively combat the growing danger of citizen energy poverty, due to which a new Energy Poverty National Programme is under preparation.

5.2.3 Long-Term Model of Energy Renovation Funding

Lack of soft and constantly available sources of funding leads to the implementation of exclusively commercially viable projects of energy efficiency improvement in the building sector. By establishing special programmes, funds and lines of credit in co-operation with European development banks, the Republic of Croatia has recognized the importance of financial aid to investors. Lack of public sector funding due to unfavorable macroeconomic developments was a key obstacle to wider implementation of energy efficiency projects. Croatia has not had the Cohesion Policy Funds and the European Structural and Investment Funds at its disposal in the

[147] European Commission (2012), *Directive 2012/27/EU of the European Parliament and of the Council of 25th October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC (Texts with EEA relevance)*, available at: http://eur-lex.europa.eu/legal-content/HR/ALL/?uri=celex:32012L0027 [2012]

[148] 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/resource.html?uri=cellar:c382f65d-618a-4c72-9135-1e68087499fa.0006.02 / doc_3 & format = PDF [26th October 2012]

previous implementation of the energy renovation programmes,[149] which fact greatly restricted the possibilities of providing aid to investors in this sector. At the same time, the European Union imposes and allows MSs to finance their energy renovation programmes in the building sector through these instruments. This is particularly stated in Article 20 of Directive 2012/27/EU[150] which calls upon MSs to establish national funds to promote energy efficiency if there are no sufficiently strong market instruments to implement the planned targets.

In the previous multiannual financial framework (2007-2013), ESI Funds were the primary source of most national energy renovation programmes, and their role in the financial framework was further reinforced. The European Commission has set the minimum allocation of funds from the European Regional Development Fund for less developed MSs like Croatia at 12% to achieve the Thematic Objective 4 - Supporting the shift to a low-carbon economy in all sectors[151]. Through operational programmes, funding must be used to mobilize investments in the energy renovation of the public and private building stock, promote the use of RES, advanced energy networks and urban mobility. These funds represent a significant step forward and the opportunity to support the complete renovation of the national building stock, therefore the financial mechanisms of the Long-Term Strategy are largely based on the resources of the European Funds.

During the previous financial framework for the use of ESI funds, a departure from the classic instruments of grants was made in order to achieve the three objectives that were missing from the previous programmes. Long-term funding sources of the Long-Term Strategy for the Renovation of the National Stock of the Republic of Croatia is based on these targets, and their key features are:

- Financial sustainability;
- Rationality in allocating grants in view of encouraging comprehensive energy renovation projects, which realize ambitious energy savings;
- Involvement of the private sector and market mechanisms in project funding.

In addition to complying to the requirement of introducing innovative and sustainable financial instruments and taking into account the barriers identified in Chapter 5.2.2., an overview of the financial measures facilitating the implementation of the national building stock renovation up to 2050 (Table 5.2) has been prepared.

[149] Cohesion 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) relate to the three mentioned funds and to the European Agricultural Fund for Rural Development (EAFRD) and the European Maritime and Fisheries Fund

[150] European Commission (2012), *Directive 2012/27/EU of the European Parliament and of the Council of 25th October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC (Texts with EEA relevance)*, available at: http://eur-lex.europa.eu/legal-content/HR/ALL/?uri=celex:32012L0027 [2012]

[151] 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 encourage energy renovation of buildings

Financial measures	Effects on identified barriers
Establishment of financial instruments - the urban renovation fund for energy renovation projects through the funds of the European Structural and Investment Funds and development banks which would offer long-term and sustainable funding mechanisms (loans, guarantees, equity) to public and private beneficiaries	• Ensured continued availability of funds regardless of budgetary resources of the state and regional and local government units. • Involvement of commercial financial institutions and mobilization of a larger volume of private capital. • Reduction of the risk of placing funds in energy renovation projects for financial institutions. • Possibility of receiving grants to increase the profitability of ambitious and innovative projects. • Facilitated access to capital and lower funding costs for energy service providers and projects of public-private partnerships.
Further implementation of the Programme of Energy Renovation of Public Buildings	• Encouraging the development of the energy service market. • Reducing the burden on the public-sector budget by avoiding additional debt. • Engagement of financial resources and capacity of the private sector.
Establishment of a special aid programme for co-funding the energy renovation of protected cultural heritage buildings	• Encouragement of the energy renovation of cultural heritage buildings with high economic return (ERR) and low financial return (IRR).
Establishment of a special instrument for co-funding technical project preparation	• Avoidance of high project development costs. • Creation of a database of projects ready for funding and implementation.
Introduction of a legal provision which transfers the obligation to implement energy efficiency projects for large entrepreneurs to energy suppliers through a system of contributions	• Secured grant sources for large entrepreneurs who state aid is insufficient for. • Disencumberment of financial and human capacity of public institutions.
Establishment of a tax deduction system on investments in energy renovation and higher real estate tax rates for particularly inefficient buildings	• Mobilising investment in the renovation of inefficient buildings.

The optimal financial model to support the implementation of the Strategy's targets is a complex package of financial and fiscal mechanisms combining market and public instruments. At that, the state must, by its action, ensure the maximum efficiency of public fund use in a way to avoid the displacement of private investments in commercial projects by allocating grants.

5.3 Methods of making energy renovation investments more attractive to banks and private investors

The strategy aims to provide for long-term elimination of obstacles for private investment in the energy sector by providing guidance in creating a clear, unambiguous and stable legal and administrative framework which would encourage investments in building energy renovation and which would reduce the degree of uncertainty faced by private investors. It is necessary to additionally promote investments in the energy sector due to high investments, its long-term nature and outcome sensitivity in significant market price movements, in view of making these investments more attractive to investors. This can include timely informing of all relevant stakeholders on financial and legal frameworks and a broad exchange of best practice at all levels.

Financial institutions are a key stakeholder in the strategic renovation of the national building stock because the public sector has no financial strength to support the implementation of all planned measures on its own. The involvement of private investors and banks in past energy efficiency projects was minimum and limited to commercial projects. Energy renovation projects do not provide cash directly but reduce the existing costs. These financial benefits are more susceptible to technical risk and customer behavior and are the reason banks have been less inclined to finance this type of project or why they demanded high interest rates and large guarantees. Removing and bridging these risks, as well as distrust of the ESCO funding model, is a prerequisite for a more intensive involvement of financial institutions, and the state holds the mechanisms enabling thereof. Certain advances have been achieved so far by the intervention of European development banks (EBRD and EIB), which intervention established lines of credit for sustainable energy projects and strengthened the capacity of financial institutions in evaluating and structuring projects, all in cooperation with domestic development and commercial banks.

The biggest barrier for private investors, or energy service providers, is the limited access to affordable sources of funding. Lack of support from financial institutions in the form of long-term soft loans, guarantees and project funding caused a very high cost of ESCO projects and the consequent negligence of the investor to choose this model. The EU's Cohesion Policy states that most of the investments in sustainable energy projects are driven by the participation of private investors. Public aid must take on the role of complementary financial resources that will mobilize private investors' funds by making them more attractive for their involvement in funding renovation. This target can be achieved by introducing the following financial and regulatory mechanisms:

- By establishing a national revolving fund by means of redeploying resources from ESI funds, energy service providers will be enabled access to a long-term funding source at more favorable market conditions, and banks will be enabled to place resources through the fund;
- By introducing special guarantee instruments, the risk factor of private investor funds placement will be reduced;
- Subsidizing the interest rates on commercial loans will enable commercial banks to place financial funds in the energy building renovation;
- Promoting the development of the energy service market through the implementation of the Programme of Renovation of Public Buildings;
- Developing standard energy performance contract and standardized methods for measuring and verifying energy savings that will enhance the trust of users and financial institutions in the ESCO model.

In addition to interventions regarding the offer span, it is important to increase the demand for funding energy efficiency projects through promotional and information campaigns in order to increase the awareness of beneficiaries that favorable funding sources exist. Many banks in Croatia have recognized the importance of this element, which builds on the image of socially and ecologically responsible institutions in addition to the placement of funds.

6. Estimation of expected savings and other benefits based on computational and model data

6.1 Economic modeling of integrated building renovation

In the period from 2014 to 2016, no estimates of widespread social benefits have been achieved from the sustainable building renovation set out in the Long-Term Strategy for Mobilising Investment in the Renovation of the National Building Stock of the Republic of Croatia[152](hereinafter: Strategy). Lower investment amounts than expected were realized during this period. According to the Programmes of Renovation, the realized investments in 2014-2016 amounted to about 1.3 billion, versus HRK 6.6 billion, as set out in the Strategy. However, the gap between the planned and realized is largely due to a lower standard of renovation (and lower unit investment expenditures) than the smaller number of renovated buildings - square metres than initially planned. The underperformance jeopardizes the possibility of achieving the strategic objective of reducing CO_2 emissions by 80% in the building sector, as set out in the Energy Roadmap 2050[153].

Part of the underperformance can be explained by the unrealistic initial assumption on renovations according to the nZEB standard. The audit is based on the assumption of renovations according to *Technical Regulation* requirements related to large reconstruction, with total costs (net, excluding VAT) of about 1,637 HRK/m^2.

The gap between the planned and realized in the first three years of implementation of the programme was due to the absence of a comprehensive policy or measures, whose incentives would turn investments into complete energy renovation would become widely profitable. Without this condition acting on the side of demand incentives side (investor mobilization) and on the supply side (construction industry), it will not be possible to carry out a large reallocation of resources (primarily workers) to the renovation of buildings. Therefore, it should be stressed that the new estimates given below are not a realistic scenario if the model and incentive structure does not change on the demand side (investors), as well as the supply side (construction industry). The change needed to achieve the building energy renovation objectives implies a significantly higher degree of mobilization in the sense of a greater number of stronger incentives and their coordination, which includes: (a) Increasing economic incentives for investments in complete energy renovation according to *Technical Regulation* requirements related to large reconstruction, (b) Increasing economic incentives for investing of a much greater number of building owners and (c) Increasing economic incentives for entrepreneurs to acquire new knowledge, re-allocating existing and recruiting new workers on energy renovation projects.

Below is a new budget for widespread social benefits from sustainable building renovation. The new budget is based on the assumption that in 2017, there will be a large increase in investment demand and activity. The increase is associated with a significant increase in the number of buildings (m^2) which are being renovated, but also by applying the renovation according to the *Technical Regulation* requirements related to large reconstruction with an estimated net (excluding VAT) investment cost of around 1,637 HRK/m^2. In addition to these assumptions, the projected renovation rate for buildings measured in floor area by 2050 is 91.7%. It is expected that this objective will be aligned with the strategic objective of the Energy Roadmap in terms of reducing CO_2 emissions by 80% by 2050.

It is very unlikely that the 2017 target will be achieved, and the simulations in the first years of the scenario presented in this document have the nature of a reminder to social benefits that could be expected if the economic incentives were set in such a manner that the investment offer and demand meet at the level of activity of building renovation that is several times larger than the actual one. With this assumption, social benefits are shown in terms of: (a) direct and multiplier effects on GDP growth, employment and tax revenues in construction and the wider economy, (b) effects on real estate prices, (c) reduction in energy poverty and (d) other benefits, such as effects on human health, energy security and positive side effects on other important economic activities, such as tourism.

[152]Long-Term Strategy for Mobilising Investment in the Renovation of the National Building Stock of the Republic of Croatia, June 2014, Ministry of Construction and Physical Planning, available at: http://narodne-novine.nn.hr/clanci/sluzbeni/2014_06_74_1397.html

[153]Energy Roadmap 2050. Luxembourg: Publications Office of the European Union, 2012, available at: http://ec.europa.eu/energy/sites/ener/files/documents/2012_energy_roadmap_2050_en_0.pdf [19th May 2017]

The macroeconomic framework of the projections is presented below, and then the objectives of the renovation and investment plan are presented. In addition, direct and multiplier effects on GDP, employment and government budget revenues are shown. A specific chapter is devoted to the construction sector in order to draw attention to the major reallocation of resources, especially work, which must take place in the construction industry if the aim is the realization of objectives and external effects. Finally, there are other incidental external benefits and financial incentive mechanisms that can internalize some of the external benefits to increase investment incentives.

6.2 Macroeconomic framework

Population aging, emigration and structural problems limit the potential long-term rate of economic growth in Croatia. However, in the period 2014-2017, the Croatian economy showed the ability to emerge from a long recession (20092014.) without reliance on capital inflow from abroad. Foreign debt has been reduced, public debt has been reduced (from 86.7% of the GDP in 2015 to 84.2% in 2016), and real GDP growth rates of 1.6% in 2015 and 2.9% in 2016 appeared with a surplus of the current account of the balance of payments. Sources of economic growth are healthier than prior to the crisis in 2009-2014, with an increasing share of exports of goods and services, suggesting increased chances of sustained economic growth on a sustainable path. The Government of the Republic of Croatia expects continued growth at an average rate of 2.5% per annum by the end of this decade.

The new facts about economic growth in Croatia have so far been the only long-term macroeconomic scenario created for the needs of the European Commission document, *Ageing Report 2015*[154]. Though it rests on the scenario of moderate emigration, which is still at a rapid pace since entering the EU, this scenario is still the most relevant macroeconomic framework for observing a very long period (Table 6.1). Demographics will probably consider the presented projections of the population as overoptimistic, but the presented rates of economic growth can also be achieved with the more pessimistic demographic projections of the presented ones. The renovation of the national building stock whose long-term objectives are presented below may be one of the key policies to encourage sustainable economic growth under the conditions of population decrease. Technological advances, the reduction of unemployment and the activation of the inactive part of the working-age population can be encouraged through the energy renovation policy, which also has the potential to alleviate demographic pressures.

Table 6.1. Macroeconomic scenario by 2050

	2020	2025	2030	2035	2040	2045	2050
Real GDP growth rate	2.5%	1.5%	1.5%	2.1%	1.8%	1.6%	1.4%
Index of real GDP	**114.1**	**122.9**	**132.4**	**146.9**	**160.6**	**173.9**	**186.4**
Population	4,198,876	4,145,276	4,087,043	4,024,311	3,957,957	3,892,008	3,828,405
Population index	98.2	96.9	95.6	94.1	92.6	91.0	89.5
Index of real GDP per capita	116.2	126.8	138.6	156.1	173.6	191.1	208.2
GDP per capita in PPS in % EU28	63.4	65.3	66.9	70.3	73.2	75.4	76.8

Note: The rate for the year represents the average rate for the previous five year period.
Source: Adapted to the Ageing Report 2015.

[154]The 2015 Aging Report: Economic and Budget Projections for the 28 EU Member States (2013-2060), available at: https://ec.europa.eu/eip/ageing/library/2015-ageing-report-economic-and-budgetary-projections-28-eu-member-states-2013-2060_en [19th May 2017]

6.3 Strategic objectives of building renovation, required investments and effects on GDP, energy efficiency, employment and the state budget by 2050

It is estimated that, in view of an 80% CO_2 emission reduction in the building sector by 2050, 91.7% of the national building stock requires renovation according to *Technical Regulation* requirements related to large reconstruction. The assumed net (excluding VAT) specific investment expenditure is approximately 1.637 HRK/m^2. Although the possibility of applying this renovation standard on a substantially larger volume of buildings or square metres has been very small since 2017, the strategic objectives are defined in terms of renovating 3.5% of the national building stock from 2017 to 2029, 3% from 2030 to 2039 and 1.5% in the fifth decade of the 21st century.

Investment expenditure consists of three elements. The initial investment is comprised of the result of multiplying the number of square metres and the investment expenditure for renovation according to *Technical Regulation* requirements related to large reconstruction. Current investment maintenance was estimated at 5.3% of the cumulative investment amount. Replacement investments involving thermal and lighting installations in an estimated amount of about HRK 759/m^2 are used after the expiry of fifteen years from the initial installation. Everything is expressed at fixed prices (Figure 6.1).

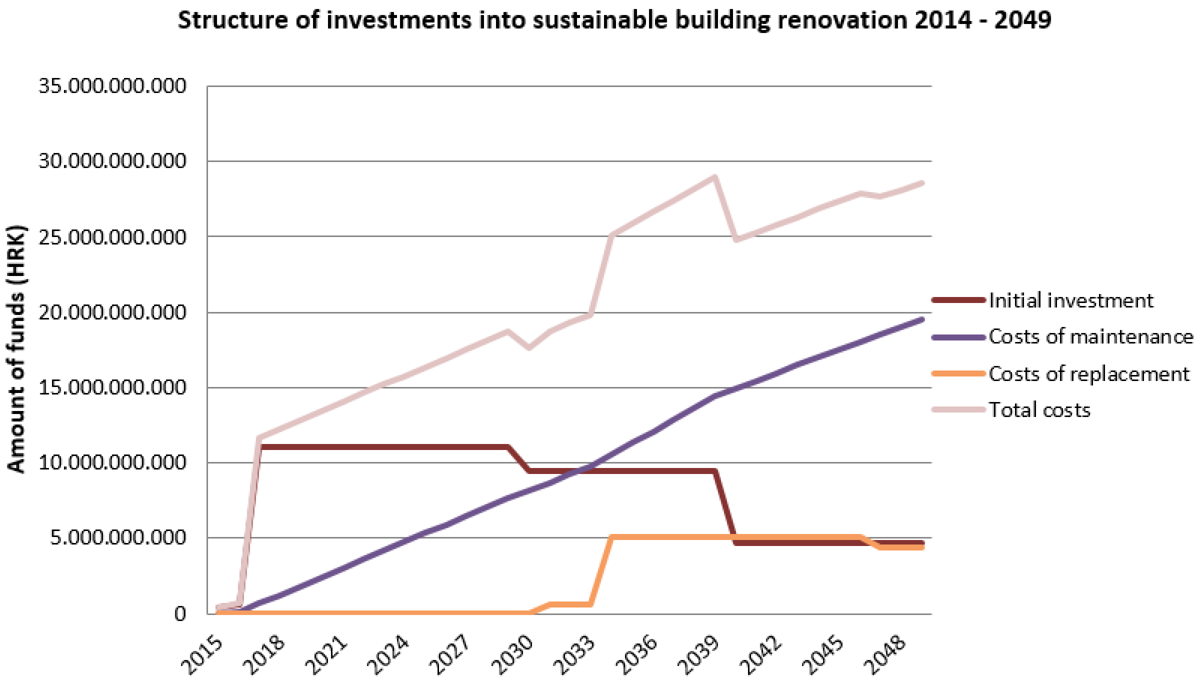


Figure 6.1 Structure of investments in sustainable building renovation 2014-2050

The investments shown in the Figure have strong effects on GDP, employment and government budget revenues. There are direct effects in construction. Indirect or multiplier effects are spread across the network of economic inputs to the entire economy.

The results in the following table (Table 6.2) show that the projected pace of renovation has significant effects on investments, which effects are visible at the macroeconomic level as well. The long-term annual average share of this type of investment in the GDP is 4.1%. The share in the first period is fairly modest (though not negligible: 1.8%), which is explained by the above initial investment shortfall. However, from 2020 to 2024, there will be a significant investment share in GDP of 3.8%, which will become an important determinant of total investment activity in the country (currently the investment ratio is about 20%). After that, the share will remain on average between 4.2% and 5.0% annually. It should be noted that current investment maintenance and replacement of equipment over time become very important determinants of total investment than the initial investment, as shown in the figure (Figure 6.1).

Realization of the investments shown has a strong impact on direct employment in construction. The impact is strongest at the beginning of the intensive investment period. Then there is a rapid mobilization of entrepreneurs and workers. Later effects are smaller since the formerly increased number of workers perform new jobs and it is fairly easy to redirect entrepreneurs and workers from initial investment to maintenance work in line with changes in the investment structure. Also, over time, there will be income increases and technological advances, and the number of new jobs opened by money units of new investments will be reduced. In the last decade of the renovation programme, the number of engaged workers will be slightly reduced, as the productivity growth effect will exceed the growth of investment.

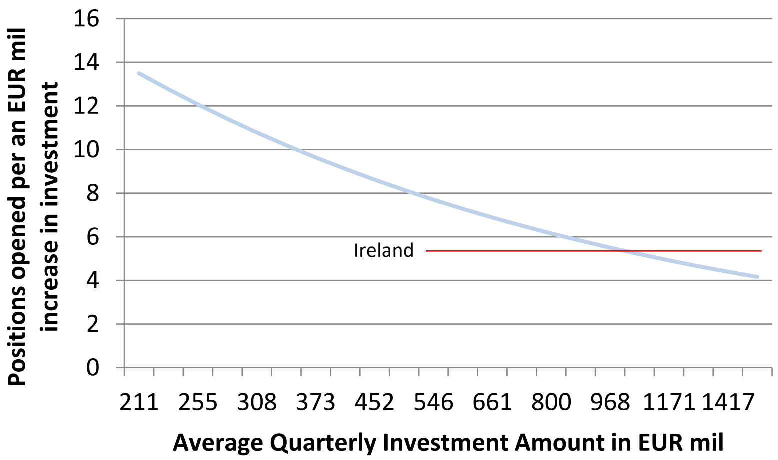
Table 6.2. Influence of the projected pace of renovation on investment expenditures and employment in construction by 2050

Period considered	2014-2019	2020 - 2024	2025 - 2029	2030 - 2039	2040 - 2049	TOTAL 2014-2049
% of renovated stock (cumulative)	11.7%	29.2%	46.7%	76.7%	91.7%	91.7%
Amount of investment - period cumulative [HRK]	38,263,581,767	73,041,407,496	87,656,566,555	237,685,815,683	268,686,372,446	705,333,743,947
- of which: initial investment - period cumulative [HRK]	34,417,994,130	55,151,543,617	55,151,543,617	94,545,503,343	47,272,751,672	286,539,336,378
- of which: maintenance - period cumulative [HRK]	3,845,587,637	17,889,863,879	32,505,022,938	110,698,711,382	172,461,487,363	337,400,673,199
- of which: replacement - period cumulative [HRK]	0	0	0	32,441,600,958	48,952,133,412	81,393,734,370
Amount of investment - period annual average [HRK]	6,377,263,628	14,608,281,499	17,531,313,311	23,768,581,568	26,868,637,245	19,592,603,999
Amount of investment - total € on average annually *	839,113,635	1,922,142,303	2,306,751,751	3,127,444,943	3,535,347,006	2,577,974,210
Average annual investment amount in % of GDP	**1.8%**	**3.8%**	**4.2%**	**4.9%**	**4.7%**	**4.1%**
New jobs	20,638	2,837	2,611	8,171	-115	34,141
New jobs per mil € of investment	11.0	7.4	6.8	6.0	5.5	6.9

* Average long-term exchange rate for HRK to EUR = 7.6

FRAMEWORK 1: PROJECTION ASSUMPTIONS

In addition to the presented input parameters, the projections are based on the assumptions regarding the relationship between new investments and employment in the building sector and regarding the impact of income growth and technological advancement on slowing employment down due to new long-term investments. The link between investment and employment in the building sector is econometrically assessed during Strategy drafting using the Error Correction Model (ECM). The dependent and independent variable have been transformed into the ln form, and thus the regression coefficients may be interpreted as elasticities. The three-month values of new orders in the building sector and the number of building sector workers in the middle of the quarter are first linked by the partial adjustment model (PAM), where the short-term coefficient is 0.11 and the long-term one is 0.61. The problem is that the variables are not stationary I(0), but integrated of first order I(1), which means that taking long-term effects into consideration would be subject to assessment of high risk. Long-term parameters are accompanied a series of impacts which are not a part of the model (e.g. return effect on the increase of real estate prices and the growth of the sector and the economy). According to long-term specifications, this reserve was confirmed by the ECM model rating (Error Correction Model). It provided a long-term coefficient rating of 0.4 which was used in the assessments. Since the model is not linear in its logarithmic form, it follows that every additional investment creates fewer jobs, which is logical in the light of technological advancement and income growth. Estimates for Ireland state that, on average, just over 5 jobs are opened for every million euro of investment, which is logical in light of the current labor price. The same pattern fits a much larger estimate for Hungary, where labor costs are much lower. Therefore, in simulations for Croatia, it is assumed that the number of newly opened jobs falls alongside the amount of long-term investments.



The projections and impacts presented in the table must be expanded with the estimates of multiplying effects on the economy - on GDP, total employment and state budget revenues. Framework 2 explains reasons to why it is very difficult to estimate the investment multiplier which budgets depend on. It is much more reliable to show results for different assumed multipliers. As the multipliers in small and open countries such as Croatia are generally low, the results are presented for a small multiplier (1.2 i.e. 20% additional investment impact), medium (1.5 i.e. 50% additional impact) and large (2 i.e. double investment impact on GDP). For simplicity, a linear multiplier effect on employment was assumed (Table 6.3). The employment elasticity related to GDP is generally less than 1, but figures show that the building renovation programme has great potential for reducing unemployment even with more conservative assumptions. This is especially important given the fact that the activity can mobilize even less educated workers.

Table 6.3 Multiplier effects on employment by 2050

Period considered	2014-2019	2020 - 2024	2025 - 2029	2030 - 2039	2040 - 2049	TOTAL 2014-2049
Total increase in employment in relation to the multiplier						
1.2	25,998	5,759	5,724	19,907	-646	56,741
1.5	32,469	7,147	7,094	24,615	-786	70,538
2	43,229	9,418	9,327	32,247	-1,003	93,218
Out of which: multiplier effect						
1.2	5,360	2,922	3,113	11,736	-531	22,600
1.5	11,831	4,310	4,483	16,444	-671	36,397
2	22,592	6,582	6,716	24,076	-888	59,077

FRAMEWORK 2: ON INVESTMENT MULTIPLIER

The investment multiplier shows how much GDP will increase if investments increase, per unit:

$$\frac{1}{1-c(1-t)+m}$$

where ***c*** is the threshold consumption tendency (which shows how much the consumption will change if the income is changed per unit, ***t*** is the tax rate, and ***m*** is the threshold import tendency (which shows how much the import will change if GDP changes per unit). In analytical terms, the multiplier is a very problematic concept because a simple mathematical construct is used to calculate an extremely complex phenomenon. Mathematics is a metaphor here, not the exact description of the actual process. This fact is visible in the fact that the multiplier "collapses" (becomes less than 1) if m> c (1-t) is applicable. In "Multiplier and Accelerator Effects" (2006) http://tutor2u.net/economics/revision-notes/as-macro-multiplier-accelerator.html, Geoff Riley points out that the lower threshold of real multipliers is around 1.4, yet, due to the exceptional openness of the Croatian economy (import tendency) and high tax burden, the possibility of the multiplier being even smaller cannot be excluded. Namely, even if we exclude imports (although the threshold tendency is high), the threshold consumption tendency in Croatia revolves around 60% (approximated by the average consumption tendency), and the threshold taxation rate ranges between 35% and 40%. Therefore, if there is no import, the multiplier of 1.7 is calculated from the assumed c = 0.6 it = 0.3. Given the assumed m = 0.4, which is very conservative for Croatia, the calculated multiplier is only slightly above 1. The review article by Milan Deskar Škrbić on the economic research of the amount of the investment multiplier in Croatia shows very large differences in estimates, which differences make recommending to use a single number in simulations impossible.

Estimates in the table below (Table 6.4) show strong potential impacts on GDP growth and government budget revenues. And even with the most conservative assumption on the investment multiplier (1.2), the impact on the level of GDP ranges from 2.2% in the initial period of 2014-2019 to almost 6% in later programming periods. This is accompanied by significant new general government revenues that have been estimated at the assumed total threshold tax rate of 38% throughout the scenario period. Fiscal impact assessments range from 0.8% to 1.4% of GDP annually in the initial period of programme realization depending on the amount of multiplier, up to 2.2% - 3.7% in the last two decades of programme realization. These impacts represent potential sources of incentive funding, but it should be recalled that the macroeconomic impacts are presented on a gross basis. This means that the impacts can be materialized as permanent social benefits only if energy savings and other side benefits increase economic competitiveness through positive impacts on lower energy consumption and positive impacts on human health and the environment. Without these impacts, the effects will not be permanent, but will disappear when investment activity is completed, as in the case of highway investments.

Table 6.4 Total impacts on the GDP and general government budget revenues with inclusive multiplier effect by 2050

Period considered	2014-2019	2020 - 2024	2025 - 2029	2030 - 2039	2040 - 2049
Impact on the GDP in relation to the multiplier - total HRK *					
1.2	45.916.298.120	87.649.688.995	105.187.879.866	282,689,113,107	322,423,646,936
1.5	57.395.372.650	109.562.111.244	131.484.849.832	350,194,059,242	403,029,558,670
2	76.527.163.533	146.082.814.992	175.313.133.109	462,702,302,801	537,372,744,893
Impact on the GDP in relation to the multiplier - average over the period					
1.2	2.2%	4.5%	5.0%	5.9%	5.7%
1.5	2.8%	5.7%	6.3%	7.3%	7.1%
2	3.7%	7.5%	8.4%	9.7%	9.5%
Impact on Budget Revenues with respect to the Multiplier - Total in HRK *					
1.2	17.448.193.286	33.306.881.818	39.971.394.349	107,421,862,980	122,520,985,836
1.5	21.810.241.607	41.633.602.273	49.964.242.936	133,073,742,512	153,151,232,294
2	29.080.322.143	55.511.469.697	66.618.990.582	175,826,875,064	204,201,643,059
Impact on the budget revenues with respect to the multiplier - average period in % of the GDP					
1.2	0.8%	1.7%	1.9%	2.2%	2.2%
1.5	1.1%	2.1%	2.4%	2.8%	2.7%
2	1.4%	2.9%	3.2%	3.7%	3.6%

* The amounts represent cumulatives within the period. Impacts on an annual basis, on average, are shown below the absolute amounts

Before the overview of other impacts, the potentials and constraints of the construction industry should be considered. Construction and related technological industries which manufacture installation products and services determine the response to the business opportunity which is enabled through the growth of investment demand in the case of implementation of the programme presented.

According to the conducted energy savings analysis as a result of the integrated energy renovation of the building stock according to the *Technical Regulation* requirements related to large reconstruction and based on the covered building stock and the application of energy efficiency improvement measures, the estimated impact of the integrated renovation programme on energy savings by 2050 is about 131.5 PJ (according to the data presented in Annex 18).

6.4 Strategic objectives of building renovation, required investments and impacts on GDP, employment and the state budget by 2030

According to the previous chapter, strategic objectives are defined at 3.5% of the national building stock during the investments 2017-2030. Investment expenditure consists of three elements. The initial investment is comprised of the result of multiplying the number of square metres and the investment expenditure for renovation according to *Technical Regulation* requirements related to large reconstruction. Current investment maintenance was estimated at 5.3% of the cumulative investment amount. Replacement investments involving thermal and lighting installations are considered after the expiry of fifteen years from the initial installation, and, therefore, will not be considered by 2030. The results in the following table (Table 6.5) show that the projected pace of renovation has significant impacts on investments, which impacts are visible at the macroeconomic level as well. The long-term annual average share of this type of investment in the GDP is 3.2%. The share in the first period is fairly modest (though not negligible: 1.8%), which is explained by the above initial investment shortfall. However, from 2020 to 2024, the long-term average of 3.8% is achieved, after which the share remains on an annual average of 4.2%. It should be noted that the current investment maintenance and equipment replacement by 2030 does not appear in calculations due to the nature of their occurrence after 15 years or later after the first year of investment.

Table 6.5 Influence of the projected pace of renovation on investment expenditures and employment in construction by 2030

Period considered	2014-2019	2020 - 2024	2025 - 2029	TOTAL 2014-2029
% of renovated stock (cumulative)	11.7%	29.2%	46.7%	46.7%
Amount of investment - period cumulative [HRK]	38,263,581,767	73,041,407,496	87,656,566,555	198,961,555,818
- of which: initial investment - period cumulative [HRK]	34,417,994,130	55,151,543,617	55,151,543,617	144,721,081,363
- of which: maintenance - period cumulative [HRK]	3,845,587,637	17,889,863,879	32,505,022,938	54,240,474,454
- of which: replacement - period cumulative [HRK]	0	0	0	0
Amount of investment - period annual average	6,377,263,628	14,608,281,499	17,531,313,311	5,526,709,884
Amount of investment - total € on average annually *	839,113,635	1,922,142,303	2,306,751,751	727,198,669
Average annual investment amount in % of GDP	**1.8%**	**3.8%**	**4.2%**	**3.2%**
New jobs	20,638	2,837	2,611	26,085
New jobs per mil € of investment	11.0	7.4	6.8	8.4

* Average long-term exchange rate for HRK to EUR = 7.6

The projections and impacts presented in the table must be expanded with the estimates of multiplying effects on the economy - on GDP, total employment and state budget revenues. As the multipliers in small and open countries such as Croatia are generally low, the results are presented for a small multiplier (1.2 i.e. 20% additional investment impact), medium (1.5 i.e. 50% additional impact) and large (2 i.e. double investment impact on GDP). For simplicity, a linear multiplier effect on employment was assumed (

Table 6.6). It should be noted that the employment elasticity related to GDP is generally less than 1, but figures show that the building renovation programme has great potential for reducing unemployment even with more conservative assumptions. This is especially important given the fact that the activity can mobilize even less educated workers.

Table 6.6 Multiplier effects on employment by 2030

Period considered	2014-2019	2020 - 2024	2025 - 2029	TOTAL 2014-2029
Total increase in employment in relation to the multiplier				
1.2	25,998	5,759	5,724	37,480
1.5	32,469	7,147	7,094	46,709
2	43,229	9,418	9,327	61,975
Out of which: multiplier effect				
1.2	5,360	2,922	3,113	11,395
1.5	11,831	4,310	4,483	20,624
2	22,592	6,582	6,716	35,889

Estimates in the table below (Table 6.7) show strong potential impacts on GDP growth and government budget revenues. And even with the most conservative assumption on the investment multiplier (1.2), the impact on the level of GDP ranges from 2.2% in the initial period of 2014-2019 to about 5% in later programme implementation periods by 2030.

Table 6.7 Total impacts on the GDP and general government budget revenues with inclusive multiplier effect by 2030

Period considered	2014-2019	2020 - 2024	2025 - 2029
Impact on the GDP in relation to the multiplier - total HRK *			
1.2	45.916.298.120	87.649.688.995	105.187.879.866
1.5	57.395.372.650	109.562.111.244	131.484.849.832
2	76.527.163.533	146.082.814.992	175.313.133.109
Impact on the GDP in relation to the multiplier - average over the period			
1.2	2.2%	4.5%	5.0%
1.5	2.8%	5.7%	6.3%
2	3.7%	7.5%	8.4%
Impact on Budget Revenues with respect to the Multiplier - Total in HRK *			
1.2	17.448.193.286	33.306.881.818	39.971.394.349
1.5	21.810.241.607	41.633.602.273	49.964.242.936
2	29.080.322.143	55.511.469.697	66.618.990.582
Impact on the budget revenues with respect to the multiplier - average period in % of the GDP			
1.2	0.8%	1.7%	1.9%
1.5	1.1%	2.1%	2.4%
2	1.4%	2.9%	3.2%

* The amounts represent cumulatives within the period. Impacts on an annual basis, on average, are shown below the absolute amounts

According to the conducted energy savings analysis as a result of the integrated energy renovation of the building stock according to the *Technical Regulation* requirements related to large reconstruction and based on the covered building stock and the application of energy efficiency improvement measures, the estimated impact of the integrated renovation programme on energy savings by 2030 is about 67 PJ (according to the data presented in Annex 18).

6.5 Potential and limitations of the construction industry in Croatia

The direct impact of the national building stock renovation programme on employment in construction up to (and including) 2020 could amount to up to 26,000 new jobs. This is a big increase compared to the current number of employees. There were 68,653 employees in companies registered in construction at the end of 2016[155]. However, it is questionable how much all companies whose main registered activity is construction are engaged solely or exclusively with this activity. According to the special report on construction of the Croatian Bureau of Statistics[156], the average number of construction site workers in 2015 was 41,037 and was still falling compared to the previous year. Although the programme of renovation of the national building stock does not only mobilize construction workers, but also designers, engineers, managers, and administrative staff, these figures clearly show that there is a great mobilization of resources, especially work in the construction industry. The mobilization potential can be roughly estimated at 40-50% of the current engagement of resources in construction.

Value indicators further show the strength of the growth of activities if a plan for investment in the renovation of the national building stock is realized. Namely, the value of completed construction works has barely exceeded HRK 15 billion by 2015. (Table 6.8). Although higher than 2014, this level of activity was significantly lower than in 2010, when there were construction works in the value of HRK 17.9 billion. It was especially lower than the cyclical peak before the crisis in 2008, when the value of completed works was HRK 27.8 billion, of which 14.6 billion was in buildings. As the average annual amount of new investments in the period from 2017 to 2019 is approximately HRK 11.5 billion, the figures in the following table show that such an increase in the value of completed works would approximately mean the return of the entire construction sector to the value level of pre-crisis activity in 2008. By doing so, the activity in the building sector itself would significantly exceed the level of activity that was more focused on building infrastructure.

Table 6.8 Value and structure of construction works in Croatia 2010-2015

million HRK	2010	2011	2012	2013	2014	2015	2015/2014 (index)
Value of construction works							
Buildings	9.320	8.252	7.169	6.263	6.530	7.241	111
Other buildings	8.564	8.532	8.807	8.829	7.561	7.907	105
TOTAL	17.884	16.784	15.976	15.092	14.091	15.148	108
Structure of construction works							
Buildings	52.1%	49.2%	44.9%	41.5%	46.3%	47.8%	
Other buildings	47.9%	50.8%	55.1%	58.5%	53.7%	52.2%	

Source: CBS, statistical reports Construction, various numbers

It should be kept in mind that construction activities on buildings are still concentrated in new buildings. According to the data in the following table (Table 6.9), the value of completed works in new construction is still about 70% higher than the value of completed works in reconstructions, adaptations, and large repairs. However, activity in this area is growing faster than in new construction in recent years, which is a natural consequence of decreasing number and aging of the population (reducing demand for new construction), as well as the start of the programme of renovation of the building stock. However, as the almost total amount of new investments set out in the programme of renovation of the national residential building stock relates to reconstruction, adaptation and major repair, an approximately five-fold increase in long-term activity should be realized in this segment. It is a very large mobilization of resources that will not happen if it is left to spontaneous market processes. Coordinated measures which would create incentives for building renovation investments on the demand side, and incentives for transferring resources into construction activities in the building sector on the supply side.

[155]Press Releases of the Croatian Bureau of Statistics, Persons in Paid Employment by Activity, available at: www.dzs.hr/Hrv_Eng/publication/2016/09-02-01_01_2016.htm [19th May 2017]
[156]SI 1563, Construction in 2015, available at: www.dzs.hr/Hrv_Eng/publication/2016/SI-1563.pdf [19th May 2017]

Table 6.9 Value of conducted construction works in buildings 2013-2015, legal persons with more than five employees

million HRK	2013	2014	2015	2015/2014 (index)
Value of construction works				
new construction	3.944	3.960	4.287	108
Reconstructions, adaptations and major repairs	1.878	2.152	2.510	117
Maintenance and minor repairs	439	418	444	106

Source: Croatian Bureau of Statistics, SI 1563, Construction in 2015

6.6 Other benefits from the implementation of the Long-Term Strategy for Mobilising Investment in Renovation of the National Building Stock of the Republic of Croatia

Additional justification for applying coordinated measures to stimulate supply and demand stems from other incidental benefits (so-called positive externalities) that act on top of energy savings, reduced emissions of pollutants, new investments and their multiplier effects on the GDP, employment and general government budget revenues. Other incidental benefits cannot be accurately estimated but can be described with respect to the preservation and growth of real estate values, incidental aesthetic benefits for other economic activities (e.g. tourism), positive effects on human health, reduction of energy poverty and energy security.

Real estate value and aesthetic external effects

Real estate prices in Croatia are slowly recovering from the crisis (Figure 6.2). The mild recovery that took place in 2016 has not yet affected new construction whose prices have continued to adjust downwards. This is expected, given the demographic trends. The reference to dispersed recovery seen in the data for 2016 highlights the incorrect allocation of construction activity that needs to be turned from new construction to adaptation, reconstruction, and major repairs. The programme of renovation of the national building stock can have the role of catalyst therein.

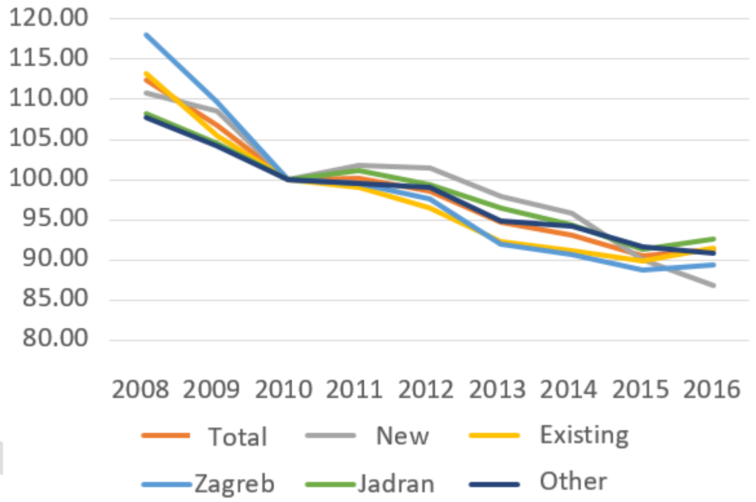


Figure 6.2 Base Real Estate Price Index, 2010 = 100)
Source: Croatian National Bank, Statistics, Table J3

Energy renovation of building leads to cost savings, aesthetic values increase and overall satisfaction with housing and quality of life. This reflects on the value of the real estate. Therefore, the long and steep decline in the value of real estate, other than the fundamental (demographic and economic) factors, should also be explained by the absence of an ambitious building renovation programme.

The renovation programme, which leads to an increase in the value of real estate, also has incidental economic effects that act in two manners. First, the growth of the value of real estate through the so-called. wealth effect affects the increase of consumption, and thus the growth of the GDP and revenues of the state budget. The wealth effect operates with a parameter of about 0.1,[157] which means that a 10% increase in real estate value increases total personal spending by 1%. The overall impact on the GDP should also take into account the positive impact on investments that is GDP-related. Secondly, positive aesthetic externalities can spill over to the wider community, especially in the areas that live off tourism, where the overall impression of buildings can also function as a factor of attraction. It is clear that valuation and esthetic effects related to real estate cannot be reliably estimated, but it is certain that it is not great as the effects directly linked to investment activities. Nevertheless, it is worth mentioning them.

Reducing the risk of health, poverty and energy supply

[157]According to: Ahec Šonje, Čeh Časni and Vizek (2014).

The group of impacts that are difficult to estimate, but should be mentioned, also includes reducing health risks, energy poverty, and energy supply. The latter effect is particularly important for Croatia, which imports up to half of its required energy, so the reduction of consumption related with increasing energy efficiency improves the balance of the current account of the pay balance and the parameters of international financial stability.

Valuable effects on people's health improvements cannot be estimated but are certainly worth mentioning with regard to the long-term trend of population decline and the need to activate the inactive part of the working-age population.

When it comes to energy poverty, renovation of the building has great potential for savings that are relatively bigger for poorer households. According to Poverty Indicators 2015, 9.9% of people in Croatia live in households that have a problem with adequate heating, and 28.7% of people live in households who are late with paying bills. Energy-generating products play an important role in this, as the average annual household, electricity, gas and other fuel consumption by the Household Expenditure Survey 2014 amounted to $ 8.569, which accounted for about 10.5% of annual cash expenditures. It should be kept in mind that this share is 2-3 times higher in households located in lower deciles of income distribution versus share in households that are in the upper income distribution. Therefore, the programme of renovation of the national residential building stock has a great potential for reducing energy poverty, but it is obvious that households living in material deprivation have limited time spans and less potential to participate in investment spending. Renovation incentive measures have to take this fact into account as well. The following figure schematically shows the classification of the estimated and mentioned effects of the national building stock renovation (Figure 6.3).

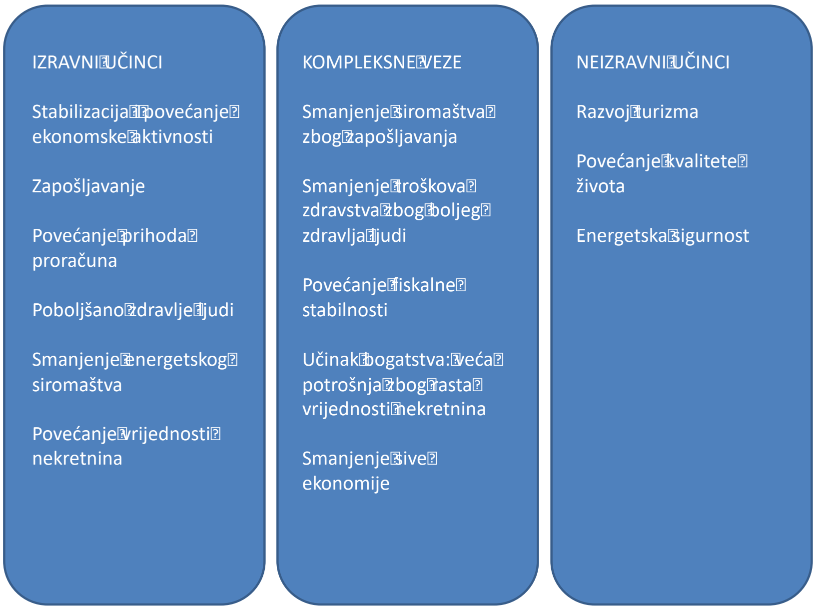


Figure 6.3 Schematic overview of all potential impacts of energy renovation of buildings

Reduction of CO_2 emissions

Pursuant to the conducted energy savings analysis as the result of integrated energy renovation of the building stock according to the *Technical regulation* requirements related to large reconstruction, and on grounds of the involved building stock and the implementation of measures to introduce EE and introduce RES, the estimated impact of the integrated renovation programme on CO_2 emission reduction by 2030 is approximately 3.197 kt, while by 2050 it is approximately 6.277 kt (according to the data presented in Annex 18). To calculate CO_2 emission savings, specific CO_2 emission factors per energy unit of fuel (kgCO_2/ kWh) were used, downloaded from the official site of the Ministry of Construction and Physical Planning[158]. The data obtained correspond to

[158]Available at: http://www.mgipu.hr/doc/EnergetskaUcinkovitost/FAKTORI_primarne_energije-do.29.9.2017.pdf[30th April 2017]

the energy savings of individual building categories and are in line with the energy source distribution in energy consumption based on data from the *International Energy Agency - IEA Statistics* database in Croatia[159].

[159]International Energy Agency (2017), Online Report for Croatia [online], available at: http://www.iea.org/statistics/statisticssearch/report/?country=CROATIA&product=Balances&year=2014 [30th April 2017]

7. Conclusion

The revision of the Long-Term Strategy for Mobilising Investment in the Renovation of the National Building Stock of the Republic of Croatia was made in accordance with the requirements of Directive 2012/27/EU (Article 4) and the Energy Efficiency Act (Article 10), and it deals with the following thematic units:

1. Overview of the Croatian national building stock;
2. Analysis of key elements of the building renovation programme;
3. Policies and measures to stimulate cost-effective integrated building renovation
4. Long-term perspective to guide investment decisions by individuals, the construction industry and financial institutions by 2050;
5. Evaluation of the expected energy savings and wider benefits based on computational and model data.

According to the conducted analysis of the national building stock in 2014, the total Croatian national stock consists of 887,321 buildings, totaling 192,519,039 m^2. Since energy renovation programmes have been implemented within the three years from drafting the Long-Term Strategy up to today, energy renovation programmes have been implemented (Programme of Energy Renovation of Family Houses 2014-2020, Programme of Energy Renovation of Multi-Residential Buildings 2014-2020, Programme of Energy Renovation of Public Buildings 2014-2015 and Programme of Energy Renovation of Commercial Non-Residential Buildings 2014-2020), the total floor area of the national building stock to be renewed from 2017 onwards has been updated in accordance with the Annual Report on the Progress towards the National Energy Efficiency Targets pursuant to Article 24(1) in accordance with Part 1 of Annex XIV of the Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC. According to the Report providing an overview of cumulative savings realized from 2014 to 2016 (1, 72767 PJ), the total floor area of the renovated building stock through the energy renovation programmes is estimated at 2,172,440 m^2. Therefore, the updated floor area of the national building stock subject to renovation from 2017 onwards amounts to 190.346.560,40 m^2.

On grounds of analyzes conducted on the annually delivered energy to coastal and continental Croatia (in particular the required heating energy), a group of buildings built up to 1987 was selected as the target group with regard to their total floor area, state of the heated space envelope and energy requirements. The above building stock was selected because of the greatest savings potential and its significant share in the total floor area of all buildings. In addition, the above input parameters in terms of the energy savings potential for all four considered building categories (public buildings, commercial buildings, multi-residential buildings and family houses) suggest that, within the buildings stock built up to 1987, the highest priority for integrated renovation should be given to family houses (potential of specific energy savings in delivered energy according to the useful floor area of the building up to 293.48 kWh/m^2 yearly) and commercial buildings (potential of specific energy savings according to the useful floor area of the building up to 274.78 kWh/m^2 yearly). In addition to the great potential for energy savings, family houses are also a priority category of buildings to be renovated in view of combating energy poverty, which is among the objectives of the Draft 4th National Energy Efficiency Action Plan 2017-2019. However, in the category of family houses, deviation from the data obtained is possible due to the high degree of firewood use and the smaller heated floor area of the building than projected, which challenges the financial viability of renovation of family houses with these characteristics, and the implementation largely depends on incentive measures (not only financial).

The main objective of the Strategy was to identify effective measures for the long-term mobilisation of cost-efficient integrated renovation of the building stock of the Republic of Croatia (all residential and non-residential buildings) by 2050 on the basis of the established economical and energy-optimal building renovation model. In order to select the optimal renovation method for each of the four building categories (public buildings, commercial buildings, multi-residential buildings and family houses), with regard to the currently applicable technical and financial parameters, five possible models of sustainable building renovation have been considered (renovation according to minimum requirements of the *Technical Regulation*, renovation according to *Technical Regulation* requirements related to large reconstruction, nZEB standard construction, passive construction standard and active construction standard). Given the technical options of implementing various EE and RES measures 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 building renovation model according to *Technical Regulation* requirements related to major reconstruction has been selected as the cost-optimal building renovation model. The specific amount of total costs (Annex 2, Annex 4, Annex 6, Annex 8, Annex 10, Annex 12, Annex 14 and Annex 16) has been considered the fundamental parameter in the comparison of various building renovation models and used as a basis for charts drawn for each building category to illustrate the total cost dependence on the primary energy level after renovation under a certain renovation model (Annex 3, Annex 5, Annex 7, Annex 9, Annex 11, Annex 13, Annex 15 and Annex 17). Although the shown charts and parameters in tables (Table 3.6 and Table 3.7) suggest that the active house standard is the most commercially viable, it should be noted that viability depends on the status of preferential RES- and cogeneration-based producer which thus covers a small fraction of the national building stock (due to the obligatory administrative procedure to be followed and due to the obligation to report regularly and to meet the technical conditions of the plant's efficiency). The model of building renovation according to *Technical Regulation* requirements related to large reconstruction was selected as optimal in terms of cost. However, it should be noted that its realization in terms of public building renovation in continental Croatia is almost impossible, given the limitations for the annual delivered energy E_{del} and the annual primary energy E_{prim}. This model does not prove optimal only in the multi-residential building category of coastal Croatia where, as a cost-optimal model, it results in a renovation model according to minimum requirements of the *Technical Regulation*. The realization of the renovation model to the nZEB standard is impossible due to the restrictions in the annually delivered energy E_{del} for public buildings in continental Croatia and the annual primary energy E_{prim} for almost all building categories (exceptions involve commercial buildings in continental Croatia and coastal Croatia). However, if reduced criteria could result in its realization, its cost-effectiveness would increase with the length of the calculation period for the buildings in continental Croatia. Building renovation model according to minimum requirements of the *Technical Regulation* is less cost-effective than the building renovation model according to *Technical Regulation* requirements related to large reconstruction, specifically to a greater extent in continental Croatia and with the extension of the calculation period.

The Strategy included an overview of existing measures for and obstacles to an integrated 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 EU Member States. It can be concluded that the main obstacles to the renovation of the Croatian national building stock are not only legislative and financial in nature, but that the integrated energy renovation of buildings is also largely hampered by a lack of information and motivation on the part of investors, the public and stakeholders. In view of the above, the Strategy identified the available sources of funding and successful ways to motivate investors and estimated the necessary investments in the national building stock renovation by 2050. Meeting the set energy renovation objectives according to the ~~nZEB standard~~ requires a mobilisation of sizeable resources for investment costs as well as maintenance and replacement costs, that are all estimated to reach almost HRK 790 billion by 2050. The proposed pace of renovation will achieve an overall reduction in CO_2 emissions by 81.1% and achieve the objectives set in the EU Energy Roadmap. Since the currently available sources of funding are insufficient to achieve the set objectives, the introduction of new, innovative funding mechanisms which combine 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 of 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.
The Strategy involves an analysis of potential energy savings, CO_2 emission reduction and the impact on employment and the economy and combating energy poverty as a result of energy building renovation. Estimate of expected energy savings and widespread benefits, based on calculation and model data, takes into account the fact that investing in integrated 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 integrated renovation on 91.7% of the national building stock is completed by the end of 2049, the expected impact on employment could produce 56 thousand new jobs in a scenario involving conservatively estimated multiplier effects, or as many as 93 thousand in a scenario involving strong multiplication. Additionally, the expected impact on employment by the year 2020 would be between 25 and 43 thousand new jobs, depending on the estimated multiplier effects, and an additional 5 to 9 thousand more are expected by 2030. The estimated impact of the integrated renovation programme on GDP growth by 2030 ranges between 5.0% and 8.4% and, by 2050, it ranges between 10% and 17%, depending on the estimated multiplier effects. The estimated impact of the integrated renovation programme on achieving energy savings by 2030 is about 67.0 PJ, and by 2050 about 131.5 PJ, which is about 62% of the overall energy savings objective.

The wider economic benefits of the integrated renovation of the national building stock do not result only in economic activities, budget revenues, and employment growth. integrated renovation of the national building stock certainly results in improved health and, consequently, in considerable cost reduction in the Croatian healthcare system, reduction of the energy poverty in Croatia and a steady increase of real estate value, while indirect benefits will be visible in the tourism sector, enhanced quality of life and strengthening of the overall national financial stability. The effect of the suggested renovation dynamics on CO_2 emission reduction by 2030 will be around 3,190 kt, and approximately 6,277 kt by 2050.

The analysis conducted within this Strategy shows that energy building renovation is a very useful measure in the conditions of an economic crisis and necessity of new job openings to encourage economic activity. Achieving the objectives set by the Strategy, shall contribute to the realization of the set national energy policy targets. Thanks to all the above reasons, it can be concluded with certainty that the implementation of the integrated renovation programme of the Croatian national building stock will result in improvements of the Croatian economy in almost all its segments in accordance with the elements of this Strategy.

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 renovation objective is to meet the requirements of the *Technical Regulation*. The existence of project documentation required in accordance with construction legislation is a prerequisite for the implementation of this measure. Energy renovation includes design, performance of works according to the main or detailed construction design, 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 biomass-fired boilers or heat pumps or, if impossible, condensation gas 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/EU, the use of individual meters or heating cost splitters to measure individual heating consumption in multi-residential 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/EU, 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. The above 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 renovation objective is to meet the requirements of the *Technical Regulation*. 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 systems using biomass-fired boilers or heat pumps or, if impossible, condensation gas 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/EU, the use of individual meters or heating cost splitters to measure individual heating consumption in multi-residential 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 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/EU, 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. The above 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
Multi-residential 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 renovation objective is to meet the requirements of the *Technical Regulation*. 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 integrated 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 multi-residential 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, non-cooperation with building managers. In accordance with par. 28 of the preamble to Directive 2012/27/EU, the use of individual meters or heating cost splitters to measure individual heating consumption in multi-residential 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 multi-residential buildings 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 these apartments in several places. However, individual heat consumption metering may be presumed to be technically possible in multi-residential 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 biomass-fired boilers or heat pumps or, if impossible, condensation gas 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. 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 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,* 2017

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

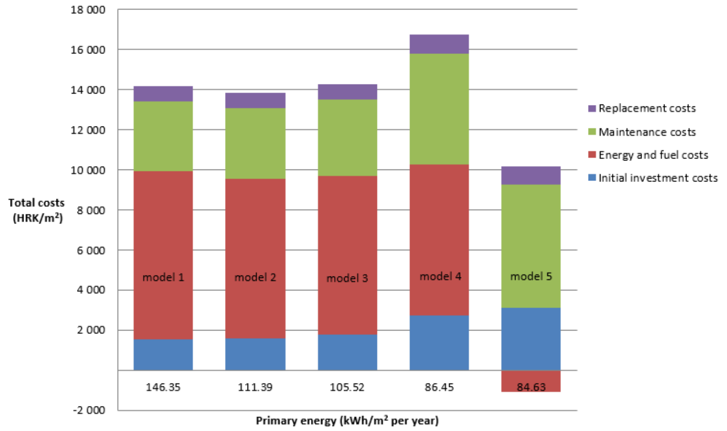
Public buildings in continental Croatia															
Measure number	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Energy savings in terms of percentage															
Building renovation according to minimum *Technical Regulation* requirements		60%					36%	40%	50%	40%					
Building renovation according to Technical Regulation requirements related to large reconstruction		82%					36%	40%	50%	40%					
Building renovation according to the nZEB construction standard		85%					36%	40%	50%	40%					
Building renovation according to the passive construction standard		93%					45%	50%	50%	40%					
Building renovation according to the active construction standard		93%					55%	50%	50%	40%				150%	
Specific energy savings (kWh/m2)															
Building renovation according to minimum *Technical Regulation* requirements		122.74					30.17	14.00	6.67	15.83					189.41
Building renovation according to *Technical Regulation* requirements related to large reconstruction		167.86					13.77	14.00	6.67	15.83					218.12
Building renovation according to the nZEB construction standard		175.43					11.01	14.00	6.67	15.83					222.94
Building renovation according to the passive construction standard		190.72					6.75	17.50	6.67	15.83					237.46
Building renovation according to the active construction standard		190.72					8.25	17.50	6.67	15.83				69.46	308.42
Specific cost savings (HRK/m²)															
Building renovation according to minimum *Technical Regulation* requirements		49.29					12.84	10.78	4.12	12.19					89.23
Building renovation according to *Technical Regulation* requirements related to large reconstruction		67.42					5.86	10.78	4.12	12.19					100.37
Building renovation according to the nZEB construction standard		70.46					4.69	10.78	4.12	12.19					102.24
Building renovation according to the passive construction standard		76.60					2.87	13.48	4.12	12.19					109.26
Building renovation according to the active construction standard		76.60					3.51	13.48	4.12	12.19				53.48	163.38
Measure 0: Building's energy management system, energy audit and energy certificate															
Measure 1: Outer window and door frame replacement															
Measure 2: Thermal insulation implementation to external walls															
Measure 3: Thermal insulation implementation to the roof/ceiling bordering unheated attic															
Measure 4: Thermal insulation implementation to the ceiling bordering unheated basement (if any)															
Measure 5: Thermal insulation implementation 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															

Calculation period	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	Building renovation according to minimum *Technical Regulation* requirements	1,550.37	8,386.86	3,469.68	762.75	14,169.65
	Building renovation according to *Technical Regulation* requirements related to large reconstruction	1,582.90	7,959.99	3,518.47	762.75	13,824.11
	Building renovation according to the nZEB construction standard	1,782.95	7,888.35	3,818.55	762.75	14,252.60
	Building renovation according to the passive construction standard	2,723.70	7,544.42	5,515.80	953.50	16,737.42
	Building renovation according to the active construction standard	3,123.70	-1,068.45	6,115.80	953.50	9,124.55
50 years	Building renovation according to minimum *Technical Regulation* requirements	1,550.37	24,290.62	9,638.19	2,304.91	37,784.09
	Building renovation according to *Technical Regulation* requirements related to large reconstruction	1,582.90	23,054.31	9,774.00	2,326.70	36,737.91
	Building renovation according to the nZEB construction standard	1,782.95	22,846.80	10,609.23	2,460.74	37,699.72
	Building renovation according to the passive construction standard	2,723.70	21,850.69	15,328.47	3,407.69	43,310.55
	Building renovation according to the active construction standard	3,123.70	-1,318.89	16,998.47	3,675.69	22,478.97
70 years	Building renovation according to minimum *Technical Regulation* requirements	1,550.37	59,050.69	18,807.46	3,823.19	83,231.72
	Building renovation according to *Technical Regulation* requirements related to large reconstruction	1,582.90	56,045.21	19,069.32	3,865.48	80,562.91
	Building renovation according to the nZEB construction standard	1,782.95	55,540.75	20,679.76	4,125.55	82,129.02
	Building renovation according to the passive construction standard	2,723.70	53,119.20	29,835.07	5,800.61	91,478.58
	Building renovation according to the active construction standard	3,123.70	-724.82	33,055.07	6,320.61	41,774.55

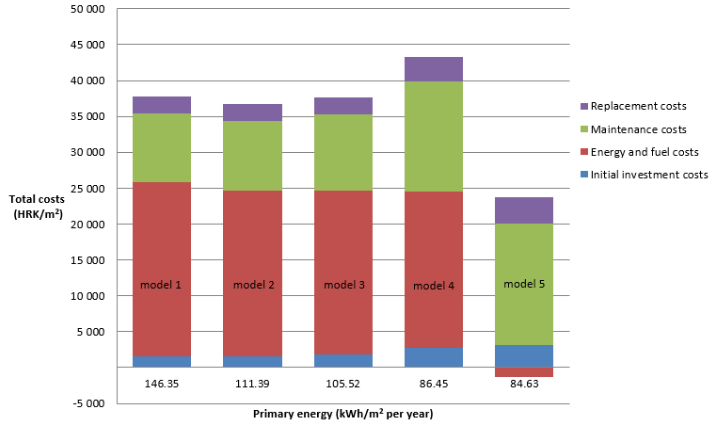
Source: *REGEA,* 2017

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

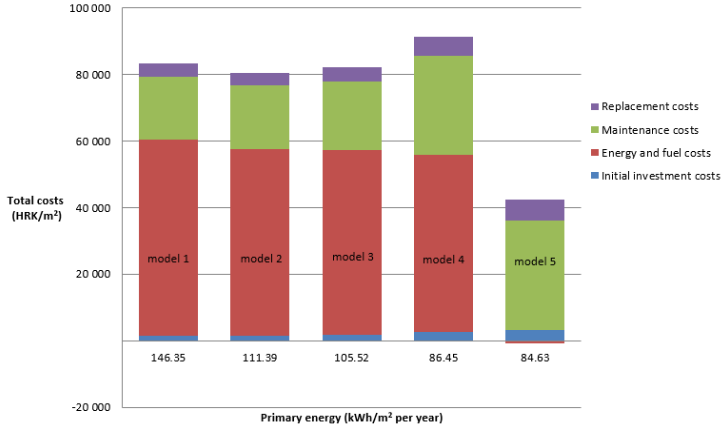
Parametres of various models of public building renovation in continental Croatia related to a 30-year calculation period



Parametres of various models of public building renovation in continental Croatia related to a 50-year calculation period



Parametres of various models of public building renovation in continental Croatia related to a 70-year calculation period



model 1	Building renovation according to minimum *Technical Regulation* requirements
model 2	Building renovation according to *Technical Regulation* requirements related to large reconstruction
model 3	Building renovation according to the nZEB construction standard
model 4	Building renovation according to the passive construction standard
model 5	Building renovation according to the active construction standard

Source: *REGEA,* 2017

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

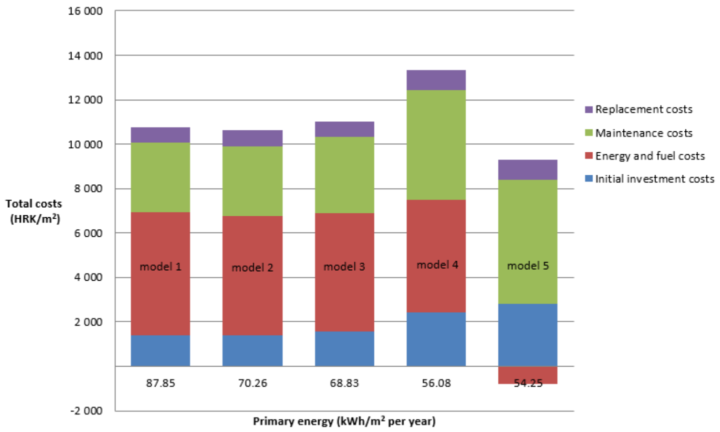
Public buildings in coastal Croatia															
Measure number	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Energy savings in terms of percentage															
Building renovation according to minimum *Technical Regulation* requirements		56%					36%	60%	75%	40%					
Building renovation according to Technical Regulation requirements related to large reconstruction		78%					36%	60%	75%	40%					
Building renovation according to the nZEB construction standard		80%					36%	60%	75%	40%					
Building renovation according to the passive construction standard		86%					45%	70%	75%	40%					
Building renovation according to the active construction standard		86%					55%	70%	75%	40%				150%	
Specific energy savings (kWh/m2)															
Building renovation according to minimum *Technical Regulation* requirements		58.54					16.64	23.65	5.65	9.98					114.46
Building renovation according to *Technical Regulation* requirements related to large reconstruction		81.24					8.38	23.65	5.65	9.98					128.91
Building renovation according to the nZEB construction standard		83.08					7.71	23.65	5.65	9.98					130.08
Building renovation according to the passive construction standard		89.30					6.75	27.59	5.65	9.98					139.27
Building renovation according to the active construction standard		89.30					8.25	27.59	5.65	9.98				47.10	187.88
Specific cost savings (HRK/m^2)															
Building renovation according to minimum *Technical Regulation* requirements		23.79					7.16	18.21	3.50	7.69					60.35
Building renovation according to *Technical Regulation* requirements related to large reconstruction		33.01					3.61	18.21	3.50	7.69					66.02
Building renovation according to the nZEB construction standard		33.76					3.32	18.21	3.50	7.69					66.48
Building renovation according to the passive construction standard		36.29					2.90	21.25	3.50	7.69					71.63
Building renovation according to the active construction standard		36.29					3.55	21.25	3.50	7.69				36.27	108.54
Measure 0: Building's energy management system, energy audit and energy certificate															
Measure 1: Outer window and door frame replacement															
Measure 2: Thermal insulation implementation to external walls															
Measure 3: Thermal insulation implementation to the roof/ceiling bordering unheated attic															
Measure 4: Thermal insulation implementation to the ceiling bordering unheated basement (if any)															
Measure 5: Thermal insulation implementation 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															

Calculation period	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	Building renovation according to minimum *Technical Regulation* requirements	1,550.37	5,559.82	3,117.52	762.75	10,990.47
	Building renovation according to *Technical Regulation* requirements related to large reconstruction	1,582.90	5,345.04	3,160.18	762.75	10,850.87
	Building renovation according to the nZEB construction standard	1,782.95	5,327.65	3,422.53	762.75	11,295.88
	Building renovation according to the passive construction standard	2,723.70	5,046.80	4,964.89	953.50	13,688.89
	Building renovation according to the active construction standard	3,123.70	-801.18	5,564.89	953.50	8,840.91
50 years	Building renovation according to minimum *Technical Regulation* requirements	1,550.37	16,102.77	9,638.19	2,304.91	29,596.24
	Building renovation according to *Technical Regulation* requirements related to large reconstruction	1,582.90	15,480.69	9,774.00	2,326.70	29,164.29
	Building renovation according to the nZEB construction standard	1,782.95	15,430.32	10,609.23	2,460.74	30,283.24
	Building renovation according to the passive construction standard	2,723.70	14,616.91	15,328.47	3,407.69	36,076.77
	Building renovation according to the active construction standard	3,123.70	-1,116.31	16,998.47	3,675.69	22,681.56
70 years	Building renovation according to minimum *Technical Regulation* requirements	1,550.37	39,145.96	18,807.46	3,823.19	63,326.98
	Building renovation according to *Technical Regulation* requirements related to large reconstruction	1,582.90	37,633.69	19,069.32	3,865.48	62,151.38
	Building renovation according to the nZEB construction standard	1,782.95	37,511.22	20,679.76	4,125.55	64,099.48
	Building renovation according to the passive construction standard	2,723.70	35,533.82	29,835.07	5,800.61	73,893.19
	Building renovation according to the active construction standard	3,123.70	-1,030.99	33,055.07	6,320.61	41,468.38

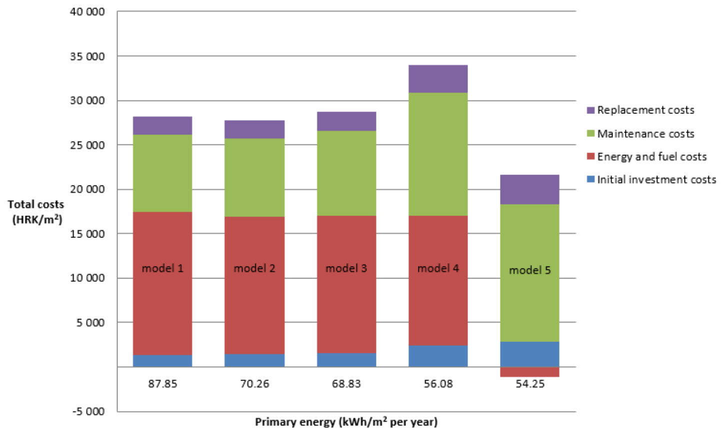
Source: *REGEA,* 2017

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

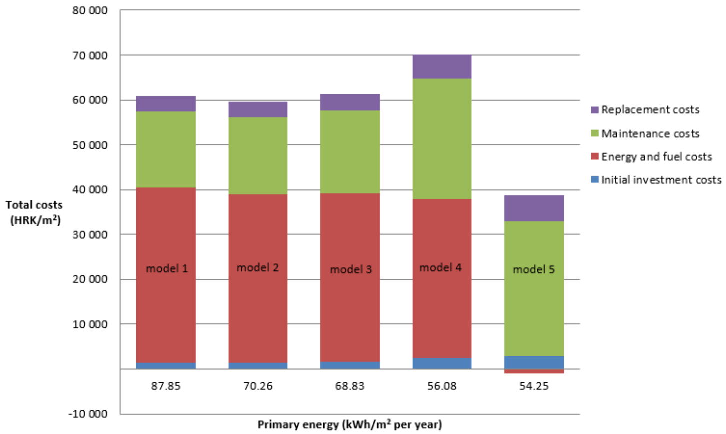
Parametres of various models of public building renovation in coastal Croatia related to a 30-year calculation period



Parametres of various models of public building renovation in coastal Croatia related to a 50-year calculation period



Parametres of various models of public building renovation in coastal Croatia related to a 70-year calculation period



model 1	Building renovation according to minimum *Technical Regulation* requirements
model 2	Building renovation according to *Technical Regulation* requirements related to large reconstruction
model 3	Building renovation according to the nZEB construction standard
model 4	Building renovation according to the passive construction standard
model 5	Building renovation according to the active construction standard

Source: *REGEA,* 2017

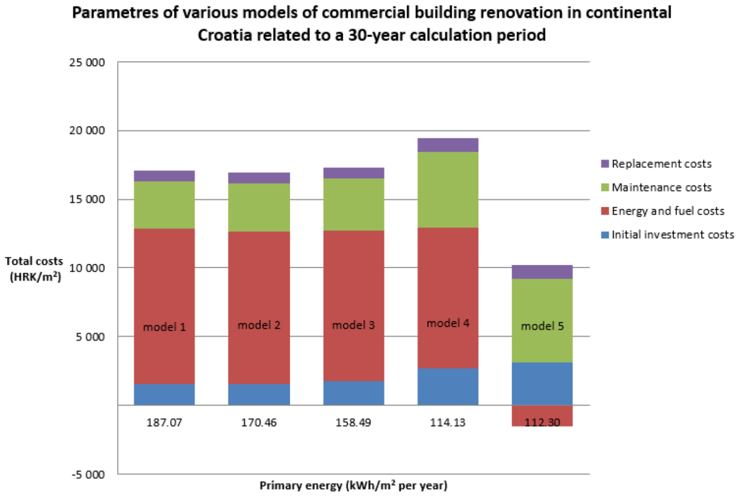
Annex 6 Overview of specific parameters of EE and RES measures under possible models of commercial building renovation in continental Croatia

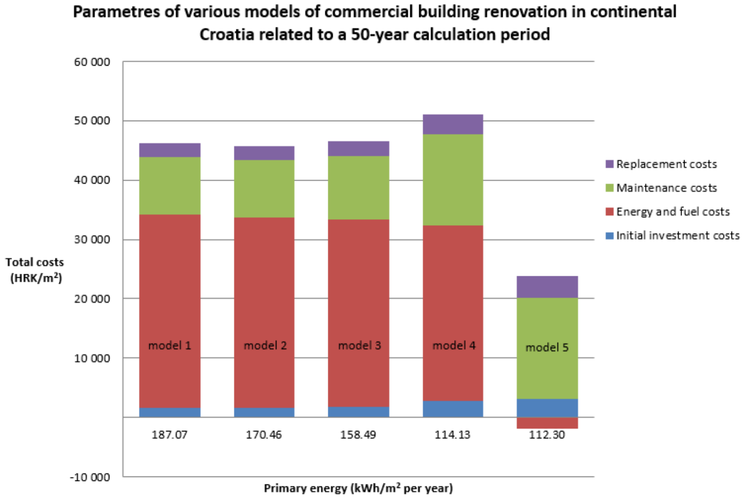
Commercial buildings in continental Croatia															
Measure number	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Energy savings in terms of percentage															
Building renovation according to minimum *Technical Regulation* requirements		64%					36%	40%	50%	40%					
Building renovation according to Technical Regulation requirements related to large reconstruction		72%					36%	40%	50%	40%					
Building renovation according to the nZEB construction standard		78%					36%	40%	50%	40%					
Building renovation according to the passive construction standard		95%					45%	50%	50%	40%					
Building renovation according to the active construction standard		95%					55%	50%	50%	40%				150%	
Specific energy savings (kWh/m2)															
Building renovation according to minimum *Technical Regulation* requirements		176.08					35.34	19.07	9.08	21.56					261.13
Building renovation according to *Technical Regulation* requirements related to large reconstruction		197.52					27.54	19.07	9.08	21.56					274.78
Building renovation according to the nZEB construction standard		212.97					21.92	19.07	9.08	21.56					284.61
Building renovation according to the passive construction standard		258.26					6.75	23.84	9.08	21.56					319.50
Building renovation according to the active construction standard		258.26					8.25	23.84	9.08	21.56				94.62	415.61
Specific cost savings (HRK/m²)															
Building renovation according to minimum *Technical Regulation* requirements		70.72					15.04	14.69	5.61	16.60					122.66
Building renovation according to *Technical Regulation* requirements related to large reconstruction		79.33					11.72	14.69	5.61	16.60					127.95
Building renovation according to the nZEB construction standard		85.53					9.33	14.69	5.61	16.60					131.77
Building renovation according to the passive construction standard		103.73					2.87	18.36	5.61	16.60					147.17
Building renovation according to the active construction standard		103.73					3.51	18.36	5.61	16.60				72.85	220.66
Measure 0: Building's energy management system, energy audit and energy certificate															
Measure 1: Outer window and door frame replacement															
Measure 2: Thermal insulation implementation to external walls															
Measure 3: Thermal insulation implementation to the roof/ceiling bordering unheated attic															
Measure 4: Thermal insulation implementation to the ceiling bordering unheated basement (if any)															
Measure 5: Thermal insulation implementation 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															

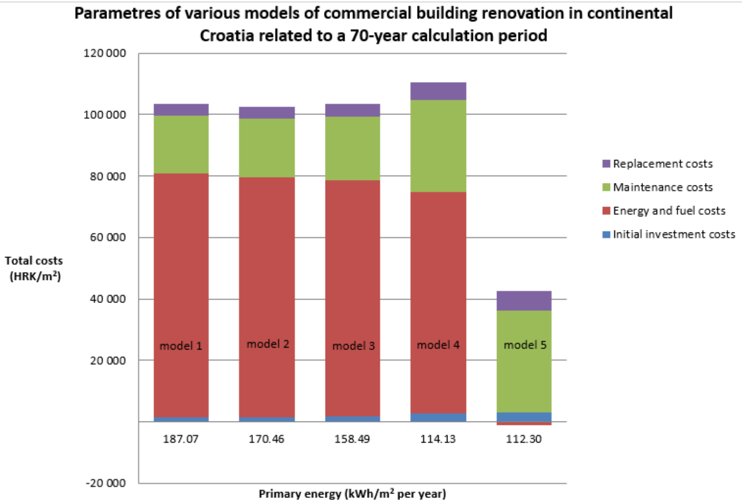
Calculation period	Type of expenditure	Initial investment (HRK/m^2)	Energy and fuel costs (HRK/m^2)	Maintenance costs (HRK/m^2)	Replacement costs (HRK/m^2)	Total expenditure (HRK/m^2)
30 years	Building renovation according to minimum *Technical Regulation* requirements	1,550.37	11,274.45	3,117.52	762.75	16,705.10
	Building renovation according to *Technical Regulation* requirements related to large reconstruction	1,582.90	11,071.64	3,160.18	762.75	16,577.46
	Building renovation according to the nZEB construction standard	1,782.95	10,925.51	3,422.53	762.75	16,893.74
	Building renovation according to the passive construction standard	2,723.70	10,232.46	4,964.89	953.50	18,874.55
	Building renovation according to the active construction standard	3,123.70	-1,491.76	5,564.89	953.50	8,150.33
50 years	Building renovation according to minimum *Technical Regulation* requirements	1,550.37	32,653.90	9,638.19	2,304.91	46,147.37
	Building renovation according to *Technical Regulation* requirements related to large reconstruction	1,582.90	32,066.48	9,774.00	2,326.70	45,750.08
	Building renovation according to the nZEB construction standard	1,782.95	31,643.25	10,609.23	2,460.74	46,496.17
	Building renovation according to the passive construction standard	2,723.70	29,636.01	15,328.47	3,407.69	51,095.87
	Building renovation according to the active construction standard	3,123.70	-1,901.82	16,998.47	3,675.69	21,896.04
70 years	Building renovation according to minimum *Technical Regulation* requirements	1,550.37	79,381.88	18,807.46	3,823.19	103,562.90
	Building renovation according to *Technical Regulation* requirements related to large reconstruction	1,582.90	77,953.86	19,069.32	3,865.48	102,471.56
	Building renovation according to the nZEB construction standard	1,782.95	76,924.99	20,679.76	4,125.55	103,513.25
	Building renovation according to the passive construction standard	2,723.70	72,045.36	29,835.07	5,800.61	110,404.73
	Building renovation according to the active construction standard	3,123.70	-1,243.22	33,055.07	6,320.61	41,256.15

Source: *REGEA,* 2017

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







model 1	Building renovation according to minimum *Technical Regulation* requirements
model 2	Building renovation according to *Technical Regulation* requirements related to large reconstruction
model 3	Building renovation according to the nZEB construction standard
model 4	Building renovation according to the passive construction standard
model 5	Building renovation according to the active construction standard

Source: *REGEA,* 2017

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

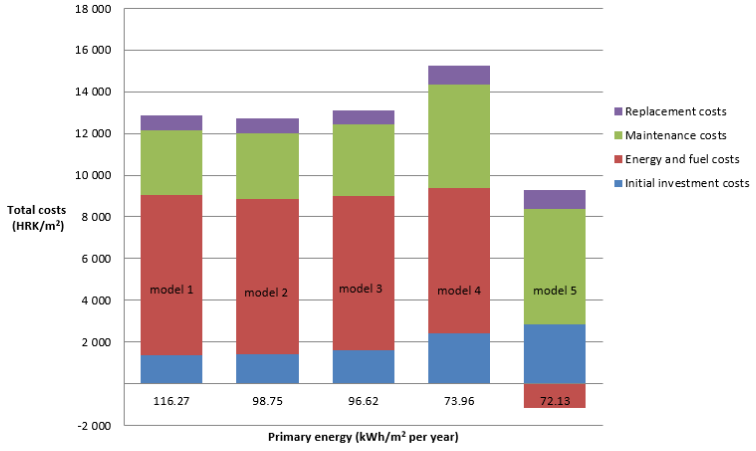
Commercial buildings in coastal Croatia															
Measure number	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Energy savings in terms of percentage															
Building renovation according to minimum *Technical Regulation* requirements		59%					36%	60%	75%	40%					
Building renovation according to Technical Regulation requirements related to large reconstruction		76%					36%	60%	75%	40%					
Building renovation according to the nZEB construction standard		78%					36%	60%	75%	40%					
Building renovation according to the passive construction standard		89%					45%	70%	75%	40%					
Building renovation according to the active construction standard		89%					55%	70%	75%	40%				150%	
Specific energy savings (kWh/m2)															
Building renovation according to minimum *Technical Regulation* requirements		81.72					20.43	32.84	7.85	13.86					156.69
Building renovation according to *Technical Regulation* requirements related to large reconstruction		104.34					12.20	32.84	7.85	13.86					171.08
Building renovation according to the nZEB construction standard		107.09					11.20	32.84	7.85	13.86					172.83
Building renovation according to the passive construction standard		122.90					6.75	38.31	7.85	13.86					189.66
Building renovation according to the active construction standard		122.90					8.25	38.31	7.85	13.86				65.40	256.56
Specific cost savings (HRK/m²)															
Building renovation according to minimum *Technical Regulation* requirements		33.21					8.79	25.28	4.86	10.67					82.82
Building renovation according to *Technical Regulation* requirements related to large reconstruction		42.40					5.25	25.28	4.86	10.67					88.47
Building renovation according to the nZEB construction standard		43.51					4.82	25.28	4.86	10.67					89.15
Building renovation according to the passive construction standard		49.94					2.90	29.50	4.86	10.67					97.88
Building renovation according to the active construction standard		49.94					3.55	29.50	4.86	10.67				50.36	148.88
Measure 0: Building's energy management system, energy audit and energy certificate															
Measure 1: Outer window and door frame replacement															
Measure 2: Thermal insulation implementation to external walls															
Measure 3: Thermal insulation implementation to the roof/ceiling bordering unheated attic															
Measure 4: Thermal insulation implementation to the ceiling bordering unheated basement (if any)															
Measure 5: Thermal insulation implementation 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															

Calculation period	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	Building renovation according to minimum *Technical Regulation* requirements	1,550.37	7,649.61	3,117.52	762.75	13,080.25
	Building renovation according to *Technical Regulation* requirements related to large reconstruction	1,582.90	7,435.66	3,160.18	762.75	12,941.49
	Building renovation according to the nZEB construction standard	1,782.95	7,409.64	3,422.53	762.75	13,377.87
	Building renovation according to the passive construction standard	2,723.70	6,959.27	4,964.89	953.50	15,601.36
	Building renovation according to the active construction standard	3,123.70	-1,151.32	5,564.89	953.50	8,490.77
50 years	Building renovation according to minimum *Technical Regulation* requirements	1,550.37	22,155.37	9,638.19	2,304.91	35,648.84
	Building renovation according to *Technical Regulation* requirements related to large reconstruction	1,582.90	21,535.71	9,774.00	2,326.70	35,219.31
	Building renovation according to the nZEB construction standard	1,782.95	21,460.34	10,609.23	2,460.74	36,313.26
	Building renovation according to the passive construction standard	2,723.70	20,155.96	15,328.47	3,407.69	41,615.82
	Building renovation according to the active construction standard	3,123.70	-1,662.73	16,998.47	3,675.69	22,135.13
70 years	Building renovation according to minimum *Technical Regulation* requirements	1,550.37	53,859.87	18,807.46	3,823.19	78,040.89
	Building renovation according to *Technical Regulation* requirements related to large reconstruction	1,582.90	52,353.47	19,069.32	3,865.48	76,871.16
	Building renovation according to the nZEB construction standard	1,782.95	52,170.25	20,679.76	4,125.55	78,758.51
	Building renovation according to the passive construction standard	2,723.70	48,999.29	29,835.07	5,800.61	87,358.66
	Building renovation according to the active construction standard	3,123.70	-1,705.80	33,055.07	6,320.61	40,793.57

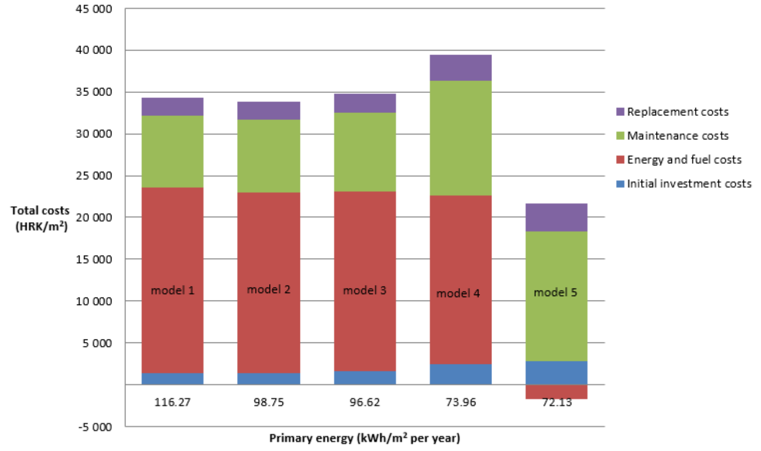
Source: *REGEA,* 2017

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

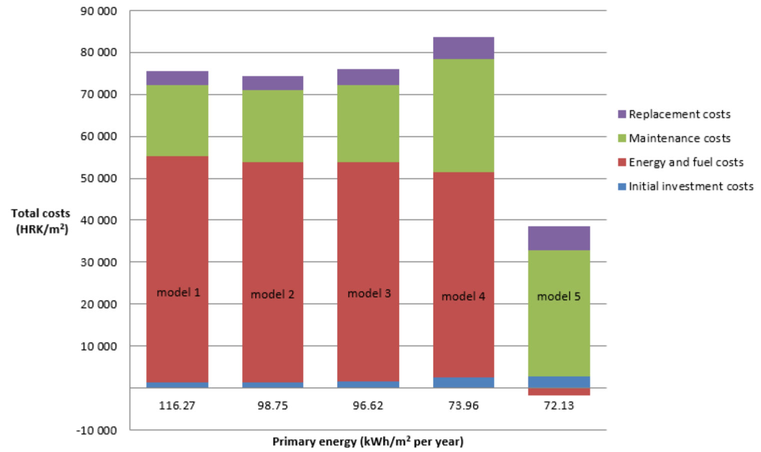
Parametres of various models of commercial building renovation in coastal Croatia related to a 30-year calculation period



Parametres of various models of commercial building renovation in coastal Croatia related to a 50-year calculation period



Parametres of various models of commercial building renovation in coastal Croatia related to a 70-year calculation period



model 1	Building renovation according to minimum *Technical Regulation* requirements
model 2	Building renovation according to *Technical Regulation* requirements related to large reconstruction
model 3	Building renovation according to the nZEB construction standard
model 4	Building renovation according to the passive construction standard
model 5	Building renovation according to the active construction standard

Source: *REGEA,* 2017

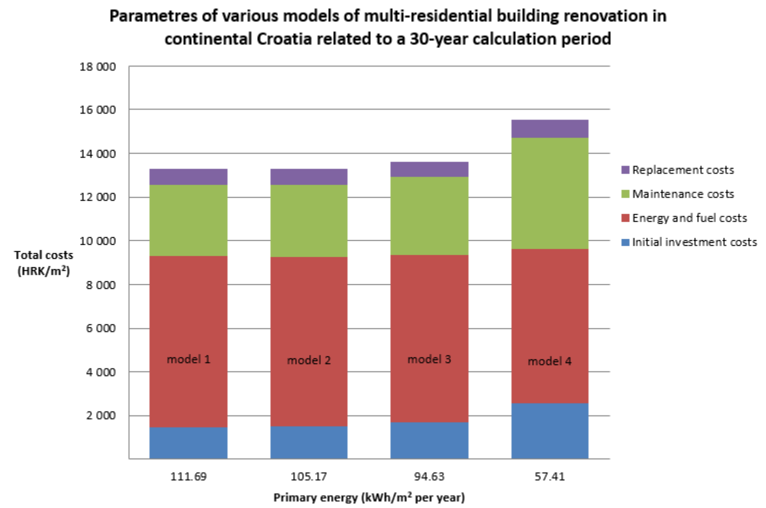
Annex 10 Overview of specific parameters of EE and RES measures under possible models of multi-residential building renovation in continental Croatia

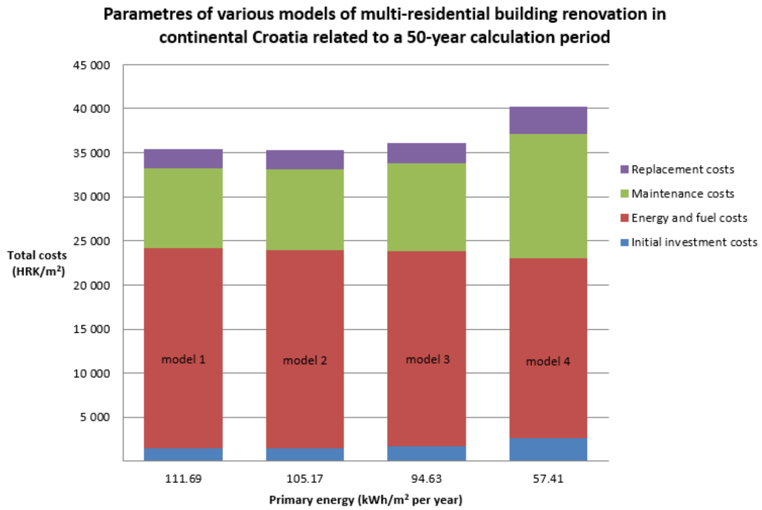
Multi-residential buildings in continental Croatia															
Measure number	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Energy savings in terms of percentage															
Building renovation according to minimum *Technical Regulation* requirements		59%					36%	40%							
Building renovation according to Technical Regulation requirements related to large reconstruction		64%					36%	40%							
Building renovation according to the nZEB construction standard		71%					36%	40%							
Building renovation according to the passive construction standard		93%					45%	50%							
Specific energy savings (kWh/m2)															
Building renovation according to minimum *Technical Regulation* requirements		120.48					30.00	10.81							161.29
Building renovation according to *Technical Regulation* requirements related to large reconstruction		129.56					26.69	10.81							167.07
Building renovation according to the nZEB construction standard		144.24					21.35	10.81							176.41
Building renovation according to the passive construction standard		187.97					6.75	13.52							208.24
Specific cost savings (HRK/m²)															
Building renovation according to minimum *Technical Regulation* requirements		31.71					7.47	8.33							47.51
Building renovation according to *Technical Regulation* requirements related to large reconstruction		34.10					6.65	8.33							49.07
Building renovation according to the nZEB construction standard		37.96					5.32	8.33							51.61
Building renovation according to the passive construction standard		49.47					1.68	10.41							61.56
Measure 0: Building's energy management system, energy audit and energy certificate															
Measure 1: Outer window and door frame replacement															
Measure 2: Thermal insulation implementation to external walls															
Measure 3: Thermal insulation implementation to the roof/ceiling bordering unheated attic															
Measure 4: Thermal insulation implementation to the ceiling bordering unheated basement (if any)															
Measure 5: Thermal insulation implementation 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															

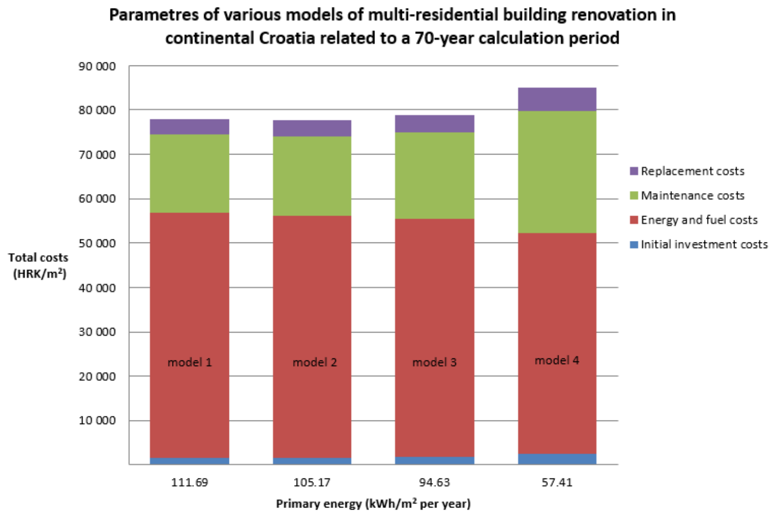
Calculation period	Type of expenditure	Initial investment (HRK/m²)	Energy and fuel costs (HRK/m²)	Maintenance costs (HRK/m²)	Replacement costs (HRK/m²)	Total expenditure (HRK/m²)
30 years	Building renovation according to minimum *Technical Regulation* requirements	1,469.00	7,849.96	3,255.88	701.58	13,276.42
	Building renovation according to *Technical Regulation* requirements related to large reconstruction	1,501.53	7,765.22	3,304.67	701.58	13,273.00
	Building renovation according to the nZEB construction standard	1,701.58	7,628.18	3,604.75	701.58	13,636.10
	Building renovation according to the passive construction standard	2,568.50	7,062.05	5,080.50	818.50	15,529.55
50 years	Building renovation according to minimum *Technical Regulation* requirements	1,469.00	22,735.63	9,044.65	2,148.86	35,398.14
	Building renovation according to *Technical Regulation* requirements related to large reconstruction	1,501.53	22,490.20	9,180.45	2,170.65	35,342.83
	Building renovation according to the nZEB construction standard	1,701.58	22,093.31	10,015.68	2,304.69	36,115.26
	Building renovation according to the passive construction standard	2,568.50	20,453.61	14,120.26	3,079.61	40,221.98
70 years	Building renovation according to minimum *Technical Regulation* requirements	1,469.00	55,270.50	17,645.08	3,572.45	77,957.03
	Building renovation according to *Technical Regulation* requirements related to large reconstruction	1,501.53	54,673.85	17,906.94	3,614.74	77,697.06
	Building renovation according to the nZEB construction standard	1,701.58	53,709.00	19,517.38	3,874.81	78,802.77
	Building renovation according to the passive construction standard	2,568.50	49,722.89	27,465.88	5,278.90	85,036.17

Source: *REGEA,* 2017

Annex 11 Overview of various model parameters of multi-residential building renovation in continental Croatia for different calculation periods







model 1	Building renovation according to minimum *Technical Regulation* requirements
model 2	Building renovation according to *Technical Regulation* requirements related to large reconstruction
model 3	Building renovation according to the nZEB construction standard
model 4	Building renovation according to the passive construction standard

Source: *REGEA,* 2017

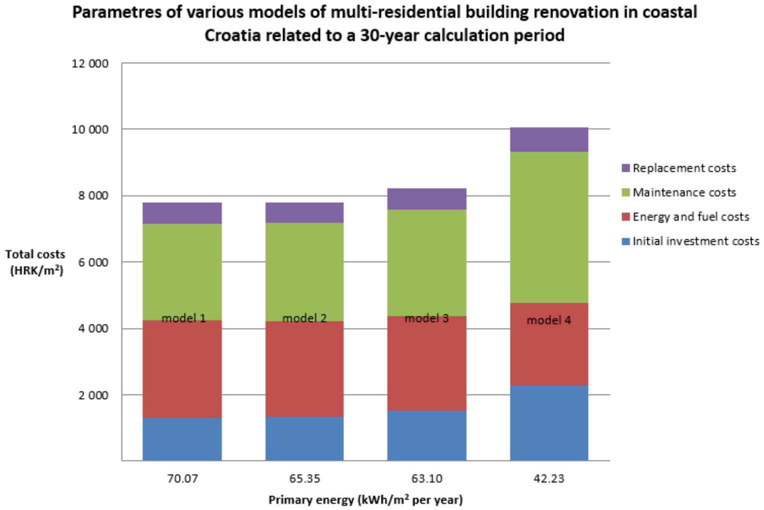
Annex 12 Overview of specific parameters of EE and RES measures under possible models of multi-residential building renovation in coastal Croatia

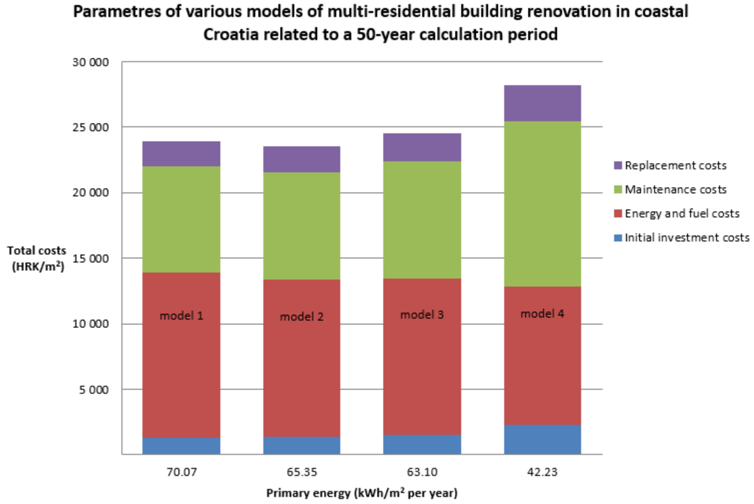
Multi-residential buildings in coastal Croatia															
Measure number	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Energy savings in terms of percentage															
Building renovation according to minimum *Technical Regulation* requirements		50%					36%	60%							
Building renovation according to Technical Regulation requirements related to large reconstruction		57%					36%	60%							
Building renovation according to the nZEB construction standard		61%					36%	60%							
Building renovation according to the passive construction standard		84%					45%	70%							
Specific energy savings (kWh/m2)															
Building renovation according to minimum *Technical Regulation* requirements		45.82					16.63	16.04							78.49
Building renovation according to *Technical Regulation* requirements related to large reconstruction		52.38					14.24	16.04							82.67
Building renovation according to the nZEB construction standard		55.52					13.10	16.04							84.66
Building renovation according to the passive construction standard		76.54					6.75	18.72							102.01
Specific cost savings (HRK/m²)															
Building renovation according to minimum *Technical Regulation* requirements		12.53					4.31	12.35							29.19
Building renovation according to *Technical Regulation* requirements related to large reconstruction		14.32					3.69	12.35							30.37
Building renovation according to the nZEB construction standard		15.18					3.40	12.35							30.93
Building renovation according to the passive construction standard		20.93					1.75	14.41							37.09
Measure 0: Building's energy management system, energy audit and energy certificate															
Measure 1: Outer window and door frame replacement															
Measure 2: Thermal insulation implementation to external walls															
Measure 3: Thermal insulation implementation to the roof/ceiling bordering unheated attic															
Measure 4: Thermal insulation implementation to the ceiling bordering unheated basement (if any)															
Measure 5: Thermal insulation implementation 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															

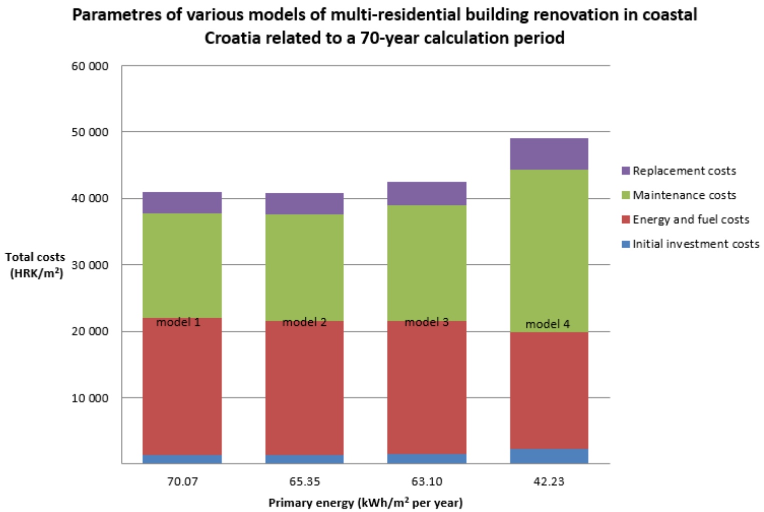
Calculation period	Type of expenditure	Initial investment (HRK/m^2)	Energy and fuel costs (HRK/m^2)	Maintenance costs (HRK/m^2)	Replacement costs (HRK/m^2)	Total expenditure (HRK/m^2)
30 years	Building renovation according to minimum *Technical Regulation* requirements	1,469.00	2,937.83	2,914.77	636.13	7,957.74
	Building renovation according to *Technical Regulation* requirements related to large reconstruction	1,501.53	2,876.54	2,957.43	636.13	7,971.63
	Building renovation according to the nZEB construction standard	1,701.58	2,847.26	3,219.78	636.13	8,404.75
	Building renovation according to the passive construction standard	2,568.50	2,494.54	4,538.89	747.99	10,349.93
50 years	Building renovation according to minimum *Technical Regulation* requirements	1,469.00	8,508.76	8,096.88	1,931.70	20,006.35
	Building renovation according to *Technical Regulation* requirements related to large reconstruction	1,501.53	8,331.24	8,215.61	1,950.76	19,999.14
	Building renovation according to the nZEB construction standard	1,701.58	8,246.43	8,945.82	2,067.94	20,961.77
	Building renovation according to the passive construction standard	2,568.50	7,224.88	12,614.55	2,767.88	25,175.81
70 years	Building renovation according to minimum *Technical Regulation* requirements	1,307.05	20,684.86	15,798.47	3,206.80	40,997.18
	Building renovation according to *Technical Regulation* requirements related to large reconstruction	1,335.49	20,253.31	16,027.40	3,243.77	40,859.97
	Building renovation according to the nZEB construction standard	1,510.39	20,047.14	17,435.33	3,471.14	42,464.00
	Building renovation according to the passive construction standard	2,277.94	17,563.73	24,541.97	4,734.06	49,117.70

Source: *REGEA,* 2017

Annex 13 Overview of various renovation model parameters involving multi-residential buildings in coastal Croatia for different calculation periods







model 1	Building renovation according to minimum *Technical Regulation* requirements
model 2	Building renovation according to *Technical Regulation* requirements related to large reconstruction
model 3	Building renovation according to the nZEB construction standard
model 4	Building renovation according to the passive construction standard

Source: *REGEA,* 2017

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

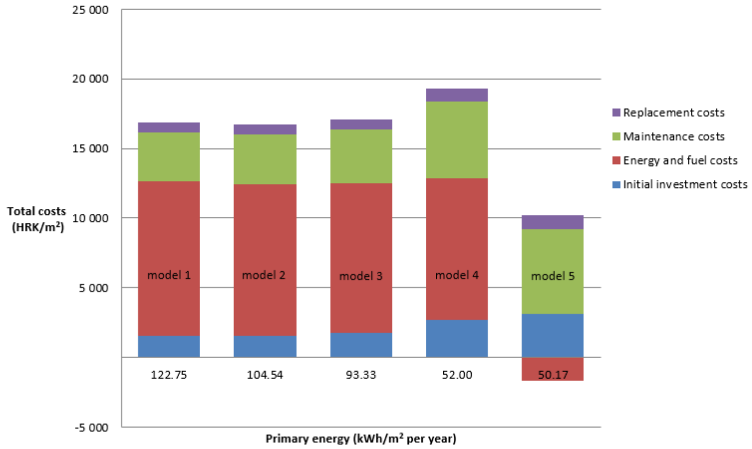
Family houses in continental Croatia															
Measure number	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Energy savings in terms of percentage															
Building renovation according to minimum *Technical Regulation* requirements		69%					36%	40%	50%	40%					
Building renovation according to Technical Regulation requirements related to large reconstruction		76%					36%	40%	50%	40%					
Building renovation according to the nZEB construction standard		81%					36%	40%	50%	40%					
Building renovation according to the passive construction standard		95%					45%	50%	50%	40%					
Building renovation according to the active construction standard		95%					55%	50%	50%	40%				150%	
Specific energy savings (kWh/m2)															
Building renovation according to minimum *Technical Regulation* requirements		209.87					34.84	16.28	6.70	10.83					278.52
Building renovation according to *Technical Regulation* requirements related to large reconstruction		233.37					26.29	16.28	6.70	10.83					293.48
Building renovation according to the nZEB construction standard		247.83					21.03	16.28	6.70	10.83					302.68
Building renovation according to the passive construction standard		290.68					6.75	20.35	6.70	10.83					335.31
Building renovation according to the active construction standard		290.68					8.25	20.35	6.70	10.83				95.02	431.83
Specific cost savings (HRK/m²)															
Building renovation according to minimum *Technical Regulation* requirements		55.23					9.51	12.53	3.16	8.34					88.78
Building renovation according to *Technical Regulation* requirements related to large reconstruction		61.42					7.18	12.53	3.16	8.34					92.64
Building renovation according to the nZEB construction standard		65.22					5.74	12.53	3.16	8.34					95.01
Building renovation according to the passive construction standard		76.50					1.84	15.67	3.16	8.34					105.52
Building renovation according to the active construction standard		76.50					2.25	15.67	3.16	8.34				73.17	179.09
Measure 0: Building's energy management system, energy audit and energy certificate															
Measure 1: Outer window and door frame replacement															
Measure 2: Thermal insulation implementation to external walls															
Measure 3: Thermal insulation implementation to the roof/ceiling bordering unheated attic															
Measure 4: Thermal insulation implementation to the ceiling bordering unheated basement (if any)															
Measure 5: Thermal insulation implementation 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															

Calculation period	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	Building renovation according to minimum *Technical Regulation* requirements	1,550.37	11,106.65	3,469.68	762.75	16,889.45
	Building renovation according to *Technical Regulation* requirements related to large reconstruction	1,582.90	10,883.53	3,518.47	762.75	16,747.64
	Building renovation according to the nZEB construction standard	1,782.95	10,746.23	3,818.55	762.75	17,110.48
	Building renovation according to the passive construction standard	2,723.70	10,110.83	5,515.80	953.50	19,303.83
	Building renovation according to the active construction standard	3,123.70	-1,663.67	6,115.80	953.50	8,529.33
50 years	Building renovation according to minimum *Technical Regulation* requirements	1,550.37	32,167.90	9,638.19	2,304.91	45,661.37
	Building renovation according to *Technical Regulation* requirements related to large reconstruction	1,582.90	31,521.68	9,774.00	2,326.70	45,205.28
	Building renovation according to the nZEB construction standard	1,782.95	31,124.02	10,609.23	2,460.74	45,976.94
	Building renovation according to the passive construction standard	2,723.70	29,283.73	15,328.47	3,407.69	50,743.60
	Building renovation according to the active construction standard	3,123.70	-2,389.34	16,998.47	3,675.69	21,408.53
70 years	Building renovation according to minimum *Technical Regulation* requirements	1,550.37	78,200.42	18,807.46	3,823.19	102,381.45
	Building renovation according to *Technical Regulation* requirements related to large reconstruction	1,582.90	76,629.44	19,069.32	3,865.48	101,147.13
	Building renovation according to the nZEB construction standard	1,782.95	75,662.73	20,679.76	4,125.55	102,250.99
	Building renovation according to the passive construction standard	2,723.70	71,188.98	29,835.07	5,800.61	109,548.36
	Building renovation according to the active construction standard	3,123.70	-2,413.87	33,055.07	6,320.61	40,085.50

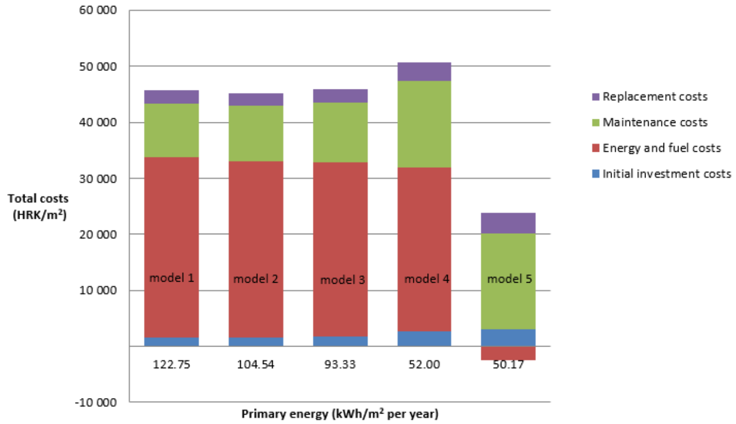
Source: *REGEA,* 2017

Annex 15 Overview of specific parameters of EE and RES measures under possible models of family house renovation in continental Croatia

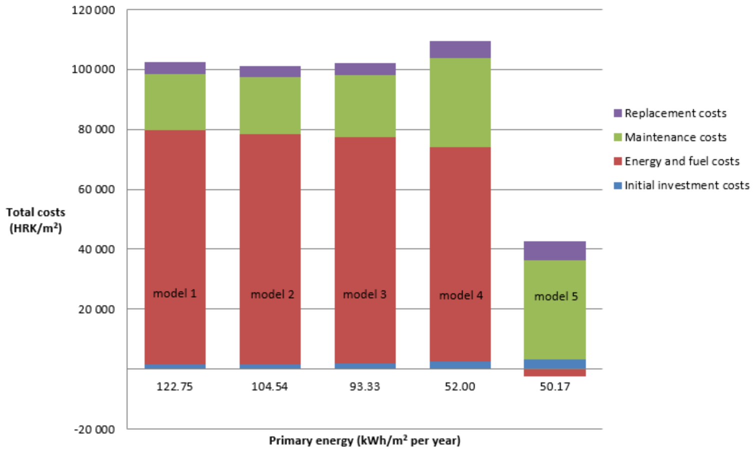
Parametres of various models of family house renovation in continental Croatia related to a 30-year calculation period



Parametres of various models of family house renovation in continental Croatia related to a 50-year calculation period



Parametres of various models of family house renovation in continental Croatia related to a 70-year calculation period



model 1	Building renovation according to minimum *Technical Regulation* requirements
model 2	Building renovation according to *Technical Regulation* requirements related to large reconstruction
model 3	Building renovation according to the nZEB construction standard
model 4	Building renovation according to the passive construction standard
model 5	Building renovation according to the active construction standard

Source: *REGEA,* 2017

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

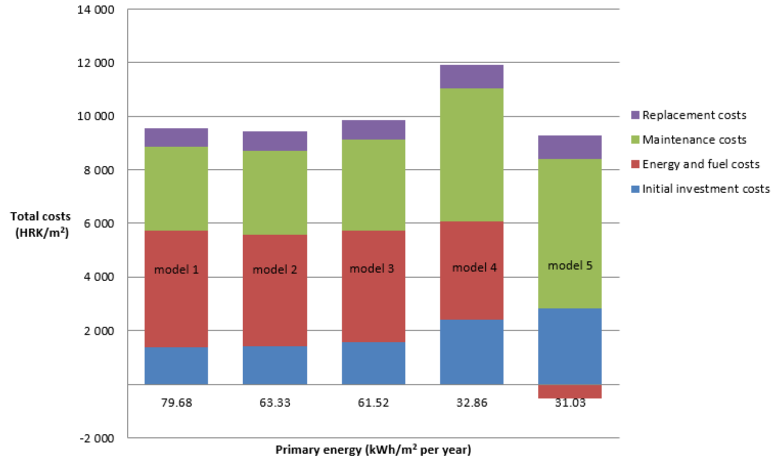
Family houses in coastal Croatia															
Measure number	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Energy savings in terms of percentage															
Building renovation according to minimum *Technical Regulation* requirements		55%					36%	60%	75%	40%					
Building renovation according to Technical Regulation requirements related to large reconstruction		70%					36%	60%	75%	40%					
Building renovation according to the nZEB construction standard		71%					36%	60%	75%	40%					
Building renovation according to the passive construction standard		90%					45%	70%	75%	40%					
Building renovation according to the active construction standard		90%					55%	70%	75%	40%				150%	
Specific energy savings (kWh/m2)															
Building renovation according to minimum *Technical Regulation* requirements		78.80					23.52	25.15	5.55	6.10					139.12
Building renovation according to *Technical Regulation* requirements related to large reconstruction		99.90					15.84	25.15	5.55	6.10					152.55
Building renovation according to the nZEB construction standard		102.23					14.99	25.15	5.55	6.10					154.03
Building renovation according to the passive construction standard		128.47					6.75	29.34	5.55	6.10					176.21
Building renovation according to the active construction standard		128.47					8.25	29.34	5.55	6.10				33.67	211.38
Specific cost savings (HRK/m²)															
Building renovation according to minimum *Technical Regulation* requirements		21.54					6.66	19.37	2.71	4.70					54.97
Building renovation according to *Technical Regulation* requirements related to large reconstruction		27.31					4.49	19.37	2.71	4.70					58.57
Building renovation according to the nZEB construction standard		27.95					4.25	19.37	2.71	4.70					58.97
Building renovation according to the passive construction standard		35.13					1.91	22.59	2.71	4.70					67.03
Building renovation according to the active construction standard		35.13					2.34	22.59	2.71	4.70				25.93	93.38
Measure 0: Building's energy management system, energy audit and energy certificate															
Measure 1: Outer window and door frame replacement															
Measure 2: Thermal insulation implementation to external walls															
Measure 3: Thermal insulation implementation to the roof/ceiling bordering unheated attic															
Measure 4: Thermal insulation implementation to the ceiling bordering unheated basement (if any)															
Measure 5: Thermal insulation implementation 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															

Calculation period	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	Building renovation according to minimum *Technical Regulation* requirements	1,550.37	4,353.95	3,469.68	762.75	10,136.74
	Building renovation according to *Technical Regulation* requirements related to large reconstruction	1,582.90	4,153.64	3,518.47	762.75	10,017.75
	Building renovation according to the nZEB construction standard	1,782.95	4,131.48	3,818.55	762.75	10,495.73
	Building renovation according to the passive construction standard	2,723.70	3,647.47	5,515.80	953.50	12,840.47
	Building renovation according to the active construction standard	3,123.70	-539.04	6,115.80	953.50	9,653.96
50 years	Building renovation according to minimum *Technical Regulation* requirements	1,550.37	12,610.22	9,638.19	2,304.91	26,103.69
	Building renovation according to *Technical Regulation* requirements related to large reconstruction	1,582.90	12,030.07	9,774.00	2,326.70	25,713.67
	Building renovation according to the nZEB construction standard	1,782.95	11,965.91	10,609.23	2,460.74	26,818.83
	Building renovation according to the passive construction standard	2,723.70	10,564.07	15,328.47	3,407.69	32,023.93
	Building renovation according to the active construction standard	3,123.70	-700.50	16,998.47	3,675.69	23,097.36
70 years	Building renovation according to minimum *Technical Regulation* requirements	1,550.37	30,655.55	18,807.46	3,823.19	54,836.57
	Building renovation according to *Technical Regulation* requirements related to large reconstruction	1,582.90	29,245.20	19,069.32	3,865.48	53,762.89
	Building renovation according to the nZEB construction standard	1,782.95	29,089.22	20,679.76	4,125.55	55,677.48
	Building renovation according to the passive construction standard	2,723.70	25,681.34	29,835.07	5,800.61	64,040.71
	Building renovation according to the active construction standard	3,123.70	-500.11	33,055.07	6,320.61	41,999.27

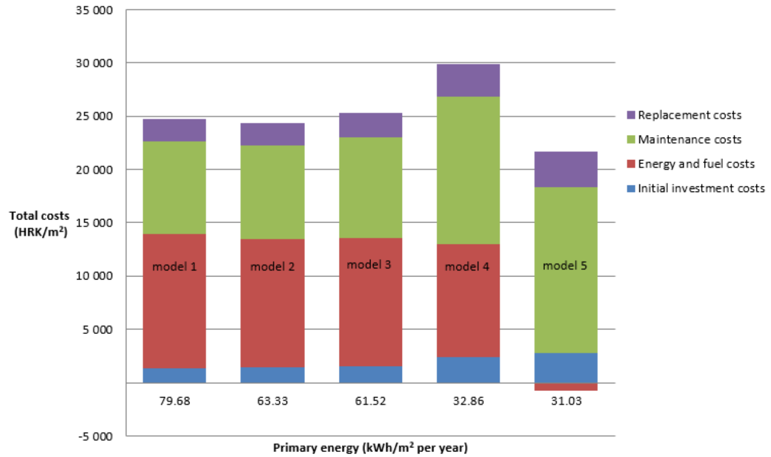
Source: *REGEA,* 2017

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

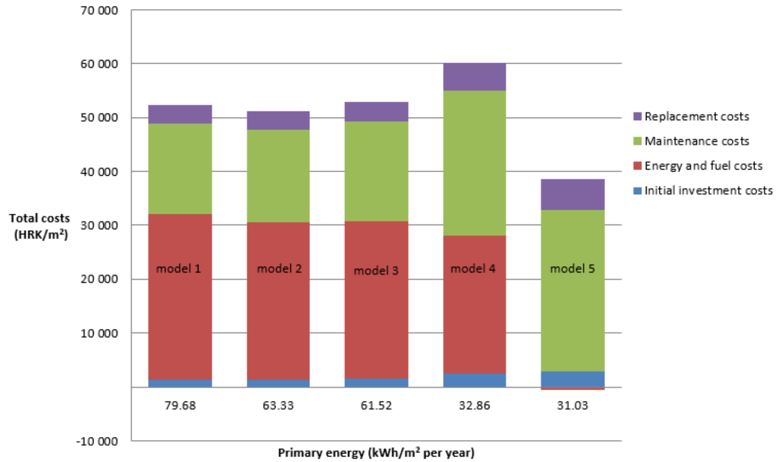
Parametres of various models of family house renovation in coastal Croatia related to a 30-year calculation period



Parametres of various models of family house renovation in coastal Croatia related to a 50-year calculation period



Parametres of various models of family house renovation in coastal Croatia related to a 70-year calculation period



Source: *REGEA,* 2017

model 1	Building renovation according to minimum *Technical Regulation* requirements
model 2	Building renovation according to *Technical Regulation* requirements related to large reconstruction
model 3	Building renovation according to the nZEB construction standard
model 4	Building renovation according to the passive construction standard
model 5	Building renovation according to the active construction standard

Annex 18 Breakdown of investments in the 2014–2049 national building stock renovation-2049

Items/year	2017	2018	2019	2020	2021	2022	2023	2024
Initial Investment [HRK]	11,030,321,661	11,030,321,661	11,030,321,661	11,030,321,661	11,030,321,661	11,030,321,661	11,030,321,661	11,030,321,661
Maintenance cost [HRK]	655,630,439	1,276,637,549	1,897,644,658	2,518,651,768	3,139,658,877	3,760,665,987	4,381,673,096	5,002,680,206
Replacement cost [HRK]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total expenditure [HRK]	11,685,952,100	12,306,959,209	12,927,966,319	13,548,973,428	14,169,980,538	14,790,987,647	15,411,994,757	16,033,001,866
Cumulative cost [HRK mil]	13,053	24,704	36,356	48,007	59,658	71,310	82,961	94,612
Average annual renovation rate [%]	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Average renovated area per year [mil. m²]	6.738	6.738	6.738	6.738	6.738	6.738	6.738	6.738
Average annual energy savings [GWh]	1,393,789	1,393,789	1,393,789	1,393,789	1,393,789	1,393,789	1,393,789	1,393,789
Average annual energy savings [PJ]	5.02	5.02	5.02	5.02	5.02	5.02	5.02	5.02
Average reduction in CO_2 emissions [Kt]	239.56	239.56	239.56	239.56	239.56	239.56	239.56	239.56

Items/year	2025	2026	2027	2028	2029	2030	2031	2032
Initial Investment [HRK]	11,030,321,661	11,030,321,661	11,030,321,661	11,030,321,661	11,030,321,661	11,030,321,661	9,454,561,423	9,454,561,423
Maintenance cost [HRK]	5,623,687,315	6,244,694,425	6,865,701,534	7,486,708,644	8,107,715,753	8,728,722,863	9,548,955,123	10,369,187,385
Replacement cost [HRK]	0	0	0	0	0	0	5,114,395,260	5,114,395,260
Total expenditure [HRK]	16,654,008,976	17,275,016,085	17,896,023,195	18,517,030,304	19,138,037,414	19,759,044,523	24,117,911,807	24,938,144,069
Cumulative cost [HRK mil]	106,264	117,915	129,566	141,218	152,869	164,520	179,910	195,299
Average annual renovation rate [%]	3.5	3.5	3.5	3.5	3.5	3.0	3.0	3.0
Average renovated area per year [mil. m²]	6.738	6.738	6.738	6.738	6.738	5.776	5.776	5.776
Average annual energy savings [GWh]	1,393,789	1,393,789	1,393,789	1,393,789	1,393,789	1,194,677	1,194,677	1,194,677
Average annual energy savings [PJ]	5.02	5.02	5.02	5.02	5.02	4.30	4.30	4.30
Average reduction in CO_2 emissions [Kt]	239.56	239.56	239.56	239.56	239.56	205.34	205.34	205.34

Items/year	2033	2034	2035	2036	2037	2038	2039	2040
Initial Investment [HRK]	9,454,561,423	9,454,561,423	9,454,561,423	9,454,561,423	9,454,561,423	9,454,561,423	9,454,561,423	9,454,561,423
Maintenance cost [HRK]	11,189,419,646	12,009,651,908	12,829,884,169	13,650,116,430	14,470,348,692	15,290,580,953	16,110,813,214	16,931,045,475
Replacement cost [HRK]	5,114,395,260	5,114,395,260	5,114,395,260	5,114,395,260	5,114,395,260	5,114,395,260	5,114,395,260	5,114,395,260
Total expenditure [HRK]	25,758,376,330	26,578,608,591	27,398,840,853	28,219,073,114	29,039,305,375	29,859,537,636	30,679,769,898	31,500,002,159
Cumulative cost [HRK mil]	210,688	226,077	241,466	256,856	272,245	287,634	303,023	318,412
Average annual renovation rate [%]	3.0	3.0	3.0	3.0	3.0	3.0	3.0	1.5
Average renovated area per year [mil. m²]	5.776	5.776	5.776	5.776	5.776	5.776	5.776	2.888
Average annual energy savings [GWh]	1,194,677	1,194,677	1,194,677	1,194,677	1,194,677	1,194,677	1,194,677	597,338
Average annual energy savings [PJ]	4.30	4.30	4.30	4.30	4.30	4.30	4.30	2.15
Average reduction in CO_2 emissions [Kt]	205.34	205.34	205.34	205.34	205.34	205.34	205.34	102.67

Items/year	2041	2042	2043	2044	2045	2046	2047	2048	2049
Initial Investment [HRK]	4,727,280,712	4,727,280,712	4,727,280,712	4,727,280,712	4,727,280,712	4,727,280,712	4,727,280,712	4,727,280,712	4,727,280,712
Maintenance cost [HRK]	17,485,131,833	18,039,218,190	18,593,304,547	19,147,390,904	19,701,477,262	20,543,504,071	21,385,530,882	22,227,557,693	23,069,584,503
Replacement cost [HRK]	5,114,395,260	5,114,395,260	5,114,395,260	5,114,395,260	5,114,395,260	10,228,790,520	10,228,790,520	10,228,790,520	10,228,790,520
Total expenditure [HRK]	27,326,807,804	27,880,894,162	28,434,980,519	28,989,066,876	29,543,153,233	35,499,575,304	36,341,602,114	37,183,628,925	38,025,655,735
Cumulative cost [HRK mil]	328,808	339,204	349,600	359,995	370,391	386,189	401,987	417,785	433,583
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]	2.888	2.888	2.888	2.888	2.888	2.888	2.888	2.888	2.888
Average annual energy savings [GWh]	597,338	597,338	597,338	597,338	597,338	597,338	597,338	597,338	597,338
Average annual energy savings [PJ]	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15
Average reduction in CO_2 emissions [Kt]	102.67	102.67	102.67	102.67	102.67	102.67	102.67	102.67	102.67