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The economic impact of energy saving retrofits of residential and public buildings in Croatia

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HIGHLIGHTS

- Estimate of the overall socioeconomic impact of energy saving renovation measures on national economy.
- Energy efficient renovation if not subsidised is not financially viable from the owner perspective.
- Total social benefits are higher than social costs due to positive externalities.
- Impact of subsidies on public deficit is neutral even in the short run.

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ABSTRACT

The purpose of this paper is to estimunate the impact of energy saving investment in residential and public buildings in Croatia for the period 2015–2020. The aim is to assess the overall socio-economic impact of energy saving renovation measures defined in Croatian strategic documents in terms of the direct, indirect and induced growth of gross value added, employment and government revenues. An estimate of the avoided costs of air pollution is also included. The overall economic impact assessment is based on an input-output methodology. From the point of view of individual investors, the benefits in terms of reduced future expenses related to energy products are usually below energy efficient renovation investment costs, making an investment financially viable only if government support is provided. If the benefits for society as a whole are included, energy efficient renovation could be assessed as viable even in the short-run. Energy saving retrofits of residential and public buildings positively contribute to economic growth, employment and protection of the environment. Because of economic growth, the tax revenues induced by these investments could compensate for government expenditures, and the overall impact on the public deficit is expected to be neutral even in the short-run.

1. Introduction

The sustainable use of energy and its implications for climate change has become one of the central topics of European politics. As much as 40% of total energy consumption and 36% of CO_2 emissions are accounted for by buildings in EU countries (European Commission, 2015). In Croatia, energy consumption in buildings is even larger due to the fact that most buildings in Croatia were built without adequate insulation. The Europe 2020 strategy for smart, sustainable and inclusive growth clearly states that achieving the objectives of increasing the use of renewable energy sources and energy efficiency by 20% by 2020 could create over 1 million new jobs in the EU. This undoubtedly confirms the general EU belief that energy efficiency projects have positive effects on the economy, and energy renovation projects represent an important tool for achieving Europe 2020 strategy priorities. In line with other European countries, Croatia is also implementing measures to reduce energy consumption. Besides energy renovation, some researches investigate the public attitudes towards photovoltaic systems and advantages of solar energy production (Tsantopoulos et al., 2014, Tampakis et al., 2013). Novak (2015) propose transition to new Sustainable Energy System which depends on energy from sun and could be enable usage of existing buildings infrastructure with minimum needs for adaption.

Most of the previous literature has stressed that energy efficient investments have a relatively high return on investment.

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However, this research was related mainly to the effects of energy renovation in more developed countries. There is much less research dealing with the effects of energy renovation in post-transition countries such as Croatia. These countries have different levels of development, prices and labour productivity than developed countries. In addition, buildings in post-transition countries are on average more energy inefficient, as measured by household specific energy consumption, than those in the EU-27 (Ürge-Vorsatz et al., 2010). Thus, it could be expected that investments in energy efficiency could have different effects in post-transition countries than in developed ones. The main aim of this research is to evaluate the effects of investment in energy efficiency in buildings in a less developed country and specifically a country with a pronounced problem of a rising elderly population which is not interested in such investment and cannot afford to finance it.

The purpose of this paper is to analyse and measure the impact of energy renovation investments in public and residential buildings. Special attention is paid to analysing conditions in which financial support from the government for saving renovation projects is necessary. Thus, we estimate the net present value of investments in energy efficiency renovation. In addition, we use an input-output methodology to estimate the impact of energy retrofit programmes on the private and government sector, as well as on achieving the general EU goal of reducing air pollutant emissions.

The paper consists of six sections. After the introduction, we proceed with a literature review. The third section has a brief overview of the building stock, energy consumption and specific economic conditions in Croatia. The methodology and data sources are described in the fourth section. In this section, we also estimate planned investments in energy renovation programmes. The fifth chapter is devoted to an assessment of the economic impact of investments from the perspective of private owners as well as from that of the government, and to a discussion of the results. The last section gives an overview of the main conclusions.

2. Literature review

Over half of the building stock in the EU was built before 1970, and up to 3% of it is renovated each year (Meijer et al., 2012). Thus, an empirical evaluation of the impact of investment in the energy renovation of buildings has gained a lot of attention in the literature in recent years. The majority of the literature confirms the existence of a positive impact of energy efficient renovation programmes on energy consumption and the environment, as well as on a variety of socio-economic processes. The implementation of energy efficiency measures can enhance job creation, energy savings and energy security, reduce air pollution and poverty, and also lead to multiple benefits for house owners and energy providers (Ryan and Campbell, 2014). One of the most comprehensive pieces of research in this area is that of Copenhagen Economics (2012), which shows that in addition to benefits in terms of energy savings and a decrease in energy dependence, investments in energy renovation encourage economic activity. They stimulate job creation, but also contribute to the improvement of household standards in financial terms, as well as in terms of health and quality of life in a broader sense. Depending on the size and scope of energy efficient investments in the renovation of buildings, Copenhagen Economics (2012) estimate that such investments could stimulate gross domestic product (GDP) growth in the EU by 1.2–2.3% annually. The positive effects are particularly pronounced in periods of economic crisis. Negative effects on GDP could be expected only in the short-term (Tuominen et al., 2013).

From the macroeconomic perspective, investment in energy renovation represents additional demand and an opportunity for domestic producers to increase economic activity. This relates mainly to entrepreneurs who produce goods or provide services for energy renewal, meaning entrepreneurs who are engaged in construction, but also in process and project design and construction supervision. In addition to the direct effects of energy renovation on production, gross value added (GVA) and the employment of entrepreneurs directly involved in projects, companies engaged in the production of goods and services used as intermediate consumption, such as construction materials, transport, craft services and similar should also benefit from the implementation of energy renovation programmes. These indirect effects are defined as an increase in the gross output, GVA and employment of all businesses involved in the production chain, i.e. the enterprises that produce intermediate products for the needs of a direct contractor, and their intensity is spread throughout the economy, depending on the value added chain. In addition to direct and indirect effects, the literature also discusses the induced effects resulting from higher personal consumption arising from the growth of household income generated by an increase in income due to realised savings and rising employment.

The ex-post analysis of energy efficiency retrofit programmes in the United Kingdom presented by Hamilton et al. (2013) shows that energy efficiency interventions decrease energy demand, while the analysis of Webber et al. (2015) reveals the link between income areas and the predicted level of impact in ex-ante estimates. However, it has to be noted that there is evidence of the existence of a rebound effect of investments, the change in behaviour arising from improved energy efficiency, which could diminish part of all the benefits. The rebound effect reflects the increase in demand for energy that is a result of the implementation of energy efficiency measures and policies or certain technological interventions (Maxwell et al., 2011). Such consequences of energy efficiency improvements can be observed at the microeconomic and macroeconomic level. Although there are still no accurate estimates of the impact of rebound effects, Copenhagen Economics (2012) in their estimate apply a rebound effect of between 10% and 30%, while Burman et al. (2014) stress the results of research in Austria showing that the rebound effect can be between 20% and 30% in space heating.

The literature also generally confirms the existence of a positive impact of energy renovation of buildings on public finances. This should even be the case in certain conditions where part of the cost has to be covered by the state, due to the fact that these costs are offset by an increase in tax and other revenues, as well as a drop in other types of expenses (Rosenow et al., 2014; Kuckshinrichs et al., 2010). Curtin's (2012) analysis of government support schemes in Ireland shows that support targeted on deeper energy efficiency measures is effective. The profitability of energy efficient retrofit investments and the necessity of government support in making these investments attractive from the house owner's perspective depend on future energy prices (Amstalden et al., 2007) and are hard to estimate. Net revenue gains in the EU could reach up to €40 billion in 2020 due to a decrease in government subsidies and energy spending, a rise in tax revenues, and a drop in public expenses caused by the improved health condition in populations (Copenhagen Economics, 2012). A part of these expected impacts should result from additional job creation caused by energy renovations. The largest positive effect can be expected in construction, community, social and personal services and manufacturing, while electricity, gas and water supply will record a drop in the number of employees (Ürge-Vorsatz et al., 2010; Markaki et al., 2013).

It has to be stressed that most studies dealing with the effects of energy renovation relate to developed countries, while those relating to transition countries are mostly calculated on the basis of average results obtained for developed countries. Ürge-Vorsatz et al. (2010) calculated 17.07 jobs per 1 million euros of investment as the effect of retrofit programmes on job creation, which was calculated as the average result of nine studies conducted in developed countries, mostly in the U.S.A. In addition, there are significant variations in results. Janssen and Staniaszek's (2012) in comparative survey of 18 studies shows that the employment effect estimates in developed countries and the EU vary from 6 to 60 per million euros. Ürge-Vorsatz et al. (2010) estimates that employment effects of retrofit programmes in Hungary is more intensive in comparison to U.S.A. and developed EU countries and could reach 37 and 49 full time equivalent employees per 1 million of Euro invested. The similar results are found for Poland (Ürge-Vorsatz et al., 2012) where 1 million of Euro invested in energy efficient renovation could generate 42 jobs. Analyses of economic impacts of renovation in Estonia conducted by Pikas et al. (2015) demonstrated that on average 17 jobs (directly and indirectly) were created annually per 1 million of Euro invested, while the tax revenue (including VAT and direct and indirect labour taxes) directly attributable to projects was between 32–33% of total renovation project cost. This study confirms that energy efficiency investments are not only important for environment, but also because they lead to economic benefits for individuals and government (Pikas et al., 2015). Schmid and Knopf (2013) quantified the long-term economic benefits that stem from an increasing integration of the pan-European electricity system by means of comparing model-based decarbonisation scenarios developed with the model LIMES-EU+ over the period 2010–2050. Their findings are in line with results of earlier studies. They showed that pan-European transmission capacity expansion causes positive social returns on investment in all mitigation scenarios under analysis. In our paper, we try to contribute to the literature estimating the effects of energy renovation measures in Croatia as post-transition countries.

3. Building stock, energy consumption, GDP and employment in Croatia

Energy consumption in buildings accounts for as much as 42.3% of total energy consumption in Croatia (Ministry of Construction and Physical Planning, 2014). The Energy Strategy of the Republic of Croatia states that an energy efficiency policy will be based on raising public awareness of energy sustainability which depends on rational energy consumption. The strategy includes financial incentives for the implementation of energy efficiency measures (Ministry of Economy, 2009).

The economic benefits of the energy efficient renovation of buildings are primarily related to current energy consumption and the expected potential for future energy savings. Residential buildings (single houses and multi-apartment buildings) comprise more than three-quarters of the total building stock in Croatia, while public buildings have a limited share of approximately 7%, with a dominant role played by buildings used in health and education services. In the case of residential buildings, more than 20% of the total building area is unoccupied (obsolete buildings or buildings devastated in war, secondary dwellings used only occasionally, etc.). The average size of occupied units is slightly above 100 m^2. Educational, health and commercial buildings have the biggest average size. In the case of multi-apartment buildings, the average size is expressed in terms of a single flat, which is on average smaller in comparison to a single family house (Tables 1 and 2).

Only about 20% of the total building area of public and residential buildings has been constructed in the last 25 years when energy standards have been higher. This certainly has had an impact on average energy consumption.

The specific energy consumption in buildings, besides the construction period, depends on the climate conditions. In general, Adriatic Croatia has more favourable weather conditions with a predominantly Mediterranean climate, and energy consumption is lower in comparison to Continental Croatia, where winters are longer and colder. Building of the same type and construction period usually demand 30–50% lower levels of energy consumption in the Adriatic part of the country. Single houses constructed before 1970 and hospitals located in Continental Croatia are the least energy efficient objects in terms of kWh per m^2 needed per year (EIZ, 2015). Construction standards regarding insulation

Table 2
Building stock in Croatia by age (construction period) in thousands of m^2.Source: Reference Building Project Phase 2: Determination of minimal requirements for energy performance for multi-apartment buildings, office buildings and other non-residential buildings (seven building uses) for Continental and Coastal Croatia for the periods up to 1970, 1971–2005 and after 2005 based on cost optimal analysis in accordance with the requirements of the EPBD Recast Directive and related Commission delegated regulation guidelines.

	Single houses	Multi-apartment	Public buildings	Total
Before 1970	38635.7	20287.1	4361.7	63284.5
1970–1990	39502.2	20742.1	5054.8	65299.0
1990–2005	15090.0	7923.6	1702.5	24716.1
After 2005	4477.8	2351.2	2683.0	9512.0
Total	97705.7	51304.1	13801.9	162811.7
Share as a %				
Before 1970	39.5	39.5	31.6	38.9
1970–1990	40.4	40.4	36.6	40.1
1990–2005	15.4	15.4	12.3	15.2
After 2005	4.6	4.6	19.4	5.8
Total	100.0	100.0	100.0	100.0

Table 1
Building stock in Croatia by main type, gross floor area and number of units.
Sources: Croatian Bureau of Statistics (2011); Ministry of Construction and Physical Planning Energy (2015).

	Total area in millions of m^2			Number of occupied units, in 000 s	Avg. size in m^2
	Total building area	Occupied building area	As a % of total area		
Residential building total:	149.0	121.1	74.8	1495.0	81.0
Single family houses	97.7	79.5	49.0	932.0	85.2
Multi-apartment buildings	51.3	41.7	25.7	563.0	74.0
Public buildings:	13.8	13.8	6.9	80.2	172.1
1. Educational buildings		2.1	1.0		2282*
1. Health buildings		1.6	0.8		2106*
Commercial non-res. buildings	36.5	36.5	18.3	45.0	817.0
Total	199.3	171.4	100.0	1620.2	105.8

* Reference building described in the calculation of technical standards.

materials and technology have significantly improved energy efficiency.

The energy balances for the Croatian economy indicate that energy consumption in public and residential buildings represents one third of the overall final energy consumption in Croatia, or approximately 23,000 GWh. Croatian domestic energy production is able to deliver less than half of gross inland consumption. Because of this, the Croatian economy is highly vulnerable in the event of disturbances on the global energy market, which could result in a reduction in supply or price increases. Promoting energy efficiency helps to protect the environment as well as increase overall energy sustainability (Figs. 1 and 2).

Energy efficient renovation projects can positively contribute to the Croatian economy, which is still affected by economic crisis (Fig. 4). An increase in demand can induce multiplicative effects if producers are able to increase supply by engaging more labour and other production inputs. According to ECORYS calculations based on EUROSTAT's input-output tables, inputs for the construction, maintenance, renovation and demolition of buildings and infrastructure represent roughly 44% of construction turnover, spread over a large number of sectors (ECORYS, 2011). The main positive impact from investment in energy efficiency is to be expected in the construction industry, which was the sector most seriously affected by the economic crisis in Croatia (Fig. 3). Until 2008, the construction industry in Croatia showed strong growth. Between 2001 and 2008, the GVA of the construction industry recorded an annual growth rate of 16.5%, while the share of construction in GDP increased from 5.5 to 8.4% (EIZ, 2015). As a result, the number of those employed in the construction industry recorded an increase of 64.1%. Nevertheless, since 2008 there have been strong changes in the sector and the Croatian construction industry is facing a significant decline (Fig. 3). Output in the construction sector fell faster than the whole economy over the same period (Fig. 3). From 2008 to 2012, the construction industry recorded an average annual decline of 12.3%. By comparison, the economy as a whole saw an average annual decline of 2.4%. Results from these developments also spread to employment. Total employment in the construction sector in legal entities in the period from 2008 to 2012 decreased by 40.8%. As a consequence of the economic downturn, about 26,681 jobs in construction were lost in Croatia during the period 2008–2012. In 2013, the construction sector's share in GDP reached 5.5%, which was significantly lower than the EU level (10%), which indicates a significant untapped potential for the development of the sector, especially within an area such as the renovation of buildings. By increasing activity in the sector in certain areas, such as the renovation of buildings, the sector could contribute significantly to job creation.

The economic crisis that occurred in the Croatian economy has had an enormous effect on national and regional development: a decline in GDP, rising unemployment, a decline in real wages, the development of consumer pessimism, weakening domestic demand, etc. Table 5 portrays the evolution of GDP per capita for Croatia over the period 2001–2013. Between 2001 and 2008, Croatia experienced an annual growth rate of GDP per capita of 8.7%. The picture changed dramatically after 2008, when the average annual growth rate of GDP per capita for Croatia was −0.3%. The impact of the crisis resulted in GDP per capita falling in relation to the EU average. The Croatian GDP per capita fell from about 63% of the EU-28 average in 2008–61% of the EU-28 average in 2012.

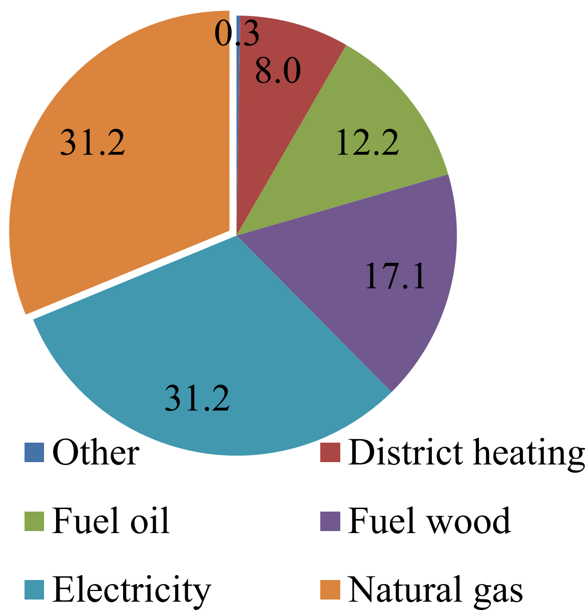

Fig. 1. Energy consumption in residential buildings by energy type as a %.

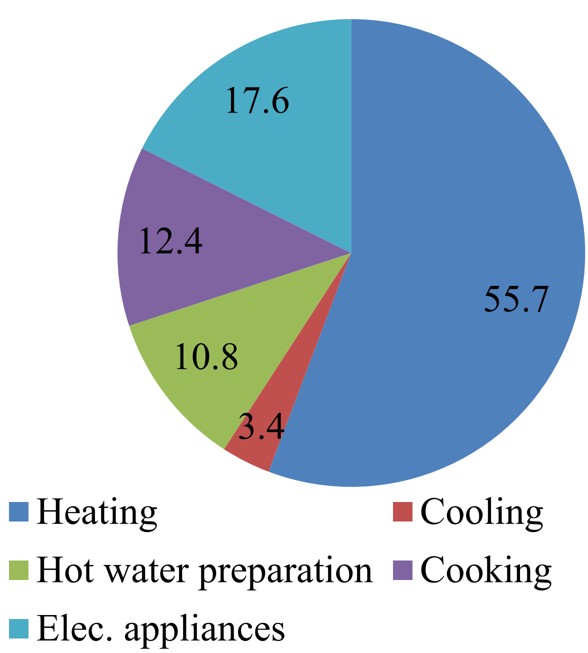

Fig. 2. Energy consumption in residential buildings by purpose as a %.

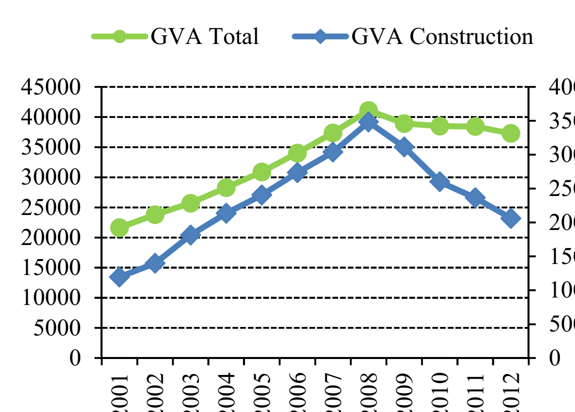

Fig. 3. GVA for the total economy and construction 2001–2012.

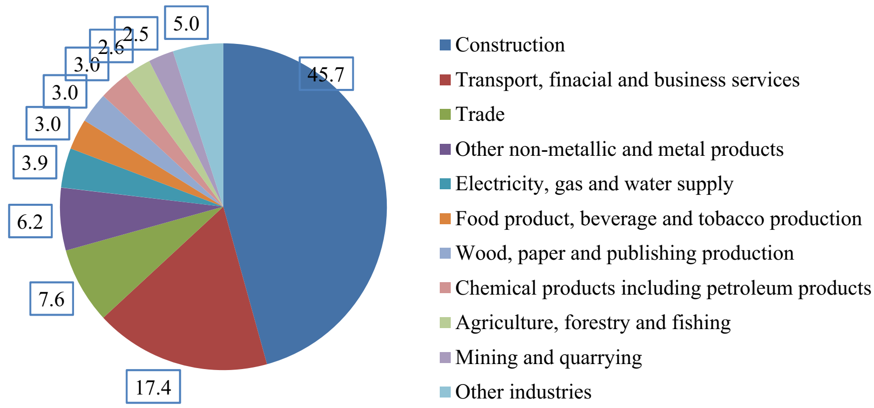

Fig. 4. Distribution of total gross output induced by investment energy efficient renovation by industry, as a %.

4. Methodology and data sources

4.1. Net present value of energy efficient renovation investments

The economic impact of investment in energy renovation of residential and public buildings is analysed from two different perspectives. The owners of residential dwellings and government units operating in public buildings are primarily concerned with financial savings in the future as a result of lower energy consumption and the initial value of investments in energy efficient renovation. In addition to direct costs and savings, renovation may also induce other benefits (Kuckshinrichs et al., 2010; Power, 2008), including an increase in the value of the building, an increase in the expected life of the building, and an increase in comfort for the inhabitants or users of public buildings. According to economic theory, the value of a dwelling is determined by the present value of total future rental income. In Croatia's case, more than 90% of dwellings are owner occupied and benefits cannot be directly expressed in monetary terms. Income in relation to the value of dwelling services should be imputed in the system of national accounts (SNA). According to SNA methodology, imputation for dwelling services for owner occupied residential buildings in new EU Member States is based on the cost principle (the sum of the consumption of fixed capital and the imputed net operating surplus). This income, according to the SNA convention, is at the same time recorded as imputed household consumption and does not present actual income for household expenditures. The same cost principle of valuation is applied to public buildings. Because of this, potential future rental income is not relevant in the calculation of the net present value of residential and public buildings, and the main factor influencing the decision to invest in energy efficiency is the net value of expected energy savings.

In principle, energy renovation measures do not affect the useful life of a building, because they comprise only the improvement of the insulation of walls and roofs and the installation of more energy efficient windows and doors which have a service life shorter than the building's life. The net present value of investment is therefore determined by expected future energy savings and the following standard NPV formula is applied:

$$NPV_{i,N} = \sum_{t=0}^{N} \frac{R_t}{(1+i)^t} = R_0 + \sum_{t=1}^{N} \frac{R_t}{(1+i)^t} \quad (1)$$

where:

R_0 is the initial investment.

R_1 to RN are the yearly savings as a sum of the energy savings costs.

N is the expected lifetime of the measure.

i is the discount rate.

Other assumptions in the calculation of the NPV of energy efficient renovations in baseline scenario are as follows:

- The calculation period (t) for packages of measures is 20 years, which is the average period proposed by EU regulations.
- The Guide to Cost-benefit Analysis of Investment Projects, Economic Appraisal Tool for Cohesion Policy 2014–2020, determined a real discount rate of 4% to be used in feasibility studies. However, a high government deficit and debt and low credit ratings[1] are factors behind significantly higher interest rates paid by government and other Croatian residents in comparison to other EU countries. Specific macroeconomic conditions and level of spreads on government bonds could justify the use of financial discount rate of 5.5% in order to calculate more reliable figures for net present value of energy retrofit investment in Croatia.
- The residual value after 20 years of the measure is zero.
- All expenses and savings are expressed as cash flow. The total investment value is treated as negative cash flow in initial year and therefore depreciation is not included as expense in subsequent period.
- All cash flows including energy costs are expressed in real terms (constant 2014 prices).
- Maintenance costs before and after investments are assumed to be equal and therefore excluded from the calculation of NPV. New equipment certainly requires regular maintenance but discussion whether the costs are higher or lower in comparison to maintenance of old equipment is inconclusive.

The net present value of energy efficient renovation is calculated for single houses, multi-apartment buildings, hospitals and educational institutions. Buildings are classified in stratums according to the construction period (three periods depending on the available data on the reference building) and region (Continental and Adriatic Croatia). All calculations are based on three different types of energy renovation measures. Categories A, B and C refer to the expected specific energy consumption after renovation and depend on the intensity of renovation (wall, roof and floor insulation material and types of windows).

Besides baseline scenario, a sensitivity analysis of results on changes of critical parameters is also included. Financial viability is assessed in scenarios which incorporate annual growth of relative energy prices[2] of 1% per year, efficiency loss which result in 20%

[1] The most recent credit ratings for Croatia are BB (Fitch and Standards and Poor's) and Ba1 (Moody's) with negative outlook estimated by all three agencies (http://old.hnb.hr/eindex.htm).

[2] All calculations are based on real cash flow using constant 2014 prices. Growth of relative energy prices of 1% per year assumes prices of energy product to

Table 3
Description of the main features of the packages of measures required to reduce energy consumption in single houses by intensity of renovation.
Source: http://www.mgipu.hr/default.aspx?id=12841.

	Renovation package C	Renovation package B	Renovation package A
Outer walls	ETICS facade insulation with 12 cm graphite EPS-F or other thermal insulation with equivalent thermal resistance (λ ≤ 0,032) Floor insulation 12 cm, minimum 30 cm above the ground	ETICS facade insulation with 12 cm graphite EPS-F or other thermal insulation with equivalent thermal resistance (λ ≤ 0,032) Floor insulation 20 cm, minimum 30 cm above the ground	ETICS facade insulation with 12 cm graphite EPS-F or other thermal insulation with equivalent thermal resistance (λ ≤ 0,032) Floor insulation 20 cm, minimum 30 cm above the ground
Roof	Perimetral insulation with 18 cm XPS λ ≤ 0,035 W/mK)	Perimetral insulation with 20 cm XPS λ ≤ 0,035 W/mK)	Perimetral insulation with 20 cm XPS λ ≤ 0,035 W/mK)
Windows	- Window replacement with double glazing without new window frames	- Window replacement with new Uf ≤ 1,40 W/m2K, double low E glazing Ug ≤ 1.1 W/m2K	- Window replacement with new Uf ≤ 1,40 W/m2K, double low E glazing Ug ≤ 1.1 W/m2K
Doors		New external doors U ≤ 1,0 W/m2K	New external doors U ≤ 1,0 W/m2K
Floors			Thermal insulation of floors with 8 cm of MW Mats between flooring battens
Heating system	Aluminum radiators Reference room thermoregulator	Aluminum radiators Reference room thermoregulator	Floor heating PI regulator

lower achieved energy savings than expected, extending the lifetime of investment to 25 years and application of EU recommended real discount rate of 4%.

The analysis of the net present value depends on the expected energy savings in physical and monetary terms and a projected investment value that is based on data from the Reference Building Project which was prepared by the Ministry of Construction and Physical Planning and Energy Hrvoje Požar Institute (EIHP) (COWI, 2014). Analysis of various models of energy efficient retrofit of existing buildings including investment costs and potential savings are available in country report for Croatia which is available at http://www.mgipu.hr/default.aspx?id=12841. For each building type a set of more than 100 scenarios of energy renovation of existing referent building (for specific geographical location and year of construction) is presented. Scenarios differ in costs and potential savings from mix of measurers which include investments in insulation of walls and roofs, replacement of windows and doors and additionally replacement of overall heating and lighting systems and installations. An analysis in this article is limited to selected three scenarios for each building stratum defined by building type, location and year of construction. Scenarios are marked as A (the most intensive retrofit), B and C (the least intensive retrofit). The scope of measures for single houses is presented in Table 3.

Measure mix for other types of buildings is similar to those for single houses but slightly differ in accordance to their specific features.[3] Tables 4 and 5 presents costs of renovation for different types of building and measures as well as initial and expected energy consumption after renovation according to the estimates of energy and economic experts included in the preparation of the national report for Croatia. Total renovation costs for each scenario includes renovation works according to the technical specification and valued at actual market prices. Actual prices for the most important individual items are presented in Appendix.

In order to convert expected energy savings into monetary values, the energy prices of different energy types are used to estimate specific energy prices for each group of buildings (Table 6). In general, energy mix is different in Continental and Adriatic Croatia as well as for residential and non-residential buildings. Significant proportion of family houses use heating systems based on the fire woods as the less expensive energy source while the share of wood as the energy source in non-residential buildings are practically zero. Continental part of Croatia has a more developed gas infrastructure and natural gas along with fire woods is used as the main energy source. Lack of infrastructural network for distribution of natural gas in southern Croatia explains a high share of the electricity as the most expensive energy source in Adriatic Croatia.

4.2. Social benefits of energy efficient renovations

Renovation costs paid by investors are valued at market prices which include all taxes and contribution which companies engaged to conduct renovation works are obliged to pay to government budget. From the point of investor taxes included in investment value are non-refundable costs. On the level of total national economy, taxes included in investment costs are actually redistribution of funds from investor to government. Additional government revenues related to renovation activity therefore should be treated as benefit for society.

Social benefits in this paper are quantified in the following areas which are most affected by investments:

1. economic activity (GVA and employment),
2. fiscal impact (an increase in public revenues due to greater economic activity), and
3. environmental impact measured by the reduction of CO2 emissions.

The energy efficient renovation of residential and public buildings directly induces additional demand in the construction industry, which is a labour intensive activity. Unlike the construction of new buildings, the renovation of existing buildings is more labour intensive and attractive for the engagement of small and medium-sized producers active in regional markets. As a positive result of such projects, the following effects on GVA and employment should be expected:

- direct impact - an increase in GVA and the number of people employed in units which are directly engaged in renovation - employment in the construction industry (e.g. wall and roof insulation) and associated services (e.g. energy audits, design and supervision);
- indirect impact - an increase in GVA and employment in industries which produce materials and equipment used as intermediate consumption in reconstruction work (construction materials, transport services, etc.)

Induced employment as a result of increased GVA and the

(*footnote continued*)
grow 1% above inflation.

[3] Complete description of measures for each building type is available at http://www.mgipu.hr/default.aspx?id=12841.

Table 4
Estimated deep renovation prices by labelled energy efficiency level in HRK per m^2.
Source: http://www.mgipu.hr/default.aspx?id=12841.

Projected energy efficiency label	Construction period					
	Before 1970		1970–1986		1987-	
	Continental Croatia	Adriatic Croatia	Continental Croatia	Adriatic Croatia	Continental Croatia	Adriatic Croatia
Single houses						
Level C	1,605	3,415	1,849	1,598	1,570	1,822
Level B	2,081	2,499	2,107	1,792	1,698	2,080
Level A	2,903	2,694	2,562	2,519	2,645	2,535
Multi-apartment dwellings						
Level C	1,093	1,309	957	1,187	1,398	1,462
Level B	1,526	1,317	1,336	1,291	1,665	1,850
Level A	2,346	1,326	2,034	1,256	2,864	1,678
Hospitals						
Level C	2,283	1,236	1,540	1,474		
Level B	2,495	1,621	1,821	1,775		
Level A	3,307	1,669	2,648	2,579		
Education						
Level C	1,342	1,348	1,421	1,438		
Level B	1,882	1,309	1,861	1,775		
Level A	1,363	1,180	1,583	1,313		

Table 5
Initial and expected energy consumption after deep renovation.
Source: http://www.mgipu.hr/default.aspx?id=12841.

Projected energy efficiency label	Construction period					
	Before 1970		1970–1986		1987-	
	Continental Croatia	Adriatic Croatia	Continental Croatia	Adriatic Croatia	Continental Croatia	Adriatic Croatia
Single houses						
Initial energy consumption	358	239	302	211	268	157
Level C	118	58	114	60	112	57
Level B	89	43	85	39	89	41
Level A	29	23	23	23	23	21
Multi-apartment dwellings						
Initial energy consumption	245	187	214	100	82	63
Level C	126	72	106	52	71	45
Level B	91	52	73	42	58	43
Level A	18	39	19	35	15	34
Hospitals						
Initial energy consumption	394	240	383	262		
Level C	184	183	211	193		
Level B	153	150	171	156		
Level A	54	108	145	136		
Education						
Initial energy consumption	166	125	152	115		
Level C	58	52	59	54		
Level B	29	28	29	26		
Level A	25	15	25	16		

wages of new employees who are directly and indirectly engaged by projects contribute positively to total disposable income. Consequently, the overall personal consumption of households is also expected to increase, which induces additional demand and employment in industries which produce goods and services for the personal consumption of households.

An additional positive impact on employment arises from the spending of income saved on energy on other types of products. As the production of energy is more capital intensive, a decrease in the number of people employed in the energy sector as a result of energy savings is generally significantly lower than the increase in employment in other sectors of the national economy. In the case of Croatia, it is to be expected that energy savings will not significantly affect domestic production and employment in the energy sector because of the high share of imported energy products which will be reduced by energy efficient investments.

The estimation of the social benefits related to government revenues from additional economic activity induced by the energy efficient renovation of residential and public buildings is based on the input-output model. An input-output analysis presents the static presentation of the structural relationship among economic sectors developed by Leontief (1986). It is primarily concerned with the estimation of the impact of change in final demand on total domestic output, value added and employment. The method

Table 6
Energy prices in Croatia by energy type, in HRK/kWh.
Source: http://www.mgipu.hr/default.aspx?id=12841.

Energy product	Energy prices in HRK, VAT included	Average energy prices in HRK by building type according to specific energy mix	
Fuel wood	0.333	Residential building	0.50
Natural gas	0.42	- Continental Croatia	0.45
District heating	0.425	- Adriatic Croatia	0.55
Fuel oil	0.71	Nonresidential building	0.65
Electricity	0.98	- Continental Croatia	0.50
LPG	0.6	- Adriatic Croatia	0.75

is applied to identify supply chains on the domestic and international market.

In the input-output model, matrix A represents the technical coefficient matrix. The columns of the matrix represent the ratios of the inputs of each industry in the gross output of a certain industry. Vector x represents the gross output and y is the vector of final demand. The following set of equations can be derived:

$$Ax + y = x \tag{2}$$

$$x - Ax = y \tag{3}$$

$$(I - A)\,x = y \tag{4}$$

The solution of the linear equation system in matrix form is:

$$x = (I - A)^{-1} * y \tag{5}$$

Matrix algebra is further used in multiplying the matrix of unit inputs (domestic and intermediate consumption, employment and value added) by the total of domestic gross output induced by foreign demand:

$$V = v * (I - A)^{-1} * y \tag{6}$$

V is the value of the inputs (vector of value added, intermediate consumption and employment) and v is the technical input coefficient (the input component used in the production of a unit of output – v=V/Y).

Vector Ax reflects the requirements for intermediates, while vector y represents the exogenous aggregate final demand. In this research, vector y represents the value of investment in energy efficient renovation. The matrix (I–A) is usually called the Leontief matrix. On the diagonal of this matrix, the net output is given for each sector with positive coefficients (revenues), while the rest of the matrix covers the input requirements with negative coefficients (costs). The Leontief inverse $(I–A)^{-1}$ reflects the direct and indirect requirements for intermediates.

The notion of multipliers rests upon the difference between the initial effect of an exogenous change in final demand (the value of investment in the energy efficient renovation of residential and public buildings) and the total effects of that change on the domestic economy. An investment multiplier for energy efficient renovation is defined as the total value of production in terms of the gross output of all domestic sectors that is necessary to satisfy an additional unit in the value of initial investment.

4.3. *Energy renovation programmes for residential and public buildings in Croatia in period 2015–2020*

In order to increase the energy efficiency of public and residential buildings, the Croatian government has adopted subsidised energy renovation programmes for single houses, and multi-apartment and public buildings. Energy efficient programmes define the measures eligible for support under the appropriate scheme but do not differentiate eligibility by location or year of construction. In principle, all owners are entitled to apply for government subsidy if reduction of energy consumption of 50% is achievable according to estimate of authorised auditors. The most preferable are projects which could be assessed as deep renovation measures which combine better insulation of walls and roofs and the incorporation of more energy effective windows and doors. The replacement of heating / hot water systems is also subsidised.

The energy renovation programme for single houses covers the period 2014–2020. In the programme, a single-family home is defined as a standalone building of less than 400 m^2 which has at most two separate units, and at least 50% of the gross area is used for residential purposes. The government subsidises energy efficient investment in building envelopes at a standard rate of 40%, while households in areas of special government concern (mainly local units devastated in war in the period 1991–1995) can apply for grants of up to 80% of the investment value. The programme for multi-apartment buildings has the same rate of subsidies. A multi-apartment building is defined as a building managed by a certified building manager that has at least three housing units and with a minimum 50% of the GFA used for housing.

The general aims of the programmes are a reduction in the energy expenditures of households in the future and consequently a reduction in fuel poverty and a general improvement in housing conditions. The specific aims of the programme are:

1. energy savings of about 270 GWh in the final consumption of fossil fuels on an annual basis (56 GWh in single houses and 215 GWh in multi-apartment buildings);
2. CO_2 emission reductions of about 76,000 t annually (14,000 t in single houses and about 62,000 t in multi-apartment buildings).

In the case of public buildings, energy efficient retrofit programmes are even more important in the context of European legislation. The European directive on energy efficiency (EED)[4] provides for a new set of policies to be adopted by Member States, including the establishment of a long-term strategy for the promotion of investments in the renovation of the national stock of residential and commercial buildings, both public and private. In particular, in the sector of public buildings used by central government, the EED has set a renovation target of 3% of the total GFA each year to meet at least the minimum energy performance requirements.

In the Croatian case, the programme for public buildings in the period 2014–2015 defined the following targets:

1. the energy efficient renovation of 100 public buildings annually covering 210,000 m^2 in total GFA;
2. the reduction of energy consumption in renovated buildings in a range of 30–60%;
3. a CO_2 emission reduction of about 20,500 t annually;
4. an investment value of 200 million HRK on an annual basis.

Table 7 summarised the key elements of Croatian energy renovation programmes by building type. Investment value which is programmed to be realised in the period 2015–2020 is a starting point for calculation of social costs and benefits which is presented in the next chapter.

[4] https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-efficiency-directive.

Table 7
Programmed value of investments in millions of HRK in the period 2015–2020.
Source: Ministry of Construction and Physical Planning, 2014.

	Single houses	Multi-apartment buildings	Public buildings[1]	Total
Average annual investments	207.5	500	200	907.5
Cumulative investments in the period 2015–2020	1245	3000	1200	5445
Government subsidies	71	200	50	321
Cumulative subsidies in the period 2015–2020	426	1200	300	1926
Renovated area, annual average in m^2	103,500[2]	333,000[3]	210,000	646,500
Cumulative renovated area in m^2 in the period 2015–2020	621,000[2]	1,665,000[3]	1,260,000	3,546,000
Share of cumulative renovated area in total building stock	0.64	3.3	9.13	2.18

Notes:
[1] Based on the annual average for 2014–2015.
[2] Not explicitly stated in the programme; estimate based on an average deep renovation price per m^2 of 2000 HRK (approximately 266 EUR).
[3] Not explicitly stated in the programme, estimate based on an average deep renovation price per m^2 of 1500 HRK (approximately 200 EUR).

5. Results and discussion

5.1. *Financial feasibility of energy efficient renovation investment*

Financial feasibility of the energy renovation projects are assessed for different types of buildings. First part analyse financial viability of individual projects and second asses financial impact of overall renovation programme adopted by Croatian government. A public grant of 40% of the investment, as specified in programmes promoting energy efficient renovation, is included in the calculation.

5.1.1. *Net present value of investment by building type*

Financial viability of renovation investments are based on methodology and data sources described in Section 4.1. It should be stressed that the initial data are related to reference building which represents the average building in a certain group defined by building type, location and year of construction. Each group comprises a set of heterogeneous buildings depending on the specific construction material used, construction year, heating system, and energy source as well as user habits and preferences and the effort put into regular maintenance. The set of technical and behavioural factors determine the energy consumption for each individual building and the energy savings which could be realised for a specific building might be significantly different in comparison to the reference building. Therefore, Table 8 presents average NPV for each stratum, while the financial viability of the investment is to be assessed individually by each interested owner.

General conclusion from Table 8 is that, energy efficient renovation investments, if not supported by government grants, are not financially viable. Results of research for Estonia show that direct government financial support to renovation amounting 32% could be considered to be economically neutral (Pikas et al., 2015),

Table 8
Net present value of investments in energy efficient renovation, NPV as a % of investment.

Intensity of renovation	Construction period					
	Before 1970		1970–1986		1987-	
	Continental Croatia	Adriatic Croatia	Continental Croatia	Adriatic Croatia	Continental Croatia	Adriatic Croatia
Single houses						
Level C	−19.6	−65.2	−45.3	−37.9	−46.6	−63.9
Subsidy 40%	20.4	−25.2	−5.3	2.1	−6.6	−23.9
Level B	−30.5	−48.6	−44.6	−36.9	−43.3	−63.3
Subsidy 40%	9.5	−8.6	−4.6	3.1	−3.3	−23.3
Level A	−39.1	−47.5	−41.4	−50.9	−50.2	−64.7
Subsidy 40%	0.9	−7.5	−1.4	−10.9	−10.2	−24.7
Multi-apartment dwellings						
Level C	−41.5	−42.1	−39.3	−73.5	−95.8	−91.8
Subsidy 40%	−1.5	−2.1	0.7	−33.5	−55.8	−51.8
Level B	−45.7	−32.7	−43.2	−70.5	−92.3	−93.0
Subsidy 40%	−5.7	7.3	−3.2	−30.5	−52.3	−53.0
Level A	−48.1	−27.1	−48.4	−66.4	−87.5	−88.9
Subsidy 40%	−8.1	12.9	−8.4	−26.4	−47.5	−48.9
Hospitals						
Level C	−45.0	−58.6	−33.3	−58.1		
Subsidy 40%	−5.0	−18.6	6.7	−18.1		
Level B	−42.3	−50.1	−30.4	−46.6		
Subsidy 40%	−2.3	−10.1	9.6	−6.6		
Level A	−38.6	−28.9	−46.3	−56.3		
Subsidy 40%	1.4	11.1	−6.3	−16.3		
Education						
Level C	−51.8	−51.4	−60.7	−62.4		
Subsidy 40%	−11.8	−11.4	−20.7	−22.4		
Level B	−56.6	−33.3	−60.6	−39.4		
Subsidy 40%	−16.6	6.7	−20.6	0.6		
Level A	−38.4	−16.7	−52.0	−32.1		
Subsidy 40%	1.6	23.3	−12.0	7.9		

Table 9
Sensitivity of the estimated financial viability of renovation projects on the change of critical parameters, Continental Croatia, NPV as a % of investment.

	Baseline scenario	Growth of relative energy prices 1% annually	FDR 4%	Efficiency loss 20%	Lifetime of investment 25 years
Single houses, before 1970, Continental Croatia					
Level C	−19.6	−12.1	−8.6	−35.7	−9.7
Level B	−30.5	−24.0	−20.9	−44.4	−22.0
Level A	−39.1	−33.4	−30.7	−51.2	−31.6
Single houses built in period 1970–1986, Continental Croatia					
Level C	−45.3	−40.3	−37.8	−56.3	−38.6
Level B	−44.6	−39.5	−37.0	−55.7	−37.8
Level A	−41.4	−36.0	−33.4	−53.2	−34.3
Multi-apartment dwelling built before 1970, Continental Croatia					
Level C	−41.5	−36.0	−33.4	−53.2	−34.3
Level B	−45.7	−40.7	−38.3	−56.6	−39.1
Level A	−48.1	−43.2	−40.9	−58.4	−41.7
Multi-apartment dwelling built in period 1970–1986, Continental Croatia					
Level C	−39.3	−33.7	−31.0	−51.4	−31.9
Level B	−43.2	−38.0	−35.5	−54.6	−36.3
Level A	−48.4	−43.6	−41.3	−58.7	−42.0
Hospital built in period 1970–1986, Continental Croatia					
Level C	−33.3	−27.1	−24.1	−46.6	−25.1
Level B	−30.4	−24.0	−20.9	−44.3	−21.9
Level A	−46.3	−41.3	−38.9	−57.0	−39.7
Educational institution built before 1970, Continental Croatia					
Level C	−51.8	−47.4	−45.2	−61.5	−45.9
Level B	−56.6	−52.6	−50.7	−65.3	−51.3
Level A	−38.4	−32.6	−29.9	−50.7	−30.8

which means that government renovation grant could be even higher when including the indirect benefits in the analysis. The net present value of investment without government subsidy is negative regardless of the type of building, the complexity of the renovation measures, and the regions concerned. In general, more pronounced energy savings and therefore a less negative net present value are expected in Continental Croatia due to the more unfavourable weather conditions.

If a government grant of 40% of the investment value is included in the financial viability calculation, the investment becomes more attractive for building owners. In terms of NPV calculation government subsidy reduces the initial investment costs to 60% of total investment and net present value from investor point of view becomes positive in all cases where the NPV before the grant is higher than −40%. Government programmes for energy efficient retrofits make investment financially attractive for the majority of buildings constructed before 1970 in Continental Croatia. On the other hand, the relatively mild climate in the winter period and the consequent lower initial consumption makes the potential for future savings less profitable in Adriatic Croatia. However, even in Adriatic Croatia, a grant rate of 40% of the investment value can motivate owners to invest in energy efficient retrofits for certain buildings like the oldest single houses or educational institutions. Therefore, it can be expected that the interest of owners will be sufficient for the success of energy efficient retrofit programmes.

Scenario analyses (Table 9) presents sensitivity of financial viability to the changes of critical parameters used in NPV calculation. Price level of energy products in Croatia are currently set at 67% of EU average[5] as a result of government control of public energy companies. Further price dynamics will depend on government energy policy and prices on international markets. Prices of main energy products recorded significant drop on the world market in last two years but World bank estimates that relative prices will slightly grow in period to 2025 toward 2014 level (World Bank, 2015). At the moment, it is not clear in which extent Croatian government is ready to liberalise prices of public energy companies which process will determine the speed of convergence of energy prices to EU average. If energy prices are projected to grow 1% above inflation, it increase energy savings in monetary terms and improves financial viability of energy renovation (approximately by 5–7 index points).

Financial viability is very sensitive to the choice of the financial discount rate. If instead of 5.5% discount rate which is used in baseline scenario, a rate of 4% (as recommended in CBA guide for EU countries) is applied net present value improves in range of 8–10 index points. On the other hand, some measures may not be technically feasible and actual energy savings could be lower than expected. Efficiency loss of 20% could be result of sub-optimal insulation of slabs or internal walls to non-heated areas, technical limitation for protected buildings in urban areas due to historical or cultural heritage, thermal bridges at parts of walls adjusted to window frames or sub-optimal quality of construction work. Efficiency loss has a strong negative impact on calculated NPV 10–15 index points). According to the EU recommendations, financial viability of the energy efficiency projects should be based on projected lifetime of investment between 15 and 25 years. Assumption of 25 years lifetime improves net present value in range of 7-10 index points, while shorter period negative affects expected NPV. In general, NPV of energy renovation is the most sensitive to quality and efficiency of reconstruction works. Potential efficiency loss could jeopardize the overall programme and investors could record negative cash flow, even if investment is subsidised with 40% of non-refundable funds.

5.1.2. Financial direct costs and benefits of the overall programme

Based on the value of estimated investments, average savings per building type, and grants, a financial flow which covers only direct cash flow of investors and government can be calculated. In the calculation of potential average savings per building type, there is the assumption that the least energy efficient buildings (older buildings situated in Continental Croatia) will play a dominant role in renovation in the analysed period. Average savings per m^2 are therefore expected to be in a range from 145 kWh per m^2 for multi-apartment buildings to 215 in the case of single home buildings.

According to the energy efficient programmes, the investments, subsidies and renovated areas are expected to have a uniform distribution throughout the whole period. On the other hand, the total renovated area covered by investments in each year comprises the cumulative amount for the period, and consequently savings will record an upward trend and reach 521 GWh in 2020. In the period up to 2020, investments of 5.5 billion HRK (in constant 2014 prices) are expected, while cumulative savings will be less than 1 billion HRK. An assumption of a lifetime of 20 years for measures has been applied. In the period from 2021 to 2039, only benefits related to energy efficient renovations are expected.[6]

As investments are to be conducted at the beginning of the analysed period, while benefits are expected in the long-term, a real discount rate of 5.5% is applied in order to compare the monetary costs and benefits discounted on present value.

[5] http://ec.europa.eu/eurostat/statistics-explained/index.php/Comparative_price_levels_of_consumer_goods_and_services.

[6] Net present value analyses cover only cash flows. Total investment presents cash outflow in the year when renovation is undertaken instead of calculation annual depreciation. Costs of maintenance are not included because there is not final conclusion in relevant literature whether new equipment increases or decreases maintenance costs of the renovated building.

Table 10
Direct monetary costs and benefits.

	2015	2016	2020	2015–2020	2021–2039	Total period 2015–2039	Present value (FDR 5.5%)
Savings in GWh	87	174	521	1,823	8,593	10,415	
- residential buildings	71	141	424	1,485	7,001	8,486	
- public buildings	16	32	96	338	1,592	1,929	
Savings in millions of HRK	46	92	277	969	4,567	5,536	3,065
- residential buildings	35	71	212	743	3,500	4,243	2,349
- public buildings	11	22	65	226	1,066	1,293	716
Investment value in millions of HRK	908	908	908	5,445	0	5,445	4,783
- residential buildings	708	708	708	4,245	0	4,245	3,729
- public buildings	200	200	200	1,200	0	1,200	1,054
Subsidies in millions of HRK	321	321	321	1,926	0	1,926	1,692
- residential buildings	271	271	271	1,626	0	1,626	1,428
- public buildings	50	50	50	300	0	300	264
Direct balance of costs and benefits for owners in millions of HRK	−540	−494	−310	−2,550	4,567	2,017	−26
- residential buildings	−401	−366	−224	−1,876	3,500	1,624	
- public buildings	−139	−128	−85	−674	1,066	393	49
Balance of government revenues and expenditures in millions of HRK	−460	−449	−406	−2,600	1,066	−1,533	−75

Consistent with the microanalyses presented in Table 10, an analysis at the total economy level also points to the conclusion that government support will be sufficient to achieve a positive net present value in terms of the direct balance between costs and benefits for owners of residential buildings.

In the approach which considers only direct financial flows related to the renovation projects, the impact of subsidies on the government deficit (direct costs and benefits for public buildings plus subsidies to owners of residential objects) will be negative, which is a significant limitation if the sustainability of Croatian public finances and excessive debt procedure (EDP) are borne in mind.

5.2. The socioeconomic impact of energy efficient renovations

Energy efficient renovation besides direct financial impact on investors has broad positive external social effects. Reduction of energy consumption improves balance of foreign trade for countries which do not have sufficient domestic energy sources and improves quality of life not only for building users but also for overall society who benefit from cleaner environment. However, quantification of the certain types of external benefits (like life quality or social welfare) in monetary terms is related to many methodological and practical issues which are beyond the scope of this article which cover only part of social benefits related to energy efficient renovation. Although induced income and employment certainly presents benefits for Croatian residents, it is not included in balance of social cost and benefits because it cannot be attributable exclusively to the energy renovation projects. Induced income is results of production activities of many units throughout national economy affected by renovation works but also by numerous other economic and behavioural factors. However, induced GVA and employment are estimated for the purpose of quantification of additional government revenues induced by renovation investment.

5.2.1. Gross value added and employment

The relatively high government deficit and level of debt in Croatia limit the scope of financial resources which can be allocated to realise strategic goals in the areas of environmental protection and energy sustainability. However, the balance between government revenues and expenditures cannot be assessed by direct monetary terms in which additional subsidies only increase government expenses and the deficit. New investments supported by government grants result in an increase in domestic demand for units engaged by investors, mainly construction companies. In order to meet supply, the construction industry will need additional intermediate inputs like insulation materials and other goods and services typically used in construction activity. All the industries included in the construction activity supply chain will also increase their intermediate consumption of various products used in their production processes. Induced additional production will positively affect demand for labour but also result in the growth of public revenues in the form of value added tax, other taxes on production, direct taxes on income and profits, and social security contributions.

If additional demand is included in the input-output model described in the methodological part of the article, the gross output and employment multipliers of energy saving investment in energy efficiency could be calculated. Most investments are related to the construction industry and the multipliers are estimated to be in the range between 2.5 and 2.9.

Based on the structural features of the Croatian construction industry, it is to be expected that the majority of investment will be contracted to domestic producers (95%), and direct domestic output could increase by 860 million HRK annually. Therefore, the direct domestic value added (after the intermediate consumption of construction activity is deducted) will increase by approximately 35% of the investment value (318 million HRK annually). In order to deliver contracted services, construction companies will need 11.5 new employees per 1 million euros invested or 1400 new employees engaged directly annually. The producers of materials delivered to the construction industry will also increase their demand for the goods and services used in their industry, as well as their demand for labour.

The gross output, value added and employment indirectly stimulated by energy efficient investment are almost the same as the direct effects. The increased value added will be distributed between the profits of enterprises and gross wages and salaries, which will induce additional household consumption. As a result, total direct, indirect and induced domestic gross output will be 2.5 times higher than the initial increase in investment. The employment induced by 1 million euros invested in energy saving renovation is estimated to be 29 new persons employed, which bearing in mind the average annual investment value, could result in 3500 people directly or indirectly employed by retrofit programmes. The expected induced impact of investments in Croatia on job creation is more intense in comparison to similar surveys for European countries (Copenhagen Economics, 2012; Nemry et al., 2010; Sauter and Volkery, 2013) because of the lower price level and labour productivity in Croatia. Results of this study are more similar to estimates for a limited number of studies available for post-transition countries which cover Hungary (Ürge-Vorsatz et al., 2010), Poland (Ürge-Vorsatz et al., 2012) and Estonia (Pikas et al., 2015). Estimated impacts on job-creation by energy renovation projects in Croatia are higher in comparison to Estonia (17 jobs per million euro) but lower in comparison to Poland (42 jobs) and Hungary 37–49 jobs).

However, results are sensitive to assumptions of input-output model. The most important assumption is existence of production function with fixed input-output coefficients for domestic and imported input-output inputs. The increase of output of each sector could be realised if domestic and imported inputs are proportionally increased and the fixed amount of each input is required to produce one unit of output. Technological change and import dependence could affect the change of input-output coefficients and therefore intensity of indirect and induced effects. Calculation of input-output table is the complex statistical activity and according to Eurostat requirements it is to be published only in five years intervals. Table 11 presents baseline scenario based exclusively on official input-output table for Croatian economy, but additionally includes some additional assumptions on domestic production and imports induced by energy efficient renovation. In the first scenario, a higher share of renovation works is directly contracted to the non-resident companies. Second scenario additionally to increased proportion of direct import assumes higher indirect import dependence which could be result of higher reliance on import materials and equipment delivered to the domestic construction company (triple-pane windows, advanced thermal insulation etc.). Increased import dependence reduces indirect benefits for national economy in terms of GVA and employment induced by energy renovation projects, but multiplier effects are still present. However, energy renovation programme assure stable, long-term demand for specific type of construction activity and could be viewed as opportunity for domestic companies to develop domestic production, cooperate more intensively in the overall supply chain and decrease import dependence. Third scenario, therefore, assumes successful development of domestic cluster of producers specialised in energy efficient renovation which could increase benefits for Croatian economy. Only ex-post analyses, based on currently unknown input-output coefficients for domestic and imported inputs in the next period, will be able to give final answers on intensity of effects induced by energy retrofit programmes. However, all sensitivity scenarios points to significant indirect and induced benefits for national economy, even if import dependence increase.

The most significant positive impact is expected in the construction activity which will be directly contracted for the majority of investments. Significant growth could also be expected in the following sectors: transport, financial and business services, and the trade and production of other non-metallic and metal products. Due to induced personal consumption, the production of food products, beverages and tobacco, agriculture, forestry and fishing will also increase.

Table 11
The annual average impact of energy efficient investment for the period 2015–2020.

	Output	GVA	Employment	Imports	Share of imports in output	Employment
	Millions of HRK, annual average					Increase per 1 million euros invested
Direct	862.1	317.6	1392	45.9	5.3	11.5
Indirect	744.2	308.6	1162	167.9	22.6	9.6
Induced	580.8	290.4	968	148.2	25.5	8.0
Total	2187.10	916.6	3521	361.9	16.5	29.1
Multiplier	2.5	2.9	2.5			
Sensitivity analyses, total effects						
Scenario I - direct import 10% of renovation costs						
Direct	817.2	301.1	1319.5	90.8	11.1	10.9
Indirect	705.4	292.5	1101.5	159.1	22.6	9.1
Induced	550.6	275.3	917.6	140.5	25.5	7.6
Total	2073.2	868.9	3338.6	390.4	18.8	27.6
Scenario II - direct import 10% of renovation costs and indirect import −30% domestic direct output						
Direct	817.2	301.1	1319.5	90.8	11.1	10.9
Indirect	619.4	256.9	967.2	245.2	39.6	8.0
Induced	483.4	241.7	805.7	123.3	25.5	6.7
Total	1920.0	799.6	3092.4	459.3	23.9	25.5
Scenario III - direct domestic output 98% and indirect import 15% of renovation costs						
Direct	889.8	327.8	1436.8	18.2	2.0	11.9
Indirect	775.9	321.7	1211.5	136.2	17.6	10.0
Induced	599.5	299.7	999.1	152.9	25.5	8.3
Total	2265.2	949.3	3647.4	307.3	13.6	30.1

5.2.2. Increase in government revenues

Additional government revenues related to retrofit programmes are estimated using an open input-output model which was extended to incorporate all the relevant sources of public revenues. Different categories of government revenue are estimated separately:

1. value added tax directly related to investments;
2. taxes on wages and salaries, including social security contributions;
3. all other government revenues (excise, taxes on income and wealth, taxes on goods and services excluding VAT, other taxes and non-tax revenues).

Investments in energy efficient retrofits of residential and public buildings in Croatia are subject to the standard 25% VAT rate. However, the standard VAT rate is not directly applied to the total value of investments. Construction companies have the right to decrease their tax obligation for VAT paid on intermediate goods and services used and their VAT obligation represents the difference between VAT applied to the value of services delivered and VAT included in the value of intermediate inputs.

On the other hand, VAT on indirect and induced delivery is spread over the entire economy and should also be included in the estimate of the total VAT related to the initial investment. Therefore, the weighted average rate (WAR) of value added tax is applied to the increase in the tax base (including indirect and induced demand), calculated by using the input-output approach.

Income tax from increased employment, including social contributions, is also based on the input-output approach. The total number of people employed in relation to the increased investment activity is estimated by using the multipliers presented in the previous table. The income tax of the induced employment is based on the total additional employment and effective income tax rates, including social security contributions. The calculation is separate for the construction industry, which is characterised by wages and salaries below the Croatian average and a lower tax wedge and revenues from induced employment in the rest of the economy (Tables 12–14).

Other government revenues include excise, taxes on income and wealth, other taxes on goods and services, and other revenues.

Table 12
Government revenues related to energy efficient renovation, annual average.

Revenue types	HRK in millions	As a % of investment value	Share in government revenues (%)	Share in GVA (%)
Taxes on wages and salaries, including social contributions	171.7	18.9	44.8	18.7
Value added tax	132.9	14.6	34.7	14.5
Other government tax and non-tax revenues	78.8	8.7	20.5	8.6
Total	383.3	42.2	100.0	41.8

Table 13
Energy consumption and CO_2 emission by energy source.Source: Energy balances, EIHP (2014).

	Primary energy factor	CO_2 emission, kg CO_2/GJ
Coal	1.082	105.13
Wood	1.111	8.08
Natural gas	1.097	61.17
Liquid fuel	1.14	83.21
Electricity	1.614	65.22
District heat energy	1.53	100.69
AVERAGE	1.3	60.00

*1 gigawatt hour (GWh)=3600.00 gigajoules (GJ)

The estimation of other revenues is based on the effective implicit tax rates in terms of GVA.

Government revenues induced by energy efficient renovation are estimated to be even slightly above the government grants provided by programmes. It can be concluded that subsidising energy efficient investment will not have a significant negative impact on government deficit and debt. The most significant effect is expected for income taxes and social contributions followed by value added tax.

In some studies (Rosenow et al., 2014), additional benefits for the government sector, such as the avoided cost of unemployment and health impacts, are also included. Unemployment benefits in Croatia are related to the period of unemployment and are limited to the first year of unemployment. A certain proportion of the people with long-term unemployment status who are not entitled to further unemployment benefits are transferred to the inactive population or informal economy. Long-term recession has had the most pronounced impact on the construction industry, and the majority of unemployed people have already used up their rights to receive unemployment benefits. Therefore, the avoided unemployment benefit cost is not included in calculations.

5.2.3. *Reduction of air pollutant emissions*

In economic terms, the cost related to the emission of air pollutants is defined as negative externality. The negative influence of emissions on climate change certainly decreases the quality of life of the overall society in the long-run. The measurement of externalities is related to various theoretical and empirical difficulties (Van Vuuren et al., 2006) which are beyond the scope of this article. According to the economic literature, the marginal damage of emissions has to be equal to the marginal abatement costs. In the long-run, external costs related to the marginal damage of emissions are expected to increase (Kuckshinrichs et al., 2010).

The estimate of the economic value related to the reduction in emissions of air pollutants depends on the expected energy savings and the average emission factor, which depends on the mix of energy sources. The energy consumed in residential and public buildings should be transformed into the total primary energy needed in order to deliver the specified amount of energy for final consumption. The primary energy factors for Croatia and CO_2 emissions per energy unit are based on Ministry of Construction

Table 15
Balance of social benefits and costs in millions of HRK.

	2015	2016	2017	2018	2019	2020	2015–2020
Private sector (benefits minus costs)	**132**	**167**	**201**	**235**	**270**	**304**	**1,308**
Costs	437	437	437	437	437	437	2,619
Benefits	569	603	637	672	706	740	3,927
Government sector (benefits minus costs)	**−77**	**−65**	**−53**	**−42**	**−30**	**−18**	**−285**
Costs	471	471	471	471	471	471	2,826
Benefits	394	406	418	429	441	453	2,541
Balance of benefits and costs	**55**	**101**	**147**	**194**	**240**	**286**	**1,023**
Economic value of reduction of CO_2 emissions	4	7	11	15	18	22	77
Balance of social benefits and costs	**59**	**109**	**158**	**208**	**258**	**308**	**1,100**

Table 14
Avoided emissions of air pollutants, CO_2.

	2015	2016	2017	2018	2019	2020	2015–2020
Savings of delivered energy in GWh	87	174	260	347	434	521	1823
- residential buildings	71	141	212	283	354	424	1485
- public buildings	16	32	48	64	80	96	338
Savings of primary energy in GWH	113	226	338	451	564	677	2369
- residential buildings	92	184	276	368	460	552	1931
- public buildings	21	42	63	84	105	125	439
Savings in CO_2 emission, tCO_2	24,372	48,743	73,115	97,487	121,858	146,230	511,806
- residential buildings	19,857	39,714	59,572	79,429	99,286	119,143	417,002
- public buildings	4514	9029	13,543	18,058	22,572	27,087	94,804
Economic value of savings in millions of HRK	4	7	11	15	18	22	77
- residential buildings	3	6	9	12	15	18	63
- public buildings	1	1	2	3	3	4	14

and Physical Planning (2014a) data. According to the energy mix used in Croatia, the average factor is 1.3, while approximately 60 kg of CO_2 is emitted by the production of 1 GJ of energy.

The energy savings which could be realised by programmes are transformed into the primary energy factor (including transformation and transportation losses). In the last year of the programme period, total savings in primary energy are estimated to be 677 GWh, while cumulative energy savings in the overall period could be 2.4 TWh. The avoided CO_2 emissions in the last year could be approximately 146,230 t. The estimated price per tCO_2 emission in national strategic documents is 20 euros or 150 HRK, and savings in monetary terms for the total period are estimated to be 77 million HRK. Additional savings will be realised each year during the lifetime of the investments (approximately the same as in the last year of the programme period: 22 million HRK). According to recent literature, reduction of energy consumption after renovation could be partially offset by higher level of energy consumption due to increase in disposable income which is recognised as rebound effect. Due to many methodological and practical obstacles, rebound effect which could diminish benefits of avoided emissions of air pollutants are not included in the estimate.

5.3. Expected social costs and benefits of energy retrofit programmes

The expected social costs and benefits of energy retrofit programmes by sector of the national economy are summarised in Table 15. Besides future energy savings, benefits for the private sector comprise the growth in disposable income which is expected to be induced by investments. Induced GVA will be distributed to the government and private sector. Private costs are related to investment costs after government subsidies are deducted. For the government sector, costs represent investments in public buildings and subsidies paid to the private owners of residential buildings. Direct benefits for the government sector include energy savings achieved in public buildings and induced government revenues. The economic value of savings related to the reduction of air pollutants cannot be directly attributed to only one sector of the national economy and is treated as a benefit for the whole of society. The table presents only direct and indirect items which can be presented in monetary terms. The improvement in the overall quality of life and energy security are additional benefits which are excluded but which are certainly additional factors in favour of energy efficient retrofits of residential and public buildings.

The balance between social benefits and costs is estimated to be positive even in the short-run, where investment costs are significantly higher than initial savings. In the period after 2020, additional benefits consisting of energy savings and a reduction in CO_2 emissions are also expected. In the case of the government sector, balance of benefits and costs in the programme period are slightly negative. However, almost the total amount of the funds invested in the renovation of public buildings and grants for residential buildings are compensated for by the tax revenues induced by the programmes, and the programme of energy efficient renovation will not significantly deteriorate the sustainability of public finance.

6. Conclusions and policy implications

The energy saving renovation of public and residential buildings have complex impact on the overall society and cannot be assessed exclusively from the financial point of view which is based solely on direct financial costs and benefits. The long-term future period, in which the benefits are expected and the high investment costs which are to be financed from limited current disposable income are the main factors which negatively affect the attractiveness of energy saving projects from the owners' viewpoint. Financial analysis point to the conclusion that the net present value is likely to be negative if projects are not supported by government subsidies and it is not to be expected that owners will undertake such projects to a significant extent.

However, investments in improving the energy efficiency of residential and public buildings could positively contribute to the fulfilment of a broad set of national and European strategic goals. Increases in employment, the reduction of poverty, and a positive impact on climate change are the most important indirect effects. Such programmes also positively affect the overall quality of life and national dependence on imported energy. Investments in buildings through the demand channel induce growth in economic activity, employment and government revenues. If a positive indirect impact is included in analyses of the social costs and benefits, such projects can be assessed as viable and the social benefits are significantly higher than the social costs.

The multiplier of the funds invested in the energy saving renovation of residential and public buildings in Croatia is estimated in the range between 2.5 and 2.9. Due to lower labour costs and productivity, employment induced by energy renovation projects in Croatia per million of euro invested (29 jobs in baseline scenario) is higher in comparison to developed EU countries and U.S. A. (17 jobs) but below the effect estimated for the other post-transitional countries as Poland and Hungary (37–49 jobs according to Ürge-Vorsatz et al., 2012). The total government revenues related to economic activity induced by energy efficient renovations are estimated to be higher than government grant rate level determined at 40% of the investment value. Government support could significantly improve the financial viability for investors and not cause significant deterioration in the government deficit which is consistent with previous researches (Copenhagen Economics, 2012; Rosenow et al., 2014; Kuckshinrichs et al., 2010; Pikas et al., 2015). If combined with EU structural funds, government subsidies allocated to energy efficient retrofit programmes could induce a broad range of other positive effects on the Croatian economy, while it is expected that the costs will not significantly deteriorate government deficit and debt. Based on results of baseline scenario, the main aims of the programmes in terms of energy savings and environment protection could be realised.

However, there is a broad set of risks and barriers associated with the successfulness of the programmes. On the individual level, the most important risk is associated with the quality of renovation works and possible efficiency loss which could result in energy savings bellow the estimated level, while low income, high unemployment level and credit constraints are main barriers which could negatively affect interest of households to participate in the programme. Relatively high import dependence and lack of international competitiveness of Croatian companies could result in reduction of indirect and induced effects of investments and consequently lower positive impact of public revenues. Having in mind high level of government deficit and debt, it could be a significant barrier which could limit the volume of resources available for subsidies of energy efficient renovation.

Appendix A

see Table A1.

Table A1
Average unit value prices of the most important measures of energy retrofit, in HRK.Source: Ministry of Construction and Physical Planning, 2014.

Measure	Unit value	Unit price (HRK)
Replace existing single layer windows with new windows - U=1,2 W/m^2 K	Window area m^2	2,700
Replace existing double windows with new windows - U=1,2 W/m^2 K	Window area m^2	2,700
Replacement of skylights to new – U=1–1.5 W/m^2 K	Window area m^2	2,640
Replacement of standard double glazing with double Low-e glazing U < 1.4	Window area m^2	420
Roof insulation, XPS, 20 cm	Roof area m^2	360
External facade insulation of heavy constructions to 0,20 W/m^2 K	Wall area m^2	390
Internal facade insulation to 0,30 W/m^2 K. Thermal bridges not included	Wall area m^2	270
Replace doors - U < 1 W/m^2 K	Door area m^2	3,000

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