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Investments in Croatian RES Plants and Energy Efficient Building Retrofits: Substitutes or Complements?

Davor Mikulić [1] and Damira Keček [2,*]

[1] Department for Macroeconomics and International Economics, The Institute of Economics, Trg J. F. Kennedyja 7, 10000 Zagreb, Croatia; dmikulic@eizg.hr

[2] University Center Varaždin, University North, 104. Brigade 1, 42000 Varazdin, Croatia

* Correspondence: dkecek@unin.hr

Abstract: Croatian energy strategy defines ambitious goals aimed at achieving energy transition toward a sustainable low-carbon society. Achieving those goals requires significant investments in the renewable energy sources and improved energy efficiency of buildings. The purpose of this paper is to estimate and compare the economic effects of the energy transition on the renewable energy supply and demand side. The estimation of the energy transition effects in Croatia in the period 2020–2050 is based on the input-output model, which identifies direct, indirect and induced effects of investments in renewable energy sources and energy efficient buildings renovation. Results of the study reveal relatively higher gross value added and employment effects induced by investments in building retrofits, but the effects of investments in renewable energy are also significant. Investments in sustainable, efficient and environmentally effective energy system could significantly contribute to Croatian GDP. While GVA effects range from 0.4% to 0.6% of annual GDP, the share of full-time equivalent jobs induced by energy transition could reach 0.5% to 1% of total employment in Croatia. Investments in RES plants and energy efficient building reconstruction are not substitutes but complements which ensure a smooth energy transition if undertaken together.

Keywords: building retrofit; renewable energy sources; input-output model; employment multipliers; GVA multipliers

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1. Introduction

The European Green Deal [1] presents a new growth model that aims to transform the European Union (EU) into a fair and prosperous society with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use. The main goal of the Green Deal is making Europe the first climate neutral continent. EU energy strategy requires good coordination of measures in different areas. The most important items which secure development of more sustainable society include improvements in energy efficiency, promotion of renewable energy sources (RES), cleaner and safer transport and more competitive industry [1]. Energy transition is expected to reduce greenhouse gas emissions for at least 40% by 2030 (compared to initial 1990 level) by increased share of RES for at least 32% and improved energy efficiency for at least 32.5% [1]. Raising awareness of the negative effects of climate change has resulted in efforts of national governments to adopt appropriate measures to limit greenhouse gas emissions in the future.

In addition to global initiatives promoted by international organizations, many national governments have developed strategies of energy transition with clear goals of mitigating climate change and increasing security of energy supply. To develop a climate-neutral economy, states are defining national long-term programs aiming at increasing the RES capacities and improvements of energy efficiency. Achieving these strategic goals will result not only in the development of a more sustainably economy but also in inducing broad economic effects. Mitigating the negative effects of climate change implies good coordination of measures aimed at offering clean energy, but also reducing energy consumption by increasing energy efficiency. There are many studies on the economic effects of the production of renewable energy on economic activity and employment. A review of more than 70 studies on the effects of renewable energy use is given in [2], which found significant differences in the results. Improved energy efficiency through building renovation also contributes to economic activity, employment and quality of life and health. The economic effects of renovation are also explored in [3,4].

Low-carbon energy realization and the transition to a new period of energy policy which ensures an affordable, secure and quality energy supply are the main goals of the Low-Carbon Development Strategy of the Republic of Croatia until 2030 with an outlook to 2050 [5]. The development of the energy sector was considered in accordance with the global requirements of climate change mitigation, global reduction of CO_2 and other greenhouse gas emissions and the EU commitment to a unique climate and energy policy.

In the long-term planning period until 2050, the scenario of accelerated energy transition contributes to greater emission reductions, greater energy renovation of buildings, higher share of electric and hybrid vehicles in road transport and higher share of RES in energy production and consumption. Croatian energy strategy defined two scenarios of energy transition to 2050:

- Scenario 1—Intensive energy transition requires reduction of greenhouse gas emissions of 40% by 2030 and 75% by 2050 (compared to the level of emissions in 1990). Energy efficient renovation of the building stock is expected at an average annual rate of 3%, which will make the entire building stock low-energy by 2050. The share of RES is expected to increase to 66% by 2030 and to 88% by 2050.
- Scenario 2—Moderate energy transition requires reduction of greenhouse gas emissions of 35% by 2030 and 65% by 2050. Energy efficient renovation of the building stock is expected at an average annual rate of 1.6. The share of renewable energy sources is expected to increase to 61% by 2030 and to 83% by 2050.

The realization of strategic goals of the energy transition requires extensive investments both in construction of RES plants and renovation of buildings. By analyzing both scenarios, in the observed sub-periods, investments in RES and buildings retrofit will grow slightly more significantly based on Scenario 1 (Table 1). According to Scenario 1, total investments in RES and buildings retrofit would amount EUR 18.4 billion, out of which 60% will be invested in building retrofitting. On average, annually over EUR 600 million is to be invested in RES and building retrofits which is 1.2% of Croatian GDP. The moderate energy transition scenario will require not as much financial resources (EUR 11.3 billion) but still a relatively high amount (0.8% of GDP annually). Scenarios differ more on energy demand side where total investments in buildings retrofit are almost double in Scenario 1. The necessity to increase the share of renewable energy in total supply is recognized in both scenarios, and Scenario 2 requires only 20% less investment than Scenario 1. To achieve climate neutrality in 2050, as required by the European Green Deal, energy transition in Croatia should be even more intensive than described by Scenario 1 in Croatian energy strategy. Potential obstacles which could jeopardize the achievement of this goal are mainly related to financial constraints of private and public sector. However, investments in the transition are not to be viewed only as a financial burden, but as an opportunity to increase efficiency and productivity of the Croatian economy.

Table 1. Investments required for successful energy transition by two scenarios, in million EUR.

	Scenario 1				Scenario 2			
	2020–2030	**2031–2040**	**2041–2050**	**2020–2050**	**2020–2030**	**2031–2040**	**2041–2050**	**2020–2050**
RES	2192	2442	2887	7520	1815	1803	2261	5879
Wind power plants	852	1062	1296	3209	647	743	907	2297
Solar energy	663	1069	791	2523	490	748	554	1792
Biomass	122	0	125	247	122	0	125	247
Hydro energy	555	311.5	675	1542	555	311.5	675	1542
Buildings retrofit	3468	3626	3783	10,877	1733	1813	1891	5438
Private buildings	2292	2432	2572	7296	1111	1181	1249	3541
Public buildings	1176	1194	1210	3580	622	632	642	1897
Total	5660	6068	6669	18,397	3549	3616	4152	11,316

Source: [5].

The aim of this paper is to calculate and compare the expected economic effects of the energy transition of two scenarios defined by the Croatian Energy Development Strategy until 2050. Starting from the goals of the strategy and planned investments in the construction of RES plants and the improvement of energy efficiency through building insulation, the effects of energy transition on the supply and demand side of energy are estimated and compared. An input-output (IO) approach is used to estimate the long-term effects of the energy transition on gross value added (GVA) and employment in Croatia in the period 2020–2050. The IO method is suitable for quantifying overall economic effects. In addition to direct effects, the IO model evaluates indirect and induced effects, considering the production relationships between economic sectors in the overall economy [6].

The paper is structured as follows: after the introduction, Section 2 presents a review of the relevant recent literature on the socio-economic and environmental effects of RES and buildings renovation. The research methodology is presented in Section 3. In Section 4, the empirical results of the economic effects of RES and building retrofit are shared. In the discussion and conclusions, policy implications and suggestions for further research are discussed.

2. Literature Review

Awareness of the threats of global warming and the demand for climate change mitigation has resulted in growing interest in the topic of energy transition that could lead to more sustainable development. The number of studies dealing with various aspects of energy transition is increasing in the recent period. Energy transition could be viewed from many different angles. Technological, ecological, socioeconomic and health effects are only a few of numerous dimensions [7,8]. In this paper, a literature review is limited only to studies which estimate the economic effects of investments in RES and energy efficient building retrofit and which are based on the IO methodology to compare effects for Croatian economy with findings from previous studies for other economies.

In the context of energy consumption and CO_2 emissions reduction, different approaches based on IO models have been developed. The analysis of relevant and latest research dealing with the socio-economic and environmental effects of RES and buildings renovation, in which the IO analysis is used as a methodological basis, is presented in the continuation.

The transition to decarbonized and more efficient energy systems in industry, transport and buildings, as well as the replacement of fossil fuels with RES in the Swiss economy, could induce a net positive impact on employment [9]. The more intensive employment effects are found on the demand side, by decreased energy requirements achieved with improved building energy efficiency, although supply effects, based on the increased share of RES, are also substantial. Total employment in energy activities is estimated to increase by approximately 17%, which represents a net increase in employment by 1.5% of the active population in 2050. The effects of energy efficiency measures in Greece are also found to be significant [10]. More intense effects are estimated in construction than in transportation, while there are also significant differences between effects in residential and commercial buildings.

Dejuan, Portella-Carbo and Ortiz (2020) analyzed the impact of decarbonization in the generation of electricity, road transport and household consumption on value added, employment, energy consumption and emissions of pollutants [11]. The authors assumed a reduction in emissions and employment when replacing fossil fuels with renewable energy sources. In the EU, decarbonization is expected to reduce energy consumption by 22%, CO_2 emissions by 19% and employment by 4% after the transition period. According to [12] the transition to low-carbon energy will reduce the number of jobs in the fossil fuel sector. Employment requirements of USD 1 million energy spending in fossil fuels are estimated to 2.65, while spending on renewable energy results in 7.49 jobs compared to job effects in energy efficiency estimated to 7.72 FTE jobs. Based on the EU energy sector transformation, past net effects of employment, i.e., job creation in the transition to a green economy were analyzed [13]. Out of 27 EU member states, 21 countries had a positive total effect on employment, while one third of jobs created are the result of spillovers. By 2030, the transition to renewable energy will contribute to almost 50,000 new jobs and add almost 1% of gross domestic product to the Dutch economy [14]. A rapid development policy combined with optimistic export expectations could increase total gross employment in the EU RES sector by up to 3.4 million by 2030 [15]. The impact of multiplier effects of investments in power grid infrastructure in Germany was analyzed in terms of output, value added, employment and fiscal income [16]. Net multiplier effects on outputs are positive and other effects are negative. A reduction in employment was found between 130, 170 and 158,940 jobs. The production of electricity from renewable sources itself in Germany led to small positive effects on industries, but also to a significant outflow of household income [17]. Negative impacts can be transformed in a positive direction for most households by investing in new capacities. Global employment based on two energy scenarios was explored in [18]. The current plans scenario is based on governments' current energy plans, targets and policies, and on climate commitments according to the Paris Agreement. Energy Transition scenario implies a major shift to renewable energy, electrification and ramped-up energy efficiency in the period to 2050. Compared to 2017, in 2050 the total renewable energy employment would be 3.5 times higher according to the Energy Transition scenario, and two times higher according to Current Plans scenario.

The positive economic effects of deployment of renewable energy have also been found for Croatian economy [19]. The largest GVA multipliers were detected for biogas plants and hydropower, while total effects for wind farms were lower due to the high share of imported equipment. Per each EUR 1 million of investments in wind power plant EUR 345,000 of GVA and 14 FTE jobs were generated in the Croatian economy [20]. During regular operation of wind power plants 11 FTE jobs were generated per EUR 1 million revenues of RES plants.

Besides economic effects, RES induce other socioeconomic benefits. Wind power plants can significantly reduce total CO_2 emissions by production of clean energy. CO_2 emission factor in the three analyzed wind farms installed in Mailiao, Jhongtun and Chunfong was on average 3.9 g/kWh for the entire life cycle [21]. The contribution to CO_2 reduction by replacing electricity from coal with solar and wind energy in Taiwan was compared in [22]. Authors concluded that in the renewable energy transition, CO_2 emissions could be reduced by 95–98%.

The economic and ecological effects of wood biomass processing in a rural area in central Appalachia were analyzed in [23]. By wood biomass processing introduction, gross regional product is expected to increase by 0.5–1.3% and regional employment by 218–1128 of jobs. The value-added chain related to photovoltaic industry has become the main driver for global development in China. The overall efficiency of the solar photovoltaic industry in the six Chinese regions has an increasing trend with a positive impact on reducing CO_2 emissions [24]. The increase in the number of electric vehicles and RES in Russia is viewed as an opportunity in a reduction in CO_2 but increases the import dependency of the Russian economy and reduces the revenues of domestic companies from the sale of natural gas or coal [25].

Wang and Liu explored patterns of renewable energy consumption and drivers of energy transition in India. The authors concluded that domestic demand was the main contribution to the basic consumption of renewable energy [26]. Wen, Guang and Sharp analyzed low-carbon transition of energy consumption in New Zealand and concluded that population growth is the major factor that determines trends in energy consumption, while direct energy intensity has the most significant impact on limiting energy consumption growth [27]. Increasing final demand increases CO_2 emissions, while CO_2 emissions can be reduced if the increase in demand is based on RES or if economic growth is sustainable [28].

Energy consumption of buildings, for the set of analyzed EU countries, can be reduced by 5–10% if different parts of the envelope, and up to 50% if the entire envelope, are retrofitted [29]. Positive employment effects within the EU induced by investments in energy renovation of the housing stock are found in [30] where EUR 1 million invested in the energy renovation could create 12 to 17 new jobs. According to [31], investments in the energy efficient retrofit in Hungary have the greatest impact on employment where EUR 1 million of investment in building retrofit generates on average 17 jobs, predominantly in the construction and manufacturing industries.

Through improved ventilation systems potential reductions are higher for non-residential buildings, on average 19%, and for residential building, 14%. Based on the optimized building envelope parameters, heating annual savings in an office building can reach 70% and cooling savings up to 40% [32]. The positive effects of energy buildings renovation in Croatia on climate change, especially in the reduction of energy consumption and the reduction of CO_2 have been confirmed in [4,33]. In terms of employment effects, EUR 1 million of investments in multi apartment building renovations induced 32, while EUR 1 million of investments in public buildings induced 35, jobs in the Croatian economy.

Ex post evaluation of the impacts of household retrofit and domestic energy efficiency schemes in the UK show that impacts of a retrofit have been 1.2–1.7 times higher than predicted [34]. Energy efficiency measures in Germany's buildings have a significant positive effect on gross output and employment [35]. With regard to additional energy efficiency measures in buildings, gross output will grow by an average of about 0.27% and the number of employees on average 0.30%. A recent study identified significant positive macroeconomic effects stemming from Germany's energy efficiency initiatives, with growth GDP and employment effects in the range from 0.88% to 3.38% [36]. Enhanced standards and less floor space for new buildings in China will reduce energy consumption by up to 20 billion tons of coal equivalent during the 2011–2050 survey period [37]. The development of energy-saving technology and greater emphasis on key areas will significantly reduce the building's energy consumption in the short term. Changes in household lifestyles and enhanced building energy efficiency will have higher priority in the long run. Some of the multiple benefits of energy efficiency are reflected in health and wellbeing impacts, industrial productivity and competitiveness, energy provider and infrastructure benefits, job creation, reduced energy-related public expenditures, reduced greenhouse gas emissions, moderating energy prices [38].

Mancini and Basso (2020) discussed how different climatic zones are associated with heating and cooling requirements of the buildings [38]. Results of the research show that there is a significant difference in energy consumption for heating and cooling between the four Italian cities. Energy consumption for heating is significantly higher in cities with colder climates, while energy consumption for cooling could be twice as high as it was in the period before the temperature rose. Energy transition at the regional level dependent on relevant elements such as structural characteristics of the regional actor network, actor characteristics and regional governance arrangements [39].

A literature review on economic effects of investments in RES plants and energy efficient building retrofit indicate that effects of energy transition are significant. Multiplicative effects estimated by the IO method have been used in many studies for individual economies or on international level. A limited number of studies for Croatian economy are focused on the effects recorded in the past period. The research on potential effects of energy transition for the Croatian economy in the future period, when the process of energy transition is expected to be more intensive, is currently not available.

3. Research Methodology

Estimation of economic effects induced by RES deployment and energy efficient buildings renovation is based on the IO analysis. In its standard matrix form [6], IO equation is described as:

$$X = (I - A)^{-1}Y \tag{1}$$

where X is the column vector of the total production, Y is column vector of final consumption and A is matrix of technical coefficients showing the share of the intermediate inputs delivered by one sector required to produce unit value of output in the other sector. Matrix A reveal technology is applied. It depicts the structure of inputs required from different economic sectors which are used in production process of final goods and services delivered by certain economic sectors.

$$L = (I - A)^{-1} \tag{2}$$

Matrix is Leontief inverse matrix or matrix multiplier whose elements show the sum of direct and indirect output of one economic sector required per unit of the output produced and delivered by the other economic sector to the final user. Indicators covering direct and indirect effects are determined based on the Leontief inverse matrix and are called type I multipliers. Type II multipliers include direct, indirect and induced effects and are based on the assumption that increase in employment and gross wages boost personal consumption. The Type II multipliers calculation is based on the matrix

$$\overline{L} = \left(I - \overline{A}\right)^{-1} = \begin{bmatrix} \overline{L_{11}} & \overline{L_{12}} \\ \overline{L_{21}} & \overline{L_{22}} \end{bmatrix} \tag{3}$$

where $\overline{A}$ is expanded matrix A with the additional row representing coefficients for wages and an additional column representing input coefficients for personal consumption [40,41].

Total effects on the production induced by investments in RES plants and energy efficient renovation of buildings are estimated according to (1). Furthermore, the IO model can be applied to the quantification of total GVA and employment effects. Direct, indirect and induced effects of final demand on the GVA are calculated by application of the formula:

$$\overline{VA} = V \cdot \overline{L_{11}} \cdot Y \tag{4}$$

where V is a diagonal matrix whose elements represent the share of value added in the output of each economic sector. Direct, indirect and induced effects of final demand on the employment are calculated by the formula:

$$\overline{EM} = E \cdot \overline{L_{11}} \cdot Y \tag{5}$$

where E is a diagonal matrix, whose elements represent the share of the number of employees in the output of each economic sector. A detailed description of the IO model, direct, indirect and induced effects in terms of GVA and employment can be found in [6,40,41].

Economic benefits of investments in energy buildings renovation, or on the other hand, by investments in renewable energy sources, are spreading from direct contractors (direct effects) to other domestic producers included in the value-added chain (indirect and induced effects). Direct effects include additional output, GVA and employment in industries which are directly involved in the performance of buildings energy renovation or producers of renewable energy plants. Direct effects of retrofit in the period when the investment was undertaken are one-time and are directly related to the increase in output, income and employment in the sector that performs building renovation (construction company, experts included in the design and project preparation and supervision company). In the case of RES investments, direct benefits are realized by the units that deliver investment goods (manufacturers of machinery and equipment incorporated in RES plants) to investors. Besides one-time effects related to the increase in investment demand, positive economic effects are generated by the change of the structure of expenditures in the long-term period. In the case of renovated buildings, households and the public sector redirect the funds generated from energy savings to other types of final goods and services. Companies that produce and distribute energy from traditional sources are faced with loss in revenues due to lower demand and substitution with renewable energy, while RES plants are expected to increase revenues, GVA and employment.

Indirect effects of building renovation include indirect output, GVA and employment in industries that deliver inputs required by construction companies which are directly engaged in renovation works. The most significant indirect effects relate to companies involved in the production of materials for energy efficiency improvements such as insulation materials, facades, roofs and energy efficient windows and doors. In the case of investment of RES plants, indirect effects of investments include industries that produce machinery and equipment for renewable energy plants, to the wood industry and industries that produce other intermediate inputs required in RES deployment.

The increase in employment and income in sectors along value-added chain of energy efficient renovation of buildings or investments in RES plants results in an increase of net wages and household income. This encourages additional personal consumption, and thus an increase in output of sectors that deliver goods and services for personal consumption.

Estimation of total effects of investments in RES and building retrofit is based on following steps:

1. Calculation of matrix of technical coefficients (A), and diagonal matrices V (GVA coefficients) and E (employment coefficients) are based on the official Croatian IO table (available at www.dzs.hr, accessed on 2 October 2021).
2. Vectors of final demand (Y) present the value of investments in RES plants (wind, solar, biomass and hydro energy) and energy efficient building retrofit (private and public buildings). Total value for each type of investment is based on the Croatian energy strategy data (Table 1). The structure of investments in RES is based on the survey conducted on the sample which include more than 70% of totally installed capacities of RES plants in Croatia. The investors provided a detailed investment structure according to the types of equipment installed in the plant and separated to the domestic and imported equipment. The cost structures of retrofit works are based on project applications collected by Ministry of Construction and Physical Planning of the Republic of Croatia in the scope of the government's grant scheme.
3. Direct effects include output, GVA and employment generated by economic units which directly contracted delivery of equipment to investors. Indirect effects include output, GVA and employment generated by all domestic producers which deliver intermediate inputs that are directly or indirectly required for the investment. Direct and indirect output induced by different type of investment are estimated by Equation (1).
4. Total GVA and employment effects for different types of investments, which include effects of induced personal consumption, are estimated by Equations (4) and (5).
5. Results are expressed as absolute values (total GVA and employment induced in period to 2050) and in relative terms (effects induced by EUR 1 million of investments).

4. Results

4.1. Relative Gross Value Added (GVA) and Employment Effects by Categories

Investments in RES plants and building retrofits have significantly different cost structure and require inputs from different economic sectors. Renovations are relatively simple activity requiring construction workers and a limited set of materials used for more qualitative building insulation. On the other hand, more complex technology is incorporated in the development of RES plants. Therefore, the potential for spreading up of multiplicative effects is more pronounced for RES plants, especially in economies which produce RES equipment. In the case of less technologically developed economies, such as Croatia, domestic production of complex equipment is underdeveloped and most of the components used in construction of RES plants are imported. The cost structure of investments distributed by domestic sectors and imports is based on the results of an investors' survey as described in [4] for building retrofits and in [19] for RES plants. Results of the IO model indicates that the same value of investments in RES plants induce relatively less economic benefits in comparison to retrofitting in Croatia (Table 2).

Table 2. Total gross value added (GVA) and employment effects per EUR 1 million investments.

	Direct Effect	Indirect Effect	Induced Effect	Total Effect
		GVA induced by investments in RES [a]		
Wind power plants	130	94	120	344
Solar energy	238	181	217	636
Biomass	217	178	200	595
Biogas	241	213	220	674
Hydro energy	236	201	211	647
		GVA induced by investments in energy efficient building retrofit [a]		
Private buildings	308	295	271	874
Public buildings	311	299	275	883
		Employment (FTE) induced by investments in RES		
Wind power plants	6.1	3.2	5.0	14.3
Solar energy	8.2	6.5	8.5	23.2
Biomass	9.8	6.5	8.6	24.9
Biogas	11.9	6.6	9.0	27.5
Hydro energy	11.6	6.1	8.3	26.0
		Employment (FTE) induced by investments in energy efficient building retrofit		
Private buildings	15.0	11.1	9.4	35.5
Public buildings	15.0	11.2	9.4	35.5

Source: authors' calculation. [a] in thousands EUR.

One EUR invested in building retrofit results in the increase of Croatian GVA of EUR 0.88, regardless of the building type (private or public). Because of high labor intensity in the construction sector, total labor requirements are significant in renovation works and approximately 35 employees are required per investment of a EUR 1 million. GVA effects estimated for various types of RES plants, differ substantially in the Croatian case. The GVA and employment effects induced by EUR 1 million of investments are the highest in the development of biogas power plants, followed by hydropower and solar energy plants. Investments in those types of RES plant induce GVA in the range from 60% to 67% of the investment value, while employment effects are estimated at approximately 25 FTE jobs per investment of EUR 1 million. Investments in wind power plants generate GVA equal to only one third of the investment value and induce 14 FTE jobs per EUR 1 million of investments.

The structure of direct, indirect and induced GVA effects estimated by the IO model is presented in Figure 1. Direct effects present GVA generated in the Croatian companies which directly participate in the RES or retrofit projects. Domestic contractors realize GVA of approximately 30% investment value in the case of retrofitting of public or private buildings, and only 13% in the case of construction of wind power plants. Wind plants are usually imported to Croatia, and domestic units participate only in supporting activities such as project and location preparation. In the case of other RES plants, there are Croatian companies that produce complete plants or certain vital parts and participation of domestic producers is higher. Indirect effects, which include domestic units delivering goods and services required by direct contractors, are also higher in retrofit projects. Suppliers of inputs generate almost the same GVA as direct contractors of renovation works. On average, the direct effects accounted for approximately 36% of total GVA effects. The share of induced effects in total GVA effects are higher than the share of indirect effects in RES investments. Induced effects are the lowest component of total GVA effects in renovation works.

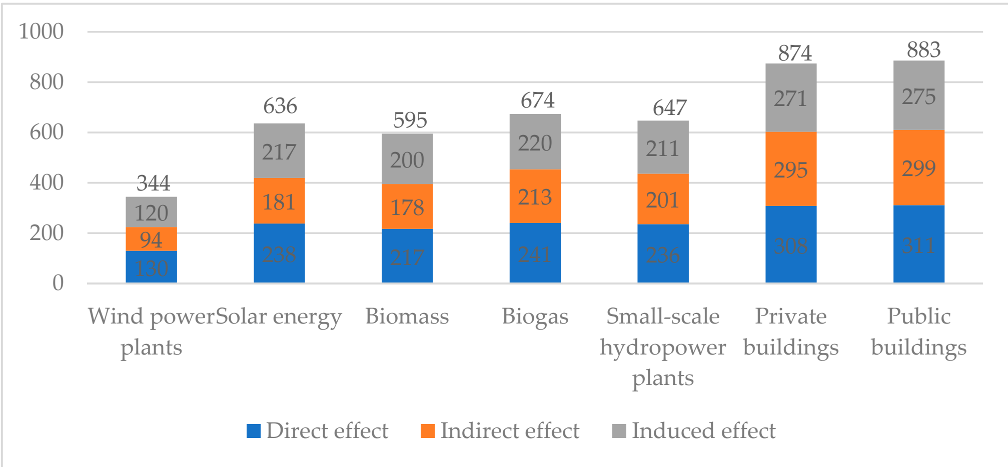

Figure 1. GVA effects induced by EUR 1 million, effects in thousands EUR. Source: authors' calculation.

4.2. Productivity Growth and Employment Factors in the Period 2020–2050

The IO model is based on monetary transactions between economic sectors. Technological coefficients reveal the cost structure of production in each sector. Based on historical data, GVA to output ratio is relatively stable with short term oscillations in both directions. Technological improvements and increase in relative prices of final products to intermediary inputs tend to increase the share of GVA in output. By contrast, more competition in the final product markets because of globalization or an increase in relative prices of some important intermediary inputs on global market tend to decrease the GVA to output ratio in some short-term periods. Although GVA coefficients in the future could deviate from long-term averages, application on fixed average GVA to output ratios based on current IO data is the most reasonable assumption.

On the other hand, the assumption of fixed labor productivity could lead to overestimated employment effects in the long term. Therefore, employment to output ratios (E in Equation (5)) should account for expected productivity increase. Based on the Croatian national accounts data for the period 2005–2020, the average annual productivity growth varies on sectoral level. Because of more complex technological processes, productivity growth in manufacturing industry were higher than in some traditional labor-intensive sectors, such as construction or personal services. Based on long-term trends in the Croatian economy, productivity on an annual level is expected to increase 2.4% in manufacturing, 0.65% in construction, 1.7% in trade and transport and 1.75% in the rest of the economy. Expected labor requirements for various types of RES plants and retrofit projects are presented by Table 3.

Table 3. Expected employment effects per EUR 1 million investment by periods.

	Current	**Average 2020–2030**	**Average 2031–2040**	**Average 2041–2050**
RES				
Wind power plants	14.3	12.0	10.0	8.3
Solar energy	23.2	19.4	16.1	13.4
Biomass	24.9	21.0	17.6	14.7
Hydro energy	26.0	22.5	19.4	16.7
Retrofit				
Private buildings	35.5	31.3	27.5	24.1
Public buildings	35.5	31.1	27.1	23.6

Source: authors' calculation.

As requirements for construction workers dominate in building renovation projects, a modest decrease in employment effects is expected for retrofit works. The decreasing trend in labor requirements is more evident for RES plants because of higher share of required manufacturing products. In the last sub-period, it is expected that investments in wind power plants will require only one third of persons employed than investments in building retrofit per unit value of investments.

4.3. GVA Effects of Energy Transition in Croatia in the Period 2020–2050

In both scenarios, intensive (Scenario 1) or modest (Scenario 2) energy transition, economic effects of building retrofit are expected to dominate over the effects of RES deployment. Speed energy transition, which can ensure reduction of greenhouse gas emissions of 75% compared to 1990, requires energy efficient renovation of total Croatian building stock by 2050 which is a highly optimistic goal. In the total period, those investments could induce EUR 9.5 billion GVA (Table 4). A more realistic scenario of modest transition results in total GVA effects of building retrofits estimated at EUR 4.8 billion.

Table 4. GVA effects of energy transition in Croatia, in million EUR.

	Scenario 1				**Scenario 2**			
	2020–2030	**2031–2040**	**2041–2050**	**2020–2050**	**2020–2030**	**2031–2040**	**2041–2050**	**2020–2050**
RES	1162	1255	1478	3895	982	942	1194	3117
Wind power plants	293	365	446	1104	223	256	312	790
Solar energy	422	680	503	1605	312	476	352	1140
Biomass	73	0	74	147	73	0	74	147
Hydro energy	374	210	455	1039	374	210	455	1039
Buildings retrofit	3043	3182	3319	9544	1521	1591	1660	4772
Private buildings	2004	2127	2249	6380	971	1032	1093	3097
Public buildings	1039	1055	1069	3163	550	559	567	1676
Total	4205	4437	4797	13,439	2503	2533	2853	7889

Source: authors' calculation.

GVA effects induced by investments in RES plants are less sensitive to variations in scenarios (Figure 2). High dependence on imported energy and necessity to substitute ecologically unacceptable energy sources require strong adjustments toward renewable energy in both scenarios. As a potential for deployment of certain kinds of renewable energy is limited by natural factors, differences in scenarios regarding GVA effects either do not exist (hydro energy and biomass) or are less significant (solar and wind plants).

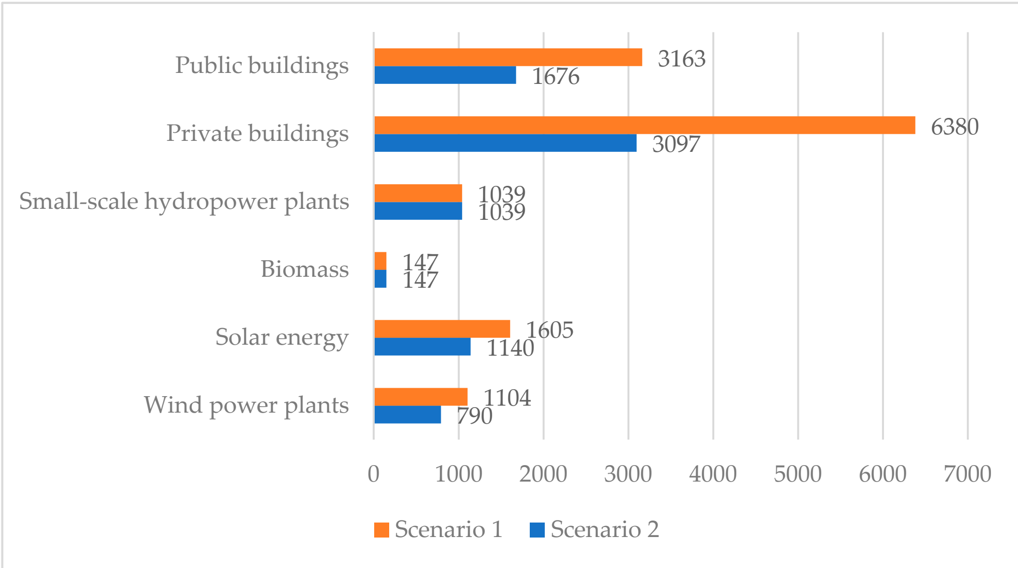

Figure 2. Total GVA effects of investments in RES and buildings retrofit in the period 2020–2050, in million EUR. Source: authors' calculation.

The energy transition is expected to significantly contribute to the increase of Croatian GDP in the future. GVA induced by investments in RES and building retrofit is estimated at range of 0.4% (Scenario 2) to 0.6% (Scenario 1) of Croatian GDP in the 2020–2050 period (Table 5). In both scenarios relative effects are the highest in the first sub-period 2020–2030. Estimated GVA effects of building retrofits are more than two times higher than effects of RES deployment in Scenario 1 and approximately 50% higher in the more realistic Scenario 2. The highest share of total GVA effects of RES deployment in the future period is expected for solar energy. Favorable climate conditions in Croatia present an opportunity for better utilization of solar energy benefits.

Table 5. GVA induced by energy transition, as % of GDP.

	Scenario 1				**Scenario 2**			
	2020–2030	**2031–2040**	**2041–2050**	**2020–2050**	**2020–2030**	**2031–2040**	**2041–2050**	**2020–2050**
RES	0.18	0.17	0.18	0.18	0.15	0.13	0.15	0.14
Wind power plants	0.05	0.05	0.05	0.05	0.03	0.04	0.04	0.04
Solar energy	0.07	0.09	0.06	0.07	0.05	0.07	0.04	0.05
Biomass	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.01
Hydro Energy	0.06	0.03	0.06	0.05	0.06	0.03	0.06	0.05
Buildings retrofit	0.47	0.44	0.41	0.44	0.24	0.22	0.20	0.22
Private buildings	0.31	0.29	0.27	0.29	0.15	0.14	0.13	0.14
Public buildings	0.16	0.15	0.13	0.14	0.09	0.08	0.07	0.08
Total	0.65	0.61	0.59	0.61	0.39	0.35	0.35	0.36

Source: authors' calculation.

4.4. Employment Effects of Energy Transition in the Period 2020–2050

In the period 2020–2050, the total number of FTE jobs induced by investments in RES and in energy efficient building retrofits is expected to reach over 404,000 with respect to Scenario 1 (Table 6). According to Scenario 2, labor requirements are estimated at 235,000 FTE jobs. It is expected that 7000–15,000 employees will be directly or indirectly engaged in the construction of RES plants or building renovations. In relative terms, annual labor requirements of energy transition are estimated at 0.5% to 1% of employment in Croatia (according to the current number of employees). According to demographic projections, total Croatian population is expected to reduce significantly and reach approximately 3 million persons compared to the current 4.1 million [42]. In addition, ageing of the population will result in the even more significant reduction of working age population (persons aged 15–64). Therefore, labor requirements of the energy transition expressed as share of actual employment in future period will probably be higher. It is possible that the availability of labor, especially in construction sector, could jeopardize realization of ambitious plan contained in the intensive energy transition scenario.

Table 6. Labor requirements of energy transition.

	Scenario 1				Scenario 2			
	2020–2030	**2031–2040**	**2041–2050**	**2020–2050**	**2020–2030**	**2031–2040**	**2041–2050**	**2020–2050**
RES	38,110	33,905	34,497	106,511	32,322	25,548	28,082	85,953
Wind power plants	10,203	10,630	10,816	31,649	7758	7442	7571	22,770
Solar energy	12,845	17,224	10,566	40,635	9502	12,056	7396	28,955
Biomass	2562	0	1843	4405	2562	0	1843	4405
Hydro Energy	12,499	6051	11,272	29,822	12,499	6051	11,272	29,822
Buildings retrofit	108,347	99,348	90,539	298,235	54,145	49,660	45,251	149,056
Private buildings	71,783	66,954	61,987	200,723	34,795	32,502	30,110	97,406
Public buildings	36,565	32,394	28,553	97,512	19,350	17,158	15,141	51,649
Total	146,457	133,253	125,036	404,746	86,467	75,208	73,333	235,008

Source: authors' calculation.

According to both scenarios, retrofitting of private buildings will generate the highest number of FTE jobs. In the group of RES plants, the labor requirements in the future period will be the highest in the construction of solar and hydro energy plants.

5. Discussion and Conclusions

Energy transition in Croatia implies the achievement of ambitious goals aimed at decarbonizing the economy and ensuring an affordable, secure and quality energy supply [5]. Broad adjustments are required in energy production and consumption. On the energy supply side, an increase in the share of energy production from renewable sources is strongly demanded, while on the energy demand side, it is crucial to improve energy efficiency. The strategic goals cover many areas, such as transport, agriculture, or the application of energy-efficient household appliances. However, the most important and demanding goals, in terms of efforts and required financial resources, include the increase in the share of energy production from renewable sources and improved efficiency in the energy consumption of buildings. Significant financial resources need to be invested in these two areas, and huge investments besides achievement of the energy strategy goals also result in significant economic and social effects.

The IO analysis of economic effects of an energy transition estimates high multiplicative effects of investments in RES plants and building retrofits. Relative GVA and employment effects, expressed as effects per EUR 1 million investment are higher for building retrofits. In relative terms, GVA and employment effects are more intensive for hydro and biomass energy. Less-intensive multiplicative effects of investments in the construction of RES plants are the result of a high share of imported equipment required by investment. In the case of building retrofits, the relative economic effects are higher, but most of effects include construction and other industries characterized by slow technological progress. IO analysis points to the conclusion that investments required to transform Croatian energy system toward system which is more sustainable and environmentally friendly could contribute to Croatian GDP at range of 0.4 (Scenario 2) to 0.6% of GDP (Scenario 1) on annual level. Employment effects are estimated to be even higher and the share of FTE jobs generated by investments in renewable energy and retrofit could reach 0.5% to 1% of total employment in Croatia. It can be concluded that investments in RES plants and energy efficient building retrofits are not to be treated as substitutes but complements. Both types of investment are required to ensure smooth energy transition. The advantage of building retrofits is related to relatively higher multiplicative effects, but the scope of energy savings is limited by various factors, such as financial constraints, user habits and building features. On the other hand, RES investments, although induce less indirect GVA effects in Croatian economy have lower labor requirements. Trend of increasing energy prices along with technological progress which bring more efficient RES technology could result in commercial viability without public subsidies which is generally not the case for building retrofit projects.

The results of the study on economic effects of energy transition in Croatia confirm the conclusions from previous studies on the significant positive socio-economic effects of investments in RES [9,10,18] and buildings renovation [3,30,35,36]. Multiplicative effects related to the deployment and operation of the RES in Croatia are slightly lower compared to the effects in countries that have developed the production of equipment required for RES plants installation [15]. On the other hand, the estimated total number of FTE jobs induced by investments in RES is significantly higher than the estimated FTE jobs for more developed economies [12,14]. The employment effects of energy efficient building retrofits are even more intensive and significantly higher than found for some other economies [30,31]. The factor of higher effect on employment is lower productivity of Croatian employees in comparison with more developed European economies.

Based on the results of this study, labor requirements for qualified construction workers could jeopardize the realization of the ambitious strategic goals, especially in the contexts of negative demographic trends and an expected decrease of the labor force in Croatia. As found previously [18], results for Croatia also indicate that availability of a quality labor force could present a potential obstacle for successful energy transition. Opening of new jobs is expected in industries supporting the energy transition while some jobs will become redundant in the energy sector based on fossil fuels, but also in other sectors such as traditional production of motor vehicles. It will probably result in temporary educational and sectoral misalignments. The government should take an active role in monitoring and predicting future employment trends and formulate an appropriate educational system, grant schemes and other policy measures which could stimulate formal and informal education, retraining and job facilitation.

The IO methodology applied in this study is a well-known approach the implications of which are primarily related to application of a rigid assumptions on stability of technological coefficients and unlimited availability of all economic inputs [6]. Application of the standard IO model limit the methodological originality of this work, but the advantage is the comparability of results to many previous studies described in the literature review which are based on the same methodological framework. In future research, the upgrading of the IO approach to a general equilibrium model could provide the estimation of the robustness of results by putting economic aspects of the energy transition in broader macroeconomic context.

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