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THE USE OF SOLAR ENERGY IN CROATIA

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Abstract: The Europeans are still facing extraordinary challenges and uncertainties in their daily lives to the extent that all efforts will still focus on protecting citizens and overcoming the crisis. The COVID-19 poses a challenge to Europe on a historical scale. At the request of Heads of State or Governments, the European Commission has presented a comprehensive package combining the future Multiannual Financial Framework (MFF) and specific recovery efforts within the next generation EU (NGEU). The EU's Next Generation Fund (NGEU) represents the European Union's recovery package to support Member States affected by the COVID-19 pandemic. The fund was approved by the European Council on July 21, 2020, and is worth €750 billion. The NGEU fund covers the period 2021 – 2023 and will be linked to the regular EU budget (MFF) from 2021 to 2027. The comprehensive NGEU and VFO packages are projected to reach €1,824.3 billion. Most of the investment relates to the reforms and investments regarding green and digital transition. To achieve the European Green Plan and the next generation EU plan, policies related to clean energy supply in the economy, industry, general production and consumption, infrastructure, transport, agriculture, construction, etc., need to be reconsidered. In the light of all the above mentioned, and to achieve the green and digital transition, one of the significant areas in Croatia is the use of renewable energy sources, especially solar energy, which will be discussed in more detail in this paper.

Keywords: Multiannual Financial Framework (MFF), Next Generation EU (NGEU), European Recovery and Resilience Plan, grant, green and digital transition, European Green Deal, use of solar energy

1. INTRODUCTION

The Multiannual Financial Framework for 2021-2027 provides for €1,824.3 billion for the recovery and strengthening of the resilience of the European economy, of which €750 billion is allotted for the „Next Generation EU" and €1,074.3 billion for the Multiannual Financial Framework. The „Next Generation EU" instrument has introduced a Recovery and Resilience Mechanism which will allow the Member States to use grants and loans totalling €672.5 billion. Out of this amount, 37% of the funds are related to the green transition and 20% to the digital transition. For the European Recovery and Resilience Plan, the European Commission will for the first time leverage its excellent credit rating and, by 2058, borrow on the international markets. Under this Mechanism, respective grants and loans of €6.3 billion and approximately €3.6 billion will be available to Croatia. A prerequisite for using funds is the National Recovery and Resilience Plan 2021-2026 (NRRP), which will be implemented in the coming years and no later than August 31, 2026. For the Republic of Croatia, this means reforms and investments related to the green and digital transition, employment, skills development, education, research and innovation, improving the business environment, efficiency of public administration, health system and the like. The European Green Agenda covers all economic sectors, especially transport, energy, agriculture, building maintenance and construction, and industries such as steel, cement, textiles and chemicals.

2. HOW TO KEEP ABREAST OF THE EUROPEAN UNION?

An analysis of the state and perspectives of the use of solar energy in the European Union is given regarding the current situation in the Republic of Croatia in obtaining electricity, heat and cooling,

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concerning the new climate and energy goals of the European Union for 2030 and 2050 regarding a secure and low-carbon economy. It was an attempt to answer and convince the drafters of the Energy Strategy of the Republic of Croatia, based on scientific and professional facts, and referring to the positive legal guidelines of the European Union, of the advantages solar energy production brings to Croatia. Based on a series of demonstration projects of solar systems and accurate indicators of obtained heat and cooling energy, electricity and reduction of carbon dioxide emissions, the conclusion is that the generation of energy from solar thermal collectors and photovoltaic systems would create up to 20,000 jobs in production, design, installation, supervision, commissioning, maintenance, marketing and promotion of solar thermal and photovoltaic systems. Ultimately, this would lead to economic recovery through creating new jobs in green technologies, primarily for young people and the general development of Croatia, and environmental protection, which is extremely important for the Republic of Croatia.

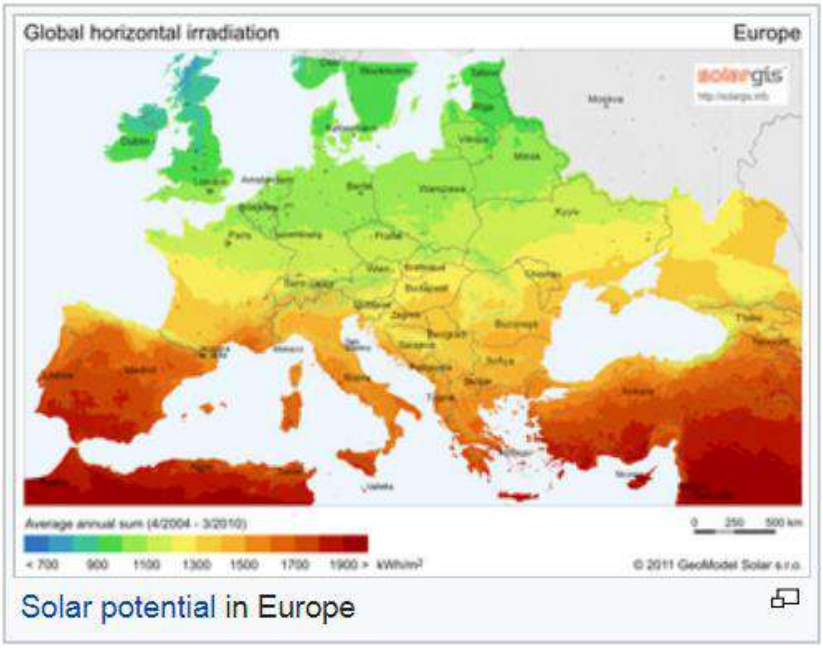

Figure 1. Solar potential in Europe

Unfortunately, the Republic of Croatia, although in a far better geographical position in terms of solar irradiance than other EU countries (Figure 1), does not use enough solar radiation energy to produce heat, cooling and electricity. However, accelerated research is expected in the next period, as well as the development and application of photovoltaic and solar thermal systems, which must be clearly and unequivocally included in the strategies and plans for energy development of the Republic of Croatia.

Support from both public and private sectors is required to fully implement the Directive 2018/2001 of the European Parliament and the Council of December 11, 2018, on the promotion of the use of energy generated by renewable sources (OG 328, 21.12.2018) and the Integrated National Energy and Climate Plan for the Republic of Croatia for 2021 – 2030, and to increase renewable energy and achieve the planned share of renewable energy in the final gross energy consumption in the observed ten-year period in the decarbonization of the energy sector and energy transition to a low-carbon economy.

Solar Power Europe and *European Photovoltaic Industry Association (EPIA)* gave a clear message and predictions of the development of photovoltaic technology until 2030 with a view to 2040 [1]. EPIA predicts that solar photovoltaic technology will cover 15% of electricity consumption in the European Union by 2030 and as much as 30% in 2040. They estimate that, in 2030, about 2.5 million people will be employed in the field of photovoltaic systems. According to a report by the European Solar Thermal Industry Federation (ESTIF), in 2019, about 37,000 MW_{th} of heat output was installed in solar collectors in the European Union and Switzerland [2].

3. SOLAR THERMAL COLLECTORS (PREPARATION OF DOMESTIC WATER AND SPACE HEATING)

The European solar heating & cooling market grew by 8% in 2018, reversing the trend of previous years. The total annual installation of solar collectors exceeded 1.5 GW_{th} of heat output, and the installed capacity in Europe is over 36 GW_{th} (Figure 2). This represents an increase of 2.4% of the European solar heat capacity, leading to an estimated heat production of 25.6 TWh_{th}. Each solar thermal system contains a storage unit by default. As a result, the total available capacity of solar thermal energy is 180 GWh_{th}.

According to the report of the European Solar Heat Collectors Industry Association, Solar Heat Europe/ESTIF, Europe Solar Thermal Industry Federation, ESTIF [2] in the European Union and Switzerland, a total of 51.5 million m^2 of solar heat collectors were installed by the end of 2018.

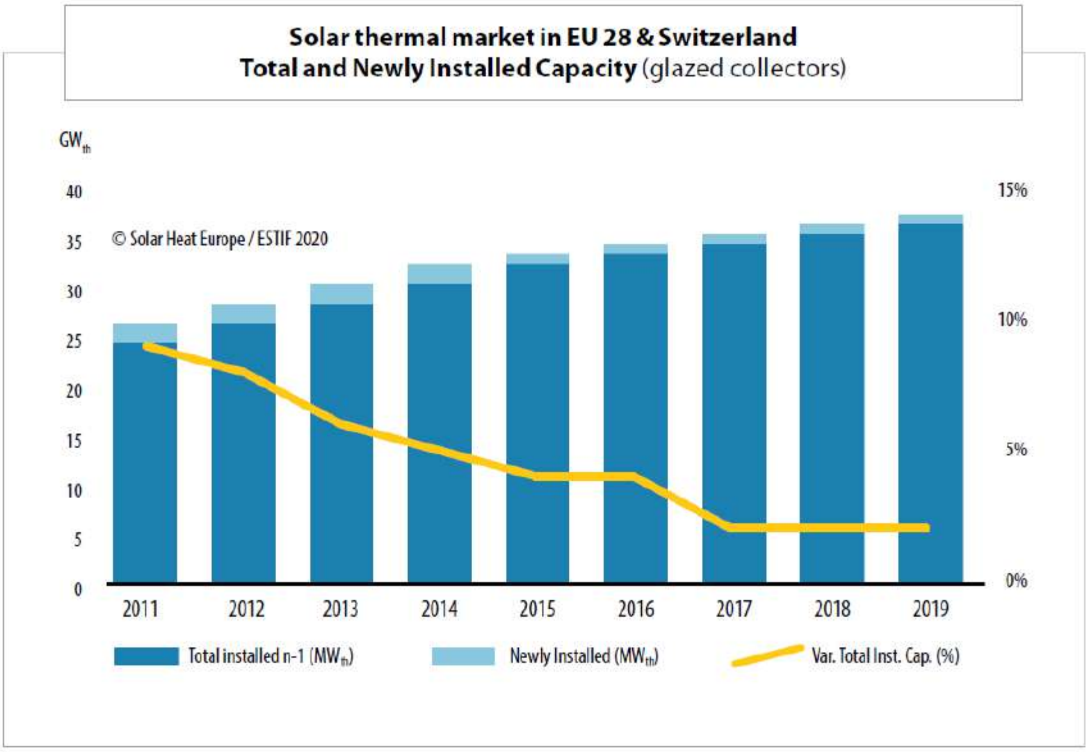

Figure 2. The total and newly installed capacity of solar systems at the EU 28 and Switzerland market in 2019

In the Croatian coastal area and on the islands, due to the increased consumption of electricity, and especially the strong increase in the number of air conditioning systems, the electricity system peak load has been growing and shifting toward the summer. As electric water heaters are always used to heat domestic water on the coast and the islands, their replacement by solar thermal systems could yield significant energy savings and thus reduce the peak load of the power distribution network.

Based on the solar heat collectors installed so far in the European Union and Switzerland (Figure 2), as well as the total area of solar collectors and power per 1000 inhabitants in the European Union (Figure 3) (European average is over 100 m^2/1000 inhabitants), it is proposed to install 1.5 m^2/ per capita in Croatia by 2030, which means 1500 m^2/per 1000 inhabitants. Some European Union countries already have almost 1000 m^2/per 1000 inhabitants. By 2050, 5 m^2/per capita is planned, which means 5000 m^2/per 1000 inhabitants. By then, Croatia will have had 20,000,000 m^2 of solar heat collectors. Figures 4 and 5 show the development of the market of solar thermal collectors and the contribution of solar collectors in thermal energy until 2050 in three scenarios in the EU countries. The Republic of Croatia should fit into the medium scenario (Figure 5).

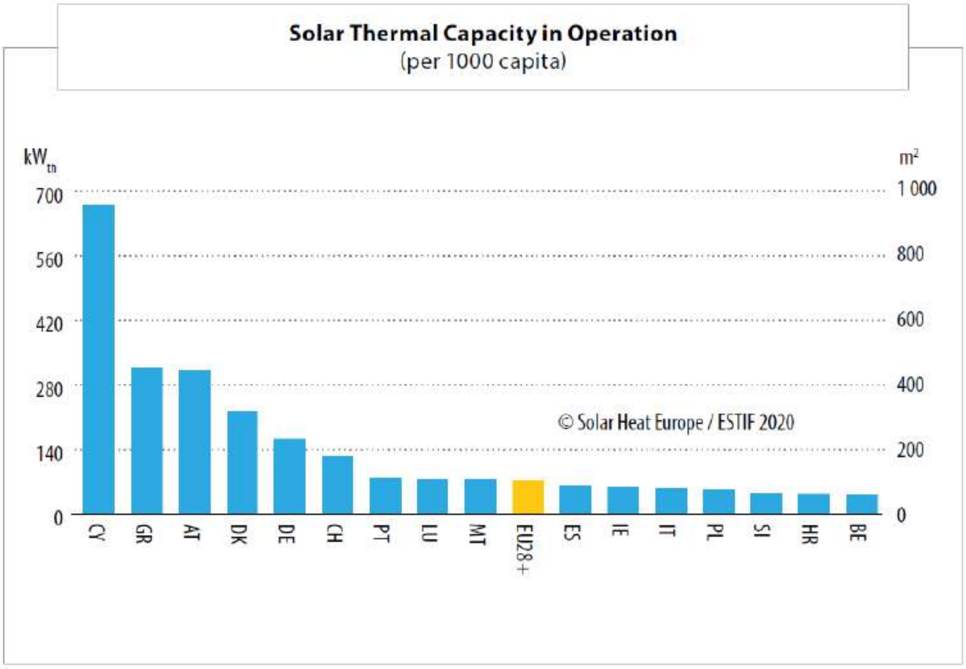

Figure 3. Total installed solar collectors and power per 1000 inhabitants in the EU countries in 2019 [2]

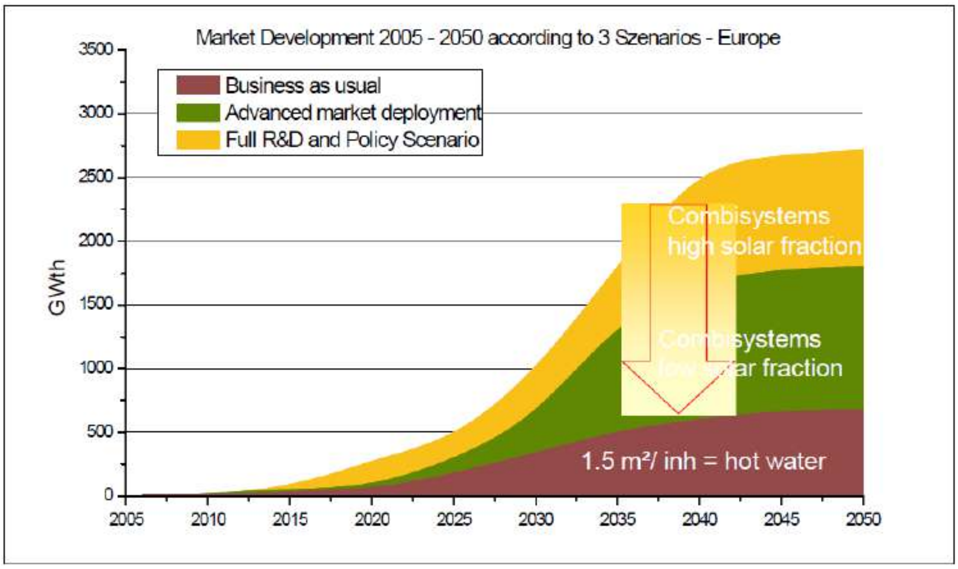

Figure 4. Development of solar heat collectors 2005 – 2050 in three scenarios in the EU countries [2]

The installed area of solar thermal collectors in Croatia until 2030 or by 2050 of 5 m^2/per capita, i.e., a total of 20,000,000 m^2 of solar heat collectors would include district heating systems of settlements and cities, as has already been installed in Denmark for a long time. There are prospects for new jobs in the production, design, installation, supervision, commissioning, maintenance, marketing and promotion of solar thermal systems in Croatia.

In the European Union and Switzerland, shares of installed solar thermal systems are different. Figure 6 shows the newly installed capacities of solar collectors on the European market in 2019. For many years, Germany has been the leading country in the European Union concerning the use of solar energy, not only in the installation of solar thermal collectors but also in photovoltaic systems in electricity generation. The respective shares of Germany, Greece, Poland, Spain and Denmark in the newly installed capacities of solar thermal collectors on the European market in 2019 were 22.4%, 15.9%, 12.6%, 9.0% and 8.6% (Figure 6).

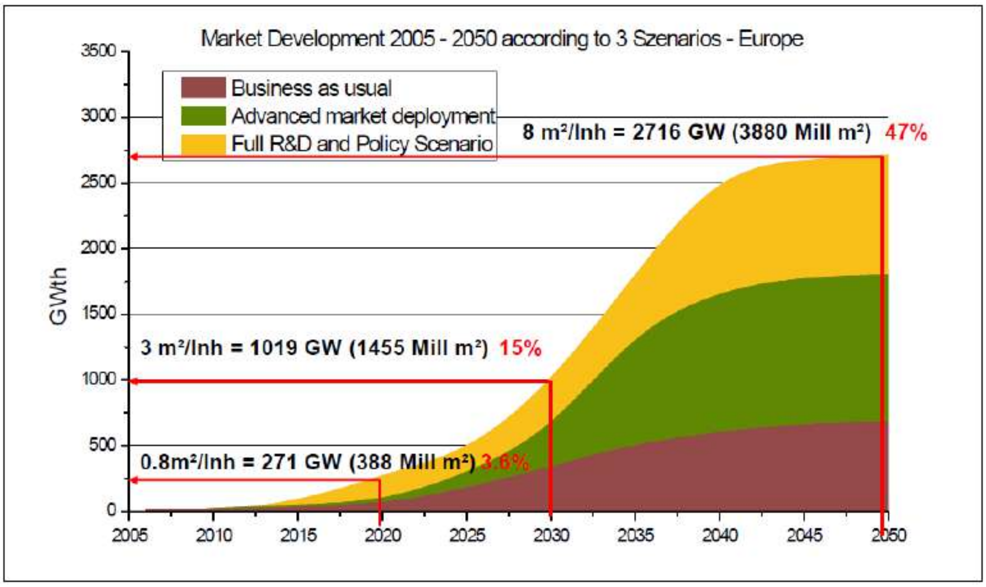

Figure 5. Share of solar collectors in heat energy up to 2050 in three scenarios in the EU countries [2]

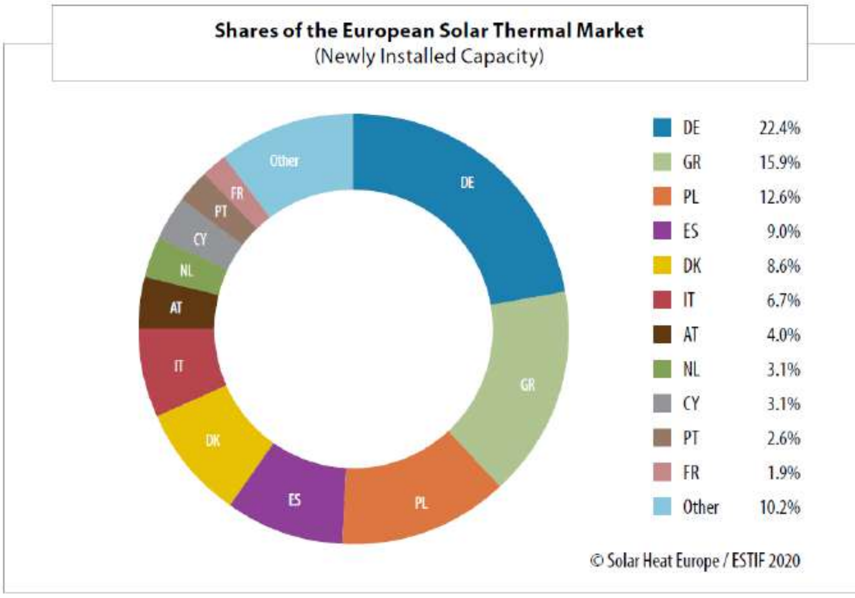

Figure 6. Shares of the solar thermal systems on the European market in 2019 (newly installed capacities)

4. PHOTOVOLTAIC (PV) SYSTEMS IN GLOBAL POWER GENERATION

The market for photovoltaic systems has grown rapidly so far, which is very likely to continue in the coming years. The market of solar energy from photovoltaic systems in 2018 not only exceeded the level of 100 GW for the first time but it was also the first time that the world had more than 0.5 TW of solar photovoltaic capacities. A year earlier, in late 2017, the total global capacity of photovoltaic power plants reached over 400 GW, after exceeding the level of 300 GW in 2016 and capacity of 200 GW in 2015. The total installed capacity of the PV systems increased by 25% (509.3 GW by the end of 2018 compared to 407 GW in 2017) (Figure 7).

Europe, the former leader in the installation of photovoltaic systems, with over 70% of the total installed systems in the world, has handed over the leading position to China with 34% of the photovoltaic systems market share, followed by Europe with 25%, the United States with 12%, Japan with 11%, India with 5% and Australia and South Korea with 2%. The remaining share is distributed in the rest of the world (Figure 8).

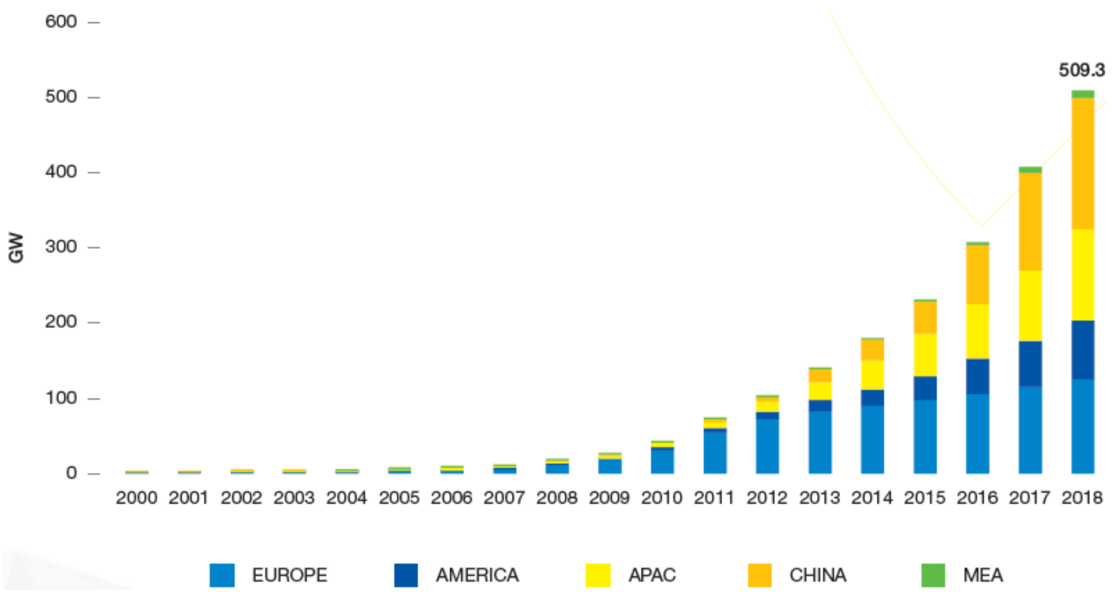

Figure 7. Total installed photovoltaic systems capacities in the world 2000 – 2018

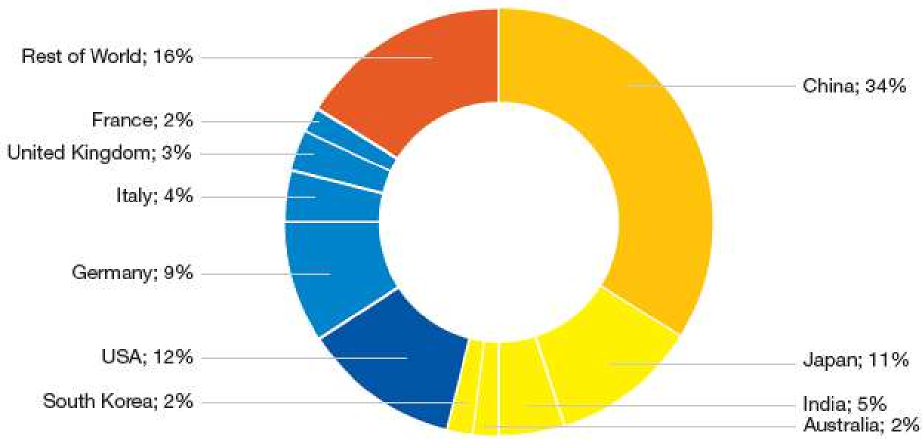

Figure 8. The total share of the ten largest world markets of the PV systems 2000 – 2018

5. PHOTOVOLTAIC (PV) SYSTEMS IN POWER GENERATION IN EUROPE

The installation of photovoltaic power plants in the European Union and the whole of Europe is on the rise. Out of the 28 EU member states, 22 have connected more photovoltaic power plants to the grid than they did a year before. The overall picture of the European total installed solar power plants in 2019 is very similar to the one from 2018 (Figure 9).

Germany remains the largest European solar power operator with 45 GW of installed capacity, followed by Italy with 20 GW in 2018. Again, Germany (36.5%) and Italy (15.8%) cover more than half of European solar production capacity. However, their share decreased slightly from 54.7% in the previous year to 52.3% in 2018. The only other European market with more than 10 GW installed was the United Kingdom. However, as it installed only 286 MW, a total of 13 GW, its share also decreased by 1% and it now totals 10.3%.

In addition to the three European double-digit photovoltaic power markets, 12 countries had single-digit GW photovoltaic capacities (France, Spain, Turkey, the Netherlands, Belgium, Greece, Switzerland, the Czech Republic, Ukraine, Austria, Romania, Bulgaria), while most countries on the continent installed less than 1 GW of the total solar power plants.

At the World Climate Conference in KATOWICE, Poland, held in late 2018, a report presented the feasibility of the European energy transition to 100% renewable energy.

According to the report of the University of Finland (LUT) in 2050, Europe could have a share of 69% of electricity generated by photovoltaic power plants, 18% by wind farms, 8% by hydropower plants, 2% by biomass and waste power plants and 1% by geothermal power plants (Figure 10).

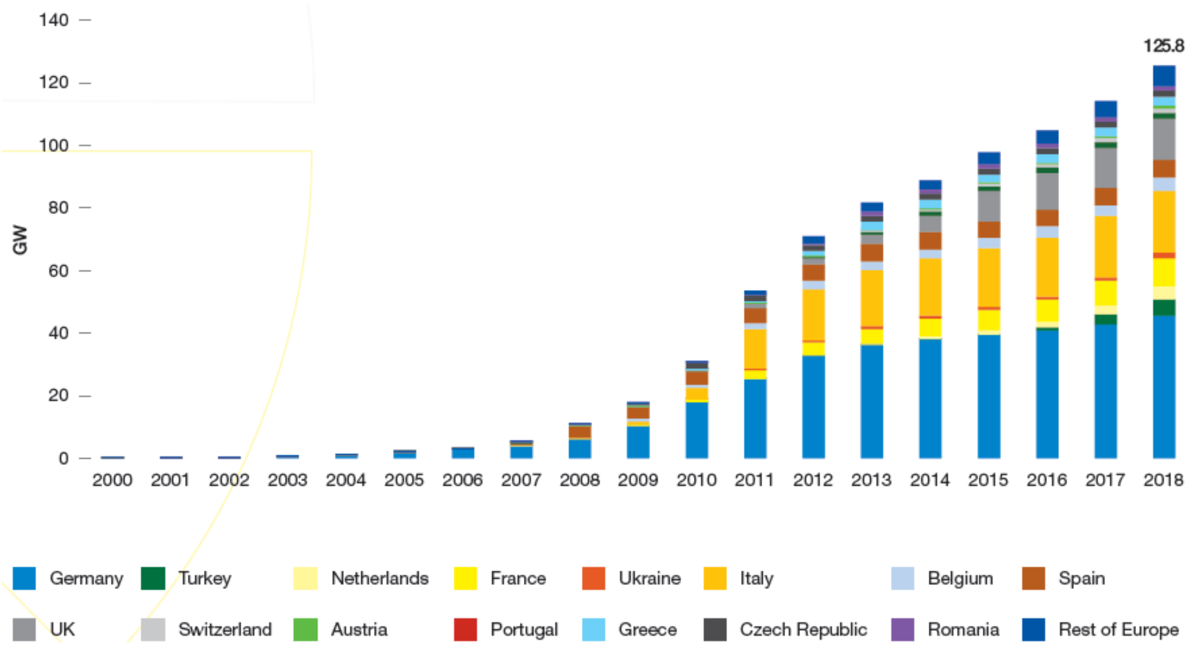

Figure 9. European total installed photovoltaic capacity in 2018

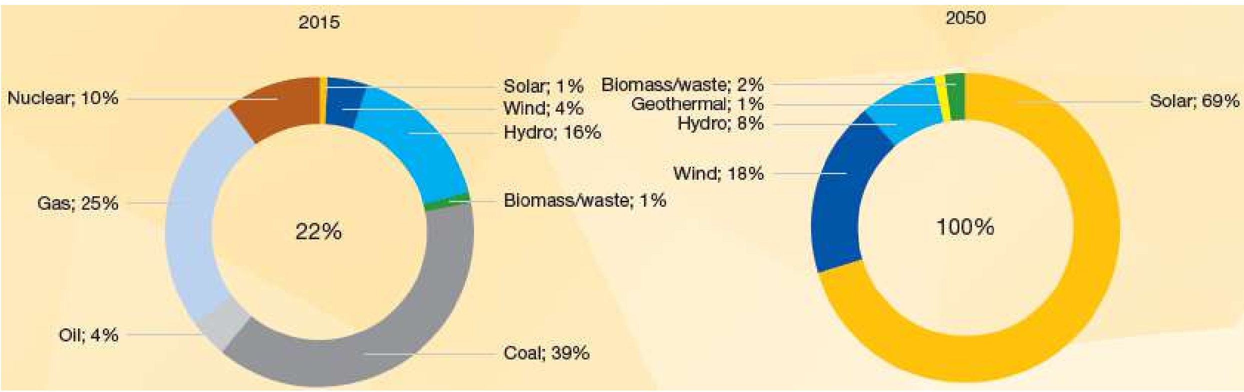

Figure 10. Shares of electricity generated in Europe by 100 renewable sources of energy in 2050 [1]

In 2018, about 19% of photovoltaic systems were mounted on the roofs of residential buildings in the European Union, about 30% on the roofs of the commercial buildings, while the industrial share accounted for 17%, and the free services market 34%, (Figure 11).

The share of electricity coverage generated by photovoltaic systems in the countries of the European Union in 2019 reached 5%, and 0.45% in Croatia. If Croatia had had such a share in the total consumption, then 800 MW of photovoltaic systems should have already been installed in Croatia, but unfortunately, at the end of 2019, Croatia had only 69 MW of built solar power plants and is ranked 26th in the European Union, (Table 1).

At the end of 2019, Germany had 49 GW of the installed photovoltaic systems. In Germany, in 2019, over 50% of all photovoltaic systems on residential buildings were built using energy storage systems (battery home systems). Italy covers 10% and Germany 8% of its electricity consumption from photovoltaic systems. For a start, small photovoltaic systems are significant for the Republic of Croatia up to the power of the building connection, i.e., covering its energy consumption. Such systems could already be installed with 1500 MW of power without any impact on the electricity distribution network. They would annually produce 1875 GWh of clean electricity, without greenhouse gases, which is 10% of the Croatian consumption or a third of the electricity imported into the country.

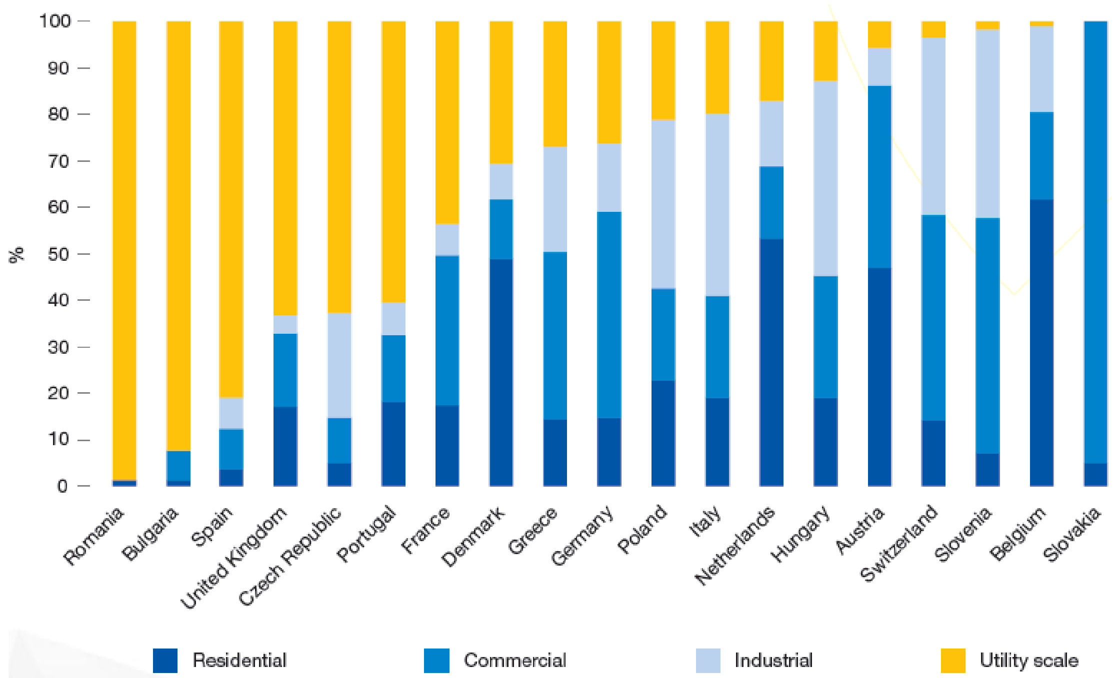

Figure 11. Locations of the installed photovoltaic systems in the EU countries in 2018 [1]

Table 1. An annual overview of the installed photovoltaic systems in the European Union countries [1]

PV in the European Union (MW_{peak})[7][8][9][10][11][12][13][14][15][16][17][18][19]																
#	Country	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
1	Germany	1,910	3,063	3,846	6,019	9,959	17,370	24,875	32,698	36,402	38,408	39,763	40,716	42,394	45,277	49,016
2	Italy	46	58	120	458	1,157	3,478	12,764	16,361	18,065	18,622	18,924	19,283	19,692	20,107	20,864
3	United Kingdom	11	14	19	23	30	75	1,014	1,657	2,782	5,380	8,918	11,899	12,760	13,054	13,616
4	France	26	33	47	104	335	1,054	2,831	4,027	4,625	5,699	6,578	7,200	8,075	9,466	10,576
5	Spain	58	118	733	3,421	3,438	3,808	4,214	4,516	4,766	4,872	4,774	4,973	4,725	4,751	9,233
6	Netherlands	51	51	53	57	68	97	118	321	739	1,048	1,405	2,049	2,903	4,300	6,924
7	Belgium	2	4	22	71	574	787	1,812	2,649	3,040	3,140	3,228	3,561	3,846	4,255	4,530
8	Greece	5	7	9	19	55	205	631	1,543	2,585	2,603	2,613	2,604	2,606	2,652	2,794
9	Czech	0	1	4	55	463	1,953	1,959	2,022	2,064	2,067	2,083	2,068	2,070	2,049	2,100
10	Austria	24	29	27	32	53	103	173	421	631	785.2	935.3	1,096	1,248	1,433	1,661
11	Romania	0	0.2	0.3	0.5	0.6	2	2.9	49	1,022	1,293	1,325	1,372	1,374	1,377	1,386
12	Poland	0.3	0.4	0.6	1	1	2	1.8	3.4	4.2	30	87	194	271	487	1,317
13	Hungary	0.2	0.2	0.4	0.5	0.7	2	4.1	3.7	35	78	138	288	344	754	1,277
14	Denmark	3	3	3	3	5	7	16	391	572	602	783	851	906	1,002	1,080
15	Bulgaria	0	0	0.8	1	6	17	132	933	1,019	1,020	1,021	1,028	1,036	1,036	1,065
16	Portugal	3	4	18	68	102	131	143	228	303	423	460	510	569	671	907
17	Sweden	4	5	6	8	9	10	18	23	43	79	130	153	231	424	698
18	Slovakia	0	0	0	<0.1	0.2	144	488	517	588	590	591	528	528	531	472
19	Slovenia	0.2	0.4	1	2	9	36	90	217	248	256	257	233	258	256	222
20	Finland	4	4	5	6	8	10	11	11	11	11	15	35	61	125	215
21	Malta	0.1	0.1	0.1	0.2	2	2	11	18	28	54	73	94	109	131	151
22	Luxembourg	24	24	24	25	26	27	30	76	95	110	125	122	127	134	141
23	Cyprus	0.5	1	1	2	3	6	10	17	35	65	70	84	105	113	129
24	Estonia	0	0	0	<0.1	<0.1	<0.1	0.2	0.2	0.2	0.2	4.1	0.0	0.0	0.0	107
25	Lithuania	0	0	0	<0.1	<0.1	0.1	0.1	6.1	68	68	73	80	82	74	83
26	Croatia	0.5	1.2	3.2	5.6	12	16	16	20	20	34.2	44.8	50	52	61	69
27	Ireland	0.3	0.3	0.4	0.4	0.6	0.6	0.7	0.7	1	1.1	2.1	6.0	9.0	29.0	36
28	Latvia	0	0	0	<0.1	<0.1	<0.1	1.5	1.5	1.5	1.5	1.5	1.3	1.3	1.0	3.0
	EU (GW_p)	**2.17**	**3.42**	**4.94**	**10.38**	**15.86**	**29.33**	**51.36**	**68.64**	**79.79**	**87.34**	**94.57**	**101.08**	**106.61**	**114.55**	**130.67**

Table 2. An annual overview of the installed power of photovoltaic systems per capita in the EU countries [1]

PV in watts per capita[12][13][14][15][16][17][18][19]										
#	Country	2011	2012	2013	2014	2015	2016	2017	2018	2019
1	Germany	304.3	399.5	447.2	474.1	489.8	503.1	512.0	546.9	590.4
2	Netherlands	7.1	19.1	39.6	65.4	83.1	120.1	160.9	250.3	400.6
3	Belgium	165.5	240.0	267.3	277.2	286.7	302.8	338.4	373.2	395.5
4	Italy	210.5	269.0	295.1	303.5	311.3	317.7	325.0	332.4	345.7
5	Malta	27.4	45.0	58.7	127.5	170.5	188.8	247.9	276.0	305.1
6	Greece	55.8	136.7	233.7	236.8	241.7	241.4	242.2	246.9	260.5
7	Luxembourg	59.9	89.9	186.2	200.1	222.0	212.8	215.0	222.6	229.0
8	United Kingdom	16.2	26.3	42.9	81.3	137.7	176.8	193.9	197.0	204.3
9	Czech	186.0	192.5	196.1	196.1	197.7	194.0	192.9	193.0	197.2
10	Spain	91.3	97.8	100.7	102.9	106.0	103.4	109.8	101.8	196.7
11	Austria	20.7	49.9	81.7	90.6	108.9	123.9	142.3	162.4	187.5
12	Denmark	3.0	70.2	94.8	106.9	138.3	150.4	158.3	173.3	186.0
13	France	43.5	61.6	71.6	87.6	99.1	107.3	120.5	141.4	157.9
14	Bulgaria	17.7	127.4	139.9	140.8	141.7	144.3	144.8	146.9	152.1
15	Cyprus	12.5	19.9	40.2	75.5	82.0	64.7	123.1	130.9	146.9
16	Hungary	0.4	0.4	1.6	3.9	14.0	29.3	37.6	77.1	130.7
17	Slovenia	44.1	105.7	123.8	124.2	124.8	125.5	124.9	123.9	106.7
18	Portugal	13.5	21.7	26.8	40.2	44.3	45.4	55.2	65.2	88.3
19	Slovakia	89.8	95.7	99.3	109.0	109.0	100.5	98.1	97.6	86.6
20	Estonia	0.1	0.1	0.1	0.1	3.1	7.7	0.0	0.0	80.8
21	Romania	0.1	0.3	51.1	64.8	66.7	69.4	70.0	70.5	71.4
22	Sweden	2.0	2.5	4.5	8.2	13.3	15.6	23.1	41.9	68.2
23	Finland	2.1	2.1	2.1	1.9	2.7	3.6	11.1	22.7	39.0
24	Poland	0.0	0.1	0.1	0.6	2.03	5.2	7.1	12.8	34.7
25	Lithuania	0.0	2.0	22.9	23.2	25.0	27.7	28.8	26.3	29.7
26	Croatia	0.1	0.1	5.1	8.1	10.6	12.0	12.4	14.9	16.9
27	Ireland	0.2	0.2	0.2	0.2	0.5	1.1	1.9	6.0	7.3
28	Latvia	0.7	0.7	0.7	0.8	0.8	0.8	0.7	0.5	1.6
–	**EU**	**102.2**	**136.3**	**155.8**	**171.5**	**186.1**	**197.8**	**208.3**	**223.6**	**254.5**

Table 2 shows the installed power of photovoltaic systems per capita in the countries of the European Union over the last ten years. The Republic of Croatia, with 69 MW of the installed photovoltaic power plants, ranks 26th in the European Union. Looking at the total installed capacity in Europe, (Tables 2 and 3) the last 15 years have been dominated by two European Union countries receiving remarkable incentives. The two countries, Germany and Italy, have had more than half of the total installed capacity of the photovoltaic power plants in Europe over the last 15 years (Table 2).

The Croatian Professional Association for Solar Energy (CPASE) proposes the installation of 2,300 MW PV plants in Croatia by 2030, 75% of which would be connected to the building power grid to cover its energy consumption. In this way, the country would fit into the average of the European Union, which plans to cover 15% of the electricity consumption from the photovoltaic power plants.

By 2050, a minimum of 1 kWp/per capita, i.e., installation of 4,500 MW of photovoltaic power plants is planned, out of which 75% are integrated into the power of the building connection, aiming to cover their energy consumption.

6. AN EXAMPLE OF THE PHOTOVOLTAIC POWER PLANT IN CROATIA

6.1. A description of the photovoltaic power plant

The project of a photovoltaic solar power plant for a customer with its power plant or an end customer with its production is described. The characteristics of measuring equipment and devices i.e., built-in photovoltaic modules and inverters are described. The results of measuring and comparing the produced electricity from the facade and roof for one month in 2021 are presented. This project will annually reduce the emission of harmful carbon dioxide into the environment by approx. 12.5 tons.

Two segments of the photovoltaic field of the power plant are mounted on the roof and the facade of the building. The field consists of 88 photovoltaic modules connected to 2 three-phase inverters with the nominal power of 15 kW (Figure 12). The inputs of the first inverter include 44 photovoltaic modules mounted on the roof and connected in two rows, each consisting of 22 modules. The inputs of the second exchanger also include 44 modules placed on the southwest façade of a residential and commercial building connected in two rows of 22 modules each. The total power of the solar power plant is 28.6 kWp for electricity generation. With this photovoltaic system, significant savings in electricity consumption on the building are planned.

The modules installed are monocrystalline modules, with nominal power of 325 Wp, type M325PE, manufactured by Viessmann. There are 88 photovoltaic modules, which make a total photovoltaic field power of 28.6 kWp. The inverter type is SMA Tripower 15000 TL, manufactured by SMA Germany. The photovoltaic modules of each row are connected in series, taking care that the maximum DC power at each input to the inverter does not exceed the allowed amount.

Figure 12. Photovoltaic modules on the roof and the facade of the building

Table 3 Characteristics of Viessmann M325PE photovoltaic modules

M325PE, Certificate IEC 61215/IEC 61730/IEC61701/IEC 62716, CE			
Maximal power	P_{max}	325	W
Maximal power voltage	U_{mp}	33.97	V
Maximal power currency	I_{mp}	9.57	A
Minimal guaranteed power	P_{max}	325 -0/+5	W
Short circuit currency	I_{sc}	10.03	A
Open circuit voltage	U_{oc}	40.58	V
Maximal system voltage		1000	V
Module dimensions	1675 x 992 x 35		mm
Weight		19	kg
Working temperature		-40 do +85	°C

Photovoltaic modules are composed of high-quality solar cells made of monocrystalline silicon with a high degree of efficiency and a warranty period of 12 years. After the first year, their efficiency decreases to 97% and to 80% after 25 years. During their lifetime, the photovoltaic modules make a safe and reliable energy contribution. The degree of usefulness of the module itself is 19.56%. The rated power of one module is 325 Wp, and the characteristics of the built-in photovoltaic modules are given in Table 3 4.

6.2. Simulation of the photovoltaic system by pv*sol program

The results and analysis are determined using a specialized program for designing solar photovoltaic systems and representing simulations of individual systems using special algorithms and mathematical models. Real data and results may vary in relation to these values due to changes in time, the efficiency of individual elements and the efficiency of the complete system.

Figure 13 shows the connection of 88 photovoltaic modules mounted on the roof and facade of a building. The project consists of two three-phase inverters with a rated power of 15 kW each, designated Sunny Tripower 15000 TL-30, manufactured by SMA Solar Technology AG, Germany. The inputs of the first inverter include 44 photovoltaic modules mounted on the roof and connected in two strings of 22 modules connected in series. The inputs of the second inverter also include 44 modules placed on the southwest facade of a residential and commercial building, also connected in two strings of 22 modules connected in series. The modules have a rated power of 325 Wp, type Vitovolt 300 M325PE, manufactured by Viessmann Werke GmbH & Co. KG, Germany. The total power of the solar power plant is 28.6 kWp.

Location:	Zagreb, CRO	
Climate Data:	Zagreb, CRO	
PV power:	28.6	kWp
Active Module Surface:	142.2	m²
Distribution of generated energy to the grid:	26,548	kWh
Specific Annual Yield:	928.26	kWh/kWp
Reduction of CO_2 emission:	12478	kg/ann.

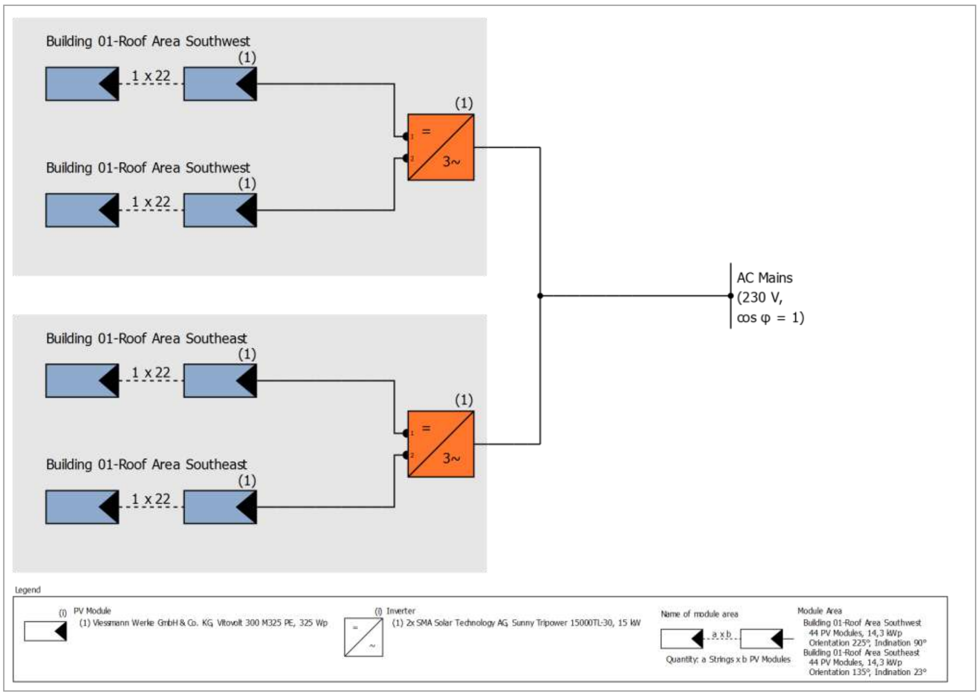

Figure 13. Schematic view of photovoltaic modules connected in strings placed on the roof and façade of a building

6.3. Communication and measurement results description

There is a communication module in the inverter itself. Envisaged is a possible option of controlling the system and its electricity production through an integrated communication module connected from the inverter via an Ethernet connection to the home LAN network. It is possible to connect the photovoltaic system to the Internet and send data to the portal, where the user can control the energy being produced. It is also possible to connect the PV system directly through a computer to the inverter via an internal communication unit.

Figure 14 shows a comparison of the inverter power from the roof (blue) and the facade (red) for February 15, 2021. Photovoltaic facades facing west can have maximum power in the evening when the peak loads of the power system are high.

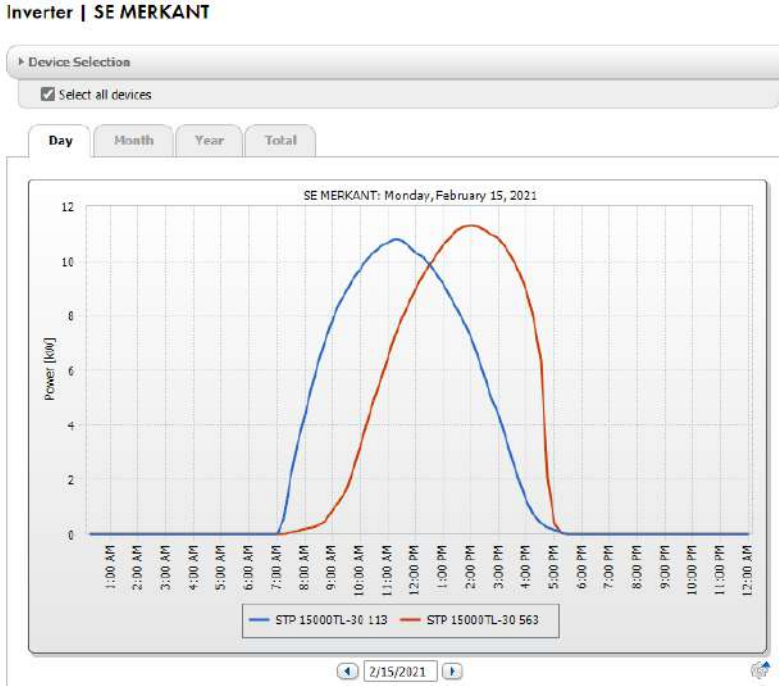

Figure 14. Comparison of the inverter power from the roof (blue) and the facade (red) on February 15, 2021.

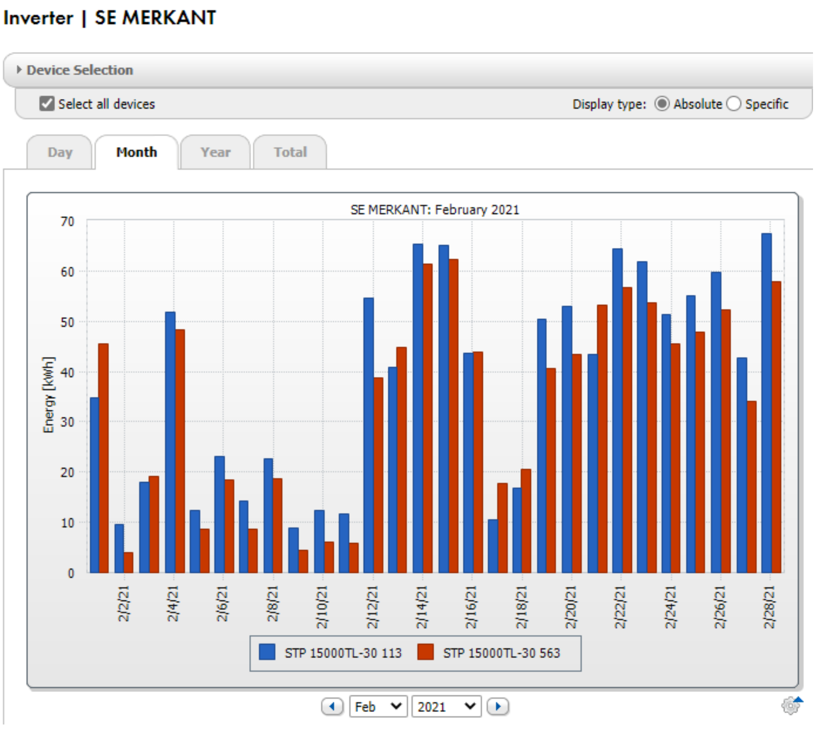

Figure 15. Comparison of the power generated from the roof (blue) and facade (red) in one month

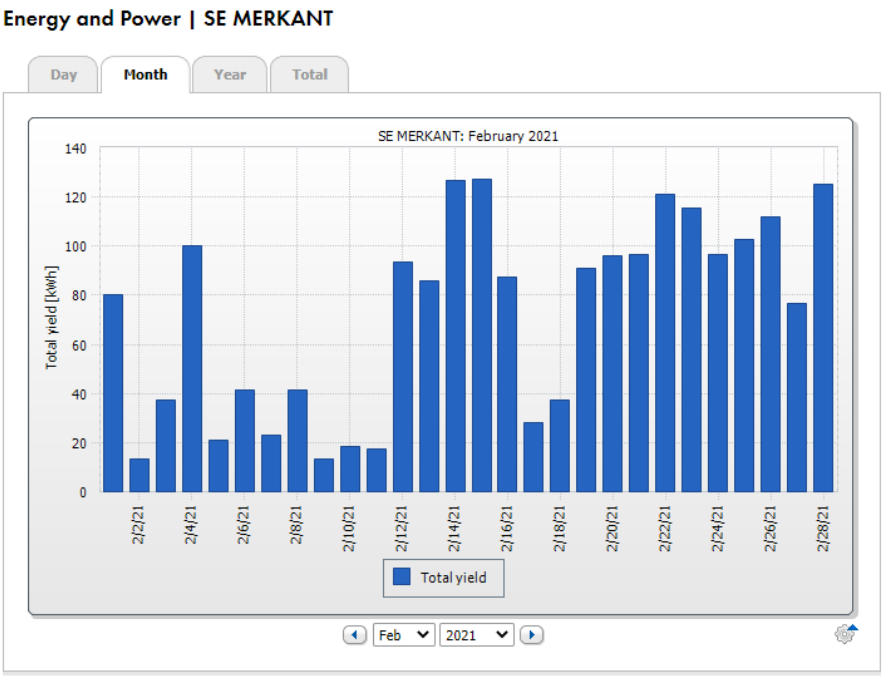

Figure 16. Total power generated from the roof (blue) and facade (red) in one month in February 2021

The end-user system with its own production is the most profitable form of investment in integrated solar power plants in entrepreneurship. The project solution should strive for the possible excess electricity that would occur in the higher tariff, HT (daily tariff) after settling its own consumption, to be less or less than the electricity taken in the lower tariff, LT (night tariff) (Figure 15). When calculating the power of a solar power plant, a key element is the assessment of the electricity needs of the building (facility) and the period of electricity consumption on a daily, nightly, weekly and monthly level. It is also important that the minimum supply of "surplus" electricity, i.e., that these possible surpluses be equated with the takeover of electricity in the night tariff when the solar photovoltaic system does not produce electricity.

Given all the above mentioned and taking into account the most efficient photovoltaic system for electricity production for the said building, a solar power plant of 28.6 kW peak power was installed whereby any daily surplus electricity would be levelled by deficits taken in the night tariff when the solar power plant does not produce electricity (Figure 16). As for the price of this turnkey investment, with annual savings of approx. HRK 26,000.00, the solar power plant will be profitable in 9.5 years.

7. CONCLUSION

Based on relevant and cited data sources in the use of solar energy such as Solar energy in the European Union, Solar Power Europe's Global Market Outlook 2019-2023, European Photovoltaic Technology Platform, European Photovoltaic Industry Association – EPIA, European Solar Thermal Industry Federation – ESTIF, we have proposed the accelerated use of solar energy in obtaining heat and electricity in the Republic of Croatia, and „How to catch up with the European Union" in terms of clean energy use, and to move Croatia away from the bottom of the list of the European countries by installed solar thermal collectors and photovoltaic power plants.

The use of solar energy is of local importance and leads to the creation of new jobs and investment in rural areas, areas of special state concern, the coast, the coastline, and islands. Ultimately, Croatia is reducing electricity imports and greenhouse gas emissions, and new jobs are being created for the economy in the production, design, installation, supervision, commissioning, maintenance, marketing and promotion of solar thermal and photovoltaic systems. By accepting the project named „Solarization of Croatia", Croatia would, in the 21st century, become an ecologically clean and recognizable country, socially richer and economically more developed, and thus integrated into Europe and the world as well.

Naturally, we should build residential buildings, energy self-sufficient and sustainable, using modern materials and technologies and renewable energy sources. Given that most European Union countries have adopted standards for the construction of near-zero energy buildings (Nearly

Zero-Energy Buildings- nZEB), in which almost zero or very low energy consumption should be provided mainly by renewable sources of energy, it is extremely important to choose a technical solution or synergies of several systems in obtaining useful energy to get the best technological and economic optimum investment and profit. One of the technically optimal solutions for calculating almost zero energy of buildings with their production of heat, cooling and electricity, in addition to installing solar thermal collectors and photovoltaic systems in such buildings, measures electricity through the same metering point through which the building buys electricity from suppliers, but with the installation of a two-way meter and energy billing on an annual basis (the so-called „net-metering”).

Figure 17. Solar roof Špansko-Zagreb, the first solar power plant in Croatia connected to HEP's electricity network, installed in 2003, designer, contractor and investor: Prof. dr. sc. Ljubomir Majdandžić, B. Sc

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KORIŠTENJE SOLARNE ENERGIJE U HRVATSKOJ

Sažetak: Europljani se i dalje suočavaju s izvanrednim izazovima i neizvjesnošću u svom svakodnevnom životu te će svi napori i dalje biti usmjereni na zaštitu građana i prevladavanje krize. Kriza COVID-19 Europi predstavlja izazov povijesnih razmjera. Na zahtjev šefova država ili vlada, Europska komisija je predstavila vrlo širok paket koji kombinira budući Višegodišnji financijski okvir (VFO) i specifične napore za oporavak u okviru EU sljedeće generacije (NGEU). Fond EU za sljedeću generaciju (NGEU) je paket oporavka Europske unije za potporu državama članicama pogođenim pandemijom COVID-19. Fond je dogovorio Europsko vijeće 21. srpnja 2020. godine, a vrijedan je 750 milijardi eura. Fond NGEU obuhvaća razdoblje od 2021. do 2023. godine, a bit će vezan za redovni proračun EU (VFO) za razdoblje od 2021. do 2027. godine. Predviđa se da će sveobuhvatni NGEU i VFO paket doseći 1824,3 milijarde eura. Najveći dio ulaganja odnosi se na reforme i investicije povezane sa zelenom i digitalnom tranzicijom. Kako bi se ostvario europski zeleni plan i plan EU sljedeće generacije treba iznova razmotriti politike vezane za opskrbu čistom energijom u gospodarstvu, industriji, općoj proizvodnji i potrošnji, infrastrukturi, prometu, poljoprivredi, građevinarstvu itd. Iz svega navedenog, a da bi se ostvarila zelena i digitalna tranzicija, jedno od važnih područja u Hrvatskoj je korištenje obnovljivih izvora energije, posebno sunčeve energije, što će se detaljnije obraditi u ovome radu.

Ključne riječi: Višegodišnji financijski okvir (VFO), EU sljedeće generacije (NGEU), Europski plan oporavka i otpornosti, bespovratna sredstva, zelena i digitalna tranzicija, Europski zeleni plan, korištenje sunčeve energije.

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