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Energy Transition between Promises and Realities - A View from the European Semi-periphery[1]

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ABSTRACT Croatia, like some other EU countries, is poor with fossil fuels while at the same time has a significant renewable energy potential that is not sufficiently utilized. The current total energy import is around 50% of overall energy needs, and there is an increase in the share of renewables. In the electricity sector, an increase is happening due to investments in wind energy in the last decade, however, the largest share relates to the production from big hydropower plants stemming from the second half of the 20th century. Considering that Croatia's coastal region is positioned in the Mediterranean, the major potential for renewable solar energy is obvious. The current share of solar energy represents only 1% of current electricity production and is one of the lowest in the EU. Citizens' energy initiatives seem to be an important factor in intensifying the overall process of solarization, thus contributing to speeding up the process

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of energy transition. However, Croatia, like some other EU countries, has major social and legislative barriers to achieving this. In the article, we will present the multidimensionality of these obstacles by exploring energy inequalities in society (i.e. energy poverty issues), regional differences in citizens' participation in the solarization processes, and the socio-technical barriers. We will also examine the potential of citizens' engagement in energy transition. The data used for the analyses were collected as part of the ESF project "METER to a better climate".

Key words: energy transition, energy poverty, citizens' energy, socio-technical regime, socio-cultural aspects of energy.

1. Energy Transition – Between Technical Solutions and Societal Innovation

The aim of this article is to provide insight into the processes and issues that are relevant in understanding the obstacles and fortuity-led energy transition in Croatian society. The issues concerning energy have for a long time been perceived as technological issues, thus completely separating the matters of energy usage and production from society as such. Energy should be seen as an immanent dimension of social transformation thus reflecting the issues of social order and power relations in society. Access to energy is a contested issue and is as such intertwined with technological solutions and innovations, political processes, the economic system, and socio-cultural developmental paths. Geopolitical relations have been formed around access to large fossil fuel reserves, specifically to those reserves with the biggest financial utilizing potential. To have a fruitful transitional approach to envisaging new energy system completely cut-off from fossil energy and oriented towards sustainable sources of energy, with little impact on the environment and social communities, societies also need, besides technical interventions, socio-political and socio-cultural innovations, and solutions. This lies at the heart of "sustainability transition" and as such should be explored interdisciplinary with an aim of understanding barriers to systemic and radical change that is needed (Markard et al., 2012). Contemporary studies of transition focus on aspirational and goal-oriented radical transformation. To create such change, it is necessary to understand the socio-technical needs and requirements that are standing in the way of social transformation. For the enrollment into transformational pathways and plans, in developing a stable socio-technical structure societies need to include governance strategies and democratic prerequisites. Therefore, this article is an example of interdisciplinary endeavor in which sociological concepts and perspectives meet with technical understanding of potential and barriers of energy transition.

At the current historical moment, societies are globally confronted with climate emergency and a requirement to achieve rapid de-carbonization. To do so we need to swiftly move away from the situation of the lock-in to fossil fuels and move toward sustainable energy systems. Currently unsustainable production and usage of energy is severely rooted in the economic, cultural, political and material infrastructure of societies. From economic production through transport and mobility towards housing, all these key aspects and structural components of contemporary energy systems and social reproduction structures are highly addicted to fossil fuels. Severe reduction of greenhouse gas emissions and keeping the global temperature up to 1.5°C warming requires substantial transformation of societies that cannot be achieved only through optimizing the current energy system or eco-modernist approach and technological changes. It requires a radical change of the economic system, social infrastructure and modes of living.

Energy per se relates to different discourses on technological aspects, matters of resources, energy politics, examples of social practices, questions of measurability and indicators. In order to shape public opinion and influence politics and policies, framing is the most important condition. Usually matters of energy fall into a discourse on civilizational achievements and development (Cherry et al., 2015), as an achievement of capitalism and neoliberal ideology. This discourse is mostly used by politicians and businesses, while technological frame is being used as a mean of delegitimizing adversaries by claiming that they do not understand technology and making accusations that their vision of development is at fault. Technology as a tool for an argument combined with economic reasoning is often a one-sided perspective with the opposing perspective of environmentalism. This is often dichotomized through the discussion on weather developmental primacy should be given to creating or preserving "jobs" or protecting the "environment" (Evans and Phelan, 2016). It is only recently that we can witness a new frame where technological and economic perspectives are connected with the goals of climate policy. This type of framing calls for an energy transition while it is often juxtaposed with the discourse of energy security usually deployed by policymakers.

Since the late 1980s there has been a development of discourses on socio-technical transition, and mostly it was a mix of various approaches stemming from evolutionary economics and Neo-Schumpeterian economics, historical approaches to technology development towards social studies of technology (Rohracher, 2018). Taking on the ideas from evolutionary economics and the social study of technology, Schot developed a three-dimensional strategy to influence technological change (Schot, 1992). One dimension relates to the experimental approach to technology and calls for a development of alternative variations. The second one relates to the regulatory framework and policies of governance, while the third one refers to the establishment of an institutional framework for innovation processes and long-term orientations. This approach relies on the idea of a strategic management of niches (SMN) in the development of technology and energy transition. The idea is the following: if societies ensure free spaces for experiments[2] in which new socio-technical relations can develop, it will

[2] Space for experiments would imply research endeavours and piloting implementations in order to explore new socio-technical solutions. To have spaces for experiments it assumes provision of financial support and administrative deregulation in order to have the experiments put in place.

create a pressure in society thus leading to the overthrow of current energy regimes (Hoogma et al., 2002; Schot et al., 1994; Weber et al., 1999). Thus, the centre of debates on sustainability transition were at the very beginning the issues of energy, transportation and buildings. Research approaches to these issues slowly converged towards a multilevel perspective, in which the multidimensionality of socio-technical change is apostrophized. As a perspective, it speaks of a variety of actors involved in the process and the ways in which local practices are influencing the transition. Therefore, it is also important to understand the current regime of societies, which means the current socio-technical configuration that is being stabilized and driven by the inner social and economic logic and rules. The socio-technical regime refers to the social functionality of the system in terms of transport and energy, and as such refers to an interdependent relation between technological and institutional aspects of the structure. The structure as such is characterized by a low level of potential for change, which consequently leads to a very narrow space for the emergence of new technological solutions for society. The regime is for that matter structured with knowledge, technical and engineering practices, government policies, former investments, interests of private entrepreneurs and so on (Kemp, 2001).

However, the multilevel perspective has been subjected to criticism since it has some conceptual shortcomings that need to be addressed. Some authors have raised the issues of agency and power (Genus and Coles, 2008; Smith et al., 2005). Often there is a discrepancy between envisioning a new socio-technical system and designing a related policy framework with the reality of the current policy framework and how the system is set up. Tax systems, financial structures and policy goals completely differ from policy designs oriented towards the formation of a new system (Meadowcroft, 2009). Another critical perspective opens a discussion on the ambivalence of sustainability goals and the need for a planned management of the transition. The question is to what extent are societies ready for normative and collective actions in transitional pathways (Berkhout, 2006; Cochran et al., 2022; Peng et al., 2021). Addressing these conceptual shortcomings and navigating the complexities of power dynamics, policy design, and societal readiness will be crucial for driving a successful and comprehensive energy transition. It requires a nuanced understanding of the current socio-technical regime and the development of strategies that enable transformative change while addressing societal, economic, and political realities. By integrating technical innovations with socio-political and socio-cultural innovations, societies can pave the way for a sustainable energy future.

The exploration of energy transition from fossil fuels to renewable sources requires a comprehensive understanding of its social dimensions and implications. This perspective emphasizes the intricate interplay between social structures, power dynamics, and cultural influences in shaping the trajectory and outcomes of this transformative process. Energy transition is recognized as a multifaceted phenomenon involving technological advancements, economic shifts, and profound social transformations. Researchers argue that the energy transition necessitates an examination of diverse stakeholders, including governmental bodies, corporations, communities, and individuals (Cochran et al., 2022). By exploring the social implications of energy transition, scholars can shed light on issues such as energy inequality, social justice, and environmental justice. The investigation of the role of social movements, advocacy groups, and policy frameworks is crucial in discerning the facilitators and barriers to successful energy transition. Furthermore, an analysis of social norms, values, and beliefs provides valuable insights into the social acceptance and adoption of renewable energy technologies. Researchers explore the social factors that influence energy consumption patterns and attitudes towards alternative energy sources. By studying these factors, a more nuanced understanding of energy transition can be attained.

After this introductory section on the energy-society perspectives, in the second section, an overview of the current energy situation in Croatia will be provided in terms of the structure of energy sources, ratio between renewables and non-renewables, primary energy production vs energy imports, and a brief sketch of the context of politically proclaimed energy transition goals. The third section deals with regional differences in current energy poverty as a significant weight for an even and just energy transition. The fourth section is focused on the analysis of the renewable potential in terms of solar energy for the Croatian territory with an emphasis on regional differences and current contradictions occurring in the process of energy transition. The fifth section deals with the context of citizens' energy, as a potential driving force for a just energy transition and as a potential for the dynamization of energy transition. The concluding section will attempt to give an overview on energy transition obstacles and contradictions happening in Croatian society.

2. Fossil Fuel Lock-in and Unused Renewable Potential in Croatia

The total energy consumption in the Republic of Croatia in 2021 was 413.0 PJ ($413.0 \cdot 10^{15}$ J). The dominance of fossil fuels in the modern world is also reflected in the standard unit of the energy amount that can be obtained by burning one ton of crude oil. To satisfy the Croatian annual energy needs, it is necessary to burn almost 10 million tons of crude oil (10^7 tons or tons of oil equivalent). Fortunately, a significant part of the necessary energy in Croatia, although still insufficient, comes from renewable energy sources. The total production of primary energy in the Republic of Croatia amounts to 214.5 PJ, which is the equivalent of about 5 million tons of crude oil. Primary energy refers to the energy acquired from natural resources (stored in fossil fuels and renewable energy sources) before the process of conversion into another form of energy. Table 1 shows the structure of Croatian domestic primary energy production. The largest share, 33.2%, is made up of fuelwood (which is dominantly used for heat energy production), and 29.8% of hydro power (which is used in electricity production). The shares of natural gas, crude oil, and other renewable sources (wind energy, solar energy, biogas, liquid biofuels, and geothermal energy) are approximately equal and sum up to about 12%.

Table 1.
The structure of the primary energy production and the structure of energy imports in Croatia

Primary energy production		Energy imports	
Energy source	**%**	**Energy source**	**%**
Fuel wood	33.2	Coal and coke	6.6
Crude oil	12.0	Crude oil	23.4
Natural gas	12.3	Petroleum products	35.5
Hydro power	29.8	Natural gas	25
Heat	0.3	Electricity	7.5
Renewables	12.4	Biomass	2

Source: (*Energy in Croatia 2021.*)

Energy supply from domestic sources thus amounts to 51.9% (ratio of primary energy production and total energy consumption). The rest of the required energy comes from imports while at the same time, fossil fuels take up 90% of the share in the structure of imported energy (Table 1). Crude oil and petroleum products represent almost 60% of the import structure, and the share of self-supply with liquid fuels obtained as a ratio of crude oil production and total consumption of liquid fuels is only 21.5%. The percentage of Croatia's natural gas supply is shown as a ratio of production and total consumption, which in 2021 was 25%. In the observed five-year period (2016-2021), the share of Croatia's import of natural gas increased significantly, among other reasons, due to reduced production from domestic sources[3]. All coal, which is dominantly used in thermal power plants as fuel, is imported. From the available data, it can be concluded that Croatia is poor in fossil fuel deposits, therefore renewable energy sources in this context can be viewed not only from an ecological perspective but also as a means of increasing energy supply, as well as energy security and independency.

Energy transition in Croatia is politically framed, in accordance with the strategic plans of the European Union, through the goal to increase the share of renewable sources in gross final energy consumption(Lay and Šimleša, 2012; Puđak, 2014). Gross final energy consumption, in addition to final energy consumption, also includes transformation, transmission, and distribution losses. The targets are additionally set by the sector for electricity consumption, energy for heating and cooling, and

[3] Energija u Hrvatskoj, Godišnji energetski pregled 2021., Republika Hrvatska, Ministarstvo gospodarstva i održivog razvoja

transport. Table 2 shows the stated goals for 2020 determined by the Directive on the Promotion of the Use of Energy from Renewable Sources and the Energy Strategy of the Republic of Croatia[4], the accomplished status in 2020[5], and indicative goals determined by the Integrated National Energy and Climate Plan[6].

Table 2.
The strategic goals and achievements of the renewable energy shares in gross final energy consumption

	2020 objectives	2020 accomplishment	2030 objectives
The share in gross final energy consumption	20%	31.0%	39.4%
Electric power	35%	53.8%	63.8%
Heating and cooling	20%	36.9%	47.8%
Transport	10%	6.6%	14.0%

Source: (*Energy in Croatia 2021.*)

Croatia has largely achieved and surpassed the goals set for 2020. The share of renewable sources in gross final energy consumption in 2020 was 31%. Only a few countries in the European Union had a higher percentage of renewable sources in gross final consumption (Sweden, Finland, Latvia, Denmark, Estonia, Austria, and Portugal)[7]. The share of renewable sources in the electricity consumption sector was a rather high 53.8%, nevertheless primarily due to the production from large hydro power plants mostly built in the socialist time. In that time, 18 hydro power plants were constructed out of which the majority could be defined as large hydro power plants with a capacity of over 10 MW of power. In the last thirty years only two hydro power plants were built, out of which only one could be defined as a large hydro power plant. The share of renewable sources in the heating and cooling sector was 36.9%, with the largest contribution from fuel wood and biomass. In the transport sector, as in some other EU countries, Croatia did not achieve the set goal of the 10% renewable share, which was binding for all member states. In the transport sector, the use of fossil fuels is still dominant, and in addition to biofuels and biogas, the role of electricity in the transport sector decarbonization is particularly significant. Therefore, it is important that the electricity needed for electrification of the transport sector comes from environmentally friendly sources.

[4] Strategija energetskog razvoja Republike Hrvatske, Narodne novine 130/2009

[5] 2022 Report on the Achievement of the 2020 Renewable Energy Targets, European Commission

[6] Integrirani nacionalni energetski i klimatski plan za Republiku Hrvatsku za razdoblje od 2021. do 2030. godine, Ministarstvo okoliša i energetike, Republika Hrvatska, 2019.

[7] 2022 Report on the Achievement of the 2020 Renewable Energy Targets, European Commission

The total annual electricity consumption in the Republic of Croatia in 2021 was 19,171 GWh. For comparison, this is the amount of energy that a little over 2 million electric clothes irons with a power of 1,000 W would consume if they worked for a whole year without interruption. The total annual electricity production in power plants on the territory of the Republic of Croatia was 15,210 GWh. Electricity production in the Republic of Croatia has seen constant growth in recent years thanks to the installed capacity growth from renewable sources, primarily wind power plants. However, 2,709 GWh of electricity produced at the Krško Nuclear Power Plant should be added to the overall production. Thus, the share of own supply of electricity amounts to 93.5%[8].

The total installed capacity of all power plants in the Republic of Croatia is 4,873 MW, while the peak load of the Croatian power system is slightly more than 3,000 MW. The structure of installed power by different types of power plants is shown in Table 3. The largest share of installed capacity is represented by hydro power plants, followed by fossil fuel thermal power plants, wind power plants which have recorded significant growth in recent years, and other renewable sources with only 6.9%. A more detailed breakdown of other renewable sources exhibits the share of solar power plants of up to 2.8%. The same table gives comparison of the structure of electricity production with the installed power. By comparing the data, it can be noticed that the wind power plants have a smaller share in the energy produced compared to their installed capacity, i.e. 13.6% of produced energy compared to 20.3% of installed power. A similar trend is visible for solar power plants, with 1% of produced energy compared to 2.8% of installed power. These are variable energy sources with a low capacity factor since the electricity production from them depends on the availability of wind or sun.

Table 3.
The structure of installed power of power plants and the structure of electricity production in 2021 of all power plants and other renewables

Structure of installed power of power plants				Structure of electricity production			
All power plants	%	Other renewables	%	All power plants	%	Other renewables	%
Hydro power plants	44.5	Solar	2.8	Hydro power plants	46.8	Solar	1
Thermal power plants	28.4	Biomass	2.0	Thermal power plants	30.1	Biomass	4.3
Wind power plants	20.3	Biogas	1.2	Wind power plants	13.6	Biogas	2.9
Other renewable	6.9	Small hydro	0.7	Other renewable	9.6	Small hydro	0.8
		Geothermal	0.2			Geothermal	0.6

Source: (*Energy in Croatia 2021.*)

[8] Energija u Hrvatskoj, Godišnji energetski pregled 2021., Republika Hrvatska, Ministarstvo gospodarstva i održivog razvoja

Croatia faces a twofold challenge of heavy reliance on fossil fuels and the need to enhance its renewable energy capacity. While the country has tracked significant progress in increasing the share of renewable sources, particularly in electricity production and the heating sector, there is still room for improvement, especially in the transportation sector. By focusing on energy transition pathways and further harnessing renewable energy sources, Croatia can enhance its energy security, reduce the dependence on imports, and contribute to a more sustainable energy future. A significant lack of solar power utilization in Croatia is an important insight that deserves attention. Despite the country's abundant solar resources, solar power has not been extensively used to its full potential. This can be attributed to various factors, some of the most prevalent including policy limitations, inadequate infrastructure, and limited investment in solar energy projects. However, it should be explored more deeply to find out what socio-technical obstacles are disabling the usage of solar potential in Croatia. However, before dwelling into those issues it is important to explore to what extent the energy needs are met in Croatian society, whether citizens are experiencing energy poverty due to high reliance on imported fossil fuels, and whether these trends are regionally conditioned. The next section will try to provide us with an insight into some of these questions.

3. Energy Poverty as a Reality to Address within the Energy Transition

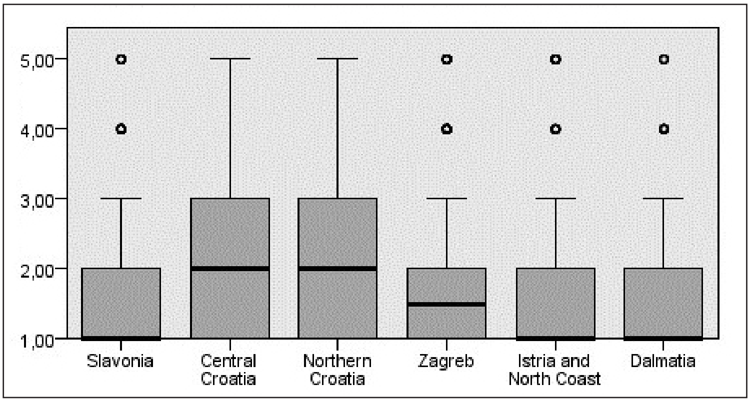
There is no clear scientific consensus regarding the understanding of the way and the extent to which our collective efforts to achieve a low carbon just transition affect the reduction of the prevalence and intensity of energy poverty, an important factor in attaining energy justice in general, and vice versa. While the integration of renewable energy sources has been recognized as a driving measure of energy poverty alleviation in some contexts, as it is the case with the areas without access to modern energy services (Streimikiene et al., 2021), much of the relevant literature at the same time recognizes a discrepancy between (a variety of) actual costs of the widespread transformation of fossil-based energy systems to renewable sources, and existing social and economic capacities to bear those costs (Streimikiene et al., 2021). In short, the scientific debate on the extent to which existing climate change mitigation policies, with the upscaling of renewable energy flows as one of the more frequently proclaimed and sought-after goals, affect the alleviation of energy poverty remains fragmented and highly contextualized within the unique economic, social, and political contexts in which such recorded and theorized effects are explored.

Nevertheless, the simultaneous ambition of the EU to achieve complete climate neutrality by 2050 while reducing certain aspects of social inequalities, such as energy poverty, remains its political reality and a high priority objective unequivocally formalized within its legislative framework, guiding directives and various initiatives concerning, directly or indirectly, the low carbon transition in the EU and its member states. However, mainly due to the recognized multi-dimensional and contextual nature of the concept and experience of energy poverty, there is currently a variety of nationally specific approaches to define, measure, tackle, and coordinate efforts with the EU in combating energy poverty. In this, not even the European Commission, despite advocating for policies, is not providing a singular overarching definition. Yet, energy poverty remains one of the focal-points in energy and just transition strivings in the EU and unsurprisingly so, given that by some estimations over 50 million people in Europe were affected by energy poverty in 2018 (Thomson and Bouzarovski, 2018). Adding to this number and thus accentuating the importance of a rapid and just energy transition, new studies identify another 78 million to 141 million people worldwide in danger of being pushed into extreme poverty due to instabilities in the global energy supply chains and rising energy prices, as a result of the intensification of the energy crisis caused by the Russia-Ukraine conflict (Guan et al., 2023).

Energy poverty can most generally be defined as a situation within which a household is unable to access or afford, materially and socially, adequate levels of basic energy services for home use, such as lighting, heating, cooling, and sufficient use of household appliances (Thomson et al., 2017). Even though the underlying causes of energy poverty vary depending on the specific geographical and social context, it is thought that the main drivers of energy poverty in the EU result from a combination of thermally inefficient residential dwellings and low household income (Bouzarovski, 2014), coupled with high energy prices (Thomson et al., 2017). Some research on energy poverty profiles identifies certain socio-demographic and housing characteristics as the driving factors behind energy poverty (Primc et al., 2019). Examining a vast body of relevant literature on energy poverty, Middlemiss (2022) established four general categories of social groups who are especially vulnerable to energy poverty in the EU context. These categories refer to specific demographic categories (women, disabled, young and elderly), ethnicity and immigration (ethnic minorities, indigenous people and immigrants), income and employment prospects (low educational attainment, unemployed adults and low-income households), and particular household types (single parent families, socially isolated people, people living alone, large households and multi-occupancy/family households). As for some of the consequences, Thomson et al. (2017) point to a large body of literature highlighting negative effects of poor housing conditions, low indoor temperatures, heating needs and debt on stress levels, anxiety and depression. Moreover, by analyzing secondary data for 32 European countries they establish that the energy poor population is statistically more likely to report poorer levels of self-reported health and emotional well-being (Robić and Ančić, 2018; Thomson et al., 2017).

In the context of conducted exploratory research, we have focused on regional-level data availability and pragmatic aspects of acquiring knowledge on (subjective) energy poverty aspect in Croatia, along with a general methodological note on perception-based, or "consensual" indicators, as they are the type of energy poverty indicators exclusively used in this research[9]. Based on the analyzed data, it is obvious that energy poverty as such is not evenly present across Croatia[10]. The analysis indicates that some differences occur and that in some regions energy poverty is more intense. Non-parametric testing shows that in the regions of Central Croatia and Northern Croatia energy poverty is more pronounced, followed by the Croatian capital in which one fifth of the overall population lives. The lowest level of energy poverty is in two coastal Mediterranean regions (Dalmatia with Istria and North Croatian Littoral - Primorje) and one continental region in the east of Croatia (Slavonia).

Graph 1.
Energy poverty index - regional comparison

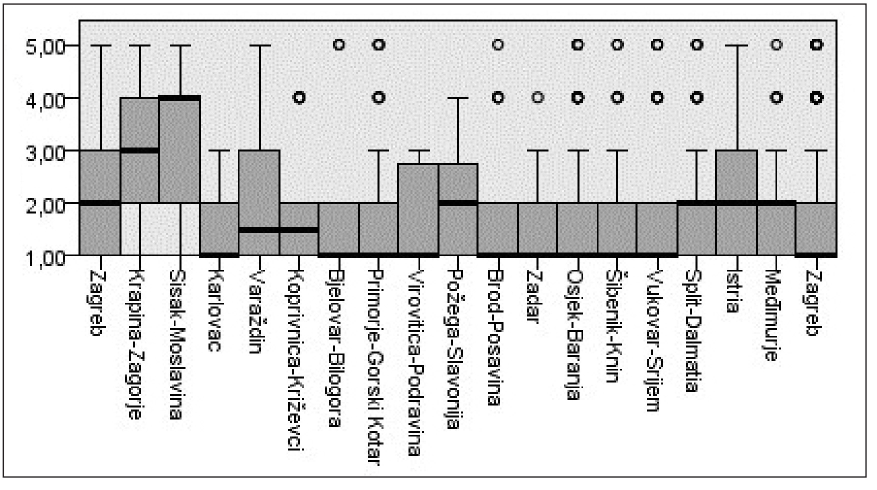


9 In this sense, even though these self-reported indicators (i.e. answers to survey questions) are sometimes characterized as “complementary” to “objective”, that is to say, quantitative and expenditure-based ones (Rademaeker, 2016), their main advantage is that they are, to a certain extent, uniquely able to portray aspects of the lived experience of material deprivation and energy poverty (Awaworyi Churchill and Smyth, 2021). Also, it is important to bear in mind that there is an inherent risk in using either self-reported or solely expenditure-based indicators as their analysis may yield incompatible results and to a significant extent result in identifying different household types as energy poor (Deller et al., 2021), ultimately leading to policy oversights.

10 The exploration of regional differences in energy poverty vulnerability in Croatia in this research is based on the data collected within the Environment IV module of the International Social Survey Programme (ISSP) conducted via face-to-face surveying during the months of June and July of 2021 on the adult population of Croatia. The questionnaire comprised of more than 150 individual variables concerning attitudes and opinions on aspects of environmental protection, climate change and energy transition in Croatia. The nationally representative structure of the sample (N = 1,000) for the first time enables disaggregated insights into regional differences concerning the measured self-reported aspects of energy poverty in Croatia. Thus, within the topic of energy transition in Croatia we have included the following three variables commonly applied in the European Union Statistics on Income and Living Conditions (EU SILC) annual survey that provides comparable cross-sectional and longitudinal data on income, poverty, social exclusion and living conditions in the EU. (see Appendix)

Regional perspective in a more focused view is presented with the regional difference in energy poverty of counties that are administrative territorial units (Graph 1). Out of 21 counties in Croatia the survey sample consists of 19 counties, and the nonparametric analysis points to statistically significant differences. The highest level of energy poverty is in Sisak-Moslavina County (Central Croatia) and Krapina-Zagorje County (Northern Croatia). Based on the indices of county development, those two counties are listed among those with lower levels of development. However, the differences in energy poverty level do not follow the pattern of developmental differences and traits among the counties. For instance, Zagreb County, the surrounding area of the City of Zagreb, although positioned among the top developed counties in Croatia, exhibits a higher level of energy poverty than some other less developed counties.

Graph 2.
Energy poverty in Croatia - county comparison

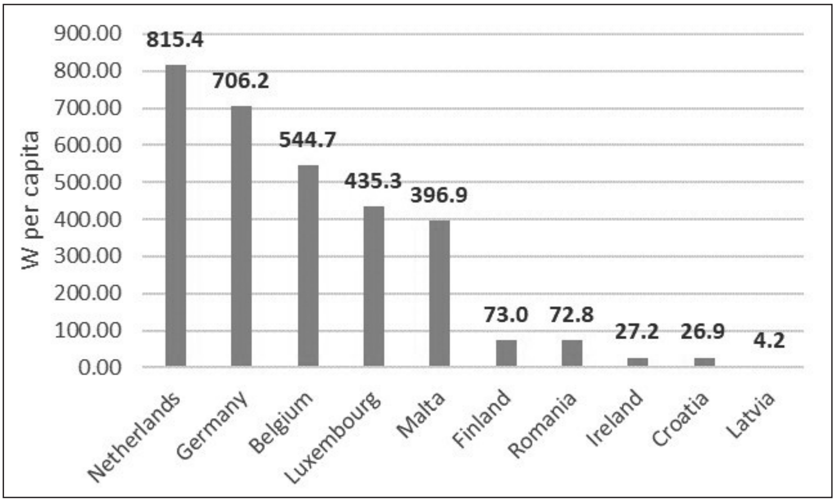


The scientific understanding of the relationship between low-carbon transitions and energy poverty reduction, and vice versa, remains fragmented and context-dependent. While renewable energy integration is seen as a means to alleviate energy poverty in some areas, the high costs associated with transitioning from fossil fuels pose a challenge. Regional disparities in energy poverty exist within Croatia, with variations not strictly aligned with developmental levels. As such, insights on energy poverty and its regional conditioning should be addressed in designing energy transition in Croatian society. Therefore, the aim of the next section is to explore the regional differences of the solar energy potential and current processes of energy transition.

4. Regional Differences and Techno-economic Aspects of Renewable Energy Integration in Croatia – Solar Energy Potential in Energy Transition

As presented in the second section, the energy mix of Croatia indicates a strong addiction to fossil fuels since almost half of the energy needed is imported fossil fuel energy, while at the same time the potential of renewables seems to be underutilized. In this regard, Croatia has extensive potential since (Holjevac et al., 2021), as was mentioned already, its current status of solar energy usage and utilization are really low. Graph 3 shows the installed capacity of photovoltaic power plants per capita in the countries of the European Union (first and last five countries). The Netherlands is at the forefront of the European Union with 815.4 W per capita, while Latvia is at the end with only 4.2 W of installed power per inhabitant. Surprisingly, Croatia, as a partly Mediterranean country with favourable natural capacities for solar energy use, is in the penultimate place with 26.9 W of installed power of photovoltaic systems per inhabitant, which is many times less than in countries with much fewer hours of sunshine and less insolation. The previously displayed data encourage reflection on current investment policies and incentives for renewable energy sources.

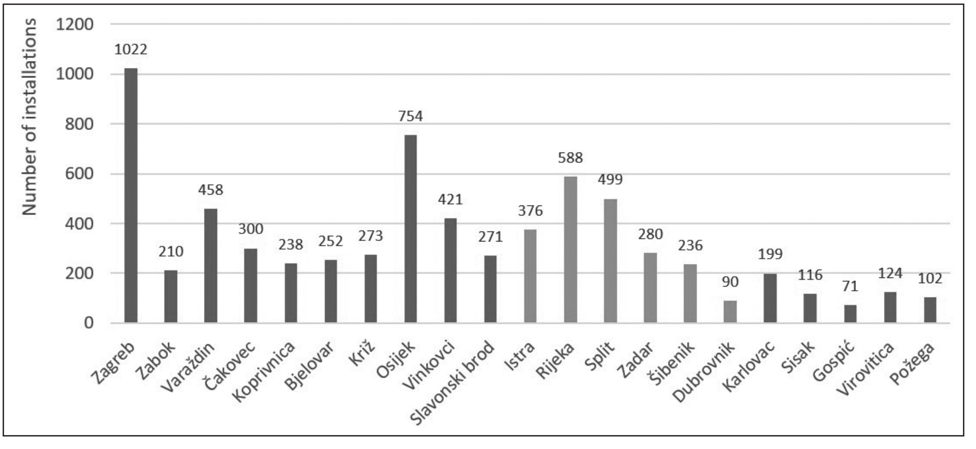
Graph 3.
Installed capacity of photovoltaic power plants in the EU per capita (first and last five countries)



Source: EU-27: solar PV capacity per inhabitant by country 2021 | Statista

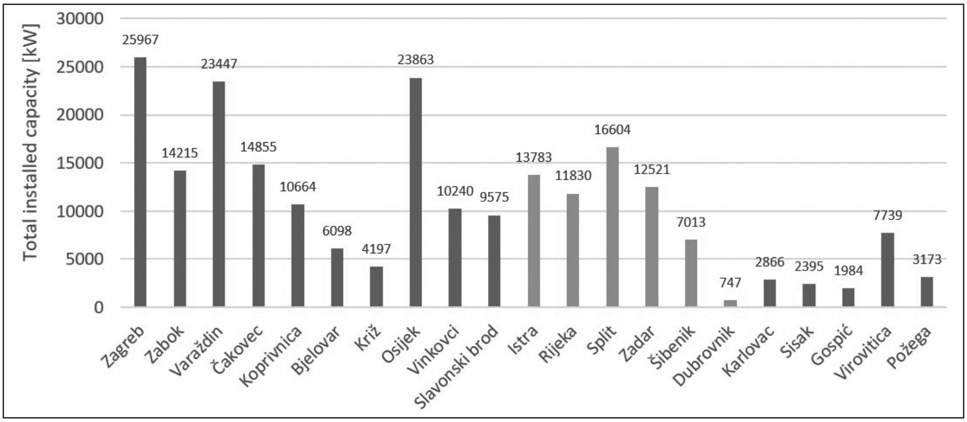
The solarization in Croatia does not come without significant regional differences that stem from both wealth distribution differences, differing technical and social aspects and from socio-cultural disparities. The continental regions have throughout the years installed many more solar power plants despite having 30% to 50% lower insolation and solar capacity. This is visible from the following figures showing the total number of solar power plants and total installed capacity of solar power plants in different distribution system segments (Graph 4 and Graph 5) and showing the total insolation in Croatia (Figure 1). It can be seen that despite the solar capacity being much greater in the coastal regions of Croatia (marked with orange bars in Graph 4 and 5), the realized number of solar power plants in these regions is much lower compared to the continental regions. This is even more significant considering the fact that the total number of newly built household units in these regions increased by more than 10% and almost none of these included integrated solar energy power plants. The approach and opportunities that were not utilized present a significant social welfare loss and show that the approach and priorities in Croatian regions also differ. In this, a higher level of thoughtfulness toward the energy issues is not necessarily linked with the highest solar resource regions, which would also have more financially beneficial indicators and return periods. The results are specifically low for the Dubrovnik, Zadar and Šibenik areas.

Graph 4.
Distribution of the number of solar power plants throughout the distribution system units in 2021-2022



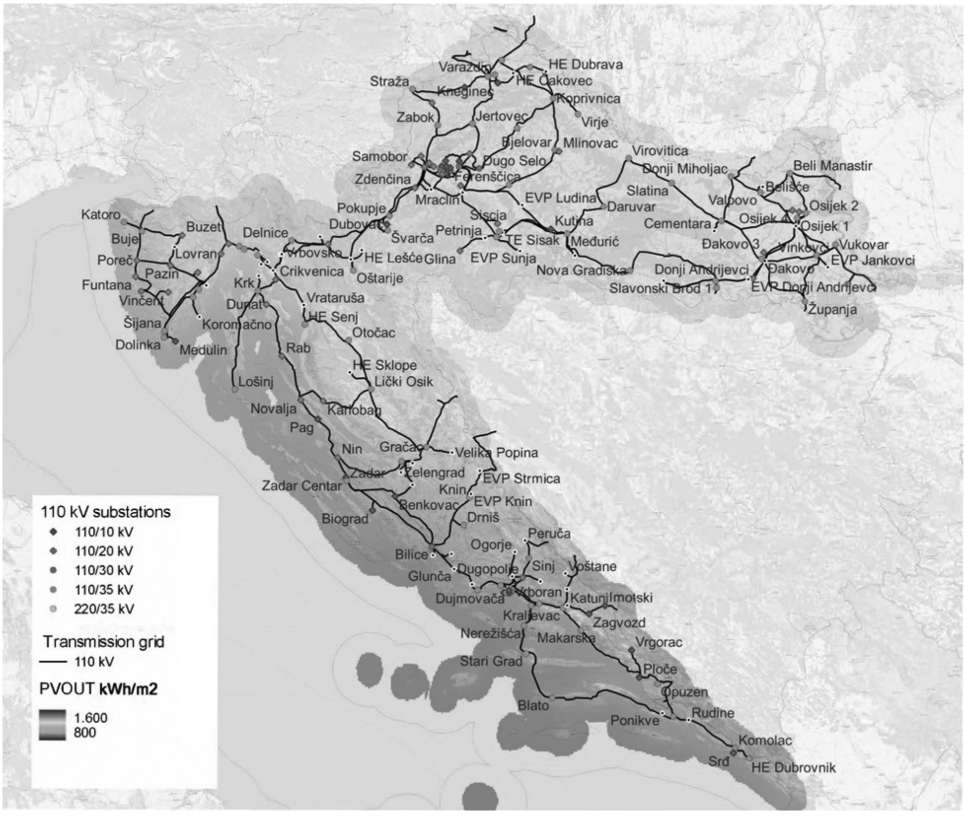
Source: Annual report HEP-ODS 2021

Graph 5.
Distribution of installed solar power plants capacity throughout the distribution system units



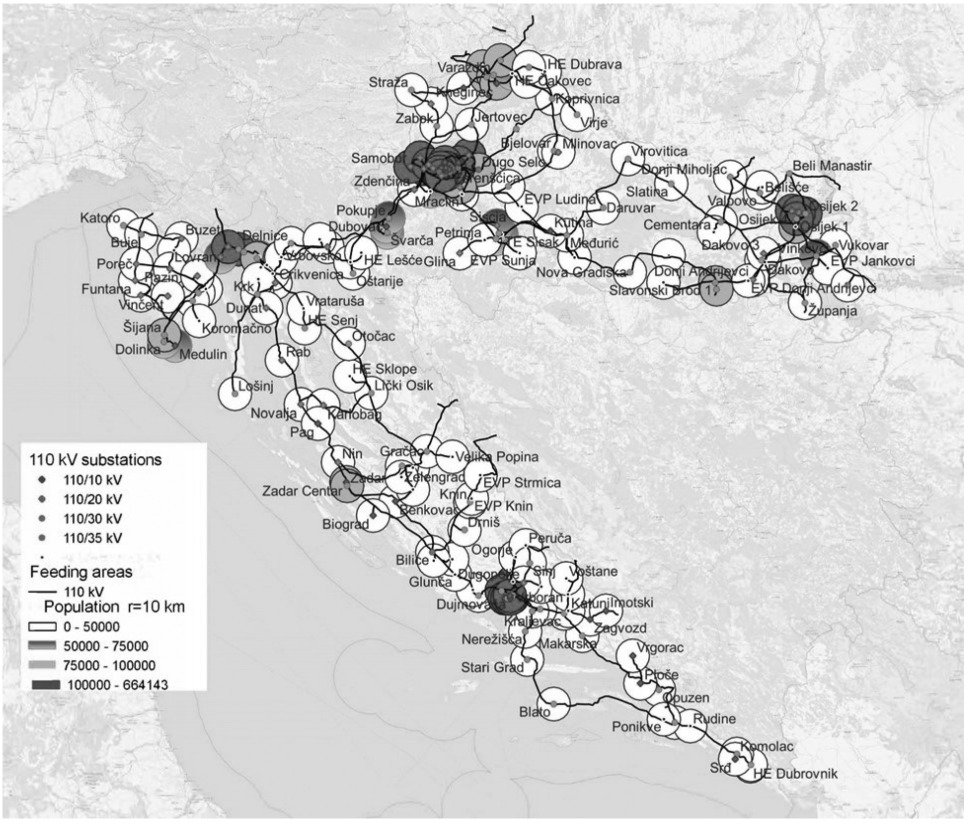
Source: Annual report HEP-ODS 2021

Figure 1.
Global horizontal irradiation for Croatia with the distribution level 110/x kV substation locations



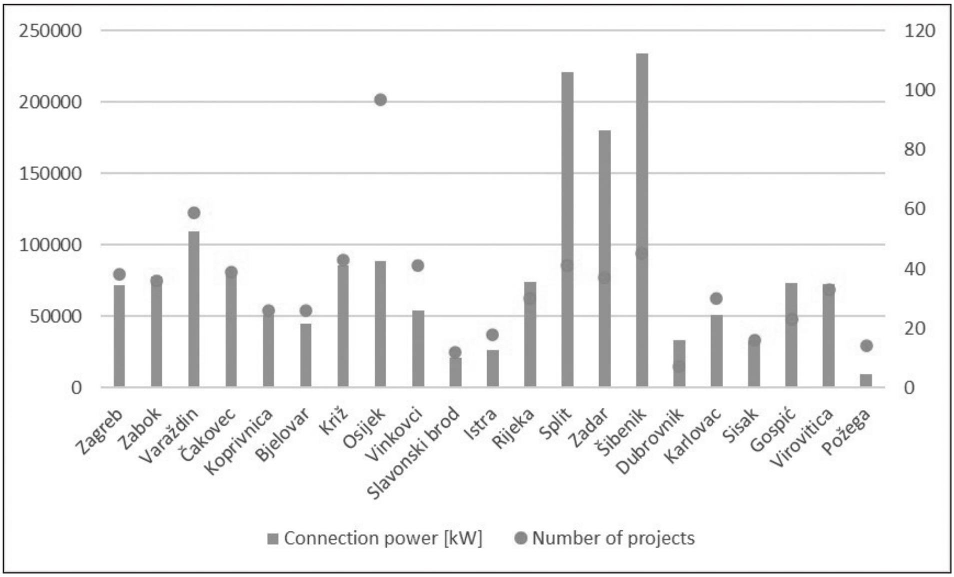
It is furthermore important to note that considering the low voltage household rooftop solar most of Croatia is covered by the feeding of 110 kV voltage level substations. The figure below (Figure 2) shows that in the majority of Croatian areas a strong feeding point providing enough grid capacity can be found in a 10 km radius, which coincides with the high consumption areas. It is important to note that in the high consumption areas, all marked with red population density circle, small rooftop solars have almost no obstacles to be installed. It is also expected that in the coming 3 to 5-year period in these areas a steep increase in the number of solar installations will be evidenced, and the distribution grid should be able to sustain the additional production.

Figure 2.
Population density directly correlated with the total load of the different 110 kV distribution system substations



Furthermore, it is interesting to note the difference between the numbers of larger solar projects (500+ kW of connection power) in different regions. The Graph 6 shows that there are many projects developed altogether on the distribution level, with approximately more than 1,500 MW of projects in different connection process stages. These data show that with regard to smaller projects, which can be driven by individuals or by privately initiated incentives, the continental regions are leading, as shown by the greater overall number of projects developed. On the other hand, the total capacity of the developed projects is larger in coastal regions, with the average capacity of a single project being significantly greater. This can signify that the capitally intensive projects tend to aim for the best financial indicators that are directly linked to energy gains, which are undoubtedly higher in regions with higher insulation like the Split, Zadar and Šibenik areas.

Graph 6.
Distribution level of projects in different connection process stages in 2021-2022 for different distribution areas

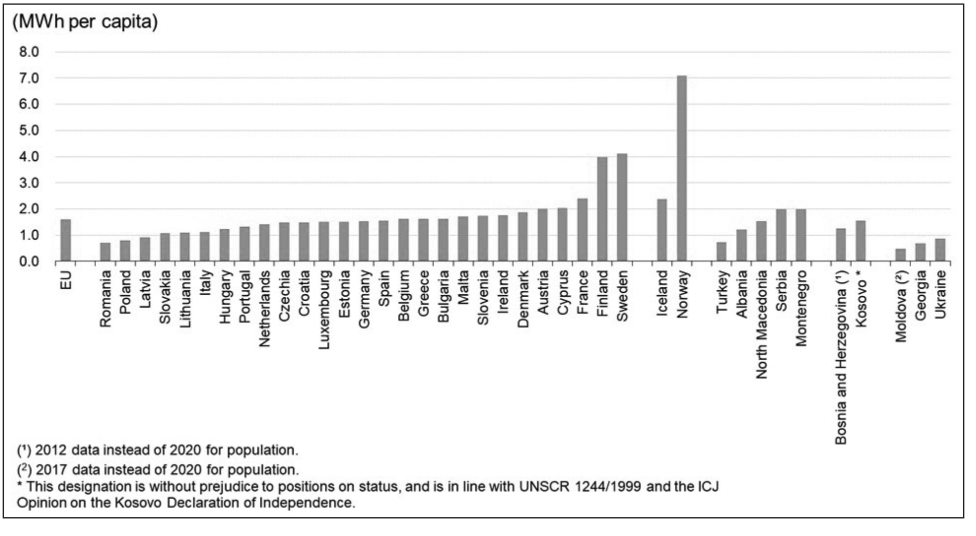


The study on the solar energy potential in Croatia underscores the need for policy interventions and incentives to promote renewable energy adoption. Despite favourable natural conditions, Croatia lags behind in solar energy utilization compared to other EU countries. The regional disparities within Croatia, where continental regions outperform coastal regions in terms of solar installations, raise questions about investment priorities and socio-cultural factors driving them. The findings suggest that a thoughtful and region-specific approach is necessary to address energy challenges effectively. It is crucial to align investment policies with solar resource availability and consider socio-economic factors to maximize energy gains and achieve a more balanced distribution of renewable energy installations. Additionally, the study emphasizes the importance of grid capacity and highlights the potential for increased solar installations, particularly in high consumption areas, which require infrastructure upgrades to accommodate additional production. One of the driving forces for better utilization of solar potential is citizens' energy actions and initiatives. In the next section we will provide a frame for the understanding of the potential of citizens' energy and citizens' enrolment in energy transition.

5. Potential of Citizens' Engagement in Energy Transition

According to the last statistical data, Croatia has roughly 3.88 million inhabitants that live in 1.44 million households. At the same time the number of housing units in Croatia is 2.35 million and has been on the increase with a 4.6% increase compared to the year 2011[11]. The comparison of these averages shows that an average household in Croatia consists of 2.7 people, which is slightly above the average of the EU where it is 2.35 (Eurostat). Furthermore, to show the potential for the increase of citizen-based energy transition, an average power consumption of a single household in Croatia is around 4,500 kWh. The Eurostat data therefore show that an average household consumption per capita in Croatia was around 1,600 kWh/annually, which is slightly below the EU average. The EU average does not show a large spread, from the lowest 800 kWh/annually in Romania to 7,200 kWh/annually in Norway (Graph 7).

Graph 7.
Average household consumption of electricity per capita in MWh in EU, 2020



Source: Eurostat online data codes: nrg_cb_e, demo_pjan

The aim to increase the participation of all citizens in the energy transition in Croatia should precisely aim to integrate rooftop solar on a wide scale since most of the households could benefit from a smaller solar system tailored for their self-consumption

11 https://podaci.dzs.hr/hr/podaci/stanovnistvo/popis-stanovnistva/

needs. Solar power production in Croatia in the year 2022 was only 79 GWh which is only up to 1% of total energy production. For comparison, the wind power share in Croatia was 2,301 GWh, which sums to 13% of total energy production. The abovementioned potential increase was initiated in the last 2 years and the data show a significant increase in the overall solar and household solar integration (Table 4).

Table 4.
Number of solar power plants in the recent years in Croatia on the distribution network level

	2020	2021	2022
The total number of connected solar power plants	**2882**	**3854**	**6880**
The number on low voltage level (0.4 kV)	2797	3741	6691
The number on medium voltage (10+ kV and 500+ kW)	85	113	189
Total connected distribution level power of solar power plants [MW]	**108.5**	**139.4**	**223.7**
The power on low voltage level (0,4 kV) [MW]	72.1	88.5	135.4
The power on medium voltage [MW]	36.4	50.9	88.3
Number of household solar in self-supply net-metering scheme	**851**	**1300**	**3805**
Total connected power of self-supply solar installations [MW]	**5.03**	**8.10**	**22.90**
Total produced energy from solar [GWh]	**95.5**	**145.2**	**252.7**

The traditional centralized energy system often fails to reach marginalized communities and low-income households, leaving them disproportionately affected by energy poverty. This highlights the need for alternative approaches that empower communities and individuals to actively participate in the energy transition process. The development of renewable energy sources in recent years has significantly changed the energy landscape, with the rise of local and small-scale low-carbon technologies (Alanne and Saari, 2006; Berka and Dreyfus, 2021). This evolution opened a possibility for new actors, such as energy communities, to participate in energy production (Bauwens et al., 2016; Hewitt et al., 2019; Wyse and Hoicka, 2019). Citizen energy, also known as community energy or decentralized energy, emerges as a promising solution to tackle energy poverty while advancing the goals of energy transition. Citizen energy involves the active involvement of local communities and individuals in the production, distribution, and consumption of renewable energy. It allows communities to take ownership of their energy systems, fostering local resilience, reducing dependence on external energy sources, and promoting social and economic empowerment. By enabling citizens to generate their own renewable energy, such as through rooftop solar panels or community-owned wind farms, citizen energy initiatives not only contribute to reducing greenhouse gas emissions but could also provide affordable and clean energy to those facing energy poverty. These initiatives can be particularly impactful in remote areas where extending the centralized grid infrastructure is economically challenging. Furthermore, citizen energy projects often prioritize community engagement, participation, and local decision-making processes, ensuring that the energy transition is inclusive and responsive to the specific needs and aspirations of communities.

However, realizing the full potential of citizen energy requires the overcoming of various challenges. These include certain aspects of public perception about energy transition, regulatory barriers, access to financing, technical knowledge, and capacity-building needs. Policymakers and stakeholders need to create an enabling environment that supports and incentivizes citizen energy initiatives, such as through favourable regulations, financial incentives, and knowledge-sharing platforms. Currently, while citizen energy initiatives and community-owned projects have gained traction in some European countries, the development of citizen energy cooperatives in Croatia has been relatively slow. So far there have been only two citizen energy cooperatives with a very limited reach. The laws adopted by the Croatian Parliament at the end of 2021 raise the issues of the quality of transposition of EU directives and the role of citizens in energy transition. The new laws limit the opportunities for citizens to participate in energy transition, independently and by joining energy communities of citizens (Boromisa, 2021).

6. Concluding Remarks

The energy situation in Croatia, while showcasing progress in renewable energy adoption, raises concerns regarding the accounting of biomass and hydro power plants in terms of carbon storage and their implications for climate change and droughts. While these energy sources contribute significantly to Croatia's renewable energy portfolio, their environmental impact and sustainability require careful evaluation. Firstly, biomass, primarily fuel wood, constitutes a substantial portion of Croatia's primary energy production. However, the use of biomass for heat energy production can lead to carbon emissions and contribute to deforestation and habitat degradation if not managed properly. The sustainability of biomass as an energy source relies on responsible forest management practices, ensuring that biomass harvesting is balanced with reforestation efforts. Adequate accounting and monitoring mechanisms are crucial to accurately assess the carbon neutrality of biomass energy production.

Secondly, hydro power plants hold a significant share in Croatia's primary energy production, predominantly through large-scale installations constructed in the past. While hydro power is considered a renewable energy source, it is essential to recognize the environmental impacts associated with large hydroelectric dams. These projects can disrupt natural river ecosystems, alter water flow patterns, and impact aquatic biodiversity. Additionally, in the face of climate change and increasing drought frequency, hydro power plants may face challenges in maintaining consistent power generation due to reduced water availability. Moreover, the issue of carbon storage and climate change mitigation deserves attention in the context of biomass and hydro power plants. Both energy sources can play a role in sequestering carbon and reducing greenhouse gas emissions. However, accurately accounting for carbon storage and emissions across the entire life cycle of these energy sources is critical to ensure their net environmental benefits.

Besides outlining what is accounted as renewable in the Croatian energy mix and to what extent energy transition goals are being fulfilled, the data presented in the article open a discussion on the regional differences and techno-economic aspects of renewable energy integration, specifically focusing on the solar energy potential in Croatia. They highlight Croatia's heavy dependence on fossil fuels and current underutilization of its renewable energy potential. Despite being a partly Mediterranean country with favourable natural characteristics for solar energy, Croatia ranks the second to last in terms of installed capacity of photovoltaic power plants per capita among EU countries. This raises concerns about current investment policies and incentives for renewable energy sources. The data presented also highlight significant regional disparities within Croatia regarding solarization. It is noted that continental regions have more solar power installations despite lower insolation and solar capacity compared to the coastal regions. This disparity suggests varying investment priorities and opportunities, resulting in a social welfare loss. Additionally, it is emphasized that most of Croatia's low-voltage household rooftop solar is located close to higher voltage level substations, particularly in high consumption areas. This indicates the potential for increased solar installations in these regions in the coming years. Moreover, the data showcased in the article demonstrate the difference in the numbers and capacities of larger solar projects in different regions. It is revealed that continental regions have a greater number of projects, while coastal regions have larger projects with better financial indicators due to higher insolation levels. This indicates the socio-cultural differences in citizens' engagement in energy transition and, as such, calls for a better understanding of citizens' potential in energy transition.

In conclusion, the integration of the issues of energy poverty and citizen energy within the broader context of energy transition is essential for achieving a just and sustainable energy future. By prioritizing equitable access to clean energy and empowering communities to actively participate in energy transition, energy poverty can be addressed and carbon emissions reduced, while fostering the social and economic development at the local level. Therefore, it could be underlined that energy issues in Croatian society are regionally conditioned and, as such, point to the need for a better understanding of the spatial dimension in energy transition. So far, it is obvious that energy transition in Croatia is happening sporadically and is contingent upon overcoming severe obstacles such as regional disparities, cultural differences, energy inequalities, and the underutilization of the renewable potential. The current socio-technical energy regime in Croatian society exhibits a configuration in which citizens' energy, as a significant factor with the potential to accelerate energy transition, is blatantly disregarded. This regime is characterized by a low potential for change and lacks the strategic planning necessary for such a complex and transformative shift. This regime as such is deeply dependent on fossil fuels and is at a high risk of imbalance due to upcoming climate change events. Consequently, it perpetuates the current condition in which empirical insights into energy poverty expose the fallacies and injustices of the socio-technical regime in Croatia. A system that empowers citizens to play an active role and have ownership in the energy system is urgently needed to rectify the current unjust and non-resilient regime.

References

1. Alanne, K. and Saari, A. (2006). Distributed energy generation and sustainable development. *Renew. Sustain. Energy Rev.,* 10: 539-558. https://doi.org/https://doi.org/10.1016/j.rser.2004.11.004
2. Awaworyi Churchill, S. and Smyth, R. (2021). Energy poverty and health: Panel data evidence from Australia. *Energy Econ.,* 97: 105219. https://doi.org/https://doi.org/10.1016/j.eneco.2021.105219
3. Bauwens, T.; Gotchev, B. and Holstenkamp, L. (2016). What drives the development of community energy in Europe? The case of wind power cooperatives. *Energy Res. Soc. Sci.,* 13: 136-147. https://doi.org/https://doi.org/10.1016/j.erss.2015.12.016
4. Berka, A. and Dreyfus, M. (2021). Decentralisation and inclusivity in the energy sector: Preconditions, impacts and avenues for further research. *Renew. Sustain. Energy Rev.,* 138: 110663. https://doi.org/https://doi.org/10.1016/j.rser.2020.110663
5. Berkhout, F. (2006). Normative expectations in systems innovation. *Technol. Anal. Strateg. Manag.,* 18: 299-311. https://doi.org/10.1080/09537320600777010
6. Boromisa, A. M. (2021). *Energetska tranzicija- bez građana?*
7. Bouzarovski, S. (2014). Energy poverty in the European Union: Landscapes of vulnerability. Wiley Interdiscip. Rev. *Energy and Environ.,* 3: 276-289. https://doi.org/10.1002/wene.89
8. Cherry, C.; Hopfe, C.; MacGillivray, B.; Pidgeon, N. (2015). Media discourses of low carbon housing: The marginalisation of social and behavioural dimensions within the British broadsheet press. *Public Underst. Sci.,* 24: 302-310. https://doi.org/10.1177/0963662513512442
9. Cochran, J.; Bak, C. L.; Francos, P. L.; McGowan, D.; Iliceto, A.; Kiseliovas, G.; Rondou, J.; Tan, J.; Trondheim, H. M.; Whiteford, J. (2022). Same Goal, Different Pathways for Energy Transition: A More Holistic, Multisector, Community-Driven Approach. *IEEE Power and Energy Mag.,* 20: 18-29. https://doi.org/10.1109/MPE.2022.3167571
10. Deller, D.; Turner, G. and Waddams Price, C. (2021). Energy poverty indicators: Inconsistencies, implications and where next? *Energy Econ.,* 103: 105551. https://doi.org/https://doi.org/10.1016/j.eneco.2021.105551

11. *Energija u Hrvatskoj 2021.*, n.d.
12. Evans, G. and Phelan, L. (2016). Transition to a post-carbon society: Linking environmental justice and just transition discourses. *Energy Policy,* 99: 329-339. https://doi.org/https://doi.org/10.1016/j.enpol.2016.05.003
13. Genus, A. and Coles, A.-M. (2008). Rethinking the multi-level perspective of technological transitions. *Res. Policy,* 37: 1436-1445. https://doi.org/https://doi.org/10.1016/j.respol.2008.05.006
14. Guan, Y.; Yan, J.; Shan, Y.; Zhou, Y.; Hang, Y.; Li, R.; Liu, Y.; Liu, B.; Nie, Q.; Bruckner, B.; Feng, K.; Hubacek, K. (2023). Burden of the global energy price crisis on households. *Nat. Energy,* 8: 304-316. https://doi.org/10.1038/s41560-023-01209-8
15. Hewitt, R. J.; Bradley, N.; Compagnucci, A. B.; Barlagne, C.; Ceglarz, A., Cremades, R.; McKeen, M.; Otto, I. M.; Slee, B. (2019). Social innovation in community energy in Europe: A review of the evidence. *Front. Energy Res.,* 7: 1-27. https://doi.org/10.3389/fenrg.2019.00031
16. Hoogma, R.; Kemp, R.; Schot, J.; Truffer, B. (2002). *Experimenting for Sustainable Transport The Approach of Strategic Niche Management*. London: Spon Press.
17. Kemp, R. (2001). Constructing transition paths through the management of niches, in: Garud, R. and Karnoe, P. (Eds.). *Path Dependance and Creation*. Mahwah, NJ; London: Lawrence Erlbaum Associates, 269-299.
18. Lay, V. i Šimleša, D. (2012). *Nacionalni interesi razvoja Hrvatske kroz prizmu koncepta održivog razvoja*. Zagreb: Institut društvenih znanosti Ivo Pilar.
19. Markard, J.; Raven, R. and Truffer, B. (2012). Sustainability transitions: An emerging field of research and its prospects. *Res. Policy,* 41: 955-967. https://doi.org/10.1016/j.respol.2012.02.013
20. Meadowcroft, J. (2009). What about the politics? Sustainable development, transition management, and long term energy transitions. *Policy Sci.,* 42: 323-340. https://doi.org/10.1007/s11077-009-9097-z
21. Middlemiss, L. (2022). Who is vulnerable to energy poverty in the Global North, and what is their experience? Wiley Interdiscip. Rev. *Energy and Environ.,* 11: 1-13. https://doi.org/10.1002/wene.455
22. Peng, G.; Xiang, Y.; Yang, J.; Liu, H.; Cen, B. (2021). Clean Energy Transition Evolution of Power Grid Based on System Dynamics, in: *2021 IEEE/IAS Industrial and Commercial Power System Asia (I&CPS Asia)*, 556-561. https://doi.org/10.1109/ICPSAsia52756.2021.9621487
23. Primc, K.; Slabe-Erker, R. and Majcen, B. (2019). Energy poverty: A macrolevel perspective. *Sustain. Dev.,* 27: 982-989. https://doi.org/10.1002/sd.1999
24. Puđak, J. (2014). Are we ready for climate policy? – A qualitative study on the state of climate change policy in Croatia, in: Domazet, M. and Marinović Jerolimov, D. (Eds.). *Sustainability Perspectives from the European Semi- Periphery*. Zagreb: Institut za društvena istraživanja u Zagrebu; Heinrich Bőll Stiftung, 295-326.

25. Robić, S. and Ančić, B. (2018). Exploring Health Impacts of Living in Energy Poverty: Case Study Sisak -Moslavina County, Croatia. *Energy Build.,* 169: 379-387. https://doi.org/10.1016/j.enbuild.2018.03.080
26. Rohracher, H. (2018). Analyzing the Socio-Technical Transformation of Energy Systems: The Concept of "Sustainability Transitions," in: Davidson, D. J. and Gross, M. (Eds.). *The Oxford Handbook of Energy and Society.* New York: Oxford University Press, 45-62.
27. Schot, J. (1992). The Policy relevance of the Quasi-evolutionary Model. The Case of Stimulating Clean Technologies, in: *Technological Change and Company Strategies: Economic and Sociological Perspectives.* London, New York: Harcourt Brace Jovanovich, 185-200.
28. Schot, J.; Hoogma, R. and Elzen, B. (1994). Strategies for shifting technological systems: The case of the automobile system. *Futures,* 26: 1060-1076. https://doi.org/https://doi.org/10.1016/0016-3287(94)90073-6
29. Smith, A.; Stirling, A. and Berkhout, F. (2005). The governance of sustainable socio-technical transitions. Res. *Policy,* 34: 1491-1510. https://doi.org/https://doi.org/10.1016/j.respol.2005.07.005
30. Streimikiene, D., Kyriakopoulos, G. L.; Lekavicius, V.; Siksnelyte-Butkiene, I. (2021). Energy Poverty and Low Carbon Just Energy Transition: Comparative Study in Lithuania and Greece. *Soc. Indic. Res.,* 158: 319-371. https://doi.org/10.1007/s11205-021-02685-9
31. Thomson, H. and Bouzarovski, S. (2018). *Addressing Energy Poverty in the European Union: State of Play and Action.* European Commission.
32. Thomson, H.; Bouzarovski, S. and Snell, C. (2017). Rethinking the measurement of energy poverty in Europe: A critical analysis of indicators and data. *Indoor Built Environ.,* 26 (7). https://doi.org/10.1177/1420326X17699260
33. Weber, M.; Hoogma, R.; Lane, B.; Schot, J. (1999). *Experimenting with Sustainable Transport Innovations. A workbook for Strategic Niche Management*. Enschede: University of Twente.
34. Wyse, S. M. and Hoicka, C. E. (2019). "By and for local people": assessing the connection between local energy plans and community energy. *Local Environ.,* 24: 883-900. https://doi.org/10.1080/13549839.2019.1652802

Appendix

Translated from Croatian, Table A.1. displays the variables applied for assessing the aspects of energy poverty within the ISSP Environment IV Croatia survey, along with the corresponding categories of responses. All three of the described indicators are listed in the EPAH's handbook "Energy Poverty National Indicators: Insights for a More Effective Measuring", with the "Arrears on utility bills" and "Ability to afford warmth" indicators considered as two out of four primary indicators.

Table A.1.
Energy poverty indicators as formulated in the ISSP Environment IV Croatia survey with response categories and EU SILC formulations for comparison.

Indicator	Item & Source	Response categories
"Housing conditions"	**ISSP Environment IV Croatia (2021)** Is there mold in your apartment on the walls or around the windows and/or are the windows, doors or floors worn and rotten? **EU SILC** Leaking roof, damp walls/floors, foundations, or rot in window frames/door (Yes/No)	1 = Yes 2 = No
"Arrears in utility bills"	**ISSP Environment IV Croatia (2021)** In the last 12 months, have you been late paying any utility bills solely for financial reasons? (electiricity, gas, water, heating...) **EU SILC** In the last 12 months, has the household been in arrears, i.e. has been unable to pay on time due to financial difficulties for: (a) rent (b) mortgage repayment, for the main dwelling?	1 = Yes, once 2 = Yes, twice or more 3 = No
"Ability to afford warmth"	**ISSP Environment IV Croatia (2021)** According to you, is your apartment/house warm enough during the winter (eg does your building/house have technically efficient heating and sufficient insulation)? **EU SILC** Can your household afford to keep its home adequately warm? (Yes/No)	1 = Yes 2 = Yes, partialy 3 = No

To assess potential regional differences of energy poverty vulnerability in Croatia, an index containing the abovementioned indicators was constructed. For this purpose, we assigned qualitative ranks to combinations of the dimensions of experienced aspects of energy poverty (insufficient warmth, living in poor housing conditions, and difficulties in paying utility bills), that is to say, to the combination of answers to the subjective indicators of energy poverty ("Ability to afford warmth", "Housing conditions" and "Arrears on utility bills"). This was done to reflect the ordinality of the said ranks, and to capture the potential heterogeneity of differing extents of energy poverty, and further explore the potential variability among them. We labelled the combination of answers referring to the absence of all dimensions of energy poverty as the **lack of vulnerability to energy poverty (1)**, which means that this category refers to a situation where:

a) The house is warm enough during the winter months;
b) There is no housing faults (mold, damp, rot, etc.);
c) The household is not late in paying their utility bills.

The combination within which energy poverty occurs only within a single item was assigned the category of **low vulnerability to energy poverty (2)**. This was done for three possible combinations of energy poverty dimensions' occurrences, with the situation of *not being able to pay utility bills*, but being warm enough during winter and not living in poor housing conditions ranked higher in the constructed categories. With this we tried to reflect the appropriate theoretical choices of assigning statistically larger weights to arrears on utility bills, such as in Sokolowski et al. (2020, in: Bouzarovski and Tirado Herrero, 2015) by Herrero and Buzarovski, where the situation of facing problems with paying utility bills was assigned a larger weight of 0.5, compared to the 0.25 for other two indicators. Along this line, **medium or moderate vulnerability of energy poverty (3)** was assigned to instances where there were at least two occurrences of energy poverty dimensions simultaneously. This accounts for two combinations of energy poverty dimensions appearing simultaneously, of either simultaneously not being warm enough during winter and living in poor housing conditions, or not being able to pay utility bills and living in poor housing conditions. Finally, the category of **high vulnerability to energy poverty (4)** was comprised of two possible situations - one in which a household had difficulties in keeping warm during the winter and paying utility bills, and the other in which this was coupled with living in poor housing conditions.

Table A.2.
Energy poverty index – description and values (ISSP, Croatia 2021)

Index value	*Index value description*	*Energy poverty vulnerability ranks*	*Categorization criteria*
1	Warm during winter Good housing conditions No arrears on utility bills	No vulnerability (1) (50.6%)	No variables indicate vulnerability to energy poverty
2	Warm during winter Poor housing conditions No arrears on utility bills	Low vulnerability (2) (29.4%)	One variable indicates vulnerability to energy poverty
3	Cold during winter Good housing conditions No arrears on utility bills		
4	Warm during winter Good housing conditions Arrears on utility bills		
5	Cold during winter Poor housing conditions No arrears on utility bills	Moderate vulnerability (3) (4.5%)	Two variables indicate vulnerability to energy poverty
6	Warm during winter Poor housing conditions Arrears on utility bills		
7	Cold during winter Good housing conditions Arrears on utility bills	High vulnerability (4) (10.3%)	
8	Cold during winter Poor housing conditions Arrears on utility bills	High(est) vulnerability (4) (5.2%)	Three variables indicate vulnerability to energy poverty

Izvorni znanstveni rad

Energetska tranzicija između obećanja i stvarnosti – pogled s europske poluperiferije

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Sažetak

Hrvatska je, poput drugih zemalja EU, siromašna fosilnim gorivima no istovremeno posjeduje značajan potencijal u obnovljivim izvorima energije, koji nije dovoljno iskorišten. Trenutačan ukupni uvoz energije iznosi oko 50% ukupnih energetskih potreba te se bilježi porast udjela obnovljivih izvora energije. U elektroenergetskom sektoru dolazi do porasta udjela primarno zbog ulaganja u vjetroelektrane u zadnjem desetljeću, međutim, najveći udio odnosi se na proizvodnju iz velikih hidroelektrana iz druge polovice 20. stoljeća. S obzirom na to da je hrvatska obalna regija smještena na Mediteranu, očit je velik potencijal obnovljive solarne energije. Trenutačan udio solarne energije predstavlja samo 1% u trenutnoj proizvodnji električne energije i jedan je od najnižih u EU-u. Inicijative građanske energije čine se važnim čimbenikom u intenziviranju ukupnog procesa solarizacije, pridonoseći tako ubrzanju procesa energetske tranzicije. Međutim, Hrvatska, poput nekih drugih zemalja EU-a, suočena je s velikim društvenim i zakonodavnim preprekama u postizanju navedenoga. U ovome članku bit će prikazana višedimenzionalnost tih prepreka kroz istraživanje energetskih nejednakosti u društvu (tj. pitanja energetskog siromaštva), regionalnih razlika u sudjelovanju građana u procesima solarizacije, socio-tehničkih prepreka te ispitivanja potencijala za angažman građana u energetskoj tranziciji. Podaci korišteni u analizama prikupljeni su u sklopu ESF projekta „METAR do bolje klime".

Ključne riječi: energetska tranzicija, energetsko siromaštvo, građanska energija, socio-tehnički režim, socio-kulturni aspekti energije.