International Journal of
Sustainable Energy Planning and Management

National Energy and Climate Planning in Serbia: From Lagging Behind to an Ambitious EU Candidate?

Ilija R. Batas Bjelic[a*], Nikola LJ. Rajakovic[b]

[a] *Institute of Technical Sciences of SASA, Knez Mihailova 35/IV, Belgrade, Serbia*
[b] *School of Electrical Engineering, University of Belgrade, Bulevar Kralja Aleksandra 73, Belgrade, Serbia*

ABSTRACT

Just in the immediate neighbourhood of the European Union (EU), the Republic of Serbia, one of the Western Balkan (WB) EU candidate countries, is lagging behind in the process of energy transition regardless of technological advances and policy instruments available. The EU created a momentum for energy transition acceleration with the European Green Deal, which has been forwarded to the WB through the Energy Community secretariat in the form of the Green Agenda; generally speaking, response in the form of National Energy and Climate Plans (NECPs) is expected in the short term. The Republic of Serbia's Low Carbon Development Strategy with Action Plan (LCDSA) and the current Energy Strategy will be analysed, commented on, and improvements will be suggested for the acceleration of energy transition, based on the newest findings from the simulation-based optimization techniques using the sector coupling approach to achieve ambitious variable renewable energy shares. The motivation of this research is to provide decision makers in Serbia with the best available insights regarding sustainable energy system planning tools and possible shortcuts for delayed planning of activities. In addition, the purpose is to improve Serbia's chance of benefitting from adoption of these strategies in the country's faster transition towards EU membership. The research compares two scenarios to illustrate a possible policy shift from small hydro power plants to photovoltaics (PV). A further increase in PV and wind power plants has been simulated using the EnergyPLAN to achieve expected scenarios of 40% renewable energy share and some more ambitious ones—up to 80%, which is realistic only with the sector coupling approach.

Keywords

European Green Deal;
energy transition;
sector coupling;
Western Balkans;
National Energy and Climate Plans;

http://doi.org/10.5278/ijsepm.6300

1. Introduction

The effects of climate change, also evident in Serbia [1] and the region of Western Balkans (WB), have put into question the use of unsustainable economic development practices from 100 years ago, and call for a shift towards new smart energy principles. Smart energy system principles [2] are seen as the enablers of 100% renewable energy systems, including transportation, with many scenarios to be considered in order to find the optimal energy mix.

The focus on smart energy systems, instead of particular sectors (electricity, gas, and heat) allows for cost synergies, but also the flexibility needed for moving the share of variable renewable energy sources in total energy consumption towards 100%, as it needs to be achieved by 2050 [3]. In addition, simultaneous redesign with technical measures on the supply and demand sides are also needed.

There are many technologies, including the low-cost ones that have limited potential for contribution to

*Corresponding author - e-mail: ilija.batas-bjelic@itn.sanu.ac.rs

Abbreviations

EASME	Executive Agency for Small and Medium-sized Enterprises
EnC	Energy Community
GHG	Greenhouse Gases
IAM	Integrated Assessment Modelling
LCDSA	Republic of Serbia's Low Carbon Development Strategy with Action Plan
LTS	Long-Term Strategies
NECP	National Energy and Climate Plan
RS	Republic of Serbia
WB	Western Balkans

decarbonisation. It is therefore necessary to install not one but a set of optimally balanced technologies into smart energy systems. Before this, simulations should be performed for technical feasibility and total cost minimization. When these costs are minimized under more than one constraint, e.g., a renewable target instead of decarbonisation only, the choice of optimal amounts (optimal sizing solution) is different from the solution of an unconstrained problem [4].

Therefore, a smart energy system approach [5], [6] is suggested for NECPs. Preparation and implementation of National Energy and Climate Plans (NECPs) has been perceived as the main energy transition step in the Western Balkans (WB), covering the topics of energy efficiency, renewables, greenhouse gas, emission reductions, interconnections, research and innovation, and centralization trend in the EU energy policy [7] among member and candidate states.

In the process of preparing NECPs, some EU Member States have two out of three objectives calculated with a traditional in-house model, or through a procurement procedure organized by official authority if outsourced. This makes it possible to simultaneously reach several energy policy objectives, instead of only particular sectoral objectives, and has intrinsic synergetic effects from modelling [8].

Therefore, goals should be set together and then modelled together using the sector coupling approach, rather than be treated separately [9]. A method for simulation-based optimization of the energy system structure under policy constraints has been presented [10] and continuously developed [11]. Soft-link tools such as OSeMOSYS [12], TIMES-Dispaset [13], and EnergyPLAN-GENOPT [10] have the capability to provide a framework for NECPs. Such tools make it possible to do modelling on most sectors contributing to energy transition using an efficient approach such as sector coupling.

Some recent studies of highly renewable energy systems including those from the Republic of Serbia are coming to the European researchers' perspective [14], [15] and it is expected that this will help to speed up the transition. Cost optimization of smart energy systems emerges from the sector coupling approach [9], [16], [17], which has been confirmed to have synergetic effects on completion of policy goals.

This approach can therefore be used for NECP preparation, since NECPs include all the national sectors, so the synergy effect would probably be the strongest. In the sector coupling approach [18], [19], heating and transportation sectors are usually coupled with the electricity sector, but industry demand and household heating demand sectors are not less important for decarbonisation.

According to [20], seven stages that are analysed are: 1) reference, 2) introduction of district heating, 3) installation of small and large-scale heat pumps, 4) reducing grid regulation requirements, 5) adding flexible electricity demands and electric vehicles, 6) producing synthetic methanol/DME for transport, and 7) using synthetic gas to replace the remaining fossil fuels.

EnergyPLAN may be used for Serbian NECP preparation since it has been used for modelling of Serbia's energy system and has advantages when coupled with other optimization tools [10], [21], [3].

The general purpose of this article is to present how smaller candidate counties perform self-governed on the daily basis with realistic politics (*ger*. real-politik) energy transition towards the EU in the presence of short deadlines, with unclear goals, insufficient or fragmented modelling capacity, influences of international modelling consortiums, and challenges of writing strategic documents.

One example to illustrate this is the fact that for significant policy changes from a small hydro power plant to a solar cadastre, modelling background is needed to understand the changes in the balances and how insignificant they might be. Ideas on how to decarbonise countries despite the impedance to decarbonisation, precede any practical energy modelling work. The prologue to Serbian NECP [22] explained these gaps and issues.

The hypothesis of this research is that lagging behind in terms of energy transition was not the result of insufficient written background (articles, dissertations, and books) to explain the method of finding optimal decarbonisation paths. In addition, lagging behind does not happen because there are no modelling tools, but due to country's own characteristic impedance to energy transition.

When enough stakeholders identified this impedance, including the Ministry of Energy (MoE), the real work towards decarbonisation finally started. Initially, there were bombastic media announcements, followed by actual political action of changing the legislation, and finally starting the NECP preparation process and modelling. The final result is draft NECP which is expected to be finished in September 2021.

The novelty of this article is in using EnergyPLAN as an analytical tool to produce hourly simulations of the Serbian energy system for the first time with significantly more than 40% renewable energy in its energy mix, which is currently seen as politically and technically highly ambitious, aligned with the Green Agenda and EU Green Deal.

Section 2 provides a non-technical introduction to the policy-oriented reader who wants to know more about the background of Serbia's increased ambition to produce the first draft NECP. Section 3 follows the expected analytical basis of Serbia's NECP, with reflections of EU member states' NECPs and analytics. Section 4 discusses setting the ambition above 40% via sector coupling trough 6 scenario steps.

2. Serbian NECP in the WB context: a non-technical introduction

WB counties have shown various interest and methodology in the preparation of their NECPs. The Energy Community (EnC) has recommended the preparation of NECPs from December 2017 and provided guidelines, but there was little progress in 2018, 2019, and 2020. Some progress has been made in the naming of the teams that are carrying out the work, but preparation has not arrived to the technical annexes part until this day (September 2021).

Most success in the preparation of NECPs in the WB has been achieved in North Macedonia, while this topic has not been addressed properly in other WB countries, with a possible pessimistic conclusion that none of the WB countries have perceived themselves as part of Energy Union any time soon. In the Republic of Serbia (RS), it could be ready by the end of 2021 under the auspices of the recently established and reformed MoE.

The NECPs proposed by the European Commission are currently seen as an important political tool to steer energy systems toward decarbonisation. For the EU as a whole, it is legally binding to reach 27% of renewable energy in its energy mix until year 2030. As a European Greens initiative, for the first time in the EU energy policy, member states are legally obliged to create plans with specific targets to be sent to the EU. The European Parliament further clarifies this subject in its resolution from 25 March 2021 on the 2019-2020 Commission Reports on Serbia (2019/2175(INI)) in Paragraph 83:

"Urges the authorities to ensure alignment with EU standards and policy objectives on climate protection and environment as well as energy efficiency – in particular in the light of the Sofia Declaration on the Green Agenda for the Western Balkans – including but not limited to the introduction of carbon emissions pricing, the updating of energy efficiency legislation and the development and adoption of an integrated National Energy and Climate Plan, in order to facilitate the transition to a circular economy and the adoption of the necessary measures to preserve and protect environmentally sensitive areas;"

Furthermore, NECP methodology is created to enable constant monitoring and update, starting from the national ambition all the way to the delivery of planned investments. The four objectives of NECPs include:

1. Energy Union objectives (2030 targets and 2050 perspective) in 5 dimensions
   a. Decarbonisation
   b. Energy efficiency
   c. Energy security
   d. Internal market
   e. Research, innovation, and competitiveness
2. Promote better regulation and reduce administrative burden
3. Enhance investor certainty and predictability
4. Ensure compliance with the EU's international climate commitments

Each NECP is supposed to have an original vision of merging these four objectives. The structure of NECP documents is divided into two sections:

A. National plan which includes
   1. Overview and process for establishing the plan
   2. National objectives and targets
   3. Policies and measures
B. Analytical basis
   1. Current situation and reference projections
   2. Impact assessment of policies and measures

The energy sector is one of the most important economic branches in Serbia. The concept of today's energy in Serbia is still based on the economic paradigm of the 50s, characterized by sector decoupling, energy-intensity and inefficiency in the sectors of heating, transportation, and end use of electricity.

In the production of electricity, Serbia predominantly relies on low-efficiency thermal power plants that run on lignite—the local low-energy content coal. Therefore, the energy sector is a major polluter of air, water, and soil at local and regional levels, and poses a threat to the environment and human health.

The energy sector in the region also has a strong impact on greenhouse gas emissions (GHG), with over 70% share in total emissions. Today's energy structure of the region cannot meet the requirements of sustainable development in the 21st century. More broadly, it is clear that energy policy and energy crossroads have been one of the key issues of modern civilization for decades. The complexity of the challenges facing energy today is such that it requires regional connectivity and teamwork that is even more thoughtful, because the room for good solutions is limited primarily by climate change, but also by natural energy resources, economic constraints, and available technologies.

The vision of an energy system without fossil fuels implies deviation from the previous approach and conventional energy; achieving energy without fossil fuels is the essence of energy transition. Finding optimal solutions in a multidisciplinary energy sector in transition circumstances is definitely a very broad problem, for which even the borders of the continents are narrow.

The conventional concept of the electricity sector (EES), which is economically the most important part of energy in Serbia, has so far provided a secure supply of electricity for industry, households, commercial, and administrative categories of consumption. However, the power system operates under non-market conditions and is characterized by a high level of subsidies (both on the consumption side and within the thermal energy sector, especially within the lignite mine), which jeopardizes its long-term viability and ability to further develop. Therefore, it is particularly important to immediately start the process of restructuring lignite mines, which includes diversification of the economy of mining regions. Since the operation of the power system should be observed in the conditions of business in a liberalized market, the introduction of competition and setting electricity prices on an economically sustainable level is a prerequisite for its transformation and further development. Designing the development of the thermal energy sector has a special significance and urgency because a large number of thermal power plants (TPPs) in Serbia are at the end of their working life with high direct and indirect costs of operation.

It is necessary to make significant investments in new production capacities, which could be viable with 200-300 M€ per year. Since Serbia possesses economically viable potential for renewable energy sources (solar energy, wind energy, hydropower [23], biomass energy, etc.), the future development of the production portfolio in the power system should logically be based on renewable energy sources (RES). Today's electric power systems function in the conditions of business in a liberalized market with the introduction of competition and setting electricity prices which need to be economically sustainable. These are all prerequisites for transformation and further development of Serbia's energy system.

Since the current level of support for renewable energy for household consumers does not ensure full recovery of the support costs, the government closed the space for further increase of this support mechanism above 500 MW for wind and 10 MW for photovoltaics, which was needed. An ambitious step towards a more variable renewable energy scenario [20] could be a significant increase in the production from photovoltaics: it is currently around 20 MW and it should be 10, 100, and 1,000 times higher.

The EU is determined to become the first climate neutral continent by 2050, which also includes the WB. This is stated in the Green Deal, which projects that electricity sectors will use 100% renewables in 2050. This is even more important with the Green Agenda for EnC contracting parties, including Serbia. Finally, after signing the Sofia Declaration, ambition for decarbonisation grew in the Serbian parliament, which finally adopted the Law on Climate Change earlier this year. In addition, in the period 2014-2021, there has been a visible policy shift from small hydro power plants and wind to photovoltaics and medium and large hydro plants.

2.1. Background on state of play, already published strategies, and plans for new ones

Although renewable and efficient energy technologies are available, they have so far been applied under strict Serbian government control and thus not benefitting society in a wider sense. Energy transition has not occurred so far, and Serbians are at the moment brought to the *fait accompli* with energy policy and they are in a situation when they have to choose between higher energy costs and polluted environment, which is a false dilemma. Instead, from the beginning of the planning process, there should be a broader consensus with clear responsibilities and projections for all future scenarios. This can start by raising awareness of the actual costs of electricity produced from lignite.

Despite available technologies, transition has not occurred as in e.g. Germany, where households have visible economic and environmental benefits of energy transition, and where instead of lignite production, the government supports phasing out of lignite thermal plants [24]. As a result, Serbia is behind other countries when it comes to energy transition, including NECP preparation and energy and climate planning methodology in general.

Although there are several officially ratified documents (plans and strategies) covering the years 2030 and 2050, the commitments accepted from these documents are not ambitious. According to their most ambitions scenarios, Serbia should achieve decarbonisation of up to around 40% by 2030 and around 80% by 2050 according to LCDSA.

Serbia adopted a package of energy laws and started working on NECP in April, aiming to finish NECP by the end of 2021. Similarly to the delayed NECP, LCDSA has been published, presented, and debated but it has still not been adopted by the government. LCDSA has two scenarios—M3 and M4—with more ambitious decarbonisation targets than claimed by the highest government officials last year (M2); these might be used for NECP scenarios. Scenario M3 goes further from the mentioned 33.3% reduction in 2030/1990 to 45% in 2030/1990 and to 69% in 2050/1990. Scenario M4 goes even further in decarbonisation aiming for 43% in 2030/1990 and 76% in 2050/1990. Further comparison may be achieved upon presentation of the whole modelling part by the modelling consortia led by GFA to the authors of this article.

With the goal of opening Chapter 15 of negotiations with the EU at the beginning of 2022, Serbia's parliament adopted the negotiating position in June 2021, with the timing after NECP has been finished. Regarding transition periods, it is not clear what might be asked and granted in this case, but no long-time provisions (20-30 years) are to be expected, since this has not been asked from or granted to a single candidate country.

The MoE has a difficult role to prepare Serbia for membership and acceptance of the entire acquis from 1 January 2021, which is much more ambitious than ever before. The position of Serbia should therefore be based on the responses from member states to the plans developed by the European Commission.

Transition periods are not new in the energy sector, which is characterized by long-term payback periods. Some delays may be expected if economically justified; in other words, the utilization of assets should prevent significant negative impacts on investments [25]. For sure, long-term delays or even further market distortions should be avoided in general. In the case of Croatia, a minimal energy tax exemption (chapter on taxes) has been asked for electricity and the gas carriers for 10 years after the country joined the EU (1 July 2013), which is important for Serbia as a way of keeping final energy prices lower than in other countries, and ensuring they are comparable to the average salary.

For the implementation of 2001/80/EZ emission directive, transition has been granted until 31 December 2017. Neither Romania nor Bulgaria asked for transition periods regarding the energy chapter. The member states who joined the EU on 1 May 2004 have been granted transition periods regarding minimum oil and petroleum stocks for 1.5-4.5 years, which may also be interesting for Serbia.

Additionally, MoE has committed to update the Energy Strategy for 2040 with projections for the period until 2050 in the near future. Therefore, alternative ambitious scenarios have to be explored using EnergyPLAN [20] and scenarios from previous research for years 2030 and 2050 [26] also have to be updated.

3. Energy planning methods used for NECPs

The European Commission assessed each of 27 member states' NECPs on a two-page document, finding that:

- estimated renewable energy commitment is at 33.1%-33.7%, which is above the target of 32%;
- emission reduction is 41%, which is above the target of 40%;
- energy efficiency net savings are 29.4%-29.7%, which is below the target of 32.5%.

Examples of selected NECPs objectives and perspectives with energy planning tools used are shown in Table 1.

The main findings from the Section A of existing NECPs related to their five dimensions [27] are:

- Bilateral cooperation among member states will allow the EU to achieve its ambitious 2030 objectives in a cost-efficient manner.

Table 1: NECP objectives and perspectives for selected countries with analytical basis

%	Objectives 2030 (Perspectives 2050)			
Country/ Region	**GHG emission reduction (vs. 1990)**	**renewable energy penetration**	**increase of energy efficiency**	**Analytical basis and responsible bodies**
Slovakia	20	19.2	30.3	Primes/Envisage/ MESSAGE
Spain	23 (90)	42 (100)	39.5	MARKAL TIMES
Denmark	70 (100)	55 (100)		Denmark's Energy and Climate Model, Danish Energy Agency
Slovenia	15	27	35	GEM-E3, REES-SLO
Croatia	7	36.4	35	Ministry of the Environment and Energy /MAED, MESSAGE, PLEXOS
Cyprus	24	22.9		Republic of Cyprus / PRIMES, POTEnCIA, OSeMOSYS
Greece	16	35	38	HELLENIC REPUBLIC Ministry of the Environment and Energy/ PRIMES, TIMES
Romania	2	30	45.1	Ministry of Economy, Energy and Business Environment, Deloitte/ Excel
Bulgaria	0	27.09	27.89	(B)EST
North Macedonia	66 (82)	38	34.5	MARKAL TIMES
Poland	7	21	23	MESSAGE-PL, PRIMES, STEAM-PL, other

- *Efficiency measures* that would achieve cost-efficient emission reductions, while reducing energy bills for households and increasing employment in the construction sector could be exploited more rapidly in some member states.
- The role of flexibility instruments, such as demand response and storage, is key to ensuring *energy security*.
- It is necessary to use more forward-looking concepts of energy system integration and sector coupling, including further integration of the power, gas, and heat sectors, as they become central for a decarbonised energy system.
- Additional efforts should be made to integrate *research, innovation, and competitiveness* into NECPs.
- Efficient investments in infrastructure should be encouraged in alignment national energy security goals, while taking into account synergies across different dimensions of the plans.

Some practices of EU member states include:

- Austrian and Spanish draft NECPs provide good examples of how to combine quantified emission reduction objectives for the transportation sector with the underpinning policies and measures to achieve them.
- The following countries are phasing out coal for electricity generation: France by 2022, Italy and Ireland by 2025, Denmark, Spain, Netherlands, Portugal, and Finland by 2030.
- The Czech Republic and Ireland include contributions to national objectives for each sector and the respective technologies on a yearly basis and in absolute values.
- It is helpful to have a systematic description and quantification of all types of energy subsidies (grants, support schemes, tax benefits, subsidies resulting from regulatory obligations), based on existing definitions used internationally.
- Eleven member states have estimated either overall investment required to achieve their objectives (France, Italy and Spain) or parts of their investment needs (Greece, Finland, Hungary, Ireland, Italy, Latvia, Poland, and Romania), while providing varying levels of detail on the sources of funding.
- Denmark, Spain, France, Netherlands, Portugal, and Sweden aim for climate neutrality by 2050

Table 2: Modelling tools suggested for NECPs based on H2020 ongoing projects

Model name	Features	Focus	H2020 project
GENeSYS MOD	Energy pathway, costs, emissions, employment, sensitivity analysis	Open code, exact modelling of energy system	Open ENTRANCE
Multi Carrier Market Design Tool	Energy volumes and prices	Market operation, multi-energy vectors	MAGNITUDE
plan4EU	Generation/Transmission/Distribution optimal sizing, different climatic scenarios, costs of generation and moderation	Optimal operation (UC), demand response, technical feasibility	plan4res
openTEPES	Generation/Transmission optimal sizing, least-cost investment plan	Optimal operation (UC)	Open ENTRANCE
FRESH:COM and GUSTO	Social welfare maximization, cost minimization, peer-to-peer, multiple agent based modelling	Open code, urban neighbourhoods and local energy communities, rooftop PV and batteries	Open ENTRANCE
EXIOMOD	Macro-economic approach (energy, employment, trade, fuel prices)	Economic impact of measures	Open ENTRANCE
REMES EU	Energy volumes and prices, markets, value added, employment	Economic impact of measures	Open ENTRANCE

at the latest. France and the United Kingdom have established legally binding 2050 targets in their domestic legislation and use carbon budgets as mechanism to ensure consistency of medium and long-term objectives.

- Poland has been an example of delayed transition on the road towards the European Green Deal [28].

More findings that are interesting for Section B of NECPs are presented in terms of models used as analytical basis of the findings in the last column of Table 1. Other tools from the open source code with national geo-resolution, covering all sectors [29] potentially suitable for NECPs are the following: EnergyScope, Energy Transition Model, Backbone, Oemof, MEDEAS, DESSTinEE, and OpenTUMFlex. Another applicable modelling tool was developed by Focus Group 6 within EMP-E 2020 at the conference on 8 October 2020. It is called "How can energy modelling tools from H2020 projects contribute to National Energy and Climate Plans?" and it is shown in Table 2.

4. A prologue to Serbian NECP

The NECPs method that will most probably be used for Serbia is called "SEMS". It is based on TIMES and this choice could be justified by harmonizing the planning procedure with North Macedonia and Spain. The second choice for Serbia could be the use of the PRIMES model, which has recently been used for developing LCDSA, and probably practiced right now. In addition, LEAP was used some years ago in Serbia for the preparation of "Energy Sector Development Strategy of the RS for the period by 2025 with projections by 2030" (ESDSRS). The tool such as POTEnCIA [30] or any other of the mentioned tools are not likely to be used by the Serbian Ministry of Energy and Mining.

4.1. Policy shift scenario for Serbian NECP 2030 and beyond

The outline of the Serbian NECP should be more ambitious than the current Strategy in order to achieve harmonization with the Green Agenda. The current ESDSRS places a significant focus on small hydro power plants (SHPP), based on an outdated study from the 1980s (written amendments of the study are still expected to appear), where they are treated as medium capital-intensive investments. This idea led to environmental protests and events of the political importance, stopping many projects in the development and commission phase. Some critics of SHPP claim that the benefit of their dispachability has unjustly been put forward in front of other resources such as wind and photovoltaics. The fact is that streams are very variable and therefore mostly operated as run-off river hydro power plants with insignificant storage capability, which makes them unprofitable at current investment cost levels in current market conditions [31] without significant government support.

Therefore, SHPP can be replaced by many small PV plants with equal yearly production, with different hourly production curve, without dispatchability, and

Table 3: Scenario assumptions for year 2030: Base and Alternative

Variable	Unit	Base 2030	Alternative 2030	Difference
PV (RES34)	MW	200	1,200	1,000
SHPP(RES12)	MW	750	300	-450
Correction factor for RES2 in EnergyPLAN		0.73	0.73	0
$Energy_{PV}$	TWh/a	0.31	1.85	1.54
$Energy_{SHPP}$	TWh/a	2.5	1	-1.5
$Energy_{PV+SHPP}$	TWh/a	2.81	2.85	0.04

thus some additional flexibility requirements. These flexibility requirements should be simulated in order to check the feasibility of a policy switch. For that purpose, the EnergyPLAN tool has been used as the analytical basis for creating two scenarios. According to the current Serbian energy strategy for 2030, a base scenario has been created, while alternatives have been suggested to switch from SHPP to PV power plants in the same energy amount as shown in Table 3:

According to these assumptions, two hourly scenarios have been modelled for one year using the EnergyPLAN tool: Base 2030 and Alternative 2030, which is shown in Figure 1.

Comparison between yearly and daily levels shows differences in operation of the two scenarios: *Base2030* and *Alternative2030*. The main difference at the yearly level is visible in the first row, originating from the photovoltaic production during summer months. The contribution from increased PV capacity is visible in the second row for some days at the beginning and at the end of October, but it is more obvious at the weekly level in the third row. It is also visible that PV generation prevents or decreases import for a few days during peak hours. The fourth row shows how PV generation pushes storage use to the peak hours and prevents import during peak prices.

Further results, which are not visible from the previous figure, are the environmental and economic benefits of the alternative scenario. These are shown in Table 4.

Alternative2030 scenario has more benefits than Base2030 (current Energy Strategy) regarding decreased yearly CO2 emissions for 0.27 Mt, primary energy savings of 0.72 TWh, mostly due to decrease in lignite consumption in thermal power plants of 0.74 TWh. Since the Energy Strategy (Base2030 scenario) has not been superior to Alternative2030 scenario, it should be amended trough NECP preparation.

This illustration has only symbolic contribution to decarbonisation, but provides directions how once suggested policies may be updated. The comparison of two fringe alternatives only covering a very small part of the Serbian energy system, and thus insignificantly affecting it, although they have different policy perspectives and feasibilities. Therefore, much ambitious alternatives must be pursued either from political [32] or from technical points of view.

4.2. Raising the political and technical ambition for Serbian NECP

Based on the previously shown benefits of PV, a more politically and technically ambitious NECP for the Republic of Serbia could be:

- significant increase in renewable production power plants
  - o new solar (cca. 2,000 MW)
  - o new wind (cca. 2,000 MW),
- improved energy efficiency,
- wide flexibilization portfolio on supply and demand side,
- increased level of electrification in the sectors of transportation and heating/cooling,
- precise timing for thermal power plants phase out (cca. 1,500 MW).

Even more ambitious political goals regarding the share of renewables in the total production mix are realistic. On the other hand, the contribution of SHPP is very small, but the contribution of new medium and large hydro power plants such as Buk Bijela (river Drina, 95 MW, 330 GWh) is more relevant.

The media announcements of the MoE about 40% of RES share in TPES until 2040 were followed by expectations of 8-10 GW until 2050. Having in mind the study about the potential [33], there is cost-competitive potential in the amount of 6,890 MW (9,298 GWh) for rooftop areas (household and commercial). Some first estimates show that 4-6 GW is possible in the roof area, while an additional area can be found in abandoned mines [34]. Technical measures can include a large number (e.g., 1,000,000) of PV roofs, storage batteries, and individual efficient heat boilers. Study [35] showed that 61 km2 is a suitable area for PV in residential and commercial/government buildings (122 km2 in total), with the potential capacity of a suitable area in 2050 (DC-peak) being 29,331 MW (DC-peak), out of which 22,399 MW has been proposed. This is aligned with some studies of utilizing 33TWh of photovoltaic energy production [36].

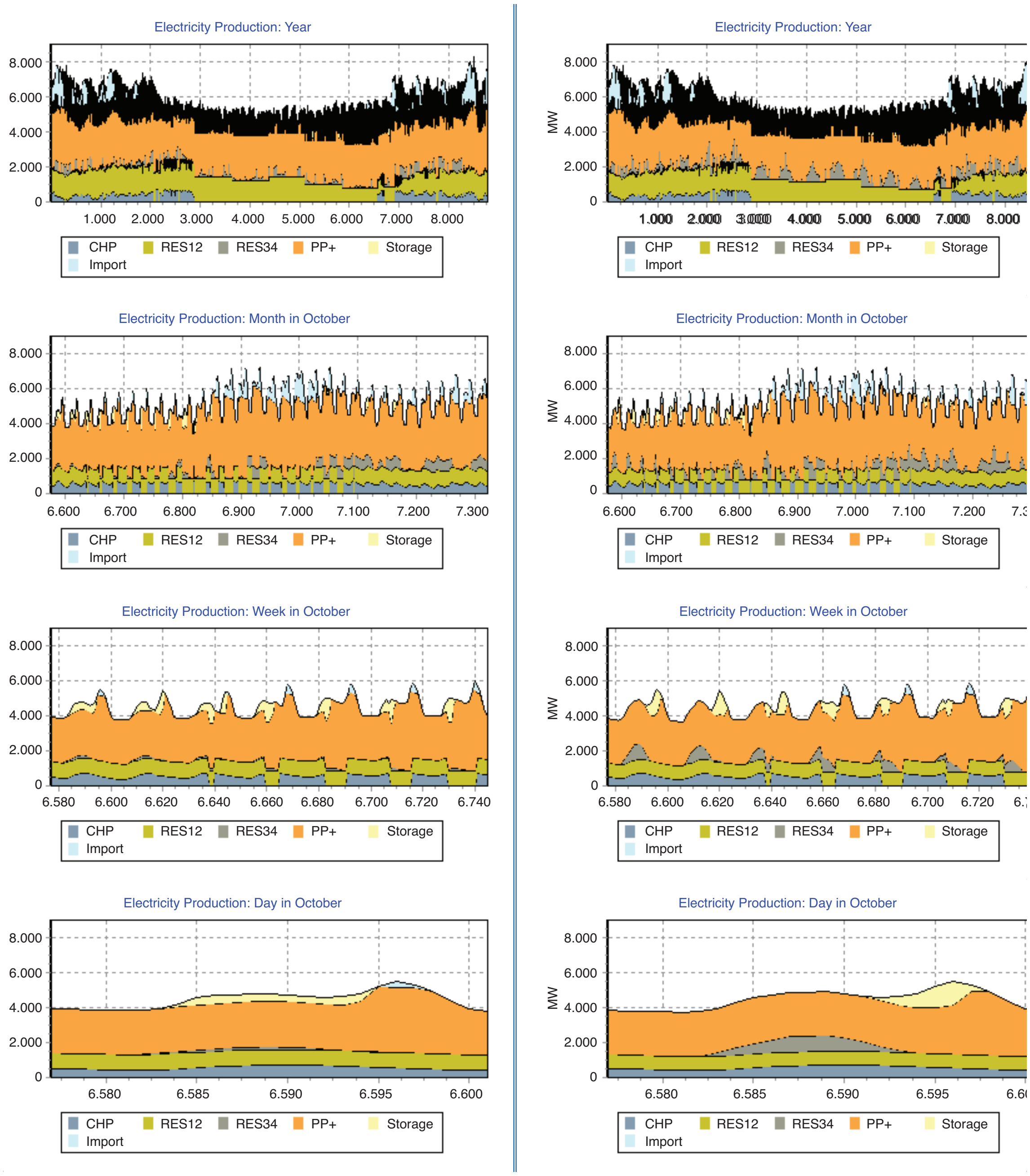

Figure 1: **Base2030 (left) and Alternative2030 (right) scenario comparison at the level of a: year** (1st row), **month** (2nd row), **week** (3rd row), **and day** (4th row) **in October electricity production**. Legend: **CHP** – combined heat and power, **RES12** – run-off hydro and small hydro power plants, **RES34** – wind and photovoltaic power plants, **PP+** – thermal power plants and (reservoir) hydro power plants, **Storage** – pumped storage hydro power plant and electric transport (source: EnergyPLANv11.2).

Assuming perfect interconnection conditions (no export constraints, in addition to EnergyPLAN), Fig. 2 presents the effects of increasing Serbia's currently installed PV power 1,000 times, from 20 to 20,000 MW.

With such increased PV power, Serbia will be able to reach only 23% of RES share in TPES. This is equal to the huge 94% of RES share in electricity production. This is a significant share having in mind the present one, which is around 30%. However, the contribution to decarbonisation is still limited due lignite TPPs and reaches only 20 Mt of CO2 per year. Increasing wind up to the full potential of 30,000 MW is also possible, but

Table 4: Environmental and economic benefits of the alternative scenario

Variable	Unit	Base 2030	Alternative 2030	Benefit
CO2 emission	**Mt/year**	45.47	45.20	0.27
TPES	**TWh/year**	185.89	185.17	0.72
Lignite consumption	**TWh/year**	91.21	90.47	0.74
Lignite costs	**M€/year**	607	602	5
Emission costs	**M€/year**	1,364	1,356	8

there is a need for the sector coupling approach in decarbonisation.

4.3. Sector coupling approach for ambitious Serbian NECP

The authors' own approach for Serbian NECP is based on six flexibility options for large-scale integration of VRES technologies:

1. Electricity demand electrification and response (household and industry)
2. Thermal/nuclear power plants and combined heat and power (CHP) flexibilization
3. Power to heat coupling (CHP, heat pump (HP) district/individual)
4. Transport coupling (Vehicle to grid + smart charge, synthetic fuels)
5. Interconnection
6. Storage (batteries, pumped hydro, rock bed, compressed air, hydrogen, etc.).

To start with, half of the household electricity demand has been assumed as either inflexible or flexible within one day, for one week, and for one month (each 25%), while half of the industry demand has been electrified, and half of the household heating demand has been replaced with a heat pump (COP=5).

As the second step, all TPPs and CHPs are assumed flexible (0-100%) and grid stabilization services are provided from the grid, batteries, etc.

In the third step, large HPs are added to district plants (1,000 MW, COP =5) to replace fuel boilers, so fuel consumption is halved simultaneously.

In the fourth step, fossil fuel used for transportation is halved and replaced with electricity, 1/2 smart, 1/2 dump charge, with storage of 30 GWh and no charging limits in the grid.

In the fifth step, the interconnection capacity is doubled.

In the last, sixth step, the demand of remaining industry switches to hydrogen; natural gas for individual heating is replaced with hydrogen, while other fuels are replaced with biomass. District heating demand switches from natural gas to hydrogen.

The resulting final scenario (6^{th} step) with 80% RES in TPES and with 83% RES electricity production is shown in Fig. 3.

A significant part of the demand is flexible, while additional demand is created from electrolysis of excess electricity from VRES. Excess electricity is still visible, even with significant exports. On the production side, RES34 is the dominant source (10 GW wind and 30 GW PV), in addition to hydro RES12. Electricity production from lignite (PP+) is still significant and only fossil fuel remains in the fuel mix. The use of storage is significant and shall be analysed further. Heat production and demand is shown in Fig. 4.

District heating demand is dominantly met via CHP, HP, and boiler heat production. Additional RES shares might be increased with more waste heat and geothermal or solar heating. Finally, grid gas demand and production are shown in Fig. 5.

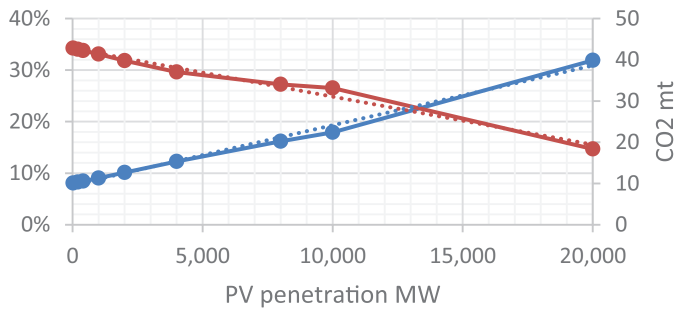

Figure 2: Increasing PV power in the Serbian energy system: effect on the CO^2 emissions.

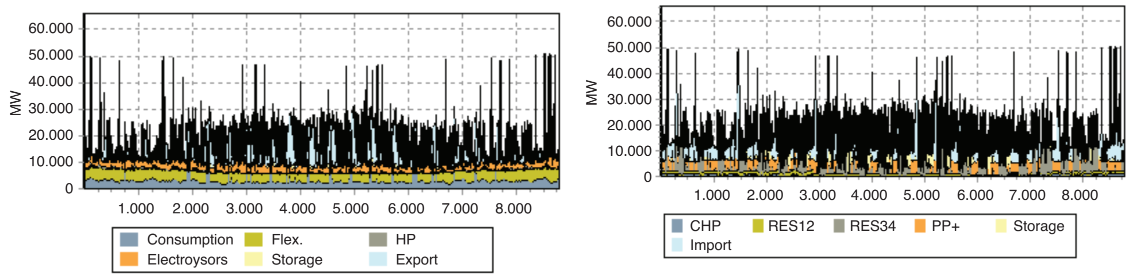

Figure 3: **Electricity demand (upper) and production (lower) in the final scenario for 2050** Legend: CHP – Combined Heat and Power, **RES12** – Run-off Hydro and Small Hydro Power Plants, **RES34** – Wind and Photovoltaic Power Plants, **PP** + – Thermal Power Plants and (Reservoir) Hydro Power Plants, **Storage** – Pumped Storage Hydro Power Plant and Electric Transport (source: EnergyPLANv11.2)

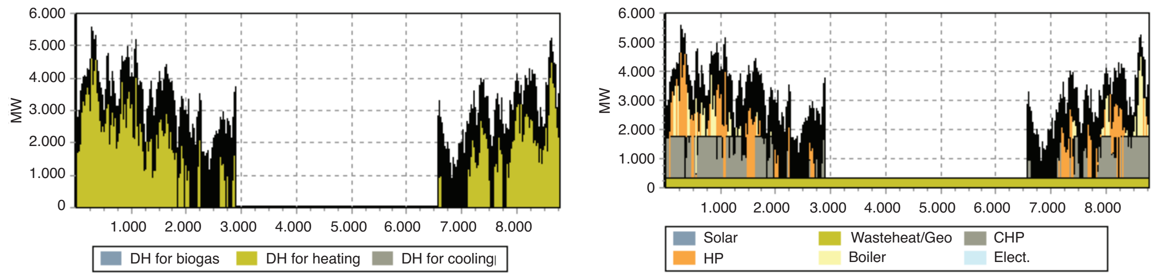

Figure 4: District heating demand (upper) and production (lower).

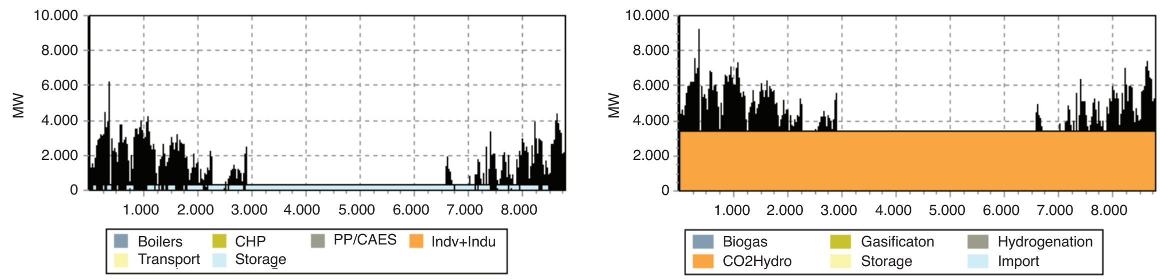

Figure 5: Grid gas demand (upper) and production (lower).

As shown in the gas grid, demand is coupled with low temperatures during the heating season, while on the production side there is a significant amount of green hydrogen obtained from CO2 hydrogenation.

The result of increased RES share in TPES and CO2 hydrogenation, CO2 equivalent emissions decline to 12 Mt, which is 25% of BASE scenario emissions (75% decarbonisation).

These results are comparable with LCDSA where 81% of emission reduction has been achieved in energy industries, 45% in manufacturing, and 37% in transport. Therefore, at first glance one may say that this is less ambitious than the results of this study, but significant reductions are achieved in the sectors not covered by the EnergyPLAN model (forest, agriculture, etc.).

Comparing the Republic of Serbia to a recently published report "D7.4 Modelling Variability, EROI and Energy Intensity" shows that energy structure is similar to the Russian Federation due to the significant share of district heating and sector de-coupling, in which main breakthroughs might be achieved. In comparison to other developed countries and regions, Serbia has a more comprehensive method of flexibilization—up to 100% RES can be found in [3]. Further comparisons in economic terms are possible with LCDSA but also with a study by Agora-Energiewende (and many others), which conclude that carbon taxing is a relevant measure for decarbonisation. This economic comparison should be based on the real cost of electricity from lignite mines and economic reality of their further operation.

Those are the first published results, which have to be improved especially in the part regarding geothermal energy utilization [37], green hydrogen production [38], etc. Other improvements are viable in the direction of better spatial allocation of PV rooftop resources. Significant improvements are to be achieved through energy efficiency measures simulation and the synergetic effect between all of them [9].

5. Conclusions

The most populated WB country, the Republic of Serbia, has been lagging behind the region in energy transition, failing to start the energy planning process in terms of NECP, despite the numerous preparation tools available in-house, or at a request by official authority (MoE). However, ambition for energy transition has recently increased and Serbia adopted a negotiating position with the EU. The expected starting contribution of renewable energy in the total primary energy supply has to be raised from around 20% to around 40%.

To achieve more ambitious contributions (above 40%), the sector coupling approach has been suggested on top of the currently available experiences. For the first time, a larger renewable energy share of up to 80% in the total primary energy supply scenarios was presented using EnergyPLAN for hourly simulations, and it proved to be applicable. It firstly showed a possible benefit of switching from the small hydro power plant energy policy to solar photovoltaic plants. The results suggest that there is a vast opportunity in photovoltaic integration in the vision of Serbian draft NECP. The next steps should be to find the optimal set of measures (including efficiency) to reach the policy objectives set in NECP by comparing the costs of numerous alternative scenario simulations. Furthermore, Serbia has an opportunity to develop and apply a highly ambitious renewable energy action plan (even beyond 80% RES in TPES), based on its own potential (solar, wind, water, biomass), which is not possible for major industrialized countries of G8 or China. The electricity currently produced from large lignite power plants, the heat produced from natural gas, transport based on oil, and industry processes demanding fossil fuels can be replaced with sustainable energy carriers. Therefore, Serbia, who was once an example of lagging behind in energy transition, could become the leader of energy transition in the Western Balkans region.

A possible shortcut for the Republic of Serbia is to look for the low cost options in the integrated Western Balkans power market and regional complementarity and interdependence, rather than traditional self-sufficiency and restraint from exchanges. Another shortcut could be searching for synergies among sectors using the sector coupling approach. The whole region of WB except North Macedonia is lagging behind in NECP preparation due to several reasons grouped around the fact that energy planning capacity was divided after the dissolution of Former Yugoslavia. Therefore, there is a chance that if these countries work together to solve the regional problem, national NECPs could be created as a by-product, with significant quantifiable benefit from regional complementarities. For Serbia, which is centrally positioned (comparative advantage) and has a developed electricity exchange market, this approach is highly attractive. In addition, the regional approach prevents carbon leakage, which is an expected outcome of gradual integration of contracting parties into carbon taxing schemes.

6. Acknowledgment

Funds for I.B.B. are provided by the Ministry of Education, Science and Technological Development of the Republic of Serbia according to the Agreement on the Implementation and Financing of Scientific Research of the Institute of Technical Sciences of SASA in 2020 (Registration number: 451-03-68 / 2020-14 / 200175). The authors acknowledge the support of the “LOCOMOTION” Horizon 2020 project from EASME grant Nr. 821105.

This paper has been developed from the paper entitled *“National Energy and Climate Planning Approach for the Western Balkans: Case Study Republic of Serbia”*, presented online on Tuesday June 30th 2020 during the 4th SDEWES SEE Conference in Sarajevo.

References

[1] A. J. VUKOVIĆ *et al*., “GLOBAL WARMING IMPACT ON CLIMATE CHANGE IN SERBIA FOR THE PERIOD 1961-2100,” *Therm. Sci*., vol. 22, no. 6, 2018.

[2] H. Lund, J. Z. Thellufsen, P. A. Østergaard, P. Sorknæs, I. R. Skov, and B. V. Mathiesen, “EnergyPLAN – Advanced analysis of smart energy systems,” *Smart Energy*, vol. 1, p. 100007, Feb. 2021, http://dx.doi.org/10.1016/j.segy.2021.100007.

[3] A. Pfeifer, L. Herc, I. Batas Bjelić, and N. Duić, “Flexibility index and decreasing the costs in energy systems with high share of renewable energy,” *Energy Convers. Manag*., vol. 240,

p. 114258, Jul. 2021, http://dx.doi.org/10.1016/j.enconman.2021.114258.

[4] P. A. Østergaard, "Reviewing EnergyPLAN simulations and performance indicator applications in EnergyPLAN simulations," *Appl. Energy*, vol. 154, pp. 921–933, Sep. 2015, doi: http://dx.doi.org/10.1016/j.apenergy.2015.05.086.

[5] B. V Mathiesen and H. Lund, "Comparative analyses of seven technologies to facilitate the integration of fluctuating renewable energy sources," *IET Renew. Power Gener*., vol. 3, no. 2, pp. 190–204, 2009, http://dx.doi.org/10.1049/iet-rpg:20080049.

[6] B. V. Mathiesen et al., "Smart Energy Systems for coherent 100% renewable energy and transport solutions," *Appl. Energy*, vol. 145, no. 0, pp. 139–154, May 2015, http://dx.doi.org/10.1016/j.apenergy.2015.01.075.

[7] D. Buschle and K. Westphal, "A Challenge to Governance in the EU: Decarbonization and Energy Security," *Eur. Energy J*., vol. 8, no. 3–4, pp. 53–64, 2018, [Online]. Available: https://heinonline.org/HOL/P?h=hein.journals/euenj8&i=122.

[8] I. B. Bjelic and N. Rajakovic, "Total Costs Minimization by Using Synergy Effect Among EU 2020 Goals," in *Proceedings of the 1st South East Europe Conference on Sustainable Development of Energy, Water and Environment Systems*, 2014, no. SEE2014.0059, p. 167.

[9] N. R. Ilija Batas Bjelic, "Advantages of Sector Coupling to the Sustainable Energy Systems Planning," in *SDEWES2019.0596*, 2019, p. 563.

[10] I. Batas Bjelić and N. Rajaković, "Simulation-based optimization of sustainable national energy systems," *Energy*, vol. 91, pp. 1087–1098, Nov. 2015, http://dx.doi.org/10.1016/j.energy.2015.09.006.

[11] S. Bellocchi, M. Manno, M. Noussan, M. G. Prina, and M. Vellini, "Electrification of transport and residential heating sectors in support of renewable penetration: Scenarios for the Italian energy system," *Energy*, vol. 196, p. 117062, 2020, http://dx.doi.org/10.1016/j.energy.2020.117062.

[12] M. Welsch et al., "Incorporating flexibility requirements into long-term energy system models - A case study on high levels of renewable electricity penetration in Ireland," *Appl. Energy*, vol. 135, no. 0, pp. 600–615, 2014, http://dx.doi.org/10.1016/j.apenergy.2014.08.072.

[13] S. Quoilin, W. Nijs, I. H. Gonzalez, A. Zucker, and C. Thiel, "Evaluation of simplified flexibility evaluation tools using a unit commitment model," in *2015 12th International Conference on the European Energy Market (EEM)*, 2015, pp. 1–5, http://dx.doi.org/10.1109/eem.2015.7216757.

[14] M. Victoria, K. Zhu, T. Brown, G. B. Andresen, and M. Greiner, "The role of photovoltaics in a sustainable European energy system under variable CO2 emissions targets, transmission capacities, and costs assumptions," *Prog. Photovoltaics Res. Appl*., vol. 28, no. 6, pp. 483–492, 2020, http://dx.doi.org/10.1002/pip.3198.

[15] D. Bogdanov *et al*., "Radical transformation pathway towards sustainable electricity via evolutionary steps," *Nat. Commun*., vol. 10, no. 1, pp. 1–16, 2019, http://dx.doi.org/10.1038/s41467-019-08855-1.

[16] H. C. Gils, S. Simon, and R. Soria, "100% Renewable Energy Supply for Brazil—The Role of Sector Coupling and Regional Development," *Energies*, vol. 10, no. 11, p. 1859, 2017, [Online]. Available: http://www.mdpi.com/1996-1073/10/11/1859.

[17] T. Brown, D. Schlachtberger, A. Kies, S. Schramm, and M. Greiner, "Synergies of sector coupling and transmission reinforcement in a cost-optimised, highly renewable European energy system," *Energy*, vol. 160, pp. 720–739, 2018, doi: https://doi.org/10.1016/j.energy.2018.06.222.

[18] J. C. O. Aravena, A. Aghahosseini, D. Bogdanov, U. Caldera, E. Muñoz-Cerón, and C. Breyer, "The role of solar PV, wind energy, and storage technologies in the transition toward a fully sustainable energy system in Chile by 2050 across power, heat, transport and desalination sectors," *Int. J. Sustain. Energy Plan. Manag*., vol. 25, pp. 77–94, 2020, http://dx.doi.org/10.5278/ijsepm.3385.

[19] D. Keiner, C. Breyer, and M. Sterner, "Coupling heat and electricity storage technologies for cost and self-consumption optimised residential PV prosumer systems in Germany," *Int. J. Sustain. Energy Plan. Manag*., vol. 21, 2019, http://dx.doi.org/10.5278/ijsepm.2019.21.4.

[20] D. Connolly and B. V. Mathiesen, "A technical and economic analysis of one potential pathway to a 100% renewable energy system," *Int. J. Sustain. Energy Plan. Manag*., vol. 1, pp. 7–28, 2014, http://dx.doi.org/10.5278/ijsepm.2014.1.2.

[21] M. G. Prina, D. Moser, R. Vaccaro, and W. Sparber, "EPLANopt optimization model based on EnergyPLAN applied at regional level: The future competition on excess electricity production from renewables," *Int. J. Sustain. Energy Plan. Manag*., vol. 27, no. Special Issue, pp. 35–50, Mar. 2020, http://dx.doi.org/10.5278/ijsepm.3504.

[22] I. Batas Bjelic and N. Rajaković, "National Energy and Climate Planning Approach for the Western Balkans: Newest achievements from Republic of Serbia and Bosnia and Herzegovina," in *Proceedings of the 14th Conference on Sustainable Development of Energy, Water, and Environment Systems, SDEWES.SEE2020.0182*, 2020, pp. 1–10.

[23] D. Stratimirovic, I. Batas-Bjelic, V. Djurdjevic, and S. Blesic, "Changes in long-term properties and natural cycles of the Danube river level and flow induced by damming," *Phys.*

A Stat. Mech. its Appl., vol. 566, p. 125607, 2021, doi: https://doi.org/10.1016/j.physa.2020.125607.

[24] D. Miljević, M. Mumović, and J. Kopač, "Rocking the Boat: What is Keeping the Energy Community's Coal Sector Afloat?" Energy Community Secretariat, 2019, [Online]. Available: https://www.euneighbours.eu/sites/default/files/publications/2020-02/EnC_Coal_Study_092019.pdf.

[25] L. Hancher, K. Talus, and M. Wüstenberg, "Retrospective application of legal rules in the European Union: recent practice in the energy sector," *J. Energy Nat. Resour. Law*, vol. 39, no. 1, pp. 65–81, 2021, http://dx.doi.org/10.1080/02646811.2020.1804712.

[26] I. Batas Bjelić, *Prilog planiranju energetske tranzicije Republike Srbije*. Beograd: Instant system, 2018.

[27] "EUR-Lex - 52019DC0285 - EN - EUR-Lex." https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1565713062913&uri=CELEX:52019DC0285 (accessed Nov. 18, 2020).

[28] K. Tomaszewski, "The Polish road to the new European Green Deal - Challenges and threats to the national energy policy," *Polityka Energ*., vol. 23, no. 2, pp. 5–18, Jun. 2020, http://dx.doi.org/10.33223/EPJ/123411.

[29] "Open Models - wiki.openmod-initiative.org." https://wiki.openmod-initiative.org/wiki/Open_Models (accessed Aug. 20, 2021).

[30] L. Mantzos et al., "POTEnCIA model description - version 0.9," European Commission, 2016. [Online]. Available: https://publications.jrc.ec.europa.eu/repository/handle/111111111/40252.

[31] J. Cunha and P. V. Ferreira, "A Risk Analysis of Small-Hydro Power (SHP) Plants Investments," *Int. J. Sustain. Energy Plan. Manag. Vol 2*, 2014, [Online]. Available: http://journals.aau.dk/index.php/sepm/article/view/263.

[32] V. ALEKSIĆ and I. BATAS BJELIĆ, "Do We Need More Ambition for the Renewable Energy Transition in Serbia? Foundations of Energy Governance and Planning," 2021.

[33] IRENA, "Cost-competitive renewable power generation: Potential across South East Europe," International Renewable Energy Agency (IRENA), Abu Dhabi, 2017.

[34] D. L. Doljak, G. B. Stanojević, M. M. Radovanović, and S. B. Malinović-Milićević, "Estimation of photovoltaic power generation potential in Serbia based on irradiance, air temperature, and wind speed data," *Therm. Sci*., vol. 22, no. 6A, pp. 2297–2307, 2018.

[35] M. Z. Jacobson et al., "100% Clean and Renewable Wind, Water, and Sunlight All-Sector Energy Roadmaps for 139 Countries of the World," *Joule*, vol. 1, no. 1, pp. 108–121, 2017, http://dx.doi.org/10.1016/j.joule.2017.07.005.

[36] S. Baruch-Mordo, J. M. Kiesecker, C. M. Kennedy, J. R. Oakleaf, and J. J. Opperman, "From Paris to practice: sustainable implementation of renewable energy goals," *Environ. Res*. Lett., vol. 14, no. 2, p. 024013, Feb. 2019, http://dx.doi.org/10.1088/1748-9326/AAF6E0.

[37] D. Milenić, P. Vasiljević, and A. Vranješ, "Criteria for use of groundwater as renewable energy source in geothermal heat pump systems for building heating/cooling purposes," *Energy Build*., vol. 42, no. 5, pp. 649–657, May 2010, http://dx.doi.org/10.1016/j.enbuild.2009.11.002.

[38] S. Cvetković, T. Kaluđerović Radoičić, B. Vukadinović, and M. Kijevčanin, "Potentials and status of biogas as energy source in the Republic of Serbia," *Renew. Sustain. Energy Rev*., vol. 31, no. 0, pp. 407–416, Mar. 2014, doi: http://dx.doi.org/10.1016/j.rser.2013.12.005.