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# TECHNICAL ASPECTS OF INTEGRATING PHOTOVOLTAIC DISTRIBUTED GENERATION IN THE WESTERN BALKANS POWER SYSTEMS

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# CONTENT

# THE LIST OF ACRONYMS

| | |
|---|---|
| **CBAM** | Carbon Border Adjustment Mechanism |
| **DEN** | Distribution Electric Network |
| **DG** | Distributed Generator or Distributed Generation |
| **DG-PV** | Distributed Generation from photovoltaic (PV) installation |
| **DNO** | Distribution Network Operator |
| **DR** | Demand Response |
| **DSM** | Demand Side Management |
| **DSO** | Distribution System Operator |
| **EnC** | Energy Community |
| **EU** | European Union |
| **ETS** | Emissions Trading System |
| **FiT** | Feed-in-Tariff |
| **HC** | Hosting Capacity |
| **HPP** | Hydro Power Plant |
| **LV** | Low Voltage |
| **MV** | Medium Voltage |
| **NECP** | National Energy and Climate Plan |
| **NTC** | Net Transfer Capacity |
| **PV** | Photovoltaic |
| **RES** | Renewable Energy Source |
| **QoS** | Quality of Supply |
| **SoS** | Security of Supply |
| **TPP** | Thermal Power Plant |
| **TSO** | Transmission System Operator |
| **VPP** | Virtual Power Plants |
| **WB6** | The Western Balkans countries: Albania, Bosnia and Herzegovina, Kosovo, North Macedonia, Montenegro, and Serbia |
| **WPP** | Wind Power Plant |

# EXECUTIVE SUMMARY

This policy paper, prepared by a team of regional experts for the Open Society Foundations – Western Balkans, presents the technical aspects of integrating solar photovoltaic (PV) distributed generators (DG) – DG-PVs, in the distribution electric networks (DENs) in the Western Balkans countries (WB6).

The deployment of DG-PVs in the WB6 power sectors is a "win-win-win" strategy for the consumers (prosumers), the distribution network operators (DNOs) and the power utilities as dominant electricity suppliers, since the positive socioeconomic effects of connecting PV generators to the DEN outweighs the technical challenges. *The distributed PV technology, especially when connected to the low-voltage (LV) level, is identified as a key driver for decentralization and democratization of the imminent energy transition in the region.* Hence, the objective of the policy paper is to support large-scale deployment of DG-PVs by identifying potential technical barriers from the electric network and power system aspects, also proposing measures and actions for the smooth integration of the prosumers connected to the LV networks.

Since conventional DENs are not designed to integrate substantial amounts of DGs, the connection of DG-PVs can have both positive and negative effects on the existing DENs, especially regarding the quality of supply aspects. In principle, today's DENs in the WB6 are ill-prepared for the intake of electricity from DG-PVs, especially in LV networks. Usually, DNOs observe the quality of supply violations as the limiting constraints to the maximum power of DGs which can be connected to a part (i.e. feeder, transformer area) of the DEN.

For the estimation of the maximum power of the DGs that can be connected to a part of the DEN, the use of the Hosting Capacity (HC) method is proposed. The HC concept is not a defined approach but rather a framework for the estimation of maximum absorption of DG capacity in a DEN, based on specific performance indices. Since the use of this method requires extensive data regarding network and load characteristics, a simple conservative "rule-of-thumb" method is applied in this analysis to estimate the value of LV-PV capacity which can be connected to the national DENs in the region, without requiring major changes in the network operation and control and grid enforcement and reconstruction interventions. Finally, the list of measures and actions for increasing the Hosting Capacity of the DENs in the region which will enable integration of larger capacities of DG-PVs is proposed.

It is expected that this policy paper will serve as base for initiating an evidence-based discussion with the DNOs, national and local governments and power sector regulators regarding future policies, technical and regulatory improvements aiming to enable the increased share of the LV prosumers (i.e. households, local public institutions, municipal utilities and small businesses) in the generation mix of the future low-carbon power sectors in the WB6 region.

# 1. INTRODUCTION

The third industrial revolution[1], supported by *decarbonization* and *digitalization* infrastructures has already unfolded. Leaders of this revolution will be the most technologically and economically advanced countries: the USA, the EU, China, and Japan. The EU has proclaimed the intention to be the leader in the decarbonization component of this revolution and has adopted a vision of *Europe as the first climate neutral continent by 2050.* Accomplishing the vision of European climate neutrality is not possible without implementing the energy transition in the Western Balkans countries (WB6)[2]. Since the WB6 have never been among the leaders of social and technological change, but rather the followers, it is realistic to expect that the energy transition in the WB6 is initiated and supported by EU actions. Key components of the energy transition concept for the WB6 are presented in the *Declaration on Energy Security and Green Transition in the Western Balkans*[3]. At the Berlin Process Leader's Summit in Tirana in 2023, the Energy Community (EnC) Secretariat presented a comprehensive report on the *Implementation of the Declaration on Energy Security and Green Transition in the Western Balkans.*[4]

The implementation of the energy transition in the WB6 power sectors started in 2021 by means of a decision of the EnC Ministerial Council to start the transposition of the directives and regulations from the EU Clean Energy for All Europeans package. *A distinctive feature of the Clean energy package is the empowerment of the local actors: citizens, small businesses and local governments to become active participants in the energy transition*. This energy package, actually, presents the framework for a *sustainable energy transition* that is characterized not only by *decarbonization* but also by *decentralization*, *digitalization* and *democratization* of the power sectors, which are the building blocks of an *energy transition process* that is also *inclusive* and *just.*

The main objective of decarbonizing the WB6 power sectors is substituting the coal-based generation and/or complementing the variable hydro-based generation with the increased scale and diversity of renewable energy generation mix. To coordinate deployment of renewable energy sources (RES), the WB6 governments are preparing the first National Energy and Climate Plans (NECP)[5]. Key component of reaching decarbonization targets in a NECP is a dynamic plan for the scale-up of RES for the period up to 2030. Different RES mixes are planned in the drafts of the NECPs in the WB6 and the photovoltaic (PV) technology plays a significant role in all of them. This matches the current trend in the region of developing large utility-scale PV projects[6]. In some NECPs a quota for distributed generation from solar PV installations (DG-PV) is allocated.[7] DG-PV installations can be commercial (production for the electricity market) and production for self-consumption (*prosumers*). In general, DG-PV contributes to decentralization of a power system but only prosumers and energy communities (so-called citizens' energy) result in sector democratization also enabling the implementation of innovative solutions for a just and inclusive energy transition.

The energy transition is a complex process from political, economic, social, and technical aspects. Technical aspects of deploying modern variable RES (wind and solar) comprise *technology* (i.e., PV and storage technologies) and *grid and power system integration* aspects*.* Grid integration studies deal with the *Quality of Supply* (QoS), system security and stability aspects. System integration studies encompass the *Security of Supply* (SoS), the spatial-temporal "generation-consumption" balancing, frequency regulation and system adequacy aspects.

1 Rifkin, J. (2011). *The Third Industrial Revolution: How Lateral Power is Transforming Energy, the Economy, and the World*. Palgrave Macmillan, New York, NY

2 The WB6 are: Albania, Bosnia and Herzegovina (BiH), Kosovo, Montenegro, North Macedonia, and Serbia.

3 https://www.berlinprocess.de/uploads/documents/221103-energy-declaration-final_1678468569.pdf

4 https://www.energy-community.org/news/Energy-Community-News/2023/10/17.html

5 https://www.energy-comm sunity.org/implementation/package/Decarb.html

6 Currently the cumulative power of utility-scale PV projects in the submitted requests for the grid connection in the WB6 power systems substantially surpass the transmission grid absorption capacity.

7 In BiH's draft of the NECP a quota of 500 MW, out of the planned 1500 MW for PV capacity, is allocated to the DG-PV (prosumers). However, the quota for the roof-top LV prosumers is not specifically determined.

Conventional distribution electrical networks (DENs) are not designed to integrate substantial amounts of DGs. Since ever-increasing integration of DGs to the DEN might cause violations of the QoS performance indices, like overvoltage, equipment overloading, harmonics propagation, and failure of protection schemes, the integration of DGs is becoming an important aspect for the operation and planning of modern DENs. *Connection of a DG to the DEN, depending of the size and location of the unit, can have both positive and negative effects on the network operation.* Positive effects, like decrease in the network losses, improvement in the voltage profile on a distribution feeder, and enabling deployment of Demand Side Management and Smart Grids concepts, are frequently neglected by the Distribution Network Operators (DNOs). Usually, DNOs observe the QoS violations as the limiting constraints to the maximum power of DGs in a part (i.e., feeder, transformer supply area) of the DEN. For the estimation of the maximum power of the DGs that can be connected to a DEN, the concept of *Hosting Capacity* (*HC*) is used.[8] *The HC concept is not a defined approach but rather a framework for the estimation of the maximum absorption of DG capacity in a DEN, based on specific performance indices.*[9]

The connection of DG-PV creates several challenges for the DNOs, especially if higher shares of DG connected in a certain part of the DEN cause reverse power flows during maximum generation from DG-PV. Integration of generation from PV prosumers also imposes requirements on the power suppliers, usually public power utilities, regarding short-term and long-term power and energy balancing. *However, deployment of DG-PV in the WB6 power sectors is a "win-win-win" strategy for the consumers (prosumers), the DNOs and the power utilities as dominant electricity suppliers, since the positive effects of connecting DGs outweighs the challenges*. Main benefits for the prosumers are: a. predictable and in the long-term lower costs of electricity, b. possibility to invest savings with a secure financial return, and c. opportunity to actively participate in the energy transition. The DNOs can benefits from: a. decreased energy losses, b. improved voltage conditions in the remote network areas, and c. a chance to invest in modernization and upgrade of the network - the opportunity to evolve from a DNO model to a digital-based Distribution System Operator (DSO) model. The benefits for the public utilities in the WB6 region are: a. supplementary production from the DG-PV to compensate the expected decrease in the production from the existing old thermal coal-based generation, b. diversification of the RES generation portfolio with the production from PVs that have a high level of complementarity with the existing hydro-based production, and c. decreased consumption of the prosumers which are, as a rule, in the WB6 supplied with the regulated, subsidized prices. *To utilize potential benefits of connecting DG-PV, the technical challenges should be assessed and overcome*. In this policy analysis, the technical aspects of integrating DG-PV in the DENs in the WB6 power systems are elaborated and recommendations for increasing the hosting (absorption) capacity of the DENs to integrate higher levels of LV PV prosumers are proposed.

8 Zobaa A.F., Ribeiro P.F., Abdel Aleem S.H.E, Ismael S.M., etc. (2020), *Hosting Capacity for Smart Power Grids*. Springer International Publishing, Switzerland.

9 Kamar N., Arshad A., Mahmoud K., Lehtonen M. (2023), *Hosting capacity in distribution grids: A review of definitions, performance indices, determination methodologies, and enhancement techniques*. Energy Science & Engineering, Vol. 11, Issue 4, Wiley Online library: https://onlinelibrary.wiley.com/doi/full/10.1002/ese3.1389

# 2. IMPACT ASSESSMENT OF CONNECTING DISTRIBUTED PHOTOVOLTAIC GENERATION TO DISTRIBUTION ELECTRIC NETWORKS

The connection of a DG to the DEN can impact:

- power system operation and control,
- the QoS performance indicators in low-voltage and medium-voltage (MV) distribution grids, and
- operational practices of the DNOs[10].

The impact on power system operation is the result of temporal (daily and seasonal) variability of the solar-based generation and is assessed in the *DG system integration studies*.[11] However, when the DG-PV annual share in the total generation mix is less than 10%, like it is currently in the WB6, there is no substantial influence on the power system operation (i.e., maintaining the active power balance between the system generation and load is possible with the existing flexibility sources). *Hence, the impact of the integration of DG-PVs on the power system operation is not elaborated in detail in this policy paper.*

In a conventional power system, the DENs are only designed for the unidirectional flow of power/energy, from the transmission grid to the distribution centers of consumption and mainly operate in a radial topology. The radial topology of the DENs has a profound influence on their design and operation, and especially on the concept of voltage regulation. The dimensioning of the lines and transformers in these grids is based on in-house empirical values. The conventional DENs operate as *passive networks* with minimum monitoring and control functions. Therefore, in principle, today's DEN can be ill-prepared for the intake of electricity from DGs. Evaluation of the impact of connecting an individual DG or a specified group of DGs to the DEN is performed in the *DG grid connection analysis.*[12] The objective of the grid connection analysis is to find a common ground for DG investors and DNOs regarding the location and requirements for the DG connection. DG grid connection analysis have shown that limitations to DG-PV integration first becomes apparent in LV grids. *Since prosumers as a rule are connected to a LV distribution grid, in the focus of this policy paper is the impact of connecting DGs on LV DENs.*

The DG impact on the local section of a LV DEN (i.e., line/feeder, transformer area) mainly depends on:

- the size (the rated power) of the generation unit and its location in the grid,
- the load profile of the local consumption, and
- the rated power and location of all DGs already connected to the DEN.

The injection of active power from a DG-PV that causes a voltage rise at the point of DG connection and potentially may result in the over-voltages in the local network. When the DG injections are greater than the total local load, the reverse power flows occur, and line and/or transformer overloading can happen. Since the connection of a DG-PV to the DEN is realized through the power inverter, which generates the current harmonics, sinusoidal voltage waveform distortion could appear in the local section of the grid, as well. However, modern power inverters are manufactured to comply with the QoS requirements, and

10 Bollen M., Hassan F.,(2011), *Integration of Distributed Generation in the Power Systems*. Wiley-IEEE Press.

11 NREL (2018), *Studying the Impact of Distributed Solar PV on Power Systems using Integrated Transmission and Distribution Models*. https://www.nrel.gov/docs/fy17osti/68995.pdf

12 NREL etc. (2016), *High-Penetration PV Integration Handbook for Distribution Engineers.* https://www.semanticscholar.org/paper/High-Penetration-PV-Integration-Handbook-for-Seguin-Woyak/1391f91bce6761b3f7fe02e2b5fdd4d2c1f46482

they do not cause waveform distortions. *To summarize, connecting a DG could cause the violation of the QoS standards in the LV and MV distribution grids* [13].

The connection of a DG can also influence DNO's concept of voltage regulation as well as the level of the active power losses in the grid. The concept of voltage regulation in a LV DEN is realized by changing the MV/LV transformer voltage ratio (in LV networks usually in the off-load transformer operation) and it is founded on the premise of the unidirectional power flows in the radial DEN grid topology. The occurrence of the reversed power flows might cause the malfunction of this voltage control concept. The impact of connecting a DG on the active power losses in the local grid is nonlinear. In the initial stage of increasing the DG level the grid losses are decreasing, resulting in the positive effect on the DNO's economic performances. Only when very high levels of DG penetration in the local grid are reached, the grid losses can increase compared to the level without the DGs.

## 2.1 THE HOSTING CAPACITY CONCEPT OF DISTRIBUTION GRIDS

The DEN resilience toward the DG-PV penetration requires an extensive study related to the quality of performance indices of the electricity supply that might not be met if the DG-PV power exceeds a certain limit. There are two approaches in the grid connection analysis:
to assess the impact of connecting an individual DG-PV on the existing network,

a) to define the limit of cumulative DG-PV capacity that will not affect the normal operation of the existing DEN.

In the first approach, the analysis is performed by using the power flow simulations for the worst possible scenario - a very conservative assumption of the maximum generation from the DG during the periods of the minimum local load level. This approach is usually applied during the process of the grid connection approval of an individual DG. In the second approach, a concept of the *Hosting Capacity* (HC) is used for the quantitative description of the DG-PV penetration impact. The concept of HC of a grid that was introduced by Math Bollen[14] became the key idea in relating the performance indices of the network to power quality constraint violations, which are directly linked to the power and location of DGs that can be integrated into the downstream network. The HC is defined as "*the total DG capacity that can be accommodated on a given feeder or a transformer without adversely impacting voltage, protection, and power quality and with no network upgrades or modifications*."

Calculation of the HC limits can be performed using the following methods:

- *Deterministic method* based on the power flow simulations using the historical data for the load profiles (i.e. the annual time series data for consumer loadings for a 15-minutes time resolution) and estimated time series for the production from the DG-PV at the specified locations in the grid – the so called *deterministic scenario analysis*. The DG-PV generation is incrementally increased until, based on the performed power flow analysis, the violation occurs. Once the violation of a specific performance indicator is detected the HC limit is set at that point.

- *Stochastic method* based on the probability power flow simulations (usually applying the Monte Carlo method) in which various scenarios are analyzed for different DG-PV locations and penetration levels.[15] In general, in this method the PV *Hosting Capacity* can be interpreted as the maximum installed power of DG-PVs (or a maximum number of consumers with PVs) that a particular network can host while keeping voltage and network element constraints within the required limits.

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13 The EN 50160 standard: https://www.neo-messtechnik.com/en/power-quality-explained-chapter5-en-50160-report-standard
14 Bollen M., Ronberg S.K, (2017). *Hosting Capacity of the Power Grid for Renewable Electricity Production and New Large Consumption Equipment.* Energies.
15 Grabner M., Souvent A., Suljanović N., Košir A., Blažič B. (2019), *Probabilistic Methodology for Calculating PV Hosting Capacity in LV Networks Using Actual Building Roof Data.* Energies.

*A major benefit of the HC concept is the clear criteria for the PV penetration assessment, which makes the PV hosting capacity concept specific, measurable, and practical.* The following QoS criteria are usually considered when applying the HC concept[14]:

a) Overvoltage and undervoltage,
b) Overcurrent or elements' overloading,
c) Fast voltage magnitude variations,
d) Voltage unbalance,
e) Harmonic voltage distortion.

The HC diagram illustrating a performance index change is presented in Figures 1 and 2. The presented HC diagram in Figure 1 is typical for the voltage performance index.[16] The HC diagram in Figure 2 is typical for the active power losses performance index.

FIGURE 1.

**THE HOSTING CAPACITY DIAGRAM WHEN THE PERFORMANCE INDEX DETERIORATES WITH INCREASING DG GENERATION**

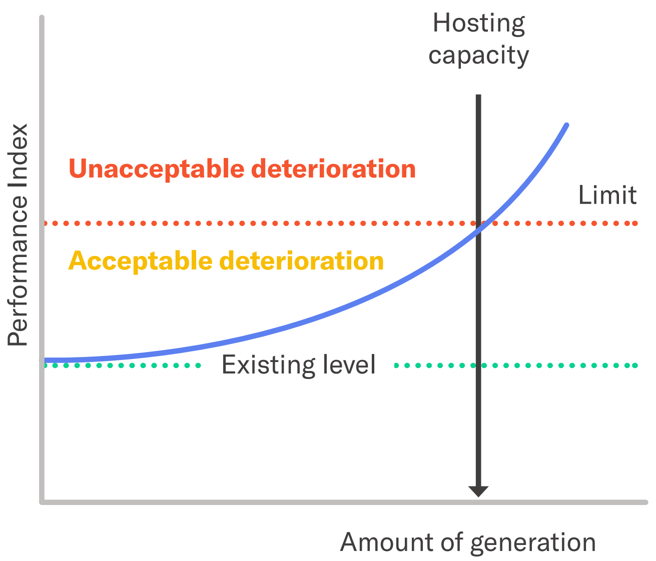
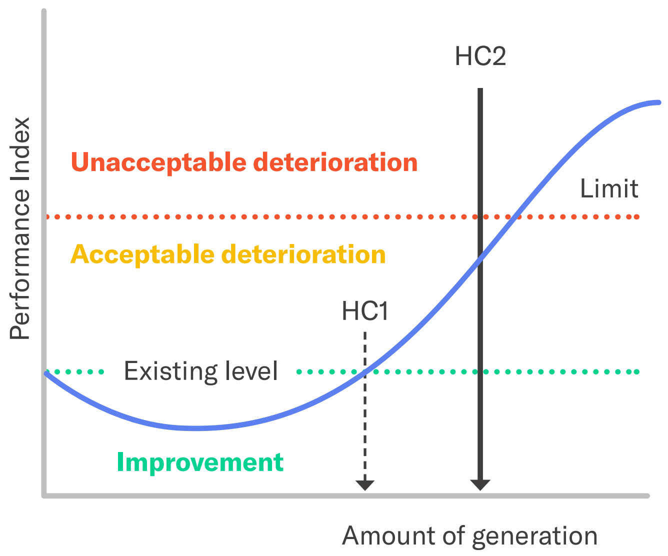



FIGURE 2.

**THE HOSTING CAPACITY DIAGRAM WHEN THE PERFORMANCE INDEX INITIALLY IMPROVES AND ONLY DETERIORATES WITH LARGER AMOUNTS OF DG GENERATION**




16 According to the EN 50160 standard the voltage limits for LV DENs are +/- 10% of the nominal voltage value for the mean 10-minutes rms value in the 95% of a week. https://powerquality.blog/2021/07/22/standard-en-50160-voltage-characteristics-of-public-distribution-systems/

## 2.2 ESTIMATING LV GRID HOSTING CAPACITY LEVEL OF PV PROSUMERS ON LOCAL AND NATIONAL SCALE

The electric grid's available capacity to accommodate LV solar PV on national scales is usually uncertain. This makes decisions about grid capacity expansion, which can be very costly for local grid operators, difficult to make. *Yet, knowledge of national solar PV hosting capacity is central in order to formulate realistic solar PV targets and strategies.* In literature, the HC limit is relative to the reference that is being utilized in the analysis and varies between 20% and 200% of the selected reference value. The utilized references to determine the PV HC limits in LV DENs are:

1. MV/LV transformer rating,
2. Number of customers having PVs,
3. Distribution network loading,
4. Annual energy share of the PV generation,
5. Active power of the connected load.

The "rule-of-thumb" estimation for the allowed total DG-PV capacity for selected limiting constraints, used by some DSOs based on the analyzed case studies and empirical evidence, is presented in Table 1.

TABLE 1.

### DSOS "RULE-OF-THUMB" ESTIMATION FOR THE MAXIMUM DG CAPACITY WITHOUT ANY INTERVENTION IN DENS.[17]

| ***Limiting constraints*** | **Country** | **DSO rules for DG capacity** |
|---|---|---|
| ***MV/LV transformer rating*** | Portugal<br>Italy<br>Spain<br>Belgium | ***<25% of the MV/LV transformer rating***<br><50% of the MV/LV transformer rating<br><65% of the MV/LV transformer rating<br><100% of the MV/LV transformer rating |
| Number of customers having PV | Real and test feeders | Feeders with less than 25 customers with PVs<br>Feeders with less than 30% of the customers with PVs |
| Network loading / feeder capacity | Real and test feeders<br><br>Canada | The ratio of the PV rated capacity to the maximum feeder loading in the range of 18,1% - 132,2%.<br>50-100%. |
| ***Annual energy share of the PV generation*** | Real and test feeders<br><br>The USA | ***The ratio of the total PV generation to the annual energy usage <23%.***<br><br><15%. |
| Active power of the load | Analysis of the real feeder in Germany | The ratio of the PV capacity to the cumulative active power of the feeder <43%. |

17 Kamar N., Arshad A., Mahmoud K., Lehtonen M. (2023), *Hosting capacity in distribution grids: A review of definitions, performance indices, determination methodologies, and enhancement techniques*. Energy Science & Engineering, Vol. 11, Issue 4, Wiley Online library: https://onlinelibrary.wiley.com/doi/full/10.1002/ese3.1389

Table 1 clearly shows that the HC limits depend on multiple factors that characterize the local DEN, load profiles and DNO's operational practice. In general, some previous studies have shown that residential customers installing solar PV systems sized between 1.3 and 5.5 kW may not require grid reinforcements, and thus, fall within the HC limit of the current grid.

*Most of the current PV capacity in the EU is installed in LV grids at roof-top residential or commercial properties.* In Germany in 2021, 70% of the current PV capacity was installed in the LV grids and in Italy 98%. *It is expected that DG-PV connected to the LV DEN will account for about 40% of the total PV capacity in 2050. The size of a typical residential solar PV system is around 5kW, while the commercial PV system size is closer to 200 kW.*

National governments usually set the NECP's targets for solar PV. However, due to the lack of national estimates on PV HC, the solar PV targets are politically set with little consideration for HC limits. *Therefore, estimation of HC on regional and national scale is important in order to provide and assess DG-PV targets, especially for prosumers*. Furthermore, knowledge about HC and its geographical distribution can improve estimations about resource use feasibility and grid limitations associated with the roof-top solar PV. In order to make estimations of DG-PV hosting capacity of LV DENs on a national level detailed data on grid components and topology is required.

Since national-level data on DENs are often distributed among numerous DNOs, the data issues present a major barrier to estimating national levels of HC. To solve this problem an approximate approach based on generating synthetic low-voltage grids, using national standards and demand estimation method has been presented in literature.[18] The HC limits in this reference are determined using overvoltage and component ratings (overloading) criteria. The method is applied to Sweden, Germany and the UK power systems (the developed countries with very high level of consumption per capita). The estimated HC values for the residential PV for the LV DENs in each country according to these criteria were found to be similar to the current total installed generation capacity in each country, i.e., in Sweden (41 GW), Germany (211 GW) and slightly lower in the United Kingdom (105 GW). The average solar PV system size per household that the LV grid may support is 7.2 (+1.1/-1.5) kW in Sweden, 6.2 (+0.1/-0.6) kW in Germany and 2.3 (+0/-0.5) kW in the United Kingdom. Accordingly, the national HC indicator, expressed as annual electricity production from residential solar PV, is: 34 (+5/-6) TWh in Sweden (*or the 24% share of the annual electricity consumption*), 307 (+6/-30) TWh in Germany (*or the 60% share*), and 69 (+1/-15) TWh in the UK (*or the 21% share).* The difference between the analyzed countries is due to the technical characteristics of their DENs.

18 Hartvigsson E., Odenberger M., Chen P. , Nyholm E. (2021), *Estimating national and local low-voltage grid capacity for residential solar photovoltaic in Sweden, UK and Germany*. Elsevier Renewable Energy.

# 3. PLANNING PV PROSUMERS DEPLOYMENT AND INCREASING DISTRIBUTION NETWORK HOSTING CAPACITY

Planning DG-PV expansion should be a transparent and coordinated process. *An important aspect of an optimal scale-up of PV prosumers is the coordination of their geographic deployment, taking into account both the spatial distribution of PV potential and the absorption limitations of the local DENs*. The acceleration of PV deployment ultimately calls for upgrading and modernizing distribution grids. This includes deploying grid enhancing technologies and unlocking the potential of demand response and energy storage through digitalization. The costs of upgrading and modernizing DENs to enable the integration of larger amounts of DG-PV could be very high.[19] *Hence, significant research efforts have been made to identify the solar PV HC and to develop cost-competitive measures that can be used to increase the DEN's absorption capacity for DG-PVs.*

## 3.1 PLANNING AND MANAGING DEPLOYMENT OF PV PROSUMERS

In national generation expansion studies the share of PV generation in the RES mix is defined and a separate quota is usually allocated to the DG-PV. However, the distinction between DGs in MV and LV grids and between LV PV commercial and residential prosumers is usually not made. *In order to ensure that the energy transition will contribute to democratization of the power sector a separate quota allocation for the LV DG-PVs, based on the potential of residential and commercial prosumers in LV grids, should be specified.* While implementing the LV PV expansion plans, an optimal allocation of prosumers' capacities based on the HC of local, regional and national DENs is needed.

*The public knowledge of the network hosting capacity can facilitate private (commercial and citizens') investments in green generation. Just as solar cadastres have become the norm to assess the roof-top PV potential, assessing the hosting capacity of the LV network for PV generation is on the path to becoming a necessity for an efficient solar production action plan.*

The best practices in several developed countries show that a web-based tool (i.e., interactive hosting capacity maps) that gives preliminary information on the remaining hosting capacity level for each local network (feeder) is a powerful tool for the scale-up of LV prosumers.[20] A typical HC map is presented in Figure 3.

## 3.2 INCREASING HOSTING CAPACITY OF LV DISTRIBUTION ELECTRIC NETWORKS21

In general, increasing the level of PV prosumers in the LV DEN requires improvement in monitoring and analyzing DENs, by using modern digital technologies (i.e. Automatic Meter Reading – AMR and Automatic Meter Infrastructure - AMI, distribution System Control and Data Acquisition – SCADA system and Advanced Distribution Management

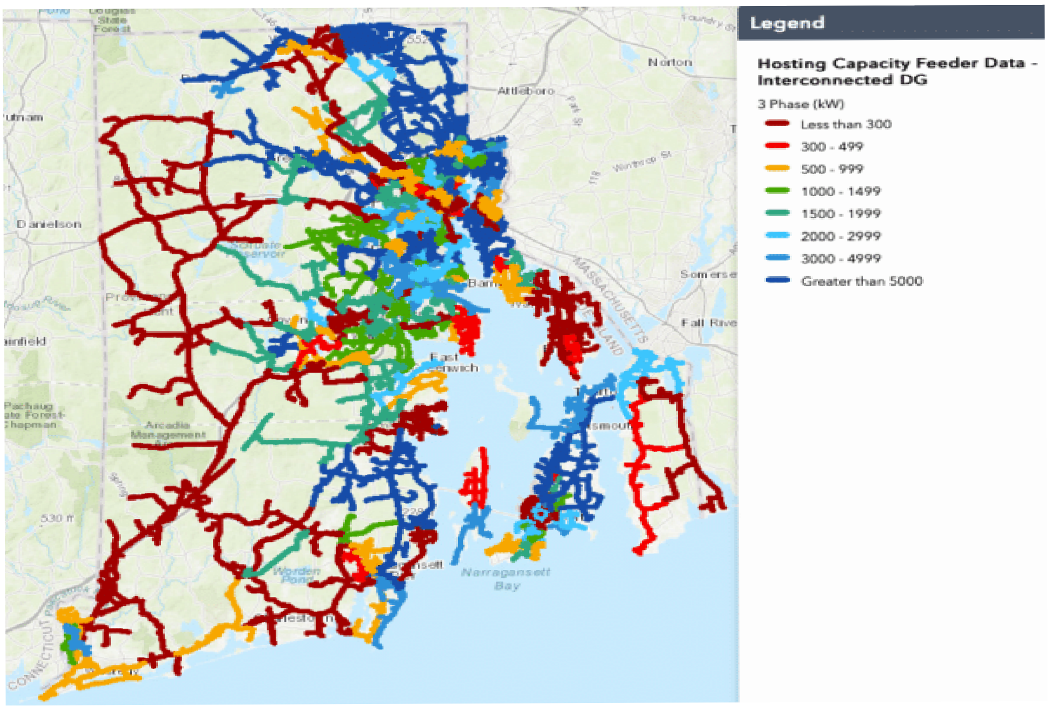
19 https://www.iea.org/events/electricity-grids-and-secure-energy-transitions?utm_content=buffer0189d

20 Joos M., Lebert N., Gaiddon B., Seguin E., (2018). *Spatial representation of low-voltage network hosting capacity for photovoltaic roof-top installations using an open-source tool.* 35th European Photovoltaic Solar Energy Conference and Exhibition.

21 https://pv-magazine-usa.com/2021/03/10/hosting-capacity-maps-a-gold-mine-for-solar-developers/

FIGURE 3.

## THE HOSTING CAPACITY MAP OF A DEN




System – ADMS). *Digitalization and automation of DENs will result in the evolution from the concept of the Distribution Network Operators (DNOs) to the concept of the Distribution System Operators (DSOs).*[22]

Recently, a great deal of research is being carried out on employing measures to enhance the HC of distribution networks.[23] Key limit that inhibits increased employment of DG-PV is the overvoltage criterion. All measures aimed to influence the voltage increase are based on one or more of the following four principles:

1. Reducing the system loop impedance,
2. Changing the voltage ratio between low and medium voltage grids,
3. Influencing the system active power flows,
4. Influencing the system reactive power flows.

Six measures were identified in literature that are able to prevent voltage level violations:[24]

1. Change of all main connection cables,
2. Grid expansion via additional parallel cables,
3. Installation of on-load tap-changers on MV/LV transformers,
4. *Reactive power and voltage control of PV inverters,*
5. *Installation of distributed storage (i.e., battery electric storage systems - BESS) for voltage control,*
6. *Demand Side Management (DSM) in smart distribution grids.*

Finally, the curtailment of DG sources that includes a reduction in the output power of some specific RESs can be implemented if the HC performance indices' limits get exceeded. During curtailment the DG-PV still produces energy but only as much permissible by the HC limits.

22 https://www.cgi.com/uk/en-gb/article/dummies-guide-series

23 Qamar N., Arshad A., Mahmoud K., Lehtonen M., (2023), *Hosting capacity in distribution grids: A review of definitions, performance indices, determination methodologies, and enhancement techniques.* Energy Science and Engineering.

24 Arnold M.P., (2016), *Integration of Residential Distributed Generators and Heat Pumps into the Low Voltage Grid from a Voltage Level Perspective.* PhD dissertation, TU Dortmund.

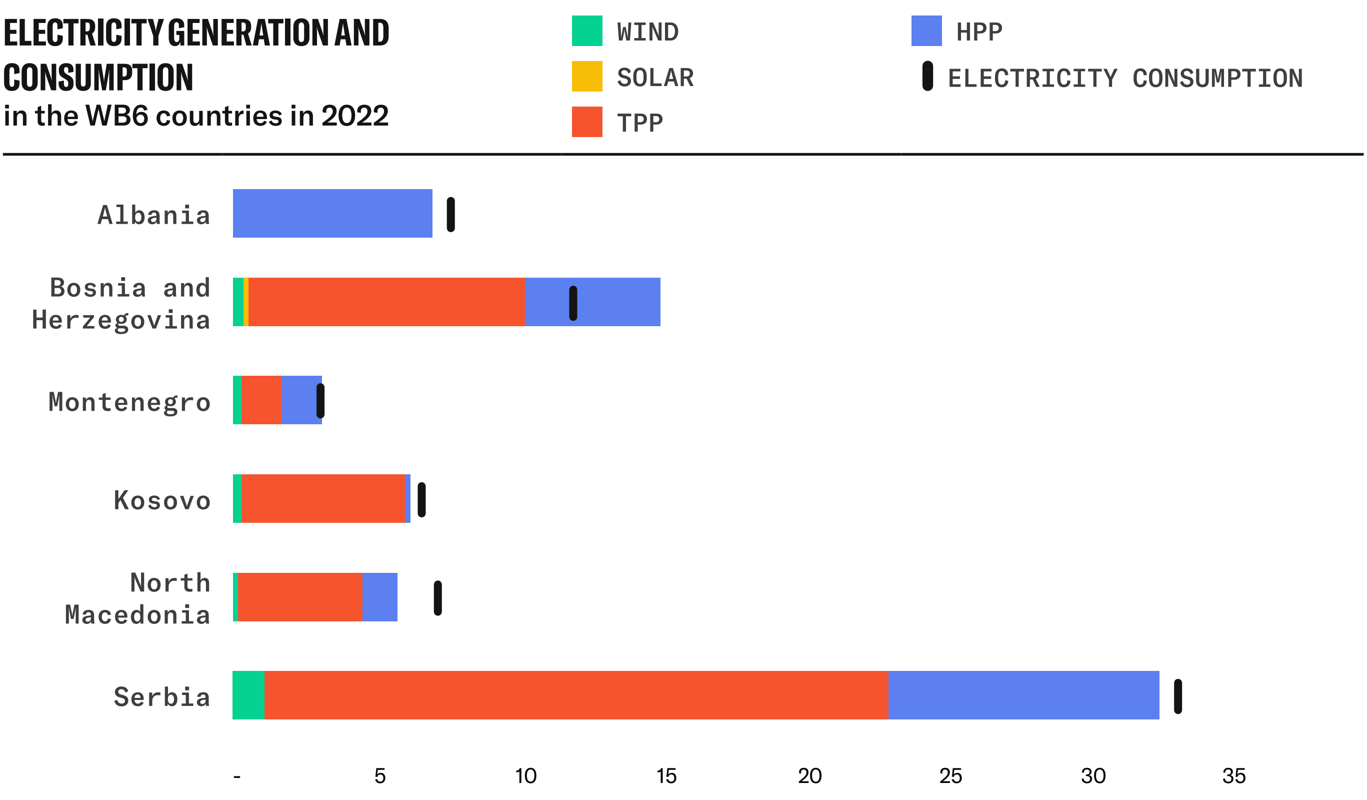
# 4. INTEGRATION OF VARIABLE RENEWABLE GENERATION IN THE WESTERN BALKANS POWER SYSTEMS

Total final electricity consumption in the WB6 in the last five years has stagnated and varied around 71 TWh. All countries in the region, except BiH, have a negative energy balance. In 2022, net exports from BiH amounted to 3 TWh, and Serbia had the largest net import of 1.8 TWh (Figure 4).[25] Total electricity generation in the region in 2022 was 69.5 TWh, with the contribution from coal-fired thermal power plants (TPPs) amounting to 43.8 TWh (63%) (Figure 5). The biggest share of coal TPPs in the generation mix is in Kosovo (92%), followed by North Macedonia (72%) and Serbia (70%).

Albania does not have coal TPPs in its generation portfolio. In the WB6 region in 2022, 36 coal TPP units operated with a total installed capacity of 8,255 MW. In 2022, hydro-power plants (HPPs) generated 23.5 TWh (34%). Since the hydro-logical situation in 2022 was unfavorable in the whole region, the generation from HPPs was 24% lower than in 2021. The share of variable RES (wind and solar) in the generation mix was small and amounted to a negligible 3.5%.

FIGURE 4.

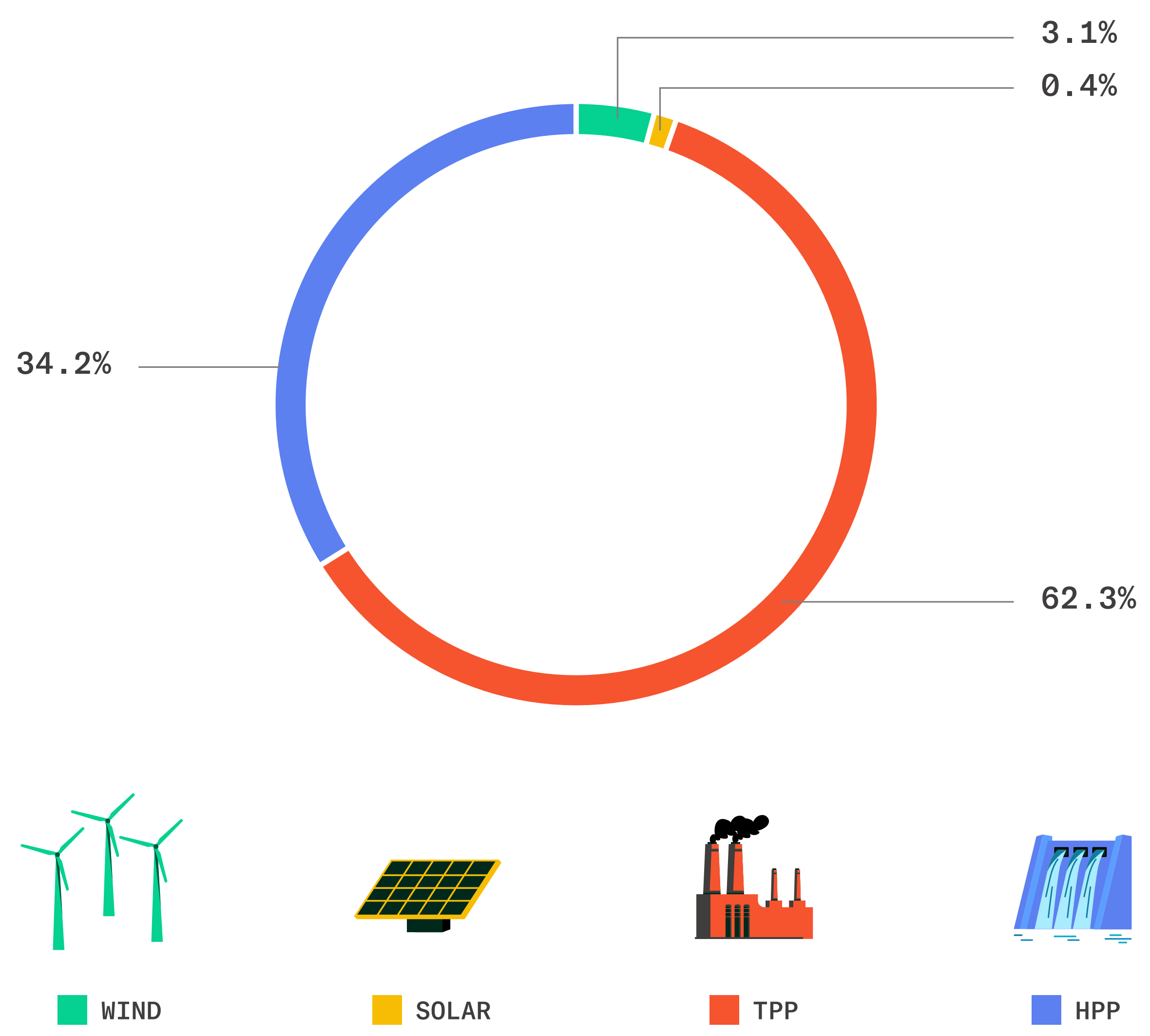
**ELECTRICITY GENERATION AND CONSUMPTION**
in the WB6 countries in 2022




25 Such a considerable net import in Serbia in 2022 is the consequence of exceptional circumstances, mainly caused by the lower electricity generation from coal due to the malfunction of several thermal power units. In general, power generation and consumption in Serbia have been balanced in the last ten years, with substantial seasonal variations.

FIGURE 5.

## ELECTRICITY GENERATION AND CONSUMPTION
in the WB6 countries in 2022

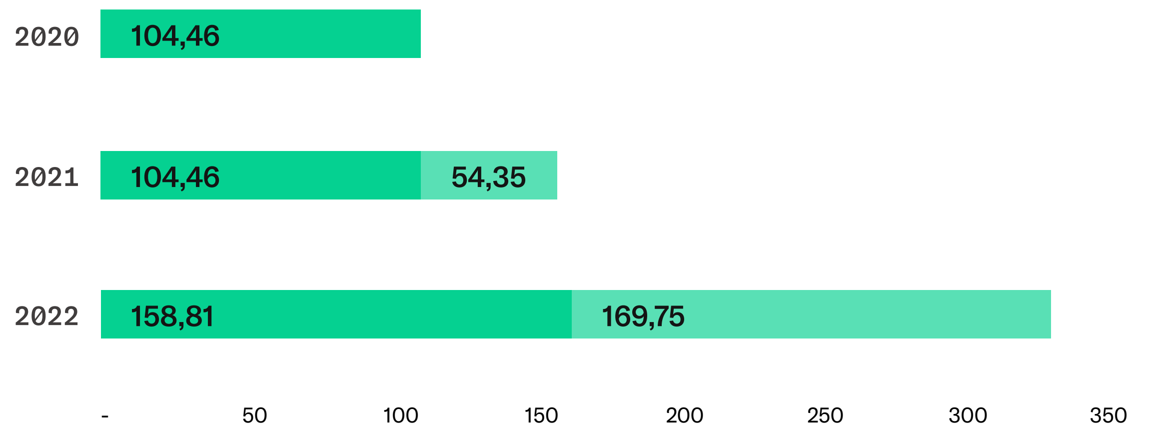



In the last two years, a substantial increase in the installed capacity of PVs in the WB6 was recorded (Figure 6). In 2022, North Macedonia has the largest capacity of PVs (144 MW). In North Macedonia and in BiH in 2022, the capacity of PVs doubled. Despite this positive trend, PV share in the total generation mix in the region in 2022 was a meager 0.44%. The exponential trend in the increase of PV capacity in the WB6 continued in 2023 as well. However, the PV prosumers' share in the new renewable energy market (wind and solar) in the WB6 is very low (i.e., in BiH 22,1 % - mainly in SMEs, Albania 10.0% - 9.5% SMEs and 0.5% households and public institutions, Serbia 1.3%, and Kosovo 0.4%).[26] For comparison, in Germany in 2021 prosumers (households, commercial and industrial) participated with a 66% share in the total PV capacity of 59 GW.[27] In addition, there were more than 200,000 residential battery installation.

26 According to the internal calculation, based on publicly available data.
27 https://metsolar.eu/blog/renewable-energy-trends-prosumers-expansion-europe-scenario/

FIGURE 6.

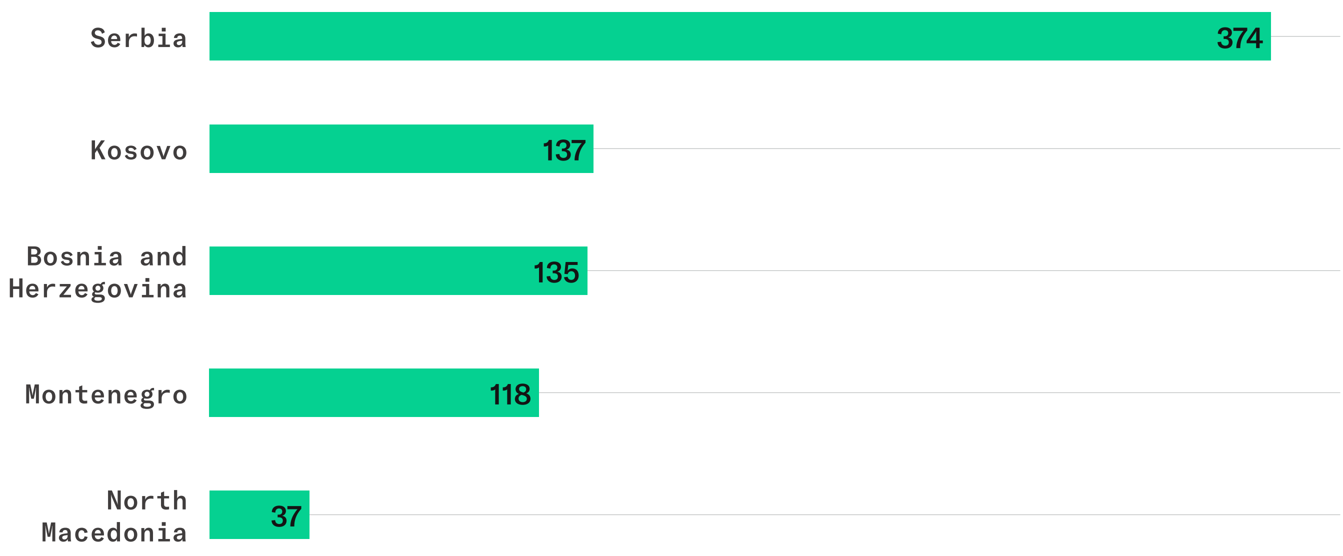
## CUMULATIVE CAPACITY OF PV (MW)
in the WB6 for the period 2020-2022




The total installed capacity of wind power plants (WPPs) in 2022 in the region was 801 MW (Figure 7), and its share in the total generation mix amounted to 3.1 %.[28]

FIGURE 7.

## INSTALLED CAPACITY OF WPPS (MW)
in the WB6 in 2022




28 For the comparison, in Croatia in 2022, 25 WPPs were operational with a nominal installed capacity of 834 MW and a 12.49% share in the total electricity generation.

The indicator expressing the installed capacity of variable RES (wind and solar) in kW per capita (pc) illustrates the level of integration of modern renewable energy. In 2022, in the EU, the total installed capacity of wind and solar plants was 465 GW (255 GW of wind and 210 GW of solar). Hence, for the EU, with a population of 447 million, that results in the value of this indicator of 1 kW/pc. In 2022 in the WB6, there was 1,130 MW of the installed wind and solar capacity thus for the population of 17.5 million the resulting value of this indicator is 0.0645 kW/pc. *Hence, 15.5 times more kW of modern RES (wind and solar) is installed per capita in the EU than in the WB6.*

Several regional generation expansion studies indicated that there is a considerable potential in the WB6 for the scale-up of modern RES.[29] From the technical point the integration of large capacity of variable RES requires solving several grid and system integration challenges of the power system in the South East Europe.[30]

## 4.1 REGIONAL COOPERATION AND INTEGRATION WITH THE EUROPEAN ELECTRICITY MARKET

Integration of variable RES generation requires increased power system flexibility.

*Flexibility refers to the ability of the power system to cope with variability and uncertainty in demand, generation and grid availability.*

There are three basic means to increase flexibility for integrating variable RES:

a) Increasing geographic coverage of the electricity market (i.e. by coupling national electricity and balancing markets),
b) Increasing flexibility of generating units (i.e. from the existing storage HPPs, and/or deploying flexible biomass and/or gas fueled thermal power plants),
c) Deploying storage capacities (i.e. flexible pump-storage hydro power plants, thermal storage and electrical batteries) and Demand Side Management – DSM (i.e. market based load shifting and smart electrical vehicle charging) and Demand Response - DR (i.e. coordinated load curtailment and load shedding) practices.

Coupling of national electricity (day-ahead and intra-day) and balancing markets and increasing the capacity of interconnection lines enable a wider market coverage, hence decreasing the total RES variability as well as the requirements for the flexibility on generation and demand side. Fully coupled electricity markets, like in the EU, enable dispatching based on actual power flows, thus contributing to smoothing variability of the total wind and solar generation in the integrated power system.

Organized electricity spot markets (power exchanges with day-ahead markets) have been established in all WB6 except in BiH. The power exchanges in Albania and Kosovo share the same trading platform (ALPEX). The power exchanges in North Macedonia (MEMO), Montenegro (BELEN/MEPX), and Albania/Kosovo (ALPEX) have been operational since the beginning of 2023. Currently, preparations for coupling power exchanges of Albania, Kosovo, North Macedonia and Greece are carried out. The SEEPEX day-ahead market in Serbia has been functioning since 2016, and from June 2023, the intra-day market has also been established. However, all power exchanges in the region face a problem of liquidity.[31] On the biggest SEEPEX day-ahead market in 2022, only 3 TWh of electricity were traded, representing less than 10% of the total consumption of Serbia. Efficient balancing market is only operational in BiH.[32] However, the existing high voltage interconnections between the WB6 power systems have sufficient capacity for full electricity market integration.

The Ministerial Council of the EnC adopted in December 2022 the Electricity Integration Package.[33] The following four acts from the *EU Clean Energy* package are now part of the EnC electricity *acquis*:

a) Electricity Directive (EU) 2019/944,
b) Electricity Regulation (EU) 2019/943,
c) Risk-preparedness Regulation (EU) 2019/941 and
d) ACER Regulation (EU) 2019/942.

29 Ecorys and others (2021), *Study on the Central and South Easter Europe energy interconnectivity (CESEC) cooperation on electricity grid development and renewables*. Study for the European Commission, DG ENER.

30 Integration of variable RES in the WB6 requires an analysis of the power system of the South East Europe that also comprises power systems of the EU member states: Slovenia, Croatia, Hungary, Romania, Bulgaria and Greece.

31 Trading on electricity markets in the WB6 region mainly takes place amongst the state-owned market participants – DSOs, TSOs and public utilities, primarily for the procurement of energy for the losses in the transmission and distribution grids.

32 https://www.derk.ba/en/trziste/trite-u-bih

33 https://www.energy-community.org/implementation/package/EL.html

Also the five Network Codes and Guidelines which establish detailed rules related to different electricity market segments and system operation are due to be transposed:

a) Forward Capacity Allocation,
b) Capacity Allocation and Congestion Management,
c) Electricity Balancing,
d) System Operation and
e) Network Code on Emergency and Restoration.

The adopted electricity integration package enables full market integration of the WB6 into the single European market for electricity, based on the principle of reciprocity. The package aims at making the markets fit to deliver on cost-efficient clean energy transition while ensuring secure and affordable electricity supply to the citizens.

As a result of the adopted EU Directives and Regulations the transmission systems operators (TSOs) in the WB6 are obliged to make available a minimum level of cross-zonal capacity considering operational security. The specified target of 70% of the rated interconnection lines capacity aims at facilitating the implementation of a fully integrated and well functioning European electricity market by enabling increased cross-zonal trade and exchange of electricity. It is recommended that the full compliance with the 70% target in the EnC is achieved by 31 December 2027.

*As concrete actions for improvement in the allocation of cross-border capacities (the so called Net Transfer Capacity – NTC) the increase of regional cooperation by putting in effect the capacity calculation regions and coordinated capacity calculation methodology is recommended, moving from the existing bilateral NTC to coordinated regional NTC calculation, and eventually to power flow based approach.* [34]

Full market integration will increase the absorption capacity of individual power systems, especially regarding the integration of generation from wind power plants. Provided market integration activities within the EnC are undertaken, the grid connection limits will remain the main barrier to deployment of variable RES. For the DG-PV the absorption limits of the DENs will remain the key challenge.[35]

## 4.2 THE IMPACT OF THE CARBON BORDER ADJUSTMENT MECHANISM (CBAM) AND CARBON PRICING ON MARKET INTEGRATION

The Carbon Border Adjustment Mechanism (CBAM),[36] applicable to the WB6 power sector, continues to be promoted by the EU as an incentive for energy sector reform and as means to stimulate new investment. Regarding the import of electricity to the EU, there is a possibility of exempting it from the application of the CBAM if third countries, among other requirements related to climate and energy regulation, meet the criteria for: [37]

a) Integrating within the EU electricity market,
b) Implementing an emissions trading system that is by 2030 compatible with the EU Emissions Trading System (EU ETS).[38]

Therefore, there is a close connection between electricity market integration and the application of the CBAM rules. The idea of a regional equivalent of the EU's ETS has been raised by the Secretariat of the EnC but there are still no concrete details on how to make this a viable option. On the contrary the CEPS Policy Brief [39] proposes to integrate the WB6 fully into the EU ETS, allowing temporary free allocations of carbon allowances. Revenues under this system could be used to initially cover the emissions from existing lignite plants whilst they are still operational and later as collateral for new investments in renewable solutions. Implementation of this proposal could facilitate the scale-up of of DG-PV as well.

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34 EIHP (2023), *Final report on the study on 70% target of electricity interconnection capacities to made available to market participants*, the EnC study. https://www.energy-community.org/documents/studies.html

35 M. Kušljugić (2019). *ENERGETSKA TRANZICIJA U BOSNI I HERCEGOVINI - Analiza barijera i prijedlog mjera za ubrzani razvoj obnovljivih izvora električne energije, Dio II – Tehnički, administrativni i ekonomski aspekti tranziciji.* Nerda REPCONS project.

36 https://taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism_en

37 https://www.energy-community.org/implementation/package/CBAM.html

38 https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets_en

39 Christian Egenhofer (2023), *The solution to phasing-out coal in the Western Balkans*, CEPS policy analysis. https://www.ceps.eu/ceps-publications/the-solution-to-phasing-out-coal-in-the-western-balka sns/

## 4.3 FLEXIBILITY OF THE WB6 POWER SYSTEMS

A fully carbon-neutral power system, based on electrified consumption and on RES generation (mostly wind and solar), will become highly weather-dependent. To manage the resulting complexity and volatility of both generation and demand, while continuing to keep the power system within acceptable levels of adequacy and resilience, a significant amount of flexibility will be required. In a carbon-neutral power system, the nature and volume of flexibility needs and the portfolio of flexibility resources will evolve. The power system will progressively stop relying on the dispatchable generation (TPPs and flexible HPPs) that provide the flexibility and ancillary services today. Timely deployment of multiple resources of carbon-neutral flexibility will be needed, including flexible generation, active demand management, storage, sector integration and flexible grid use.

From a system point of view, flexibility needs can be structured under two main types, each requiring different flexibility resources:

a) *short duration flexibilities* (from milliseconds up to a few hours, to balance the system within the day and ensure frequency regulation and system stability),
b) *long duration flexibilities* (up to several weeks, to compensate for long periods with shortage of wind, solar and hydro generation).

The flexibility requirements for the WB6 power systems have been analyzed in the EnC study.[40] The study assesses the flexibility needs and options to balance each EnC Contracting Parties' power system on different time-scales (daily, weekly and annual) until 2030 and 2040, under different assumptions mainly linked to the speed of renewables uptake and level of market integration. *The study identified that there will be no need for additional investments into flexibility sources until 2030 when variable renewables (wind and solar) might reach 30 GW.* The study also underscored the pivotal role of cross-border inter-connectors and market coupling in providing the flexibility needed to enable higher penetration of variable renewables. Annualized investment needs/costs between 2030 and 2040 into additional flexibility sources will drop by as much as EUR 150 million if organized spot (day-ahead and intra-day) and balancing markets are coupled between the Contracting Parties and with the EU.

Currently, the flexibility in the WB6 power system is provided by coal-fired TPPs (e.g., for the long duration flexibility) and flexible storage HPPs (e.g., for the short and long duration flexibility and frequency regulation). TSOs prefer to organize balancing services for each of the WB6 individual countries on the national level. However, the initial steps have been undertaken by the TSOs in the WB6 to join the EU balancing platforms.[41]

The flexibility capabilities of storage HPPs in the WB region are the best in Europe (superior to the flexibility capabilities of Norwegian and Swiss power systems). Their potential contribution to the flexibility of European power system could be significant. However, deployment of this potential would require a new development paradigm that is different from the concept on which the current National Energy and Climate Plans (NECPs) are developed. In principle, a new paradigm should secure not only decarbonization but also decentralization, democratization and a fair and inclusive energy transition, supported by system digitalization. The building blocks of such a paradigm, inter alia, should include:

a) support for the decentralized energy transition and active participation of the local actors,
b) scale-up of district heating systems based on renewable energy,
c) energy sectors couplings and innovative use of available decentralized thermal (i.e. hot water boilers) and hydraulic (i.e. water supply storage tanks) energy storage capacities,
d) deployment of distributed PV systems with the focus on mitigating energy poverty.

40 Trinomics (2022), *Study on flexibility options to support decarbonization in the Energy Community*, the Energy Community study. https://www.energy-community.org/documents/studies.html

41 https://www.acer.europa.eu/electricity/market-rules/electricity-balancing/balancing-energy-platforms#

# 5. ESTIMATING POTENTIAL FOR CONNECTING LOW VOLTAGE DG-PV

DNOs in the WB6 mainly consider connection of DG-PV, especially LV prosumers, as a technical nuisance and economic threat. They primarily point out to the technical challenges that the connection of DGs imposes on the QoS of the DENs, especially emphasizing potential impact of the resulting overvoltage. The decrease of consumption that is a consequence of proliferation of prosumers is also considered as a threat to the economic well-being of DNOs due to the consequential decrease of the network usage fees.

*Therefore, DNOs in the WB6 are currently the major barrier to development of prosumers and generally estimate very low level of LV-PV capacity that their networks can accommodate.*

This position of the DNOs is based on their perception of technical challenges that might be caused by connecting DGs but not on a strong empirical evidence. At the same time an astonishing level of interest from private investors for the development of commercial PVs, which are planned to be connected both to the transmission and MV distribution networks, is recorded.[42] The "rush" of private investors to construct distributed commercial PV installations put the pressure on the DNOs to "reserve" the network capacity for these DG-PVs, especially on the MV DENs.[43] In almost all of the WB6 the issuance of connection permits to the commercial PV projects is already constrained in certain areas due to the threat of the congestion in the transmission and MV distribution networks. In addition, while evaluating the absorption capacity of MV distribution networks for the connection of these commercial projects, the DNOs ignore the impact on the total LV consumption which the connection of the LV prosumers will induce. This approach might limit the absorption capacity of LV DEN for the connection of LV-PV prosumers. *In short, the DSOs in the WB6 are currently not well prepared to integrate a large amount of energy from LV-PV prosumers.*

The recent trend in development of the commercial distributed PV installations in the WB6, which are mainly planned to be connected to the MV DENs, if not coordinated with the expected deployment of LV-PV, prosumers might cause serious problems in the operation of MV DENs. *In order to prevent such a scenario a dedicated quota for the LV-PV prosumers should be allocated in related strategic development plans*. To initiate a discussion regarding this potential challenge in this policy paper, initial estimation of the Hosting Capacity of LV DENs in each of the WB6 is presented. It is obvious that the proposed values, which are calculated using the data for the whole power systems, are a rough estimate. However, they can be used to start the discussion with the DNOs, relevant government authorities and power sector regulators, regarding allocation of the specified quotas for the LV-PV prosumers.

Since the main objective of this policy paper is to evaluate the absorption capacity of LV distribution grids in the WB6 for the integration of DG-PV, aiming to support and facilitate deployment of prosumers and energy communities, the following "rule-of-thumb" approach is adopted:

a) Data of transmission and distribution grids' capacities in the WB6 (presented in the maps below) are taken as the base for calculation of the HC limits for LV-PV,
b) From Table 1 a conservative criteria for the estimation of the Hosting Capacity of LV-PV (*HC1 in MW), as the maximum 25% of the rated x/0,4 kV/kV transformers' power (in MVA), is calculated (the 25% $S_n$ criteria),*
c) An alternative criteria for the estimation of the LV-PV Hosting Capacity, which is based on the limit the PV electricity generation to *less than the 20% of the total yearly consumption (in GWh) is also calculated (the 20% $W_{total}$ criteria).* The total maximum LV-PV rated power (*HC2 in MW*) is calculated assuming the capacity factor of LV-PV prosumers of 1000 h/year.

42 This "rush" for development of solar PV capacities is primarily motivated by the expected extra profit that was encouraged by the extremely high electricity prices in the region in 2021-2022, which were due to the effects of the energy crisis in Europe.

43 In Gračanica municipality in BiH, the total capacity of commercial PV installations for self-consumption amounts to 5.3 MW while the requests for market-oriented PV installations (with the total capacity of more than 20 MW) substantially exceeds the limit set by the local DNO.

The calculated HC limits are conservative approximations for the national power systems which could be used in the generation and grid expansion planning processes. These data should be verified in consultation with the national DNOs. It is clear that certain distribution areas (i.e. urban, sub-urban and rural areas) will have different HC limits depending on their electrical characteristics. However, the calculated HC values could be used as an initial estimation while planning the deployment of LV-PV prosumers on local, regional and national level.

Based on the data provided in the maps above the Hosting Capacity of the LV networks is calculated for each country applying the selected "rule-of-thumb" approach. The estimated data of the HC limits for LV-PV prosumers are presented in Table 2.

TABLE 2.

## ESTIMATED MINIMUM LV-PV HOSTING CAPACITY IN THE WB6 IN 2022

| Country | TR x/0,4 kV/kV (MVA) | 25% $S_n$ (MW) HC1 criteria | 0,4 kV consumption (GWh) | 20% $W_{total}$ (MW) HC2 criteria | Estimated HC (MW) |
|---|---|---|---|---|---|
| **Albania** | 6.200 | 1.550 | 4.393 | 878 | **870** |
| **BiH** | 6.033 | 1.508 | 7.094 | 1.418 | **1.400** |
| **Kosovo** | 5.399 | 1.200 | 4.278 | 856 | **850** |
| **Montenegro** | 1.805 | 451 | 1.911 | 382 | **380** |
| **N. Macedonia** | 8.966 | 2.240 | 4.288 | 857 | **850** |
| **Serbia** | 16.108 | 4.027 | 19.075 | 3.815 | **3.800** |
| **TOTAL** | **44.511** | **11.127** | **41.039** | **8.200** | **8.150** |

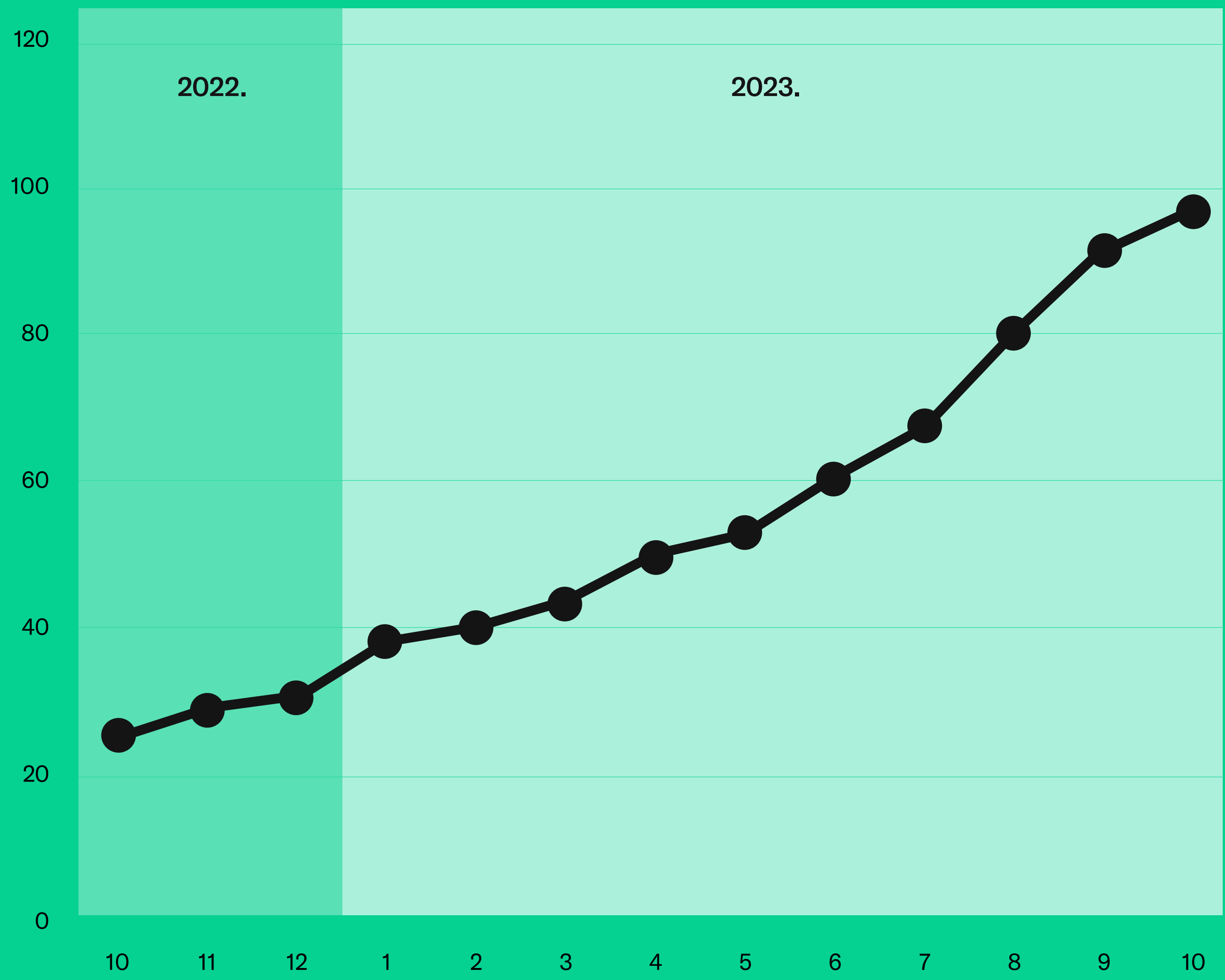
*The estimated data for the HC limits for LV-PV should be evaluated by the national DNOs and based on their findings the campaign to specify the minimum quota (MW capacity) for the LV prosumers in the NECPs will be launched.*

## COMMERCIAL INVESTMENTS – THE DRIVERS OF DEPLOYMENT OF PV IN BIH

BiH is the only country in the WB6 that has not fully implemented the legal framework for prosumers. However, commercial investments (based on the concepts of Virtual Power Plants - VPPs, Feed-in-Tariffs – FiT, and self-consumption) propelled the scale-up of PV capacities.

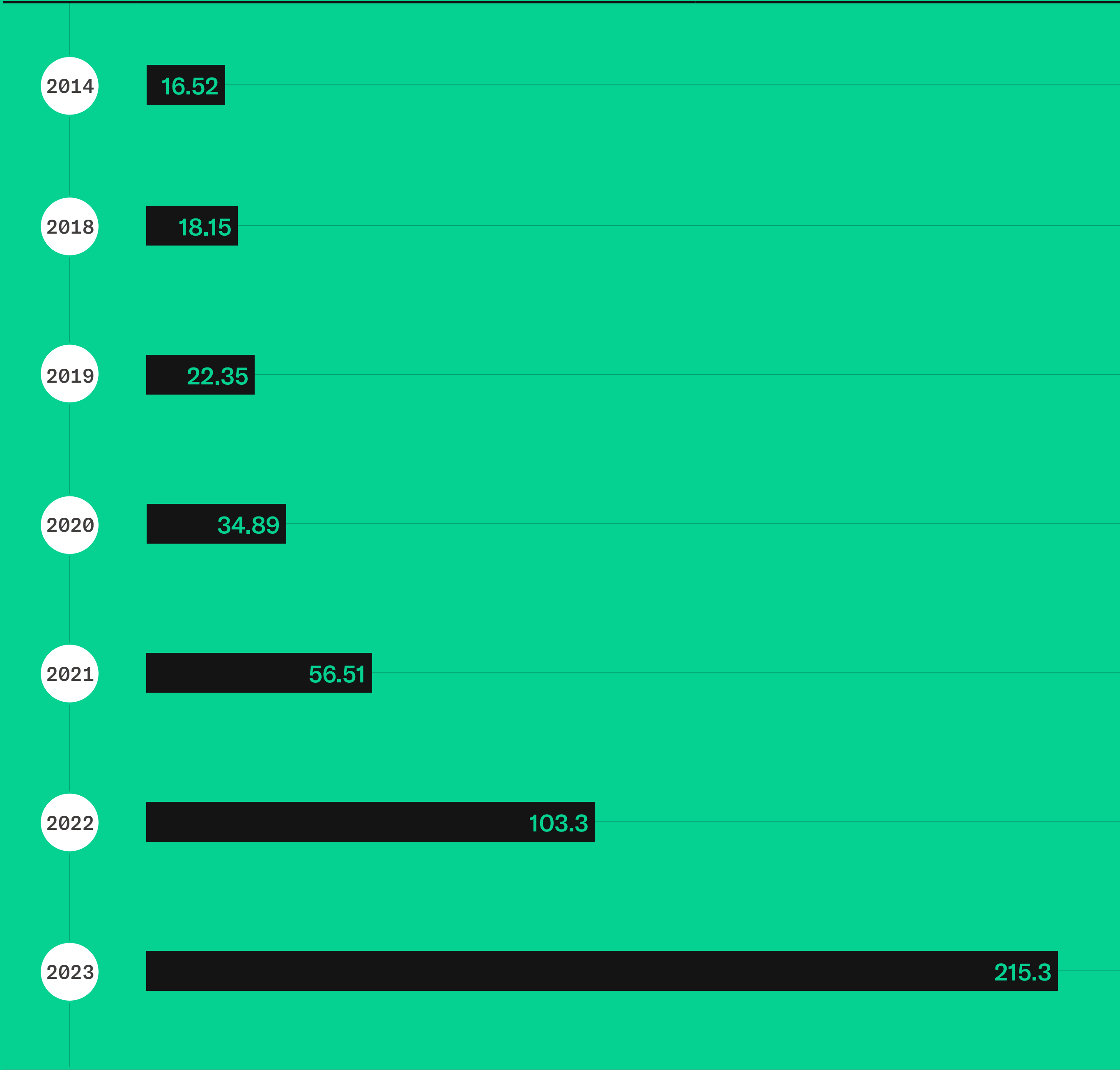
There are currently seven operators of VPPs (aggregators) that are registered in BiH, which in their portfolio aggregate a total of 754 production facilities (solar PV, small hydro power and biogas thermal power plants). *The total power of VPPs in BiH currently amounts to 204 MW, of which 104 MW are small hydro power plants, 97 MW PV solar and 3 MW thermal biogas-fueled power plants.* In the diagram below the increase in the PV capacity aggregated in the VPPs in the last ten months is presented.

### THE INCREASE IN INSTALLATIONS OF SOLAR PV THAT HAVE BEEN AGGREGATED WITHIN THE VPPS IN BIH FOR THE PERIOD OCTOBER 2022 – OCTOBER 2023 (MW).

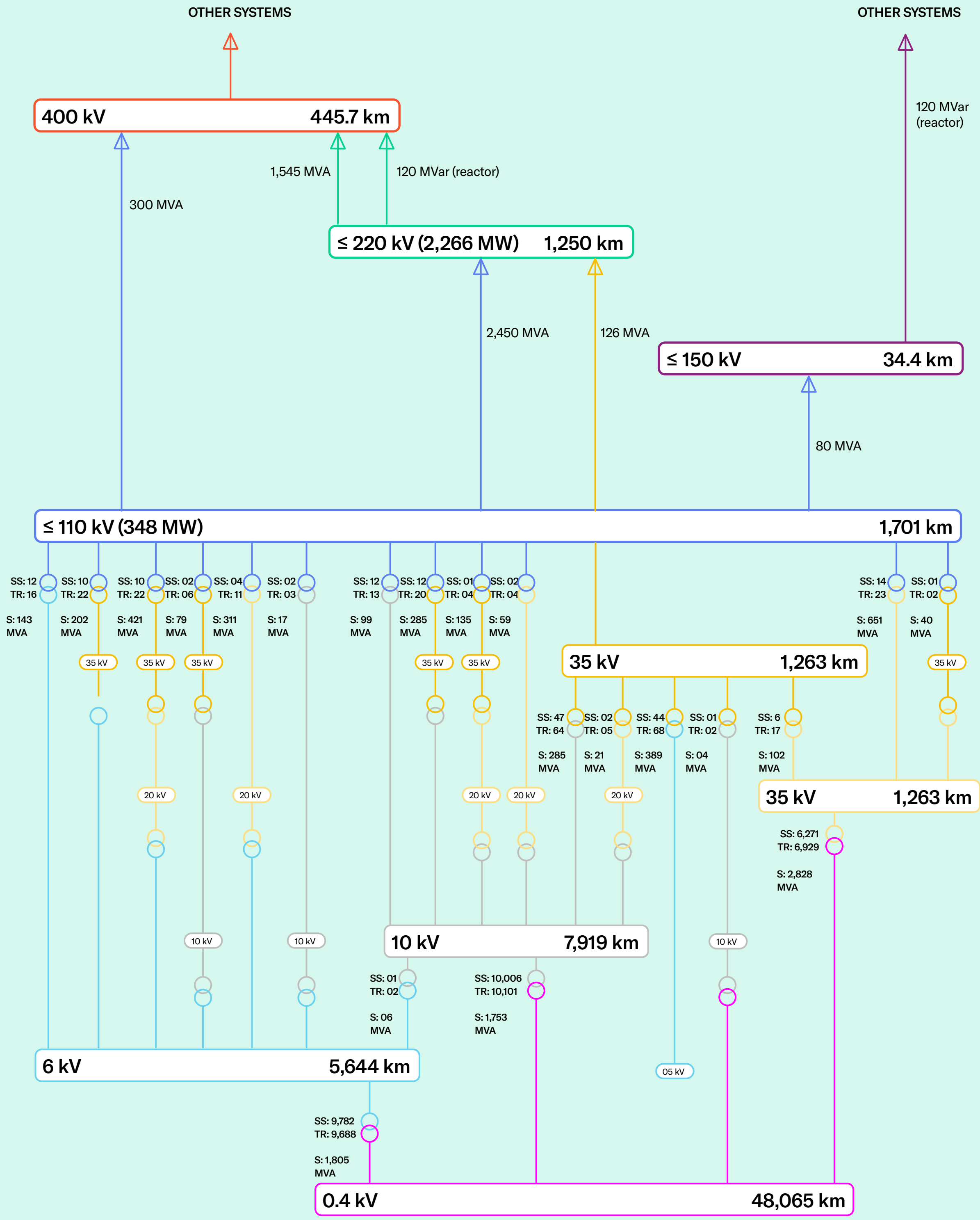


The total installed capacity of solar PV plants in BiH at the end of 2023, presented in the Figure below, is estimated at 215 MW, which is twice as much as in 2022. Significant growth was due to the start of operation in September 2023 of the first utility-scale PV solar power plant (independent power producer “Petnjik”) with an installed capacity of 30 MW (45 MWp), and due to the contribution of a large number of solar PV plants for self-consumption on the rooftops of industrial small and medium-size enterprises (SMEs). The annual output of solar PV power plants is forecast to reach 200 GWh in 2023.

## THE TOTAL INSTALLATIONS OF SOLAR POWER PLANTS IN BIH FOR THE PERIOD 2017-2023 (MW).



# BASIC DATA OF TRANSMISSION AND DISTRIBUTION SYSTEM IN ALBANIA

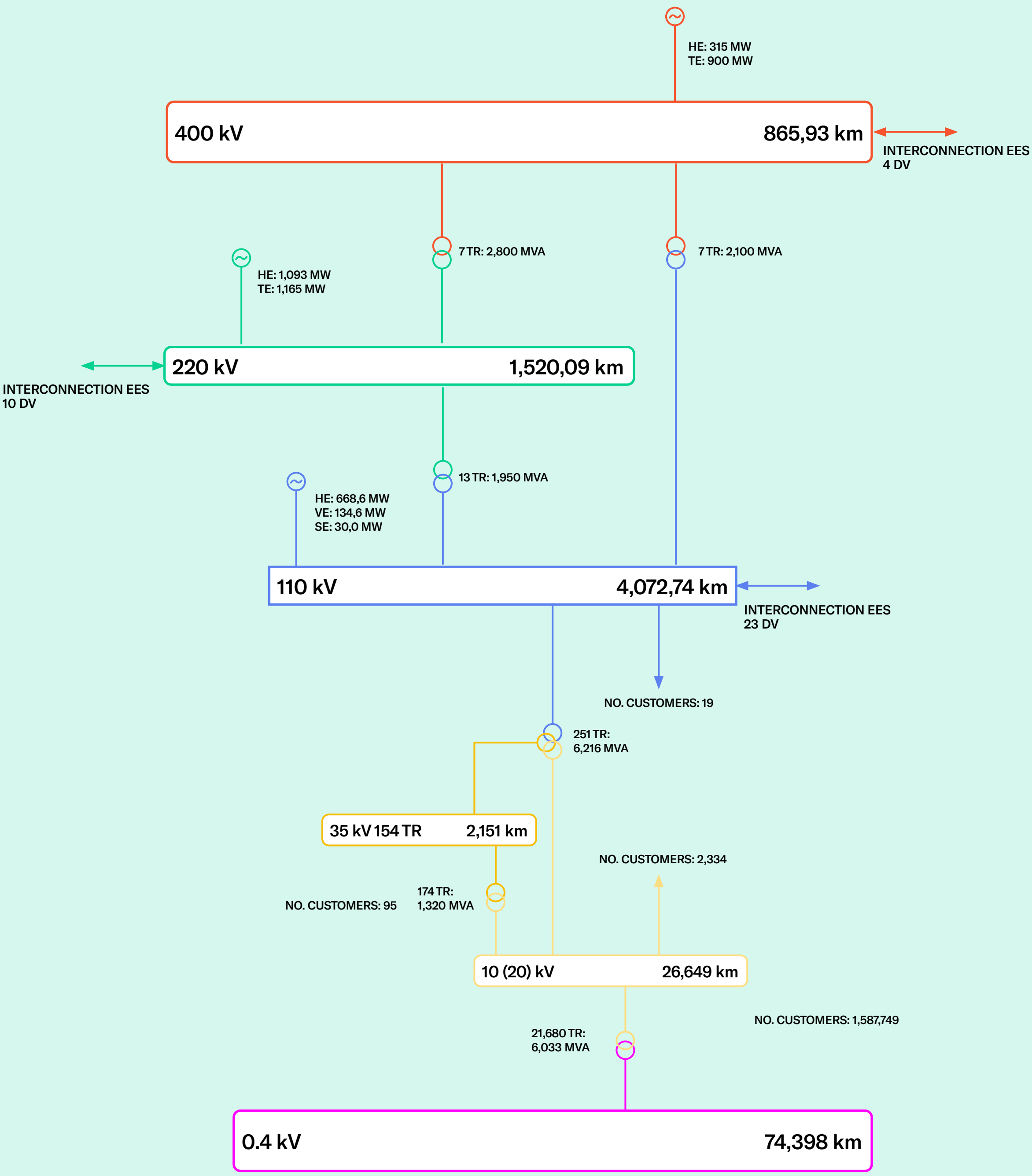



**TSO: 2,266 MW**
(2,168 MW Hydro; 98 MW Thermal)

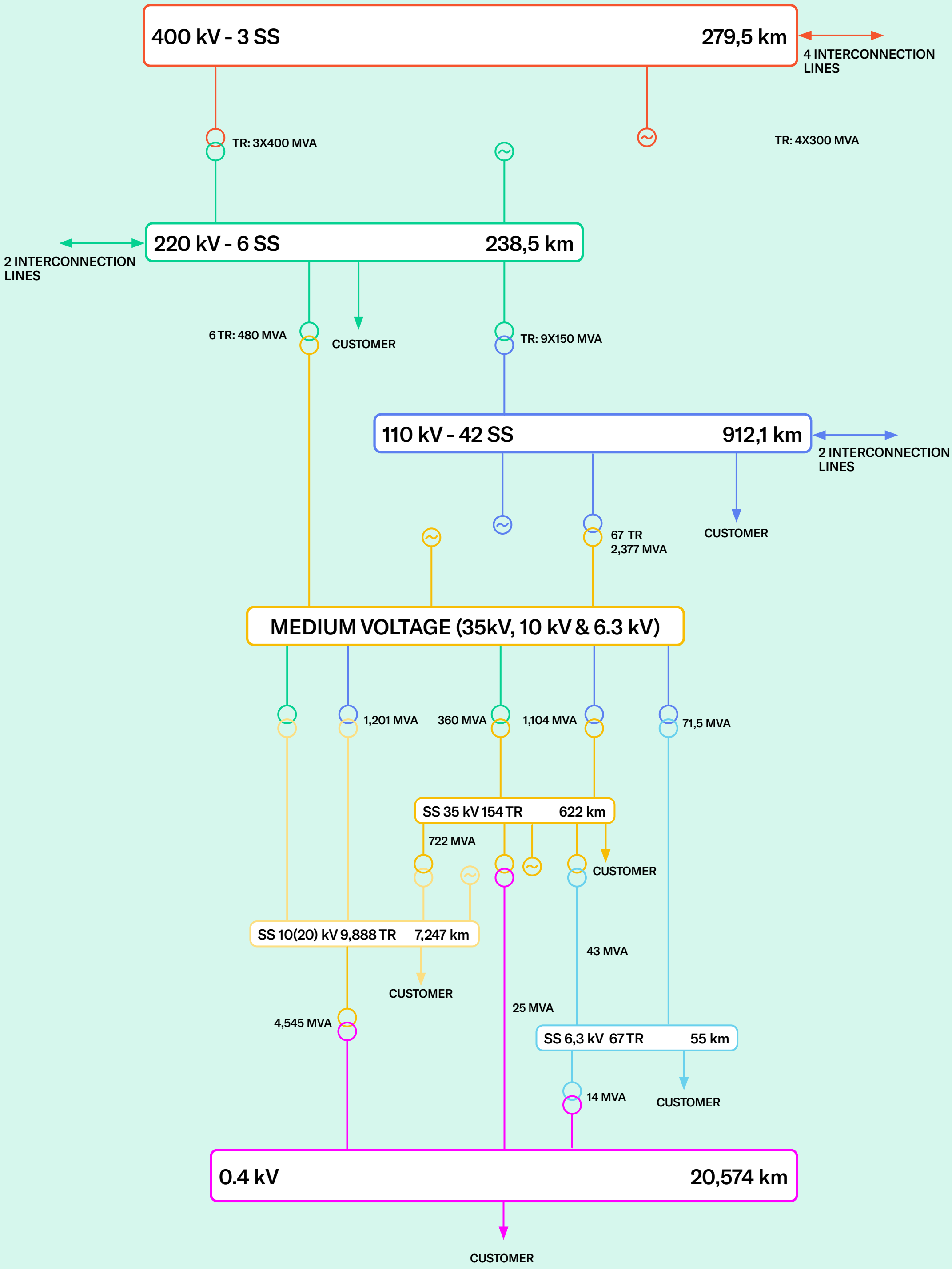
**DSO: 348 MW**
(325 MW Hydro; 23 MW OV)

**Total: 2,614 MW**

# BASIC DATA OF TRANSMISSION AND DISTRIBUTION SYSTEM IN BOSNIA AND HERZEGOVINA



# BASIC DATA OF TRANSMISSION AND DISTRIBUTION SYSTEM IN KOSOVO

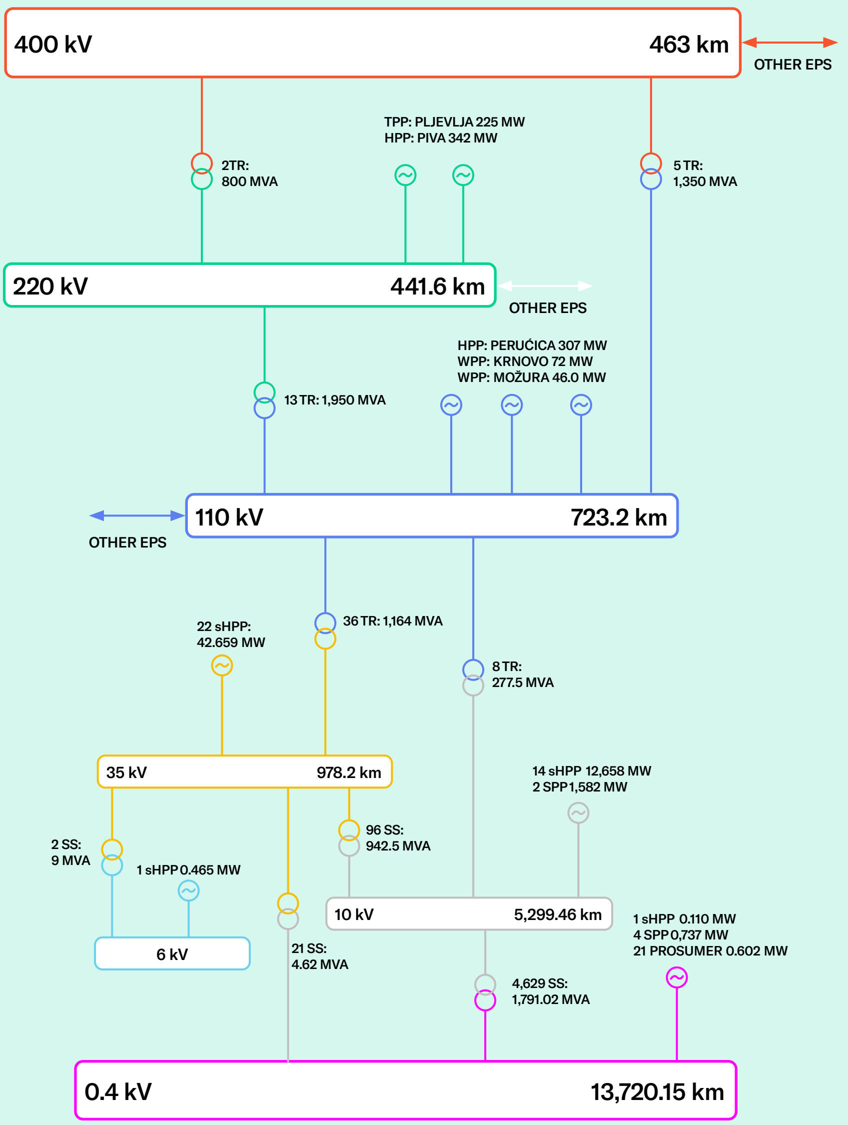



**TSO: 1,175.96 MW**
(960 MW Thermal; 135.81 MW Wind; 80.15 MW Hydro)

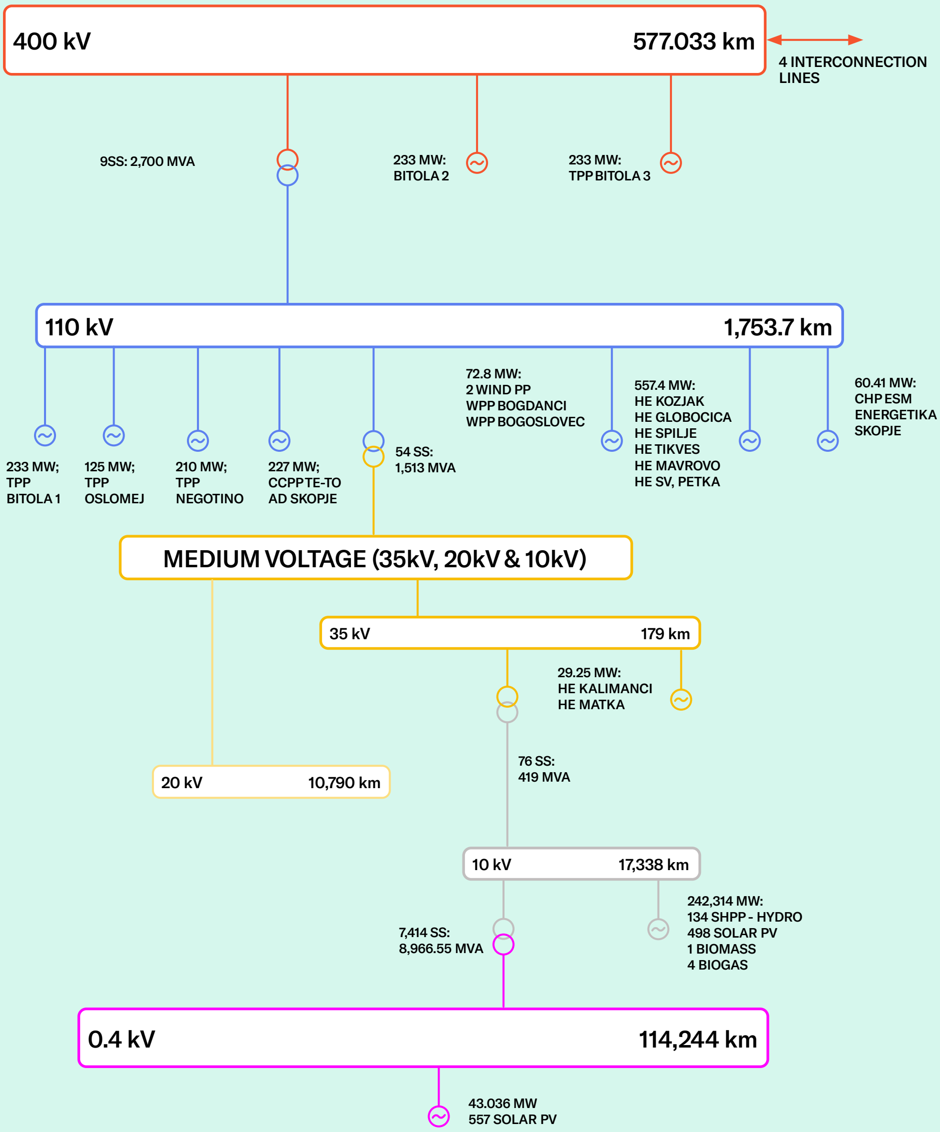
**DSO: 59.67 MW**
(48.22 MW Hydro; 10.1 MW PV; 1.35 MW Wind)

**Total: 1,235.63 MW**

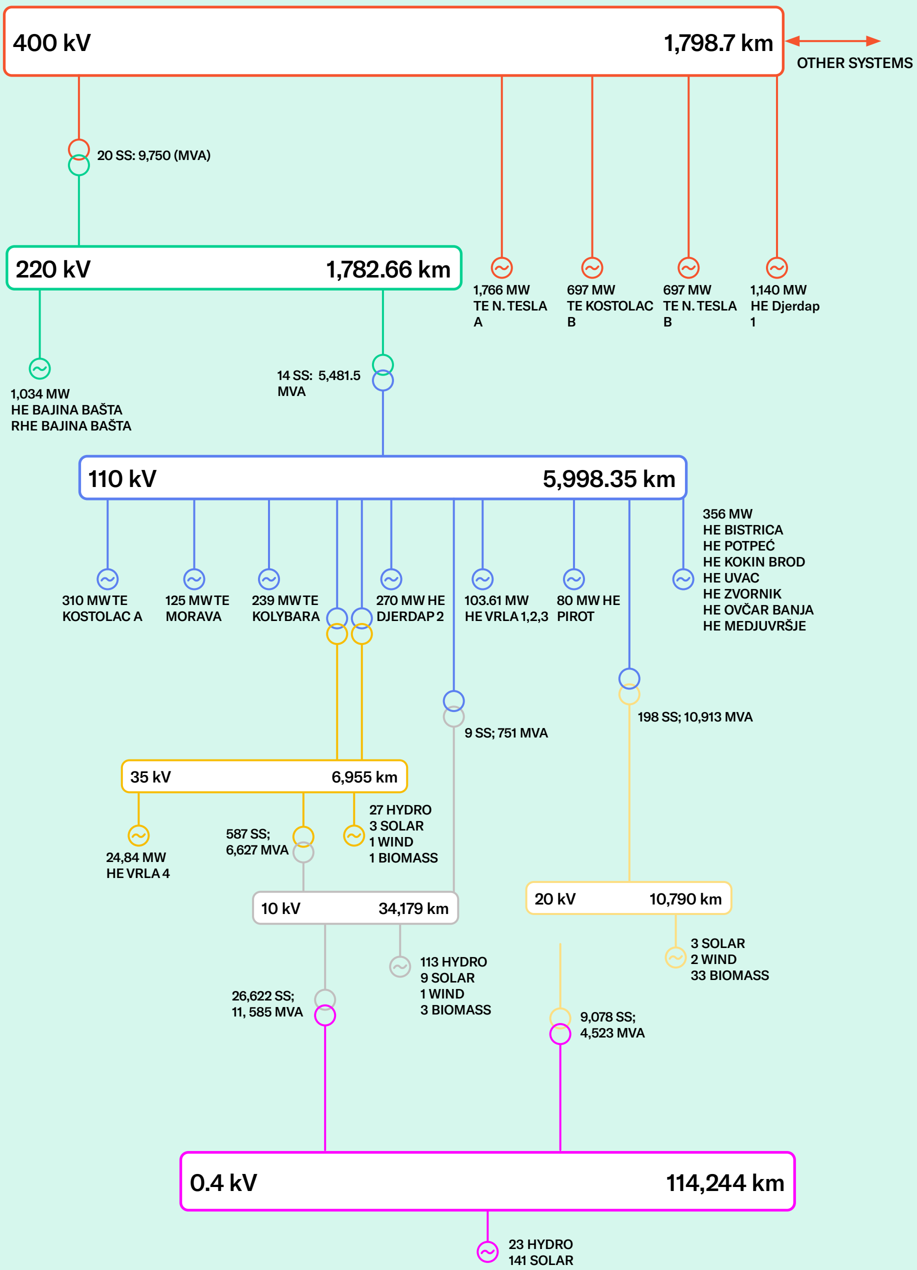
# BASIC DATA OF TRANSMISSION AND DISTRIBUTION SYSTEM IN MONTENEGRO



# BASIC DATA OF TRANSMISSION AND DISTRIBUTION SYSTEM IN NORTH MACEDONIA



# BASIC DATA OF TRANSMISSION AND DISTRIBUTION SYSTEM IN SERBIA



# 6. RECOMMENDATIONS FOR INCREASING CAPACITY OF PROSUMERS IN THE WB6 POWER SYSTEMS

Deployment of prosumers in the WB6 countries has been slow and only in 2022 the first LV-PV prosumers were connected to the network. There are four reasons for this trend:

1. The lack of necessary legal framework enabling smooth deployment of prosumers,
2. Complicated administrative procedures for obtaining necessary permits for the connection of LV-PV,
3. Very low level of electricity prices for the regulated consumers (i.e., households, public institutions and small-sized companies), due to heavy subsidies, which do not provide incentives for consumers to install PV production facilities for self-consumption,
4. Insufficient support measures (i.e., promotional, technical and financial) for the deployment of prosumers.

The situation somewhat improved in the last two years and the number of prosumers in the WB6 has been constantly growing. However, the DNOs still express their concern regarding potential negative technical impact of an uncontrolled expansion of LV-PV prosumer capacity. In order to plan and coordinate an ambitious scale-up of LV-PV prosumers, the following measures and activities are proposed that should mitigate the technical barriers in the distribution grid for the integration of low-voltage DG.

## MEASURES AND ACTIVITIES IN THE PLANNING STAGE

a) Allocate in the NECPs the separate quotas for the LV prosumers (residential, public and commercial). (***responsibility:*** *the national governments*),
b) Prepare the roof-top *PV potential cadastres* and *LV Hosting Capacity maps* on a local and regional level in order to increase the transparency of prosumer deployment. (***responsibility:*** *local governments and DNOs*),
c) Develop local energy transition action plans specifically including measures for the scale-up of PV prosumers and energy communities. (***responsibility:*** *local governments and non-governmental local actors*).

## MEASURES AND ACTIVITIES REGARDING PROSUMER CONNECTION AND DEPLOYMENT SUPPORT

a) Simplify the administrative procedures for the connection of prosumers (i.e., by establishing the electronic approval of the connection requests for prosumers). (***responsibility:*** *national and local governments and DNOs*)
b) Establish the one-stop shops for promoting and counseling citizens and small and medium-sized enterprises for the deployment of PV prosumers. (***responsibility:*** *local governments and DNOs)*

## THE DNO FACILITATES THE DEPLOYMENT OF SOLAR PV PROSUMERS IN SERBIA

Serbian DNO “Elektrodistribucija Srbije - EDS” defined the technical conditions for connection to the distribution network of renewable electricity sources in the Rules on the Operation of the Distribution System (Distribution Code). These rules are uniform for all distributed generators regardless of the technology. In terms of procedure, for each Request for preparation of conditions for connection, checks are carried out in relation to the place of connection, whether these criteria are met. What should be emphasized is that the principle of “first request first served” is applied everywhere. This principle implies that by issuing an opinion on the possibility of connection and accompanying conditions for the first power plant, it further determines the operating conditions in the distribution network that are the conditions for connecting the next power plant in the subject area.

These Rules enable normal operation. But in the disturbed operations of the distribution system, there may be a risk of a blackout, power interruption or damage to the users of the system, as well as a risk to the lives of people participating in its repair. Accordingly, customers, system operators, and producers need “information” that something has happened or that something is happening, i.e. that the normal operation of the system has been disrupted. The key element for identification, in addition to the equipment that serves protection, is the remote measurement system of smart electricity meter. This meter, which, in addition to measuring electrical quantities (i.e. current, voltage, energy, etc.), transmits information through a telecommunication channels for storing and processing. Based on this information, the DNO can take actions to protect the operation of the distribution system and provide the energy producer as well as the customer with clear proof of why an event occurred.

Accordingly, recognizing the benefits of smart meters, “Elektrodistribucija Srbije” has started a strong process of replacing electromechanical meters with the smart meters. These systems are still under development and currently at around 100,000 customers they have been implemented, which compared to approximately 3.7 million customers, is barely 2.7% coverage. The three-year business plan lays the groundwork for reaching the number of around 1,200,000 customers in the next 5 years, which would represent approximately 33% of the total number of customers. Certainly, the plan is to cover all distributed generators as well as all customer-producers (prosumers) within this number. In this way, the conditions for the development of the electricity market at the distribution level would be created. This initiative is supported by the international financial institutions (i.e. the EBRD, the EIB, with the support from the EU and the WBIF). Certainly, these systems would enable safer and more optimal functioning of distribution network with the change of technical regulation (introduction of energy storage possibility, additional switch for remote control, etc.).

In addition to smart meters, in order to ensure the full benefit from distributed generation, as many as economically feasible controllable elements should be deployed in the network. Such a strategic approach enables a quick exit as well as the entry into operation of the DGs. This means that the highest degree of automation, which is the responsibility of the DNO, must be ensured. If the DNO does not recognize the need for this, it may limit the operation of the DGs. The EDS recognized this threat, so with the help of the Government of the Republic of Serbia and the intergovernmental agreement with the Government of the Republic of France, it ensured that in the next 5 years, by acquiring appropriate equipment and accompanying software tools, the system of prevention, planning and automation will be significantly improved, with the aim of reducing network losses, enabling better planning of the distribution network for the greater deployment of DGs and in overall more efficient functioning of all technical functions of the system.

## MEASURES AND ACTIVITIES TO INCREASE THE CAPACITY OF DENS FOR INTEGRATING LV-PVS

a) Encourage and support the use of smart inverters for the PV installations enabling prosumers participation in the reactive power and voltage control, and hybrid inverters that enable the connection of energy storage systems (i.e. battery electric energy storage – BEEs systems), thus facilitating active power and voltage control, and feeders' congestion management operations.
(***responsibility:*** *national and local governments and DNOs*)

b) Develop and implement distribution network modernization and upgrade plans (i.e. the transition from the 10 kV to 20 kV voltage level, the replacement of the current off-load tap-changing (OLTP) transformers with the under-load tap-changing (ULTP) type and the coordination of the operation of ULTC transformers and the local DGs for the voltage control).
(***responsibility:*** *DNOs and power sector regulators*)

c) Increase the number of smart meters and consumers' counseling for adopting an efficient energy management system including PV generation for self-consumption.
(***responsibility:*** *DNOs and electricity suppliers*).

d) Introduce big-data and AI techniques for operation planning and system management to support integration of the distributed energy resources (i.e. prosumers, BESSs, electric vehicle charging stations, etc.). Initially, the subject of load forecasting in a distribution grid with high penetration of DERs, especially of LV-DGs, could be tackled.[44]
(***responsibility:*** *DNOs and electricity suppliers*),

e) Establishing the legal framework for BESS in the DENs (i.e. behind-the-meter and centralized BESSs).
(***responsibility:*** *national governments and power sector regulators*).

## ACTIVITIES TO INITIATE THE EVOLUTION FROM DNOS TO DSOS CONCEPTS

a) Institutional and professional capacity building of DNOs for mastering modern control and digital technologies and business methods in the smart grids concept.
(***responsibility:*** *DNOs*),

b) Digitalization of DENs and development of smart grids solutions (i.e. pilot projects for integration of DERs, smart electric vehicle charging stations, DSM, and BESS based on the micro grids, smart energy communities, and smart cities concepts).
(***responsibility:*** *DNOs, universities and think-tanks).*

44 E. B. Espejo, F.R.S. Sevilla, P. Korba (2023.), "*Monitoring and Control of Electrical Power Systems Using Machine Learning Techniques*", Elsevier.

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