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SUPPORTING CITIZEN ENERGY COMMUNITIES IN THE LIGNITE AREAS VIA A COMBINATION OF PHOTOVOLTAICS AND BATTERY ENERGY STORAGE SYSTEMS

The Green Tank
Λύσεις πολιτικής για ένα βιώσιμο μέλλον

Supporting Citizen Energy Communities in the Lignite Areas Via a Combination of Photovoltaics and Battery Energy Storage Systems

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Introduction

Greece's lignite regions are facing an enormous task: they must fundamentally change their production model, which for decades had been centered on lignite activity. This challenge becomes even greater considering the accelerating decline of lignite production that has been recorded in recent years, which was not even halted by the energy crisis.

Energy communities constitute a very important tool that can both facilitate the energy transition of these regions towards renewable energy sources and mitigate the economic and social challenges caused by the change in the energy model, making the transition more just.

The European Union has recognized that energy communities play a key role in decoupling from fossil fuels, and especially in the short term. The European RePowerEU plan[1], which primarily aims to reduce dependence on fossil gas, provides for **the establishment of at least one energy community based on renewable energy sources in every municipality with a population of more than 10,000 inhabitants by 2025.**

In this context, the Greek Ministry of Environment and Energy has announced that **€100 million will be dispersed from the Recovery Fund to local authorities (with investment cost subsidies) for the establishment of Energy Communities to meet the electricity needs of vulnerable households** in their areas of responsibility[2]. Another plan, which is still at an early stage, aims to support mountainous communities in the context of a wider **Strategic Mountainous Regions Plan[3]**. Based on preliminary planning, 48.4 MW of photovoltaics (PV) could be installed initially, so as to meet the needs of the residential sector in selected mountainous communities via virtual net metering. Meeting household needs forms part of a wider €100 million support plan for mountainous areas, which aims to install a total of 142.6 MW of photovoltaics in mountainous communities.

Particularly with regard to the lignite regions, the provision of funding for energy community self-production projects that is included in the **€1.63 billion Just Development Transition Program (PDAM) 2021-2027**[4] is very encouraging. This program is based on European funds and is intended to transform the production model of the country's regions under transition. In fact, the PDAM's Monitoring Committee recently decided to allocate 26.845 million euros to the development of self-production projects by energy communities of lignite municipalities.[5]. These projects could also be supported by the **national Green Fund resources derived from the auctioning of greenhouse gas emission allowances and channeled to Greece's lignite areas**. In the first five years of this measure, 127.6 million euros[6] have been raised to support the

[1] European Commission, 18.05.2022. REPowerEU: A plan to rapidly reduce dependence on Russian fossil fuels and fast forward the green transition https://bit.ly/44vYxq7
[2] Central Union of Greece's Municipalities (KEDE), 24.04.2023. €100 million to fund municipal energy communities https://bit.ly/45eeH7U
[3] Tratsa, M. 21.02.2023. Greece's countryside: Strategic plan with incentives for 2,158 mountainous villages https://bit.ly/3YFqidS
[4] Special Service for Just Development Transition (EYDAM); Just Development Transition Program 2021-2027 https://bit.ly/46VoIbG
[5] The Green Tank, 07.08.2023. YES but with asterisks by the Green Tank to the plans of supporting energy communities and installing heat pumps in transition regions https://rb.gy/9ta3j
[6] The Green Tank, 04.05.2023. National Resources for the Just Transition, Policy text, https://rb.gy/b9519

transition of lignite areas; however, so far, only €3 million of these resources have been allocated to the support of energy community projects.

What is even more encouraging is that the citizens of the lignite areas themselves -especially in Kozani and Florina- have already shown great interest in employing the institution of energy communities to produce and sell electricity to the grid, as well as for self-production in order to meet their own needs. As the official data of the General Commercial Registry (GEMI) showed in November 2022 (publicly available until then), Western Macedonia ranked second nationwide with regard to the number of energy communities (261) - behind Central Macedonia (263)[7]. At the same time, an increase is observed in the number of requests for self-production projects by energy communities that are rejected by the Hellenic Electricity Distribution Network Operator (HEDNO) due to inability to connect to the grid.

Thus, the great opportunity for energy community development in Greece's lignite areas risks to be missed, despite citizen interest and the existence of significant funds available for such projects.

In this context, this report examines the potential of meeting the electricity needs of residential consumers living in lignite areas under transition through energy communities, which shall develop photovoltaic power stations, possibly in combination with energy storage systems and demand response measures.

First, Greece's new institutional landscape regarding energy communities (Law 5037/2023) is examined; the new framework partially modifies what was previously in force with regard to virtual net-metering, while providing additional options to consumers by introducing the measure of virtual net-billing.

The current situation with regard to Energy Communities initiatives in selected regions is presented next (our analysis focused on twelve (12) Greek municipalities, eligible to receive funding from the Just Transition Fund, namely: **Kozani, Voio, Eordaia, Servia, Velventos, Florina, Amyntaio, Prespes, Megalopoli, Oichalia, Gortynia, and Tripoli**). Subsequently, a map of the current demand of the residential sector in the lignite areas under consideration is displayed, along with a realistic forecast of future demand, in order to estimate the required photovoltaic capacity.

Given that, presently, the lack of grid space constitutes the biggest obstacle for RES development in Greece, the current availability of electrical space in the areas under consideration is recorded next, so as to identify gaps and plan the expansion of the necessary networks. Moreover, in order to better manage the existing grid, the possibility of adding storage systems to the proposed photovoltaic stations is also considered; this solution would create a time shift of the electricity fed into the grid OR enable load shifting, thus, mitigating the problems caused by grid congestion. Also listed are the different connection priority criteria of energy community stations in lignite areas, based on the relevant legislation.

[7] The Green Tank, 26.01.2023 Energy communities in Greece's lignite areas, Review #3, https://rb.gy/babqo

Furthermore, the required investment costs of the aforementioned projects are estimated and possible sources of funding (NSRF, Regional Operational Program (ROP), Just Transition Fund, Recovery and Resilience Fund, Green Fund, etc.) are examined. Finally, an assessment of the resulting benefits (economic, environmental, social) is also provided.

The report concludes with a number of recommendations to the State, which would enable this project to be implemented quickly and on a large scale.

A new institutional landscape for energy communities

Through Law 5037/2023[8], two important European Union Directives were incorporated into the national regulatory framework (2018/2001[9] on Renewable Energy Sources, which established, inter alia, Renewable Energy Communities; and 2019/944[10] on Electricity Markets, which established Citizen Energy Communities). At the same time, the existing Energy Communities under Law 4513/2018[11] will continue to operate.

As of 1/4/2023, new energy communities can no longer be established under the old regime of Law 4513/2018. Energy Communities under Law 4513/2018 may be transformed into Renewable Energy Communities (RECs) or Citizen Energy Communities (CECs). As of 1/11/2023, Energy Communities under Law 4513/2018 are not allowed to submit new requests for a Producer's Certificate or for a Final Connection Offer in case of Exempted Stations. Moreover, from 1/11/2023 onward, Energy Communities under Law No. 4513/2018 are not allowed to submit new requests to the competent Operator for stations implementing virtual net-metering; such requests may only be submitted by Renewable Energy Communities and Citizen Energy Communities.

According to article 64 of Law 5037/2023, the installation of RES and CHP stations and storage systems aimed at meeting own needs, through the **implementation of virtual net metering**, is permitted to Renewable Energy Communities, Citizen Energy Communities and Energy Communities under Law 4513 /2018 for meeting the electricity needs of members who are **exclusively** residential consumers, farmers registered in the Register of Farmers and Agricultural Holdings of Law 3874/2010, or for meeting the electricity needs of citizens living below the poverty line and households affected by energy poverty, as well as for meeting the energy needs of regional and local authorities.

At the same time, Article 121 of Law 5043/2023[12] offered the possibility to owners of RES power stations who have received a production license or a producer's certificate or of exempted stations that have received or are receiving a final connection offer, to convert the above licenses

[8] Law No. 5037 GG A 78/29.3.2023 https://bit.ly/47FYs5t
[9] DIRECTIVE (EU) 2018/2001 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018 on the promotion of the use of energy from renewable sources (recast)) https://rb.gy/jvj2a
[10] DIRECTIVE (EU) 2019/944 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (recast) https://rb.gy/vqlia
[11] Law No. 4513 GG A 9/23.01.2018 https://bit.ly/3P36i1N
[12] Law No. 5043 GG A 91/13-04-2023 https://bit.ly/3P4M2wM

or the Final Connection Offer, so that they can operate as self-production stations or as stations under article 14A of Law 3468/2006, namely, as stations implementing virtual net metering. This regulation allows Energy Communities under Law 4513/2018 that initially aimed at selling the electricity produced to switch to self-consumption, while enabling new energy communities to acquire private projects with a Final Connection Offer to achieve their objectives, bypassing a major obstacle that is finding electrical space.

An X-ray of energy communities in the lignite regions

Based on the latest published data of the HEDNO (August 2023) and the Independent Power Transmission Operator (ADMIE) (April 2023), the following active requests for energy communities projects (projects intended for **the sale of the electricity produced**) are recorded in the lignite areas under consideration (municipalities of Kozani, Voio, Eordaia, Servia, Velventos, Florina, Amyntaio, Prespes, Megalopoli, Oichalia, Gortynia, and Tripoli):

Table 1: Active requests for commercial energy community projects

Area	Number of active requests excluding already interconnected projects	Total photovoltaic capacity (MWp)
Regional Unit of Kozani	295	247.6
Regional Unit of Florina	193	152.9
Municipalities of the Peloponnese included in the sample	3	1.1
TOTAL	**491**	**428.6**

The HEDNO is unable to connect a large percentage of the above active requests (75% in Western Macedonia and 66.7% in the Peloponnese). The analysis of the data presented on HEDNO's website[13] indicate the number of requests that can go forward immediately, without having to wait for infrastructure upgrades in order to obtain future terms of connection and proceed; these are presented in Table 2. It is noted that, in the event of inability to connect, the legislation allows the request to remain pending for a period of five years.

Table 2: Active requests for commercial projects not requiring infrastructure upgrades

Area	Number of active requests excluding already interconnected projects and those unable to obtain connection	Total photovoltaic capacity (MWp)
Regional Unit of Kozani	53	42.4

[13] HEDNO, RES station capacity absorption potential by geographical area in the Interconnected Grid https://bit.ly/3E0dBRd

Regional Unit of Florina	69	52.1
Municipalities of the Peloponnese included in the sample	1	0.5
TOTAL	**123**	**95**

Regarding the energy communities that have applied for terms of connection to implement **virtual net metering**, Tables 3 and 4 below show the respective situation up until August 2023.

Table 3: Active requests for virtual net metering projects by energy communities

Area	Number of active requests	Total photovoltaic capacity (MWp)
Regional Unit of Kozani	29	18.9
Regional Unit of Florina	1	1
Municipalities of the Peloponnese included in the sample	21	6
TOTAL	**51**	**25.9**

Table 4: Active requests for virtual net metering projects not requiring infrastructure upgrades

Area	Number of active requests excluding already interconnected projects and those unable to obtain connection	Total photovoltaic capacity (MWp)
Regional Unit of Kozani	11	7
Regional Unit of Florina	0	0
Municipalities of the Peloponnese included in the sample	20	5
TOTAL	**31**	**12**

Record of current and future electricity demand from residential consumers in the lignite areas

Data provided to the Green Tank by HEDNO was used to record the residential sector's electricity demand. Estimates for 2030 were formulated by the HEDNO, based on the 2019 National Energy and Climate Plan (NECP) (which is currently under revision), taking into account, inter alia, the penetration of electric vehicles and heat pumps, as projected by the NECP[14,15]. Population data refer to the last census conducted by the Hellenic Statistical Authority (ELSTAT) in 2021. The figures below illustrate the general trends of total electricity consumption in the examined

[14] Grid Development Plan (SAD) by the Hellenic Electricity Distribution Network Operator (HEDNO) for the period 2022-2026 https://bit.ly/3OkclP6

[15] The 4 scenarios studied were: [1] Electromobility according to the NECP's forward-bearing scenario; [2] Electromobility according to an increased vehicle penetration scenario; [3] as in scenario 1 with high capacity requests; [4] as in scenario 2 with high capacity requests

Regions of Western Macedonia and the Peloponnese, based on the four scenarios studied by the HEDNO. The residential sector consumption for 2030 was estimated based on these trends.

Table 5: Consumption and consumption forecast regarding the residential sector in the examined areas

Area	Population 2021	Average annual consumption in the residential sector 2020-2022(MWh)	Forecast of consumption in the residential sector in 2030 (MWh)
Regional Unit of Kozani	137,343	188,044	226,500-255,000
Regional Unit of Florina	44,880	59,242	71,000-80,000
Municipalities of the Peloponnese included in the sample	62,629	107,294	118,000-123,400
TOTAL	**244,852**	**355,380**	**415,500-458,400**

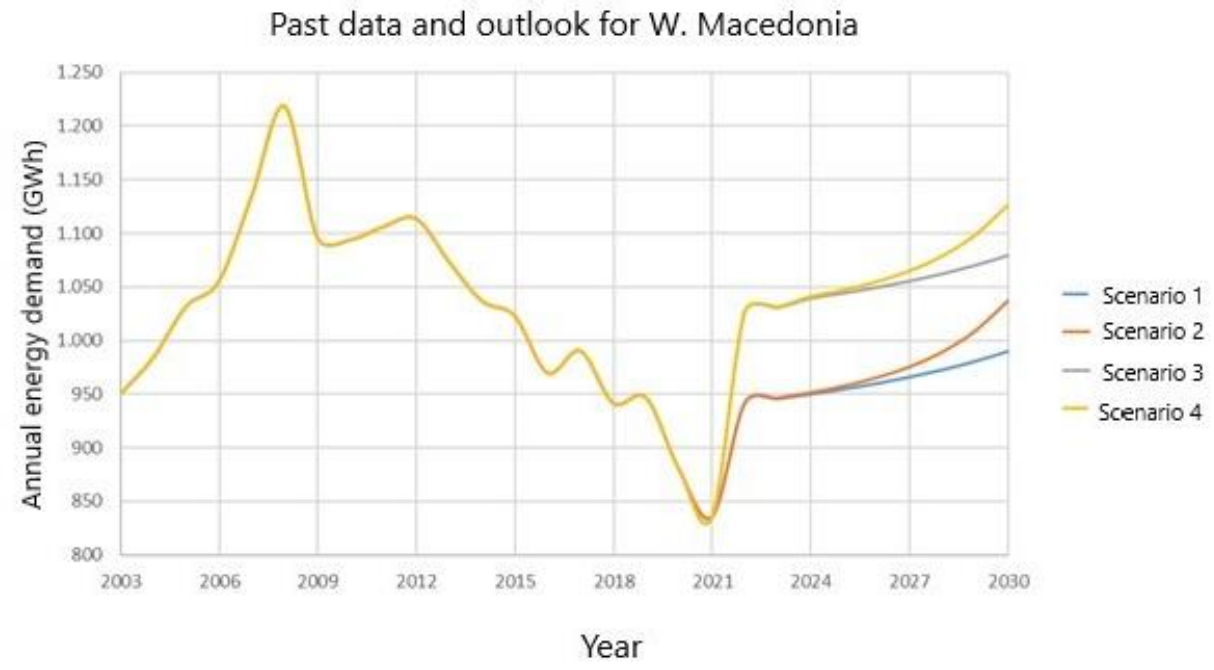


Figure 1: Historical data -up to 2021- on electricity consumption and consumption forecast until 2030, based on the four scenarios examined by the HEDNO for the Region of Western Macedonia.

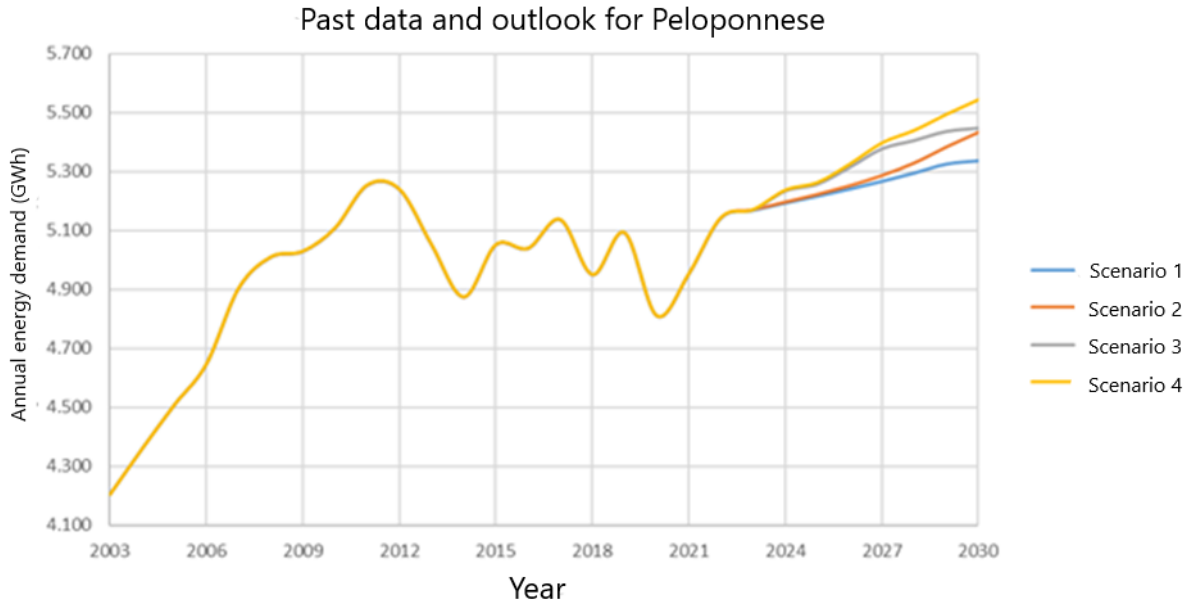


Figure 2: Historical data -up to 2021- on electricity consumption and consumption forecast until 2030, based on the four scenarios examined by the HEDNO for the Region of the Peloponnese.

Estimation of the necessary capacity of photovoltaic stations

Based on the above estimates of electricity consumption, and assuming the average annual energy yield of new photovoltaic stations to be 1,500 kWh/kWp for the region of Western Macedonia and 1,600 kWh/kWp for the Peloponnese, the necessary capacity of photovoltaic stations in order to meet the electricity needs of residential consumers in Greece's lignite regional units was obtained, as follows.

Table 6: Forecasts of the photovoltaic capacity that is necessary to meet the residential sector's electricity demand

Area	Necessary photovoltaic capacity based on the average residential sector consumption 2020-2022 (MWp)	Necessary photovoltaic capacity based on the forecast of residential sector consumption for 2030 (MWp)
Regional Unit of Kozani	126	151-170
Regional Unit of Florina	39.5	47-53
Municipalities of the Peloponnese included in the sample	67	74-77
TOTAL	**232.5**	**272-300**

In other words, and based on the data of the 2021 census, fully meeting the future needs of the residential sector in these regions will require the installation of 1.11-1.23 kWp of photovoltaics per inhabitant.

The current carrying capacity of the grid

At present, the lack of grid space constitutes the principal obstacle for RES development. On its website, the HEDNO publishes details of the current availability of electrical space[13], noting the following:

- The power absorption margins shall be calculated on the basis of the nominal capacity of each high-to-medium voltage transformer (available margin against the thermal limit) and the total capacity of production units to contribute to the short-circuit capacity of the corresponding medium voltage yoke (available margin against design capacity). Any constraints resulting from the operation of the Transmission System shall not be taken into account.

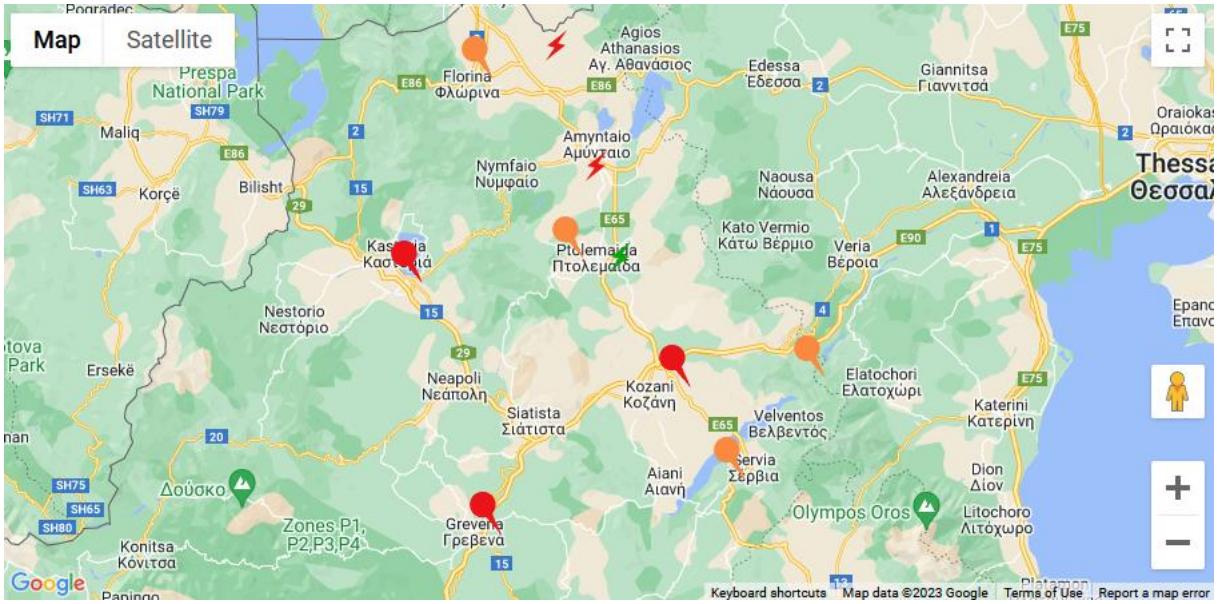
- The power absorption margins are obtained by taking into account the stations that commit power to the grid, namely, all stations in operation, stations with a connection contract and stations with a final connection offer in force.

- Requests for which a non-binding connection offer has been issued and those that are currently being processed shall not be taken into account.

- The margins are given per substation and high-to-medium voltage transformer and are color-coded according to their size.

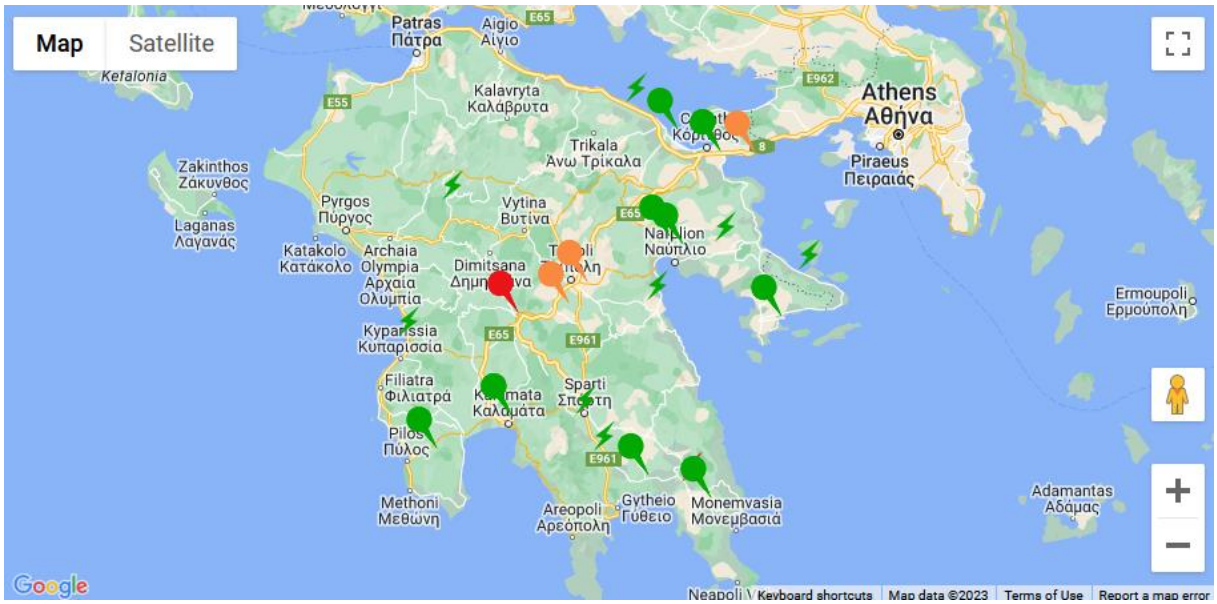
- The existence of a power margin at the level of a substation or a high-to-medium-voltage transformer does not imply that it is possible to connect production capacity to every medium-voltage line leaving it, as other technical constraints may apply.

- The data are updated on a daily basis, by extracting the data from the computerized application developed by the Network Operator for the management of requests for connection of RES and CHP stations.



Availability Limited Availability No availability

Map 1: Grid availability in HEDNO's substations in the areas of Western Macedonia under consideration (21/8/2023)



Availability Limited Availability No Availability

Map 2: Grid availability in HEDNO's substations in the areas of the Peloponnese under consideration (21/8/2023)

The table below presents the margins of the substations in the areas under consideration (data obtained on 21/8/2023). These margins do not include the projects included in Tables 2 and 4 that have already been offered terms of connection.

Table 7: High/medium voltage substations' margins

HV/MV Substation	Transformer name	Thermal Limit (MVA)	Short-circuit Margin (MVA)	Available Margin (MVA)
KOZANI	TF1	9.4	0	0
	TF2	0	0	0
EHVC OF AMYNTAIO	TF1	21.1	0	0
EHVC OF MELITI	TF1	0	111.5	0
POLYFYTOS	TF1	10.9	0	0
	TF2	21.3	15.3	15.3
PTOLEMAIDA I (D1)	TF1	4	137	4
PTOLEMAIDA II	TF2	0	108.1	0
	TF3	2.5	116.5	2.5
SERVIA	TF1	0	107	0

	TF2	0	110.7	0
FLORINA	TF1	0	109.8	0
	TF2	5.8	118.4	5.8
WESTERN MACEDONIA				**27.6**
ASTROS	TF1	34.7	23.7	23.7
DORIZAS I	TF1	3	24.9	3
	TF2	18.8	0	0
LADONAS	TF1	5.3	69.9	5.3
MEGALOPOLI	TF1	31.1	0	0
	TF2	35	0	0
SPARTI II	TF1- TF2	19.5	26.5	19.5
TRIPOLI	TF1	24.6	26.3	24.6
	TF2	18.6	0	0
RU OF ARCADIA				**76.1**

Priority in the provision of terms of connection

Two ministerial decisions[16,17] have established a priority framework for the granting of final Connection Offers for RES, CHP, and storage stations by the Network Operator (HEDNO) and the System Operator (Independent Power Transmission Operator, IPTO).

As far as the System Operator is concerned, the areas under consideration and energy community projects are classified under Subgroups C1 and C2, according to the following:

Subgroup C1: Exempted Stations for which joint requests for granting a final connection offer have been submitted until 10.12.2022 exclusively by Energy Communities under Law 4513/2018 which include regional and local authorities as members. The maximum capacity limit of connection offers for this subgroup has been set at 200 MW, with a maximum limit of 50 MW per Regional Unit.

Subgroup C2: Exempted Stations to be established exclusively within the Regional Units of Kozani and Florina, for which joint requests for granting a final connection offer have been submitted until 10.12.2022 and which belong exclusively to Energy Communities under Law 4513/2018[11] with a joint request total capacity greater than or equal to 100 MW. The maximum capacity limit for connection offers for this subgroup has been set at 400 MW.

With regard to the Network Operator, the priorities are set out as follows:

Group B: Electricity production stations belonging to energy communities implementing virtual net metering, in accordance with article 11 of Law 4513/2018[11].

[16] Ministerial Decision. ΥΠΕΝ/ΓΔΕ/84014/7123, GG 4333 B/12.8.2022 https://bit.ly/44fs5r9
[17] Ministerial Decision ΥΠΕΝ/ΔΑΠΕΕΚ/7063/374, GG 275 B/20.1.2023 https://shorturl.at/ajRW1

Group C: Wind and photovoltaic stations belonging to energy communities, which in their statutes explicitly state that they do not distribute surpluses to their members, in accordance with paragraph 2 of article 6 of Law 4513/2018[11] or to energy communities which include regional or local authorities as members or to energy communities with more than 60 members, of which at least 50 are natural persons.

The above categories refer primarily to energy communities aiming to sell the electricity produced; however, the provision of article 121 of Law 5043/2023[12], mentioned above, allows owners of RES power stations who have received a production license or a producer's certificate or of exempted stations that have received or are receiving a final connection offer to convert the above licenses or the Final Connection Offer, so that they can operate as self-production stations or as stations under Article 14A of Law 3468/2006[18], namely, as stations implementing virtual net metering. This regulation enables Energy Communities under Law 4513/2018[11] that initially aimed to sell the electricity produced to switch to self-consumption.

Seeking solutions for the grid

Given the vast number of pending connection requests by investors of various categories, securing grid space for energy communities, which could accommodate residential consumers through virtual net metering, is evidently at stake. The data presented above point to issues regarding both the thermal limits of the lines and the so-called short-circuit capacity of the medium voltage distribution network (in the areas of Kozani, Amyntaio and Megalopolis). Solutions should, therefore, include a series of measures to reinforce the grid and optimize its use.

The grid obviously needs to be expanded and reinforced, which objectively takes time and resources; nonetheless, there are other indirect ways of making use of the existing infrastructure.

In accordance with article 10, par. 5 of Law 4951/2022[19], a decision of the Minister of Environment and Energy -upon the recommendation of the competent Operators and the opinion of the Regulatory Authority for Energy (RAE)- specifies and quantifies **the restrictions on injection** from RES stations of par. 2 and 13 of Article 10 and regulates all other necessary details. The purpose of this regulation is *'the optimal utilization of the System and Grid infrastructure and the maximization of the potential for power absorption from RES stations'*.

Exempted from these restrictions are RES stations that operate or have submitted by 31 December 2022 a statement of readiness under article 4a of Law 4414/2016[20] (A 149) or have been selected before Law 4951/2022[19] came into force to be included in an operational support scheme through a competitive tendering procedure under article 7 of Law 4414/2016 or are exempted from the competitive tendering procedures of article 7 of Law 4414/2016, and when the law came into force (4/7/2022) have either concluded a connection contract or submitted a complete request for a connection contract to the competent Operator.

[18] Law No. 3468 GG A 129/27.6.2006 https://shorturl.at/ahirz
[19] Law No. 4951 GG A 129/4.7.2022 https://shorturl.at/tvNTW
[20] Law No. 4414 GG A 149/09.08.2016 https://t.ly/aUTAA

With regard to photovoltaic power stations, the Operators proposed the application of a permanent restriction of the maximum production capacity of the station in relation to the installed capacity of its units, in line with sub-clause A of par. 2 of Article 10 of Law 4951/2022. In this case, and in order not to impose a reduction of a station's maximum production capacity that would restrict the power injected by more than 5% of the annual electricity production capacity of a reference station of the corresponding technology (paragraph 3 of article 10), the Operators estimated the maximum production capacity limit at 72%-73% of the nominal installed capacity (hence, cuts of 27% and 28%, respectively, for projects connected to Medium and High Voltage)[21].

This restriction **potentially creates additional electrical space, which could be allocated to new projects**; in other words, the purpose of the legislative regulation is achieved, namely optimizing the use of the System and Grid infrastructure and maximizing the possibility of absorbing electricity from RES stations.

At national level, this 'new' electrical space (at medium voltage level) amounts to a few hundred MW, a fraction of which concerns the areas under consideration. **However, the legislation should ensure that self-consumption and energy community projects implementing virtual net metering are given priority with regard to the allocation of this newly available electrical space.**

At the level of medium voltage (MV) networks, the short-circuit margin represents one of the principal constraints limiting the possibility to accommodate dispersed sources, often maintaining it far below the level that other constraints (for instance, capacity of network elements and voltage regulation) would allow.

The HEDNO has considered **potential solutions** in order to upgrade the grid's margin that could host RES capacity if not restricted by short-circuit capacity. These solutions are primarily the following:

- **Increasing equipment impedance** (mainly regarding HV/MV transformers) in order to increase the available short-circuit margin, which can be covered by the contribution of units connected to the grid. The use of transformers with increased short-circuit voltage constitutes an easy and obvious solution; nonetheless, this approach is not necessarily the best practice, as it leads to weaker networks, which, in turn, are more susceptible to voltage quality disturbances, while it also implies increased transformer costs. Therefore, this solution should represent a last resort, if no other way of increasing the margin is feasible.

- **Installing fault current limiting (FCL) devices**, either in the upstream network or in sources connected to it. Such devices are commercially available and used in some cases, but their integration in the Greek distribution network would require study and careful assessment of a number of parameters -technical, economic, and operational- as well as a pilot implementation before being adopted as a viable alternative.

[21] GG 3328B/19.5.2023

- **Increasing the grid's design capacity** by adopting modern equipment and structures featuring resistance to higher short-circuit current. This approach enables the absorption of a higher capacity coming from dispersed sources without weakening the networks. However, its implementation would require comprehensive studies and techno-economic weighting to select the suitable design capacity, while it would also entail the development of modern equipment and structures for new networks or upgrades of existing ones.

In addition to the above solutions, a smart and quickly implementable way to mitigate the challenge of grid saturation, especially with regard to energy communities, is **the installation of "behind-the-meter" energy storage systems**, namely, complementing photovoltaic stations with batteries. In the case of photovoltaic power stations implementing virtual net metering, batteries serve to postpone the injection of electricity into the grid, which would normally occur during daylight, namely, during the hours when grid saturation also normally ensues (or will ensue in the future). Injecting this electricity during the evening, night or morning hours would provide relief to the grid, increasing the margins for the penetration of new RES stations.

Currently, there exists an institutional framework for storage stations (Law 4951/2022[19]) and the only restraint lies in the cost of installation, which will be discussed below. As to how quickly such a solution can be implemented, it is worth noting that, recently (December 2022), a large storage system (100 MW/200 MWh) was installed in China in just 30 days[22]!

Finally, **demand response measures** can also contribute to grid saturation relief. In theory, there are two ways to make such measures feasible: [a]. changing consumer behavior, which would require mindful consumers willing to change their habits (a difficult task on such a large scale and in a short time frame); and [b]. smart meters and possibly differential pricing of electricity based on the time of consumption (which would, in turn, encourage consumers to change their behavior). The latter option is unfortunately hampered by the inability of the competent authorities to promote smart meters on a large scale, even though their necessity has been long documented. It is worth noting that the relevant tender for the supply of smart meters, launched by the HEDNO in 2014, is still dormant, besieged with pending objections and legal disputes.

Indicative business plans

Examined below are three indicative business plans by energy communities, whose members are residential consumers implementing virtual net metering. One business plan concerns an investment in photovoltaic systems, while the other two involve photovoltaics combined with batteries (with or without battery subsidies).

It is assumed that, on average, 200 households participate in each energy community, with a total annual consumption of 760 MWh (the average annual electricity consumption of households in the areas under consideration is 3,800 kWh, assuming that each household is composed of an average of 2.61 persons according to ELSTAT). Meeting their needs requires a 500 kWp

[22] Sungrow Power Supply Co., Ltd. https://bit.ly/3Y0Gfef

photovoltaic power station. In order to strengthen and stabilize the grids in these areas, it is assumed that batteries with a minimum guaranteed capacity of four (4) hours are also installed.

In addition, the following assumptions are made:

- Indicative investment cost for a photovoltaic station: €380,000 (€1,900 per household or €760 per kilowatt)
- Indicative investment cost of a 1,000 kWh battery: €300,000 (with replacement in the 16th year at 25% of the initial cost) - (€1,500 per household)
- Indicative operating cost of a photovoltaic station: €8.000 with an annual adjustment of 2%
- Indicative operating cost of a photovoltaic station with battery: €13.600 with an annual adjustment of 2%
- Indicative net metering price: €0.17/kWh. This price refers to the first year of operation and is derived by considering PPC's C1 residential tariff. In the detailed calculations carried out to determine the netting price, we assume an average market clearing price of 70 €/MWh; this price is significantly lower (up to 4 times) than the high prices at the peak of energy use and is in line with the estimates of numerous relevant bodies regarding the course of wholesale prices in the coming years.
- Indicative annual increase in electricity tariffs: 2%, equal to the inflation target
- Amortization factor: 20% (based on the current legislation on self-consumption, Government Gazette 5597 B/12/12/2018)
- Discount rate 6.3%

Scenario A. Investment in a photovoltaic power station (no battery)

Results	
Savings for Community members, over 25 years (€)	3,659,000
Benefit (savings minus costs) for Community members, over 25 years (€)	3,279,000
Benefit (savings minus costs) per household, over 25 years (€)	16,395
Net Present Value (€)	1,359,140

Scenario B. Investment in a photovoltaic power station combined with battery (no battery subsidy)

Results	
Savings for Community members, over 25 years (€)	3,361,865
Benefit (savings minus costs) for Community members, over 25 years (€)	2,681,865
Benefit (savings minus costs) per household, over 25 years (€)	13,410
Net Present Value (€)	930,405

Scenario C. Investment in a photovoltaic power station combined with battery (battery 100% subsidized)

Results	
Savings for Community members, over 25 years (€)	3,361,865
Benefit (savings minus costs) for Community members, over 25 years (€)	2,981,865
Benefit (savings minus costs) per household, over 25 years (€)	14,910

Net Present Value (€)	1,230,405

As illustrated, the investment without a storage system shows better returns, unless the battery is subsidized, in which case returns are comparable. Nevertheless, given the shortage of electrical space, the installation of a storage system may constitute a prerequisite for connecting the photovoltaic station to the grid.

Assuming that all needs are met by 500 kWp photovoltaic power stations (and not larger ones, where economies of scale would be achieved), **a total investment of €207-228 million (PV only investment scenario) or €370-408 million (PV & battery investment scenario) would be required**. This is, assuming that all households in the areas under consideration are supported by energy communities through virtual net metering, without taking into account that several residential consumers will resort to self-consumption and install a small photovoltaic system (with or without storage) on their roof.

Social and environmental benefits

These projects will provide direct financial relief (reduction of electricity bills) to local communities facing the immense challenge of transition. Moreover, the implementation and subsequent 25-year operation of 272-300 MWp of photovoltaic power stations (average capacity of 500 kWp) with storage systems implies **4,515-4,980 direct and 5,415-5,975 indirect and consequential employment years**[23].

In addition, substituting polluting fossil fuels and assuming a gradual phase out of lignite in the energy mix -based on the draft of the new NECP (August 2023)- will **prevent the emission of 2-2.2 million tons of CO_2 over the coming 25 years**.

Summary – Policy recommendations

This report examined the potential for meeting the electricity needs of residential consumers living in lignite areas under transition, through the establishment of energy communities that will develop photovoltaic power stations. In addition, these stations will probably be combined with energy storage systems; the latter will provide grid balancing services, thus, contributing to the mitigation of the electricity space shortage that currently prevents the connection of self-production projects by energy communities. The aim is to meet the needs of approximately 245,000 residential consumers in these areas via the creation of energy communities and the installation of 272-300 MW of photovoltaic stations.

The analysis of different scenarios involving photovoltaic power stations alone or photovoltaics combined with battery energy storage indicated that **a total investment of €207-228 million**

[23] The estimates are based on the methodology used by the Hellenic Association of Photovoltaic Companies, which was derived from a recent (2022) survey of its member companies. Specifically, for the station sizes described above (including storage systems), the direct employment factors are the following: project development, domestic equipment production, installation, and commissioning: 4.1 (full-time) equivalent years per MW; maintenance and operation: 0.5 (full-time) equivalent years per MW over 25 years of operation. The direct/indirect employment multiplier is set at 1.2.

(PV only) or €370-408 million (PV with batteries) will be required. Part of these resources may come from the European Just Transition Fund or from national resources supporting the Just Transition of lignite areas, through the revenues from the auctioning of greenhouse gas emission allowances. In this way, the State will actively contribute to mitigating the social and economic challenges arising from the transition, while making excellent use of the interest that has already flourished, especially among the citizens of the lignite areas in Western Macedonia, regarding self-production projects through energy communities.

A prerequisite for the implementation of the project is the existence of adequate grid. This report examined a number of technical solutions for creating sufficient electrical space.

With regard to public regulatory and funding interventions, and making optimal use of the significant financial resources already available for the lignite areas, the following are recommended:

1. **Public funds should be redirected:**
    i. **to reinforce and expand the networks so that they can accommodate the necessary investments;**
    ii. **to subsidizing hybrid photovoltaic & storage systems for self-production projects by energy communities, as these will enhance the stability of the grids and render project implementation feasible. Action 2.2.1: "Supporting energy communities in the development of self-production projects" under Specific Objective 8 of the Just Development Transition Program (PDAM 2021-2027) already provides for respective subsidies in the case of local authorities; this action could be generalized for all energy communities aiming at self-consumption.**

2. **The competent operators should revise the network development and upgrading/innovation plans, so as to facilitate the installation of projects by energy communities in the lignite areas under transition.**

3. **Legislation should provide that self-consumption and energy community projects implementing virtual net metering are given priority in the allocation of new electrical space resulting from grid expansion and/or reinforcement interventions.**

4. **State guarantees should be provided to energy communities using the virtual net metering tool, so that these communities can obtain funding from banks.**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