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PHOTOVOLTAICS SOLUTIONS AND ENERGY COMMUNITIES IN A CLEAN ENERGY ROADMAP

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Abstract. The present paper deals with solutions regarding the development of the Energy Strategy toward 2050 for a clean and sustainable future. At the national level conceptual elements are needed to draw a roadmap for the energy transition in the Republic of Moldova. The paper presents the renewable energy potential of the country with focus on photovoltaic energy production. A specific PV deployment solution is also analysed, namely the floating PV, while use cases for using this solution for serving energy communities in the rural area has been also proposed. The solutions can be considered steps that will foreshadow the national energy long-term strategy in the energy sector. An efficient transition to decarbonised energy systems requires the search for innovative solutions to increase the penetration of renewable energy sources, for changing the future energy system by promoting and evaluating innovative perspectives.

Keywords: *energy transition, roadmap, energy strategy, renewable energy sources, floating PVs, energy community.*

Rezumat. Articolul prezintă soluții privind dezvoltarea strategiei energetice a Republicii Moldova până în anul 2050, în vederea unui viitor energetic curat și sustenabil. Sunt necesare în acest sens elemente conceptuale care să traseze o foaie de parcurs pentru tranziția energetică în Republica Moldova. Articolul prezintă potențialul de energie regenerabilă a țării cu focalizare pe producția de energie bazată pe centrale fotovoltaice. Se analizează de asemenea o soluție particulară de implementare a acestora, respectiv centralele fotovoltaice plutitoare, fiind totodată propuse studii de caz care să deservească comunități energetice din zona rurală. Soluțiile pot fi considerate exemple de urmat în cadrul strategiei pe termen lung a sectorului energetic. O tranziție eficientă către diminuarea conținutului de carbon a sistemelor de energie necesită găsirea de soluții inovatoare care să crească prezența surselor de energie regenerabilă, pentru a schimba sistemul energetic al viitorului prin promovarea și evaluarea unor perspective inovative.

Cuvinte cheie: *tranziție energetică, foaie de parcurs, strategie energetică, surse de energie regenerabilă, centrale fotovoltaice plutitoare, comunități energetice.*

1. Introduction

After 2010 the supply of energy from renewable sources in the Republic of Moldova increased slowly, as first steps in learning and applying the new trend which has been pushed more strongly in countries such as Germany and some USA states, for example in California. Consequently, the energy from renewable sources in the primary energy supply increased by 27.2% in 2019 compared to 2010 and represents 22.5% of the primary energy of the country [1]. To be noted that according to [1], 67.5% of CO_2 emissions in Republic of Moldova are allocated to energy sector in 2019, as a reduction form 70% in 2010, which suggests that energy sector is a priority for reaching high decarbonisation goals.

With a gradual decarbonisation process, the Republic of Moldova can contribute not only to the global efforts to mitigate climate change, but also to improving the health and the quality of life of its citizens. More efficient use of cheap and abundant renewable energy sources, with the help of digital technologies, will transform cities, transport, industry and agriculture, reducing greenhouse gas emissions and improving air quality. Thus, decarbonisation is not just an abstract goal of the European Union or the United Nations, but a policy with immediate and tangible benefits for all. And the decisive factors that will generate these benefits will be the digitization and electrification of the usable potential.

In this context, the opportunities of the Republic of Moldova (RM) in the energy sector are considered in the long-term development. It is especially worth to mention that the electricity will have to become a strategic tool for the future of transport, air conditioning and household needs, but the promotion of smart grids will be proved to be the best way to make this to be possible. Decarbonisation and air quality are also on the list of priorities and ensuring an adequate access to the energy for the most vulnerable members of the society continues to be a subject of the maxim importance.

2. PVs as a priority and high potential in the future RES mix

In the study which has been extensively presented in [2], it has been shown that a small part of the agricultural area of the Republic of Moldova is needed to provide 30% or even 50% of the annual volume of electricity used in the country. Even so, recent studies show that such areas can be found in the form of uncultivated land, but the areas where agricultural activities take place have as well a very high potential, through the application of the technologies that are particularly promising, namely agricultural activity combined with photovoltaics.

In this respect, pilot projects in several parts of the world show that there are synergies between agriculture and the production of renewable energy sources (RES) with photovoltaics (PV), which may, in fact, change the perception that PV is in competition with agriculture.

The amount of photovoltaic power plants capacity in the Republic of Moldova can be determined in a simplified way based on the calculations performed in [2]. The average yearly energy produced for one kW of installed PV in the Republic of Moldova has been calculated in [2] by using 11 geographical points with inputs from [3] and gave 1,182 kWh / year for 1 kW of PV installations (also referred as 1 kWp, where p denotes maximum power of the photovoltaic panels in defined conditions). A revisited and more refined calculation based on more geographical points (20 points, organised in four zones: North, Middle, South and left Dniester, as per administrative organisation from [4]) gives a value of 1,191 kWh / year / kW (Table 1), which is very near to the initial estimation (only 0.7% difference in the more complex calculation).

Table 1

Average yearly energy produced by 1 kWp PV in based on 20 geographical points [3]

No	Location	County	Zone	Latitude (°)	Longitude (°)	Yearly energy (kWh/year)	Y2Y variation (kWh)
1	Edineț	Edineț	North	48.169	27.298	1,130.78	57.66
2	Briceni	Edineț		48.354	27.065	1,141.13	42.08
3	Soroca	Soroca		48.146	28.282	1,144.24	57.76
4	Costesti	Rișcani		47.866	27.235	1,174.87	40.84
5	Bălți	Bălți		47.781	27.909	1,148.16	55.43
6	Șoldănești	Șoldănești	Middle	47.812	28.776	1,179.57	51.34
7	Telenesti	Telenesti		47.512	28.354	1,182.75	46.95
8	Orhei	Orhei		47.396	28.831	1,174.61	51.81
9	Ungheni	Ungheni		47.220	27.815	1,174.53	54.02
10	Chișinău	Chișinău		47.039	28.858	1,193.99	58.97
11	Hîncești	Lăpușna		46.843	28.596	1,186.33	52.10
12	Leova	Leova	South	46.486	28.243	1,228.96	47.39
13	Căușei	Tighina		46.661	29.413	1,194.83	56.03
14	Cahul	Cahul		45.929	28.196	1,235.68	37.53
15	Palanca	Stefan Vodă		46.407	30.078	1,263.10	58.52
16	Comrat	Găgăuzia		46.315	28.661	1,213.68	49.74
17	Vulcănești	Vulcănești		45.679	28.457	1,267.61	50.59
18	Rîbnița	Nistru	Left Dniester	47.769	29.060	1,172.62	53.01
19	Dubăsari	Nistru		47.272	29.212	1,200.64	52.52
20	Tiraspol	Nistru		46.866	29.634	1,207.17	60.54
	Average energy over a year [kWh/year/kW installed]					**1,190.76**	51.74

The places considered for the refined average energy production with PVs are presented in Figure 1, while the average specific energy in each zone is also presented (based on administrative organisation from [4]), showing a slight improvement of solar energy in the south region compared with the north part (only 4% more in South). It shows that there are appropriate conditions for PV installations everywhere across RM, everywhere from North to South.

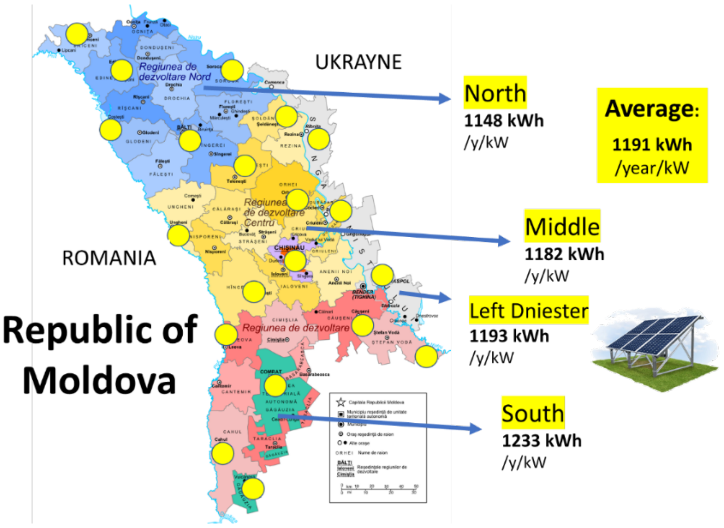


Figure 1. Places in the Republic of Moldova used to calculate the annual average energy with PV power plants.

Based on the method described in [2], the energy coverage with PVs of yearly country consumption is shown in Figure 2, which uses as inputs the following data:

a) the average value of yearly-based specific PV production in RM (1,191 kWh/year/kW) from Table 1.
b) The yearly consumption of RM, based on data from year 2020, which was 5940 GWh (based on processed data obtained from [5]).

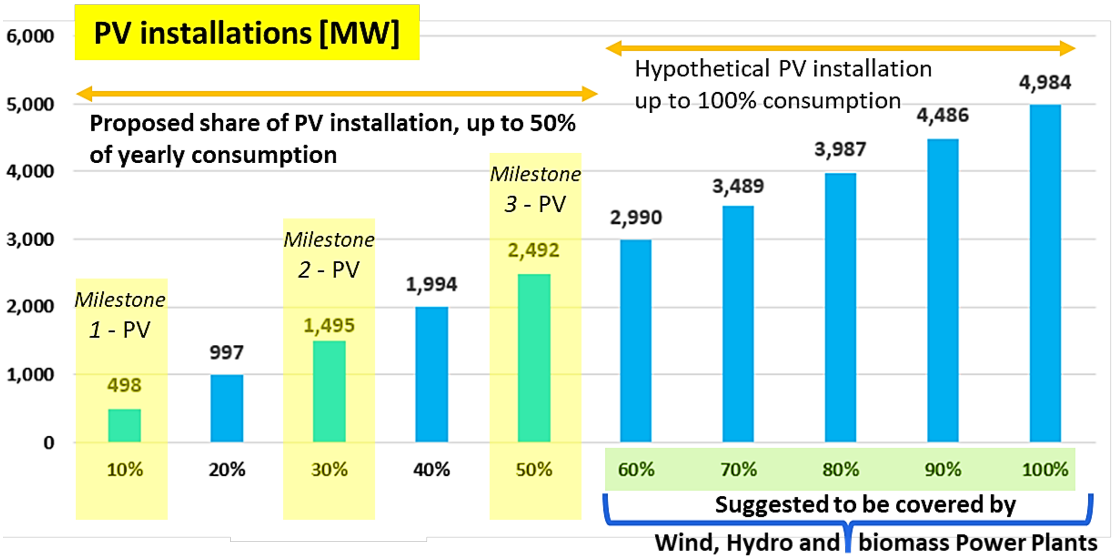


Figure 2. The need of PV power for various levels coverage of the consumption on yearly basis in Republic of Moldova and suggested share with wind, hydro and biomass.

It is observed that for 100% of required consumption the country, the needed capacity for PV installations is 4.98 GW, while for covering 50% are needed only 2.49 GW.

Wind power plants have the potential to contribute essentially to the second half of the RES energy production (as suggested in Figure 2). This is already treated in other works. For instance, in [6] are shown the areas of the Republic of Moldova with wind potential, while the paper deals extensively with their integration into the national energy system of the Republic of Moldova.

3. Impact on land use in the scenario of high PV share in the future RES mix

In order to assess if the land needed for PVs if up to 50% of RM yearly consumption is obtained from PV production, it is needed to estimate the specific area for a power unit of PVs.

Figure 3 shows the relevant geometry of PV rows for deducting the surface needed for 1 kW of PV panels.

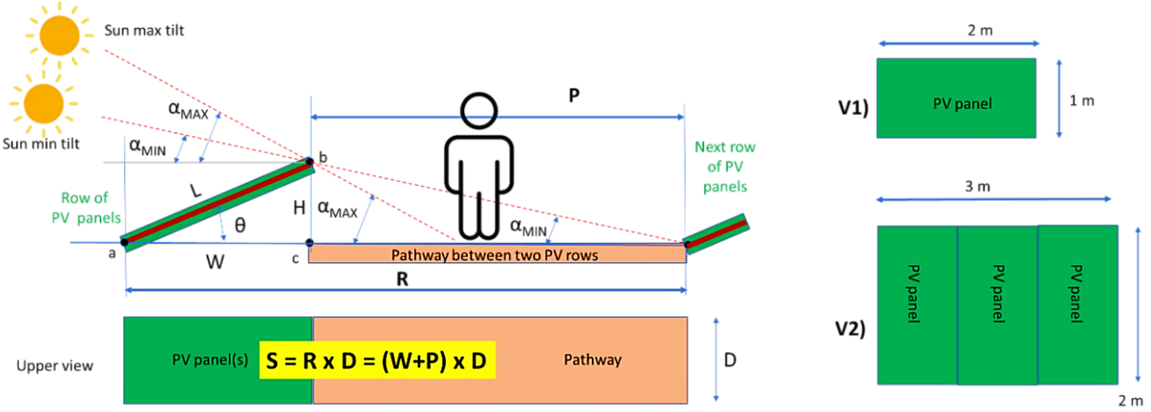


Figure 3. PV rows geometry for land-based deployment of Photovoltaic Power Plants.

The ideal tilt angle θ of the PVs - for a maximum energy obtained over a year, is around 35° for RM, similar for different points, as has been calculated with [3].

The calculation of the power density is based on geometry from Figure 3 (left side) by applying the following formulas:

$$S = R * D = (W + P) * D = (L\cos\theta + H/\tan\alpha_{MIN}) * D \tag{1}$$

$$= (L\cos\theta + L\sin\theta\,/\tan\alpha_{MIN}) * D \tag{2}$$

$$S_{1kW} = S/P_{PV\_panel} \tag{3}$$

For $\theta = 35^{o}$ (best tilt angle for highest energy over a year) and for $\alpha_{MIN} = 12^{0}$ (as a lowest sun angle during winter without shadow) we analyse two types of PV installations:

- Rows of one PV panel of 1000 x 2000 mm (D_{PV} x L_{PV}), having P_{PV} = 420 Wp/panel (conservative value, higher values may exist) and mounted with D_{PV} side on the ground (the small side), as per the design V1 in Figure 5 (lower right side). The length L is therefore equal to L_{PV} = 2 m, while the depth in the row is equal to D_{PV} = 1 m. The power of the row is P_{ROW} = P_{PV} = 420 Wp, as it is only one panel in the considered D_{PV} depth.
- Rows of 3 x PV panels of the same dimension of 1000 x 2000 mm (D_{PV} x L_{PV}), having the same output P_{PV} = 420 Wp / panel and mounted with L_{PV} side on the ground (the large side), as per the design V2 in Figure 5 (upper right side). The length L is therefore equal to 3 x D_{PV} = 3 m while the depth in the row is equal to D_{PV} = L_{PV} = 2 m. The power of the row is P_{ROW} = 3 x P_{PV} = 3 x 420 =1260 Wp.

The total needed surface for one row can be deducted as being:

$$S_{V1} = (2\cos 35^{0} + 2\sin 35^{0}\,/\tan 12^{0}) * 1 = 7.03\ m^{2} \tag{4}$$

$$S_{V2} = (2\cos 35^{0} + 3\sin 35^{0}\,/\tan 12^{0}) * 2 = 21.11\ m^{2} \tag{5}$$

$$S_{1kW\_V1} = 7.03\ /\ 0.420 = 16.7\ m^{2}/kWp \tag{6}$$

$$S_{1kW\_V2} = 21.11\ /\ 1.260 = 16.7\ m^{2}/kWp \tag{7}$$

In both situations it is needed the same land area, which shows that they are equivalent in terms of density. Therefore, both design geometries as used, as per Figure 4 real implementation examples (V1 on the left, as from [7] and V2 on the right, as shown at [8]).

Figure 4. Real PV implementation of design V1 (left) and V2 (right) geometry.

The 16.7 m²/kWp has been calculated at the most difficult situation in winter, when the sun has a min to max tilt angle which are very low (lowest is expected for 21st of December).

According to [9], in Chisinau area, during the day of 21st of December 2022, we have $\alpha \geq \alpha_{MIN} = 12^{0}$ in the time period between 9h:34m and 14h:32m, which means that there is no shadow for approximate 5 hours. From the same site, it can be deducted that $\alpha \geq \alpha_{MIN} = 10^0$ for 5 hours and 40 minutes (13.3% longer period), so the needed land for 1 kW PV is also calculated for 10°.

For $\alpha_{MIN} = 10^0$ the minimum needed land is:

$$S_{V1\_10grd} = (2\cos 35^0 + 2\sin 35^0 \,/\tan 10^0) * 1 = 8.15\, m^2 \tag{8}$$

$$S_{1kW\_V1} = 8.15 \,/\, 0.420 = 19.4\, m^2/kWp \tag{9}$$

The calculations show that in usual PV power plants, around 20 m^2 can be considered for each 1 kW installed, based on the ideal tilt angle of the PV (around 35° for Moldova) and eventually by adding some areas for access roads and other power plant necessities.

With this value $S_{Specific} = 20m^2/kWp$, a total power of 2.49 GW in PVs will need only:

$$S_{50\%} = P_{PV_{50}\%} * S_{Specific} = 2.49 * 10^6 * 20 = 49.8 * 10^6\, m^2 = 49.8\, km^2$$

Higher densities of PV panels (needing e.g. 12 m^2/kWp PV) can be obtained for instance if $\alpha_{MIN} = 15^0$ and $\theta = 25°$ (lower tilt angle, which brings lower PV specific energy per year).

The need for 4.98 GW in CEF installations (100% coverage of yearly consumption in RM) uses under 0.8% of the country's agricultural land (based on method used in [2]) to cover the entire volume on an annual basis, is consistent with similar results for other countries [10,11]. One conclusion of Greenpeace is that, at the moment, only political will is needed to achieve such a goal [12]. A World Wildlife Fund study shows that in Germany, 2% of the country's land area is enough to produce all the energy used annually from renewable sources alone [13]. The potential for electricity supply from RES alone is also highlighted in [14], showing that 1% of the EU's surface area can supply the entire usable EU electricity needs.

Moreover, a new field of sustainable development can be addressed, that of the harmonious interweaving of agriculture with CEF, i.e. an "agro-photovoltaic" development at the country level [15]. Such a concept is extremely conducive to a country like the Republic of Moldova, characterized by important activities related to the use of agricultural land, which can approach new values of their potential to support a society that can keep traditional activities in a sustainable and competitive way. In [15] are listed explicitly also floating PVs and their potential is analysed in more depth in the next section.

4. Floating PV solutions for Republic of Moldova

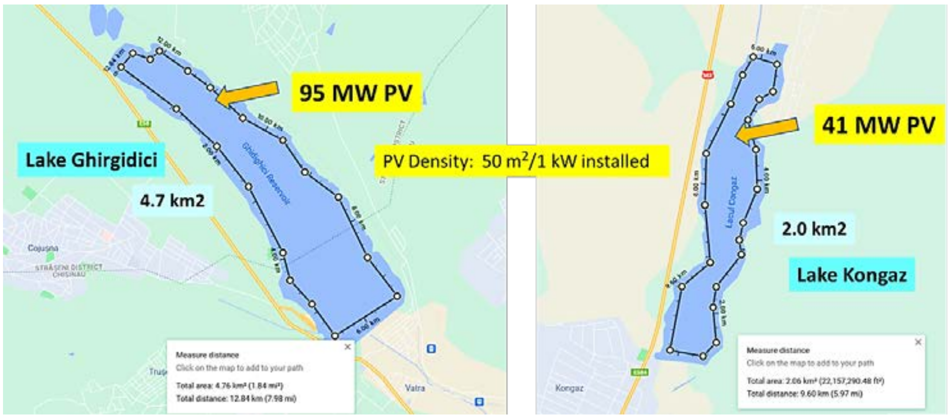
A new field of interest in deploying photovoltaics power plants is the promotion of floating PVs. There are several reasons why they may become attractive:

a) such installations do not occupy land usable for ordinary human activities (agriculture, urban areas, etc.).

b) floating PVs ensures a higher conversion yield during the summer, because the PV panels, whose efficiency decreases with increasing temperature, are better cooled by the surface of water on which they float;

c) often such water surfaces (e.g. lakes) are located near urban or suburban areas, for which it can provide energy in an area close to the place where it can be used.

This section will assess the level of installed power which can be reached with PVs when using floating PV technology. In this respect, Figures 5 [9], 6, 7 and 8 present the potential of some of these lakes in the Republic of Moldova. The lake areas have been obtained by using the “Distance” tool of [16].

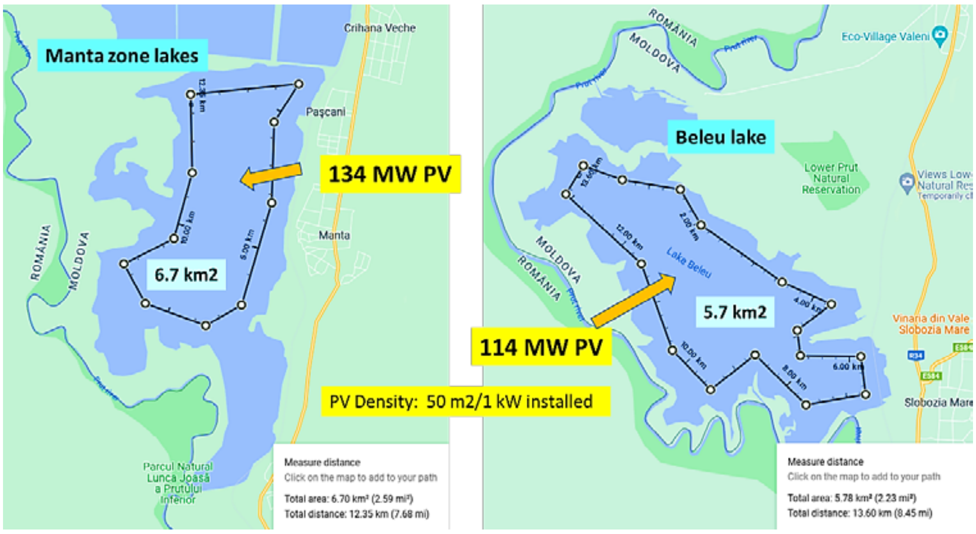


Measure distance
Click on the map to add to your path
Total area: 4.76 km^2 (1.84 mi^2)
Total distance: 12.84 km (7.98 mi)

Measure distance
Click on the map to add to your path
Total area: 2.06 km^2 (22,157,290.48 ft^2)
Total distance: 9.60 km (5.97 mi)

Figure 5. The potential of photovoltaic capacity for two lakes in the Republic of Moldova: Ghidighici and Kongaz, in the conditions of a low density of photovoltaic panels: 50 m^2/kW installed.

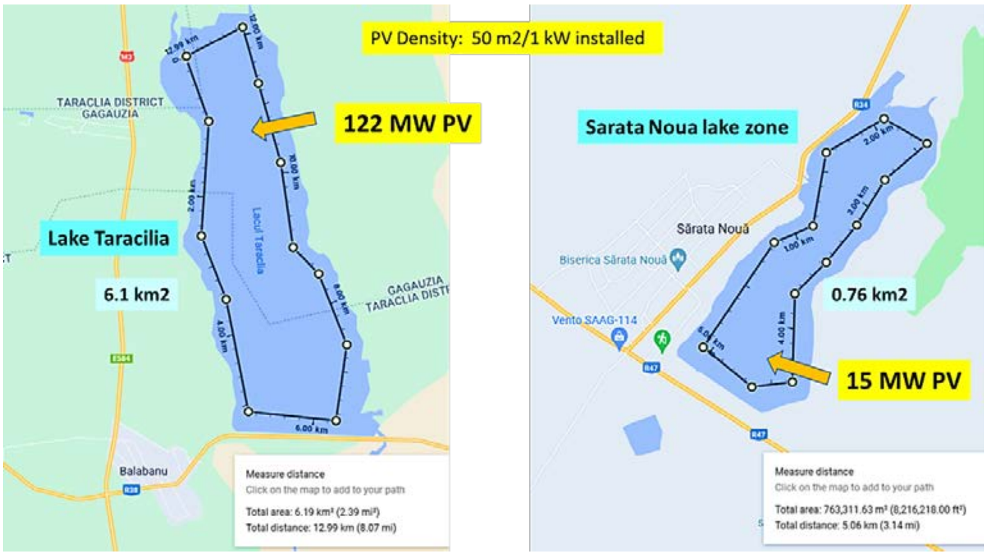
Figure 6 particularly looks in the potential of some lakes placed nearby Prut River, which can be considered as reservoirs of water related to this river.



Measure distance
Click on the map to add to your path
Total area: 6.70 km^2 (2.59 mi^2)
Total distance: 12.35 km (7.68 mi)

Measure distance
Click on the map to add to your path
Total area: 5.78 km^2 (2.23 mi^2)
Total distance: 13.60 km (8.45 mi)

Figure 6. The potential of photovoltaic capacity for two lakes in the Republic of Moldova: Manta and Beleu zones.



Measure distance
Click on the map to add to your path
Total area: 6.19 km^2 (2.39 mi^2)
Total distance: 12.99 km (8.07 mi)

Measure distance
Click on the map to add to your path
Total area: 763,311.63 m^2 (8,216,218.00 ft^2)
Total distance: 5.06 km (3.14 mi)

Figure 7. The potential of photovoltaic capacity for two lakes in the Republic of Moldova: Taracilia and Sarata Noua zone.

In Figure 8 it is analysed also the potential of using a hydro-power-plant lake (Costești, on the right side) with dual use: reservoir for the hydro-plant and lake for floating PVs. Such combination has been also discussed for other lakes around the world [17].

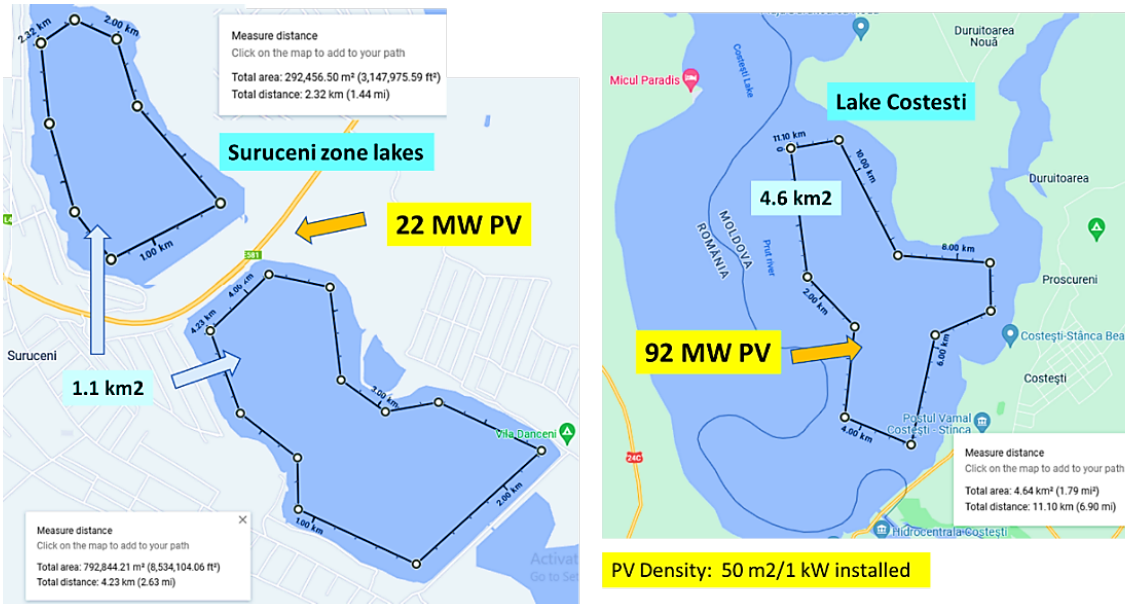


Figure 8. The potential of photovoltaic capacity for two lakes in the Republic of Moldova: Suruceni and Costești zone.

For the floating PV it is considered a lower density, to allow other lake-based activities, meaning that the area needed for 1 kW of PV is chosen to be studied in two cases:

- 50 m^2/kW (low density), which is 2.5 to 3 times lower than for usual ground-based implementations.
- 80 m^2/kW (even lower density), which is 4 times lower than for usual ground based implementations.

A brief overview of representative figures related to these locations is presented in the Table 2, while choosing the low-density PV implementation.

Table 2

Power and yearly energy potential for the selected lakes of RM for low density of 80 m^2/kW in PVs

	Lake denomination	Area (km^2)	PV power potential (MW)	Estimated yearly energy (GWh)
			Density V1: 50 m^2/kW	
1	Ghirghidici	4.7	94	111
2	Kongaz	2.0	40	47
3	Manta	6.7	134	158
4	Beleu	5.7	114	135
5	Taracilia	6.1	122	144
6	Sarata Noua	0.76	15	18
7	Suruceni	1.1	22	26
8	Costesti	4.6	92	109
	Total	**31.7**	**633**	**748**
	RM consumption coverage			**10.7%**

Table 3 presents the potential of the same lakes by considering an even lower density (80 m^2/kW) of the PV panels on the lake surface.

It can be seen that the potential of such lakes is not negligible, they also have the advantage of being close to the cities (e.g. in the case of lakes nearby Chisinau and Kongaz). Other lakes exist also in other zones of the Republic of Moldova, however even these locations can bring high contribution of PV based RES:

- 6.7% of yearly consumption in the case of lower PV density of 80 m^2 / kW installed, respectively
- 10.7% of yearly consumption in the case of low PV density of 50 m^2 / kW installed.

Table 3

PV Power and yearly energy potential for the selected lakes of RM for lower density of 80 m^2 / kW

	Lake denomination	Area (km^2)	PV power potential (MW)	Estimated yearly energy (GWh)
			Density V2: 80 m^2/kW	
1	Ghirghidici	4.7	**59**	69
2	Kongaz	2.0	**25**	30
3	Manta	6.7	**84**	99
4	Beleu	5.7	**71**	84
5	Taracilia	6.1	**76**	90
6	Sarata Noua	0.76	**10**	11
7	Suruceni	1.1	**14**	16
8	Costesti	4.6	**58**	68
	Total	**31.7**	**396**	**468**
	RM consumption coverage			**6.7%**

To be noted that usual density in fields dedicated to PV panels installations is around 20 m^2/kW. The lower densities proposed for the floating PVs placed on lakes allow the placement of the panels at least in two ways:

- With larger access lanes between PV lines allowing other activities such as fishery in between the PV lines.
- With clusters if classic density PVs (e.g. with 20 m^2/kW), other activities may be fully developed in between the clusters.

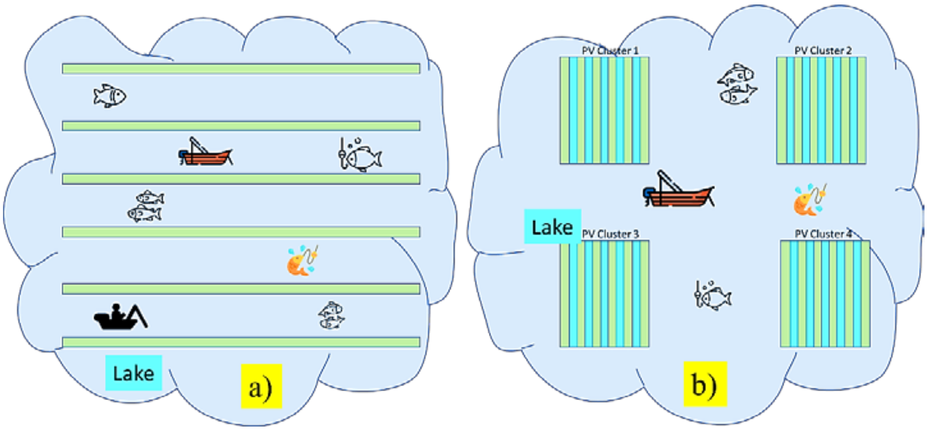


Figure 9. PV panels setups: a) Large access lanes between PVs; b) Clusters of PVs.

Moreover, placing 1 kWp of PVs on 50 or 80 m^2, creates a spatiality which practically avoids shadowing between tow PV rows nearly the whole day even in worst situations in December.

5. Rural energy communities sustained by local RES production. Examples involving floating PV solutions

A particularly important added value of encouraging energy production at the local level is the possibility to grow energy communities around these energy sources. The following advantages ca be considered:

- local production at traditional users, who thus become active users (prosumers); this type of distributed production is generally achieved through PV mounted on roofs, especially in rural areas and in urban neighbourhoods that predominantly have own houses. The power installed on these roofs, with PVs mounted usually towards south, is usually in the field of 3 to 10 kW;

- local production for the active medium size users, which refers to state institutions such as schools, hospitals and other public buildings, to industrial buildings and for commercial use. The PV power of these installations can be from 50 to hundreds of kW. If the parking lots of the shopping complexes are added, using special carports, the total power can reach the MW range;

- a third important category represents the energy community. Frequently the users of a community do not have a functional space to invest each individually in a RES installation, but are willing to organize themselves in energy "cooperatives", which may be in collaboration with the mayor's office or other public or private entity from their area. This aspect of the energy community will be developed further using two cases of small floating-PV applications.

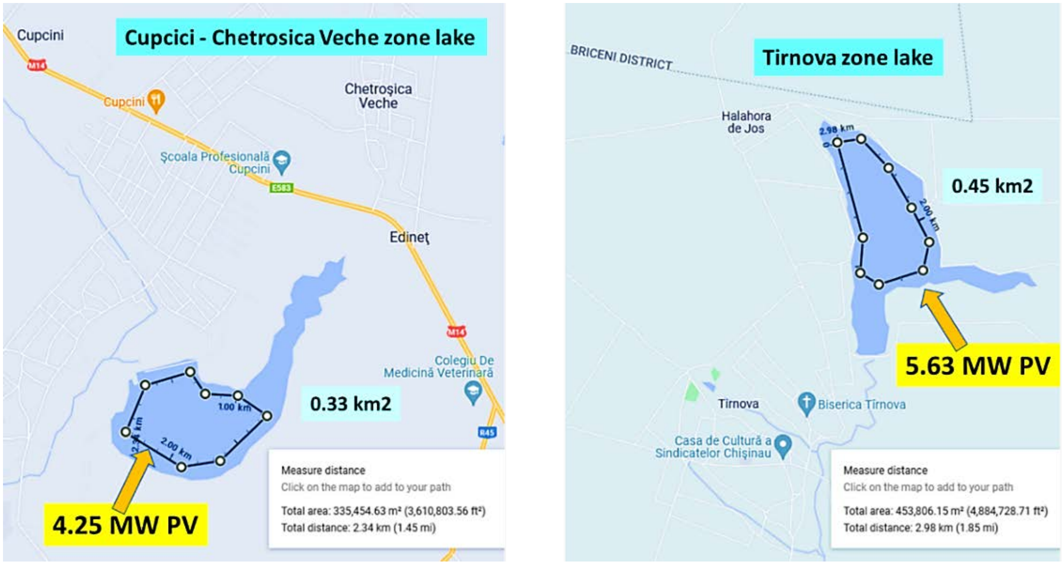


Figure 10. The potential of photovoltaic capacity for two small lakes and a potential formation of energy communities.

In can be seen that the small power between 4 to 6 MW in floating PVs can supply nearby communities, as ca be seen in Figure 11, in areas of 1 up to 7 km radius, while Table 4 estimates installed power in floating PVs and the annual energy for 1191 kWh / kW chosen in section 1.

Figure 11. Energy communities' formation: a) small community with km range radius; b) larger community, with up to 7 km radius.

Table 4

PV Power and yearly energy potential for the selected lakes of RM for lower density of 80 m^2/kW of floating PVs

	Lake denomination	**Area (km^2)**	**PV power potential (MW)**	**Estimated yearly energy (GWh)**
			Density V2: 80 m^2/kW	
1	Cupcici-Chetrosica Veche	0.34	4.25	5.06
2	Tirnova	0.45	5.62	6.70

In order to be a sustainable energy community, the energy from the floating PVs need to cover an important part of the yearly consumption of the energy community. Table 5 presents an estimated yearly production of the PVs (column 6) which is compared with the community production over the year (column 5).

The population of the two energy communities is based on [18] and [19]. As shown also in Figure 11, the energy communities have the following structure:

- Cupcici community: with 7190 inhabitants in Cupcici and 817 inhabitants in Chetroșica Veche; the total number of inhabitants of the small energy community (km range radius) is 8007
- Tîrnova community: with the following number of inhabitants: 2050 in Tirnovam 3108 in Trinca, 3265 in Gordinesti and 1921 in Hlinaia; the total number of inhabitants of the larger energy community (up to 7 km radius) is 10344.

Table 5

Energy community KPIs

Energy community	**Population**	**Houses**	**Energy/ month (kWh)**	**E_cons / year (MWh) community**	**E_prod PV / year (MWh)**	**Procent of consumption**
Cupcici	8007	2669	200	6405.6	5060	79.0%
Tirnova	10344	3448	200	8275.2	6700	81.0%

To be noted that the number of houses has been estimated as being an average of one for each 3 inhabitants, rule which provides the numbers from column 3. In order to estimate the yearly consumption of the community, a simplified approach is to base these values on an average monthly consumption per house. The study considers a value of 200 kWh/month/household, while households may consume between a lower energy of around average 100 kWh and a higher energy of around 300 kWh/month.

Table 5 shows that the yearly consumption is covered in a share of around 80% for both communities. The assessment suggests that most of the energy is therefore produced locally and that only a small share of around 20% is needed to be purchased from the public network. This result shows the potential of such approach, respectively to produce locally, on a non-agricultural surface (on a lake belonging to the community area), close to entire yearly need of the community.

This situation allows also to implement aspects of resilience such as:

- *Resilience of energy*, meaning that short to medium time periods without supply of energy from main grid can be surpassed by off-grid local supply
- *Resilience of local businesses*, as most of the energy is supplied based on already known tariffs deducted from the feasibility study of the local energy investment, which is not influenced by external factors after the objective is operational.

For the energy resilience it is needed that the PV production is also accompanied by electrical storage. The need for storage at country level has been already studied in [20] For local PV production, a usual level of 1 to 2 kWh of energy storage is used already in some applications for shaving the peak power of 1 kW of PV.

This storage resource allows also a certain resilience (e.g. 1 to two hours or more) if the main grid fails to supply energy to the community, depending on the adaptation of consumption to lower values during the power outage.

A priority can be given in this situation only to the most important loads, e.g.: refrigerators (for keeping food in good conditions), telecommunication means (modems, routers, switches etc.), low-consumption computers such as laptops or tablets, LED-based light etc.

For the resilience of the local business, it is targeted finally a sustainable development of the community, which is less influenced by volatile prices due to external factors, such as political or proxi-wars situations. This type of resilience is in many cases neglected, despite the fact that the impact of external factors may be dramatic in some cases.

While the coverage of up to 80% of the consumption over a year looks quite promising, two additional factors may be also considered:

- Shifting of classic ICE - based cars to electromobility.
- Heating with electricity

The paper is analysing only the first factor.

6. Impact of electrical vehicles

The ongoing revolution in switching to electrical vehicles plays a key role in its effect of the energy field. Due to a growing market and a smaller effect of business-as-usual inertia and the monopolies associated with maintaining this situation, electromobility is the main driver of the innovation through batteries, power electronics, artificial intelligence and associated ITC components, having a beneficial effect in the energy field, much more related to natural and historical monopolies and the fear of changes.

Let’s consider that each household has also a light vehicle and that in 2030 we may have 20% of these cars shifted to EV technology and 50% in year 2040. We consider a scenario with the following inputs:

a) an EV is driven 10000 km/year, with half of it expected to be covered by local charging.
b) the average consumption of a light EV is around 15 kWh / 100 km

It means that an EV will need 5000 km supported by local energy production, which means 15 x 50 = 750 kWh / year / EV.

With the data already used in tables 3 and 4, the table 6 shows that additional consumption energy needed for the 20% and 50% EV fleet. Table 5 shows the impact of EV charging in the community, compared with the community PV production over a year (energies shown in MWh).

Table 6

Energy community KPIs related to electrical vehicles introduction

Energy community	Vehicles	EVs-2030	EVs-2040	Energy for EVs 2030	Energy for EVs 2040	Percentage in 2030 of PV prod.	Percentage in 2040 of PV prod.
Cupcici	2669	534	1335	400.5	1001.25	7.97%	19.93%
Tirnova	3448	690	1724	517.5	1293	7.78%	19.45%

The table shows that around 8% in 2030 and 20% in 2040 of the energy community production with floating PVs is needed for covering EV charging due to the rapid expansion of EVs in the studied energy communities. This means that for the households consumption presented in table 5 it remains only around 60% of local production for the time horizon of 2040. This situation suggests that the floating PV solution need to be complemented with additional local sources, such as agri-photovoltaics. By considering also electric heating, the energy produced locally can be doubled, with a 50% share in floating PVs on the local lake, while the remaining can be mounted on ground.

The assessment shows however that a local sufficiency is a tangible target and that each solution need to be treated case by case.

7. Roadmap to 2050 in the Republic of Moldova

In continuation it is presented a roadmap to 2050 in the Republic of Moldova, based on what has been proposed in [15], with essential elements that can be the basis of the national policies.

1) It will be facilitated the development of renewable electricity sources distributed in all regions of the country where there is high consumption in the neighbourhood (cities, industry, etc.). These must be especially based on photovoltaic and wind-based power plants, in a proportion that corresponds to the environmental conditions of the Republic of Moldova, following in-depth, multi-criteria studies. A contribution of at least 50% to the solar proved to be possible [5]. The paper particularly develops specific solutions for floating PVs and their potential to help local energy communities. A suitable solar-wind combination requires further study. It will also be analyzed whether there is still hydropower potential that can be attracted in the energy mix.

2) It will be supported the increase the flexibility of the electrical power system, especially through important projects, such has the construction of at least one Pumped Hydro Plant (PHP, with favourite locations being on Dniester river), combined with Battery Energy Storage Systems (BESS), these one being projected to hold the biggest amount of the necessary [12].

3) It will be taking into consideration flexibility measures which will reduce the dependence on technological services system provided by neighbouring countries (especially Ukraine).

4) It will be electrified in stages the household heating, through various methods (direct heating through Joule effect, heating with increased efficiency – by using heat pumps, use of existing thermal power plants combined with heating, adapted for green H_2 și CH_4 etc.), all these being accompanied by the methods to increase the efficiency of heat consumption through retrofitting (modernization) at the heating installations level and at the buildings level.

5) It will be electrified in stages the small vehicles park and then the one with trucks and busses and it will be promoted EVs with V2G; this process will be accompanied by ITC charging coordination solutions (solutions equivalent to demand response) and the promotion of EVs with V2G facilities, whose potential to provide flexibility through the use of energy in batteries, is extremely high.

6) The introduction of renewable energy sources will be accompanied as much as possible by agro-photovoltaic solutions which will bring synergistic benefits to both areas, including accelerated electrification of agriculture; where feasible, floating CEFs on lakes close to large consumers will also be encouraged.

7) It will be encouraged the digitalisation of the energy activity, including through smart metering, energy and flexibility services markets, SCADA systems and promotion of initiatives which contain Smart Grid functionalities.

8) It will be encouraged the creation of resilient energy communities which will reduce their risk according to the defects in the public network, of large price fluctuations in the energy field compared to extreme climatic situations. These communities will also be formed in the perspective of building future smart cities, in which resilience and sustainability play key roles. In the same context, small RES producers will be encouraged to become active users.

9) It will be encouraged the realisation of pilots for the emerging technologies, such as Power-to-Gas, respectively obtaining and transporting green hydrogen, inclusively in mixture with methane gas; this field is to be developed cautiously by 2030, waiting for the gradual maturation of technologies at the international level.

10) It will be encouraged new business models, such as Power Purchase Agreements (PPAs) - which guarantee low prices over known periods of time (helping predictably and sustainably other activities of the society), but also appropriate approaches for new technologies, such as financial models Storage as a Service or RES + local storage coupling models, as unitary solutions.

11) It will be encouraged the high-level education and scientific research to support new energy revolution with qualified staff and appropriate solutions, in its ambitious path towards carbon neutrality.

12) Energy policies should be achieved such that they stimulate in an efficient manner these objectives, through lawmakers, government and regulation agency in the energy field.

8. Conclusions

In conclusion, the country's future in the energy field looks pretty good in the long term perspective. However, in order to ensure that this potential is exploited, the Republic of Moldova must take courageous decisions to attract investments. There is a fierce global competition between countries in the world to attract capital, especially between developing and emerging countries. The Republic of Moldova can be a good participant in this race, if it presents a solid business plan in the medium and long term development.

The paper presents the potential pf PV-based energy production at national level, with clear figures for different participations in the total RES, while suggesting a contribution of up to 50% of total yearly consumption, to be complemented by wind, hydro and biomass-based RES production. A connection between the power needed to be installed and the necessary land are is also addressed, while the calculation of needed area for 1 kWp is presented in detail. Moreover, the potential of floating PVs is assessed for various lakes in RM and is proven to be of interest in the future. Finally, the local production with floating PVs has been combined with two local communities needs, by proposing a model for energy communities, more resilient to power outages and to unpredictable energy prices from external sources.

The paper makes also a brief presentation of a roadmap of energy developments till 2050 in the Republic of Moldova. These transformations will happen if the energy strategy planned for decades, state policies and regulations will be put into practice based on specific projects to be carried out in the energy sector, in order to prepare for the inevitable energy transition. The Republic of Moldova will face a lot of challenges in the energy sector in the next ten years, but it is still a process that can be prepared and successfully implemented.

Conflicts of Interest. The authors declare no conflict of interest.

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