REGIONAL ANALYISIS OF ENVIRONMENTAL AND SOCIO-ECONOMIC IMPACTS OF PHOTOVOLTAIC PARKS IN ROMANIA. A SOWCASE OF WEST DEVELOPMENT REGION

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ABSTRACT

Electricity production has the greatest impact on socio-economic development in Romania. However, it is also responsible for the cumulative (often negative) environmental effects. In order to meet the energy demand, while achieving the Energy and Climate Change goals, Renewable Energy has become an important alternative, especially during 2010-2013 period when substantial funding has been allocated. Renewable energy sources available in Romania (hydro, solar, geothermal, wind and biomass) have the capacity to reduce greenhouse gases and improve population health by producing energy without using fossil fuels. The current study focuses on the examination of the environmental and socio-economic impact of photovoltaic (PV) energy in the West Development Region (WDR). The area is located in the western part of Romania, covering 32,028 km2 (13.4% of the country's surface) and gathering 1,828 million inhabitants (9.4% of the country's population). It includes four counties: Timiș, Arad, Caraş-Severin and Hunedoara. For the current study, 35 photovoltaic parks were identified, mapped and analysed, based on which several indicators were computed in order to highlight the environmental and socio-economic consequences: share of PV parks/land use category/main soil type; distance to forests, waters, Natura 2000; no. of jobs created during the construction/operation of the PV parks; the value of PV parks investment; the impact on the local budget. The total analyzed area covers 177.76 ha.

Keywords: *photovoltaic (PV) parks, environmental impact, socio-economic impact, West Development Region (WDR), Romania*

INTRODUCTION

Nowadays, energy consumption is a key component of the economic development of countries worldwide. The ever-expanding energy demand is linked with the increase in the living standards of the population, but also with the economic expansion of some developing countries [1]. All of these put pressure on the efficient use of energy resources, but especially on the search for alternative solutions for energy production. In addition, the exploitation of conventional energy resources (coal, oil) involves the production of a significant amount of polluting gases, i.e. greenhouse gases (e.g. CO_2, SO_2, NO_x) that affect the long-term health of the Earth's population and ecosystems through the pollution of water, soil, air or the caused greenhouse effect. However, the energy produced globally through the use of fossil fuels has a high share (over 80%), differing greatly from one region to another (over 95% in the Middle East and about 70% in Central and South America), according to the Statistical review of World Energy, 2019[1]. In Romania, the primary energy consumed was based on the following types of fuel: oil (0.45 exajoules), natural gas (0.39 exajoules), coal (0.19 exajoules), nuclear energy (0.10 exajoules), hydropower (0.14 exajoules), and other renewable energy sources (0.10 exajoules)[1].

It is estimated that the energy produced from fossil fuels will reach its peak in the next 10 years [2], and this will happen rather because of the increasing application at national level of policies that reduce pollution, than of geological reasons [3]. Currently there are alternative solutions for energy production which involves: hydropower, biomass, geothermal energy, wind energy, solar energy (captured using photovoltaic panels). Of the renewable energies, the largest amount of energy worldwide is produced by the wind energy (1250 Terawatt-hours) followed by the solar energy (750 Terawatt-hours) https://www.bp.com/content /dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2019-full-report.pdf. However, the use of renewable resources for energy production has some negative effects on the environment i.e. water accumulations behind hydropower dams alter the ecosystems, the location of wind farms or photovoltaic panels occupies significant areas that sometimes involve the conversion of productive agricultural land (see [4], [5]). In terms of environmental impact, there are studies that have analyzed the negative effects on biodiversity [6], [7], protected natural areas [8], [9], the sensitivity of ecosystems to changes etc.

As [10] pointed out, solar energy technologies involve, first of all, the emission of a small amount of pollutants in air and water (e.g. CO_2, SO_2, NO_x). Solar energy production is currently the most expensive renewable energy [11]. The positive socio-economic effects include increasing the energy independence of the area where such technologies are located [12]. The use of photovoltaic technology is driven by the application of European policies on reducing the carbon footprint [13]. The European Union has planned for 2030 a share of renewable energy of 32% in total energy production. Romania, through the Energy Strategy, aligns with European policies on renewable energy, including the ways in which community objectives can be achieved [8], [9].

The analysis of the climatic potential for energy production in different regions of Romania has been the subject of numerous studies [14], [15], [16]. As solar farms will continue to develop in Romania, integrated regional studies are needed to investigate the socio-economic and environmental impact of photovoltaic parks. The environmental impact of photovoltaic parks is different, depending on their location. For example, a forest area will be differently affected by the impact of PV parks compared to a steppe area. In line of the above, the current analysis will focus on the socio-economic and environmental impacts of PV parks in the West Development Region (WDR) in relation to the diversity of natural and human-made conditions.

STUDY AREA

The WDR is located in the western part of Romania close to the border with Hungary and Serbia (to the west and southwest). The area is covering 32,028 km^2 (13.4% of the country's surface) and gathering 1,828 million inhabitants (9.4% of the country's population). It includes four counties: Timiș, Arad, Caraş-Severin and Hunedoara. The relief forms are rather varied, the eastern part is mountainous, and the west corresponds to fertile plains with a high agricultural potential and a discontinuous strip of Piedmont hills [17].

Between 2013 and 2018, 35 photovoltaic parks were built with areas ranging from 1.13 to 41.85 ha. The distribution of PV parks is uneven at county level, but closely related to the sunshine duration, as revealed by the slopes exposure which shows a positive correlation (the longer the sunshine duration, the larger the number of PV parks) and, especially, the relief configuration (Fig. 1). In the study area, 12% of the photovoltaic parks in Romania are concentrated making it the 5th development region by the number of PV parks. The main reason is the favourable sunshine duration of 2200 hours per year, being the second region in the country registering such high values, after the Romanian Plain [8], [9].

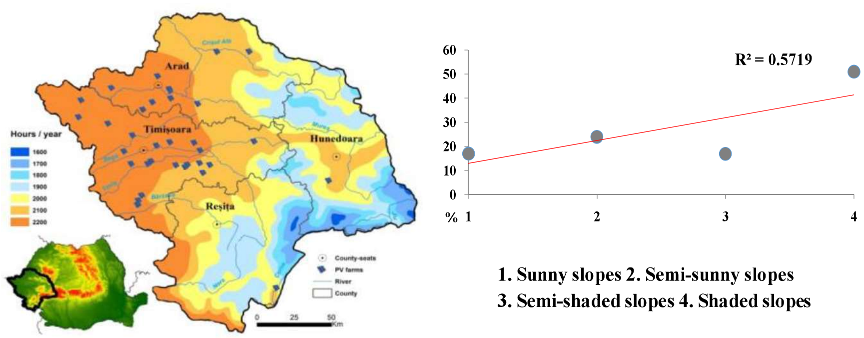

Figure 1. Sunshine duration (A) and slopes exposure (B) in WDR

More than half of the photovoltaic parks (65.7%) were built in Timiș County, followed by Arad (28.6%), Caraş-Severin (2.9%) and Hunedoara (2.9%) counties. The first two counties overlap the hill and plain relief forms, while the next two belong to the rugged mountainous relief, which cannot be exploited in order to develop PV solar energy.

The WDR overlaps with three main relief forms: plain (Western Plain), hill (Western Hills) and mountainous (parts of the Southern and Western Carpathians). Of these, most plants were built in the Western Plain (85.7%) driven by the relief conditions and the sunshine duration which are optimal for the development of this type of renewable energy. The Western Hills and the Western Carpathians concentrate a small part of the parks (8.6% and 5.7%, respectively), due to the rugged terrain, the short sunshine duration, but also the high costs involved in a construction in such areas. In terms of covered surfaces, 68.5% of the power plants have areas below 5 ha and only 5.7% exceed 10 ha (Fig. 2).

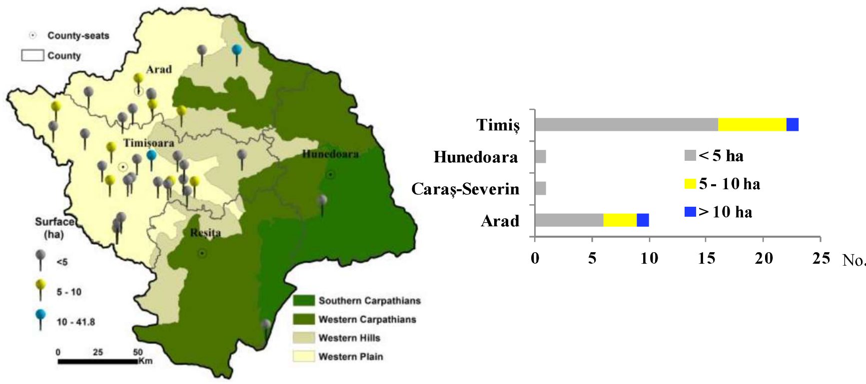

Figure 2. PV parks distribution on relief units (A) and distribution and surfaces at county level (B)

DATA SOURCES AND METHODS

The information used for the current analysis is both quantitative (statistical, spatial data) and qualitative, i.e. data obtained during field surveys (questionnaires and interviews) which, combined, helped us to understand the impact that photovoltaic parks have on socio-economic and environmental components.

The first step was to extract PV fields from satellite images (Landsat 7 ETM and Landsat 8 OLI, 2018) and the resulting spatial data was correlated and completed with the records provided by the Romanian Transmission and System Operator (TSO) Transelectrica. Subsequently, in order to highlight the potential negative effects on the environment, the following indicators were analyzed: the share of PV farms of each land use/cover category (based on CORINE Land Cover 2012 and 2018); distance to forests, protected areas (Natura 2000), waters and share of PV farms of main soil types. The last step was to assess the social and economic impact in relation to the development of photovoltaic energy in the WDR. The data sources used were imposed by and adapted to the diversity of the social and economic effects of solar projects. Thus, the data sources were identified county and local levels (e.g. County Statistics Offices, County Environment Protection Agency, and mayoralties) but also at national level (e.g. National Institute of Statistics and the National Regulatory Authority for Energy). The territorial concentration of photovoltaic farms helped us valorise the regional and local specificities of PV parks, enriching and completing the official and statistical data by field investigations (carried out in the summers of 2019 and 2020). Also, the information obtained from field investigations was completed by other, resulted from a detailed research on the web pages of companies/investors in this type of renewable energy. The interviews and internet research, as main methods used in this study, were focused on four issues: (i) land use/cover changes, (ii) investments & new created jobs and (iii) consequences for the local budget (types of taxes).

RESULTS AND DISCUSSIONS

The **environmental impacts** of PV parks. In Romania, in the plain and hill areas, photovoltaic parks were built on areas with high agricultural productivity [8], [9]. In terms of distribution on ***soil types,*** in the WDR only 43% of the PV parks have replaced high fertility lands (mollisols and alluvial soils), the rest being built on low fertile or infertile lands (cambisols, halomorphic soils, truncated uncultivated soils) or for which additional investments are needed in order to perform drainage works in order to acquire agricultural value (hydromorphic soils) (Fig. 3).

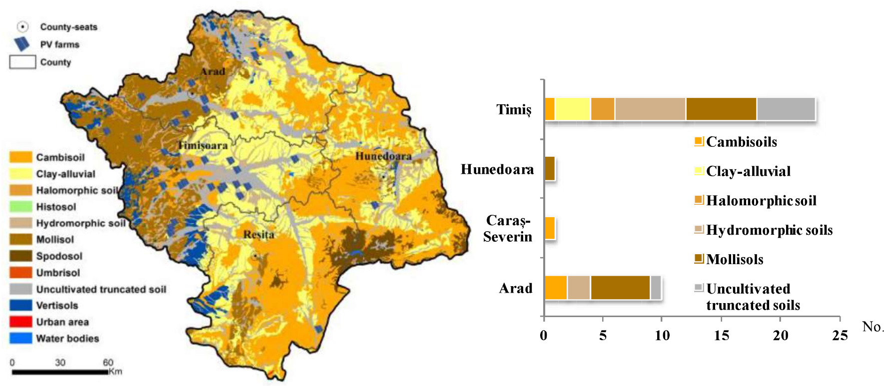

Figure 3. PV parks distribution on main soil types in WDR (A) and at county level (B)

The WDR covers an area with various ***water bodies*** or hydrographical resources. Over of 51% of the photovoltaic parks are positioned at a distance of less than 1 km from watercourses, of which 31% only in Timiş County. 74% of PV parks are located at distances under 2 km. Under these conditions, the existence of groundwater at a high level and the use of herbicides by the maintenance companies in order to stop the growth of vegetation that leads to shading of photovoltaic cells, can become a significant environmental problem for the watercourses.

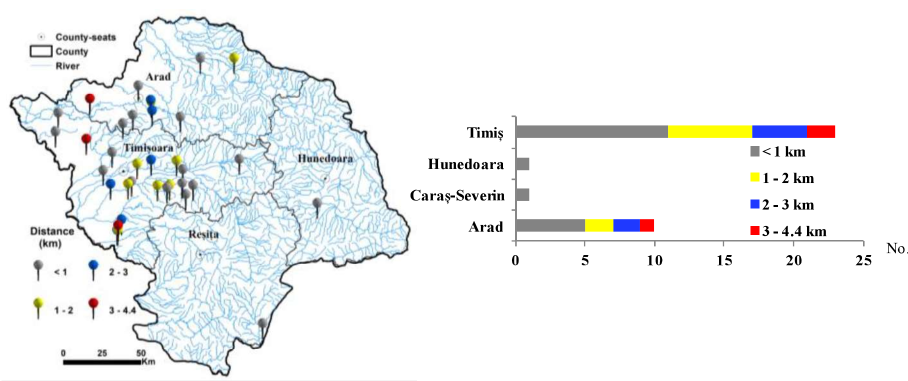

Figure 4. Distance of PV parks to water bodies in WDR (A) and at county level (B)

The ***distance to natural protected areas*** (including Natura 2000 sites and forests) involves multiple variables that must be taken into account in conducting environmental impact studies. Habitat destruction or fragmentation, the side effect (with a direct impact on wildlife - feeding mode, movement within the habitat, reproduction, etc.) and infiltration of substances for cleaning or removal of unwanted vegetation are the result of uncontrolled anthropogenic expansion.

In the study area, 60% of the photovoltaic parks are built at a distance of less than 5 km from the protected natural areas, and 20% of them at a distance of less than 1 km. In the case of ***forests***, 31% of the parks were built at a distance of less than 1 km, and 66% at less than 3 km.

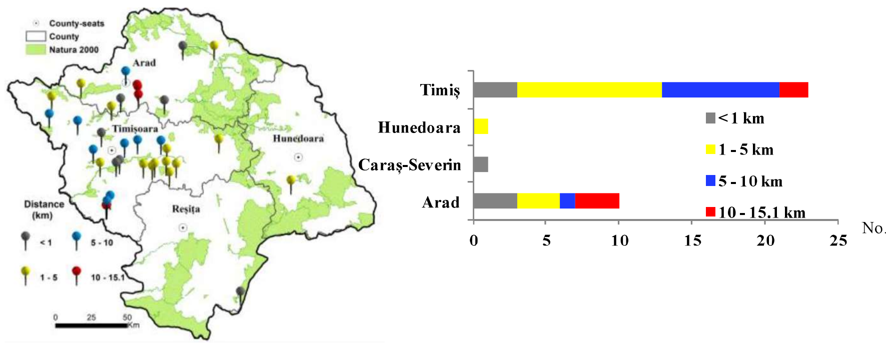

Figure 5. Distance of PV parks to Natura 2000 sites in WDR (A) and at county level (B)

Unlike other development regions where the distance to the natural areas increased over the years, in the West Development region, in 2013, 36% PV parks were built at a distance of more than 5 km, and in 2015-2016 only 16 % exceeded the 5 km threshold for Natura 2000 sites. For example, in 2015, Băile Herculane Local Council invested 4 million euro in a photovoltaic park located just 7 m from the SCI Domogled - Valea Cernei.

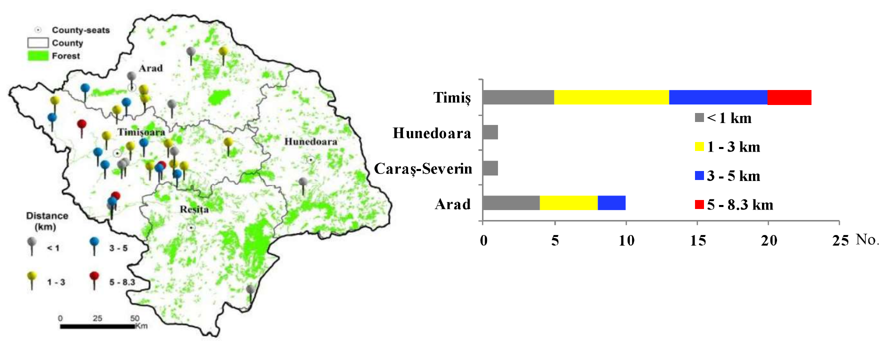

Figure 6. Distance of PV parks to forests in WDR (A) and at county level (B)

Proximity to national or county roads is an important factor that investors take into account for the easy access of equipment, which is supported by the fact that most of the photovoltaic parks were built at a distance of less than 500 m from of an access road (57%), and 74% of them are less than 1 km away. On the other hand, the easement roads that reach up to 6 km (in the case of 11% of the parks in Timiș County) contribute to the fragmentation of habitats and to the decommissioning of potentially productive areas from an agricultural point of view.

The ***distance to settlements*** is less than 1 km in 48.6% of cases and less than 2 km in the case of 77% of photovoltaic parks, depending on the relief configuration. Thus, in the Western Carpathians and in the Western Hills the parks are built much closer to the localities, compared to those built in the Western Plain, where both the relief and the duration of the sunshine allow their development.

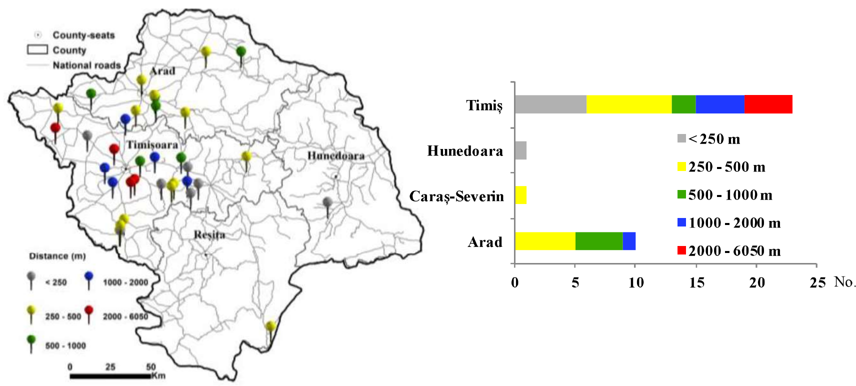

Figure 7. Distance of PV parks to national roads in WDR (A) and at county level (B)

The smaller the parks are located at a distance from a settlement and, implicitly, from a national or county road, the lower the impact on the environmental components caused by investments in access infrastructure (Fig. 8). Also, from a technical and economic point of view, it is more useful for the photovoltaic parks to be located in the immediate vicinity of the localities, as close as possible to the places of consumption and/or the electricity network because long-distance transport implies distribution losses.

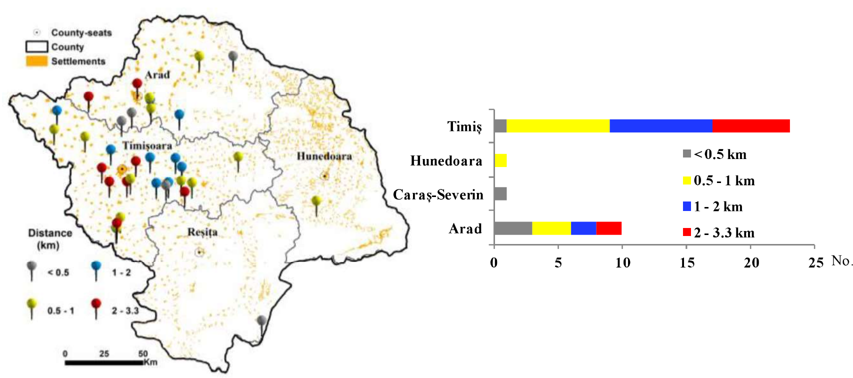

Figure 8. Distance of PV parks to settlements in WDR (A) and at county level (B)

The exploration of the **socio-economic impact** follows the aspects linked to investments in local rural economies, land/cover changes and the loss of farmland; very few jobs opportunities and positive effects on the local budget.

The analysis of *investments in local rural economies* was difficult to make because of the lack of data at local level, only in the cases of five PV parks being identified the values of investments. As other similar research experience show (i.e. [18]), this deficiency is caused by the very low level of investments, information about this type of investment being difficult to be identified in local or regional newspapers or on internet. Thus, form these PV parks, a total of 34 million Euros were summarised, the largest park in the WDR requiring an investment of 23 million Euros (Romanian company - S.C. DELTA & ZETA ENERGY SRL), in the Western Hills (Arad County).

The dimensions of investments are related to the installed capacity of PV power plants. So, considering the low level of investment in the majority of WDR's PV parks, we highlight that the installed capacity is predominantly low, 88.6% of them registering up to 3 MW/PV park and 57% below 2 MW/PV park. The most important investment above mentioned presumed the largest photovoltaic park: 42 ha and an installed capacity of 15 MW.

Land use/cover changes and loss of farmland. The photovoltaic parks were mostly built, on unirrigated arable land (71.4%), but they also replaced other categories of use, such as meadows, artificial surfaces, forests or complex crops (Fig. 9). With the adoption of Law no. 23/2014, many parks have not received licenses from producers and accreditations from Romanian Energy Regulatory Authority. Starting with 2015, the PV parks located on lands removed from the agricultural circuit received licenses from the producer, but not accreditations for the support scheme. On the other hand, the lack of irrigation, high-performance equipment and the negligence of farmers lead to underperforming agriculture.

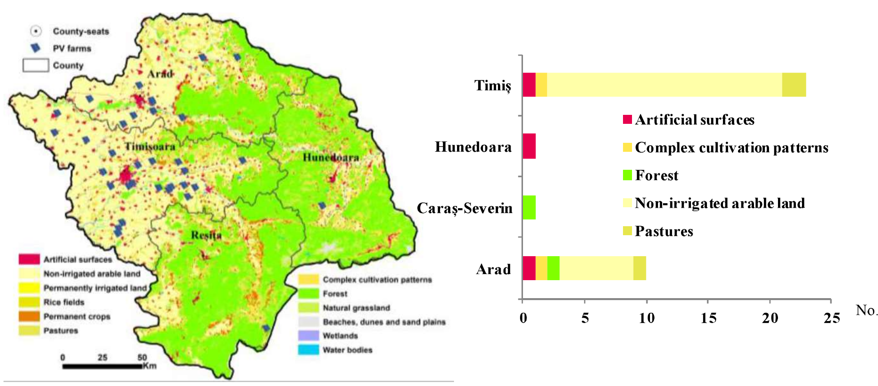

Figure 9. PV parks distribution on LUC categories in WDR (A) and at county level (B)

Therefore, investments in photovoltaic energy on uncultivated agricultural land are profitable both for investors and for local communities, through the taxes that investors pay to the local authorities, but also through the jobs created for the involved or neighbouring localities.

Regarding the issues of *jobs opportunities* and *positive impact on the local budget*, the field investigations have shown the following aspects: there exists a positive impact of the initial investment in PV parks on the local budgets exists and also a very small effect on labour force. Related to both issues, our field research highlight that the situations from WDR are similar to those emerged from other studies developed at national, regional and local levels [8], [9], [18]. Thus, the jobs opportunities are few, with a short-term positive impact in terms of small number of employees and low qualification; the taxes were perceived on land concession for the implementation of PV parks, on land sold to investors for implanting solar projects, on building licenses, tax on land, tax on special buildings (according to EGD no. 139/2004, the special buildings tax is 1.5) and a special tax on the installed operation power of each solar project.

CONCLUSION

The West Development Region is taking advantage of the natural potential in terms of high values of the sunshine duration (the second in the country after the Romanian Plain) and the relief configuration which are placing it fifth among Romania's Development Regions by PV parks number.

Although considered suppliers of clean and sustainable energy resources, PV parks involve several environmental and socio-economic constraints (e.g. land degradation, soil erosion, biodiversity loss, habitats fragmentation) as highlight by the literature (e.g. [4], [5], [6], [8], [9]. Compared to the southern Romania, where the prevalence of the plain relief, arable lands and of more fertile soils explained the removal of larger areas from the agricultural circuit at the expense of PV parks installation [8], [9], in the study area almost half of PV parks were built on low fertile or infertile lands which implies lower pressure on productive lands. The proximity to water bodies of nearly 50% of PV parks within less than 500 m shows the potential contamination of waters as a result of the PV panels cleaning during maintenance. PV parks installation in relation to natural protected areas and forests also points to a relatively distance of up to 5 km for nearly 60% of the PV farms (to Natura 2000) and of up to 1 km for nearly 30% of the PV farms (to forests). The relatively good accessibility to main roads (nearly 60% of PV parks within 500 m) and settlements (50% of PV parks within 1 km) shows an increased possibility of being valorised and maintained. These setting conditions are often considered essential since the beginning of the investment.

Also, in order to complete the overall picture of the environmental and socio-economic impacts of PV parks in the West Development Region, the authors computed a *solar electric footprint*. The solar electric footprint, as defined by [19] quoted by [20], is the land area necessary to supply all end-use electricity from solar PV related to inhabitants (expressed in sqm/inh.). As such, the solar electric footprint explains the direct relationship between ***(i)*** the main beneficiaries of the energy produced by the PV parks from a certain rural or urban settlement (i.e. the locals), and ***(ii)*** the land use category required to supply electricity from a PV park. In the WDR, the values of the solar electric footprint vary from 2.1 sqm/inh. in Săcălaz commune, to 86.7 sqm/inh. in Brestovăț, both located in Timiș County (Fig. 10).

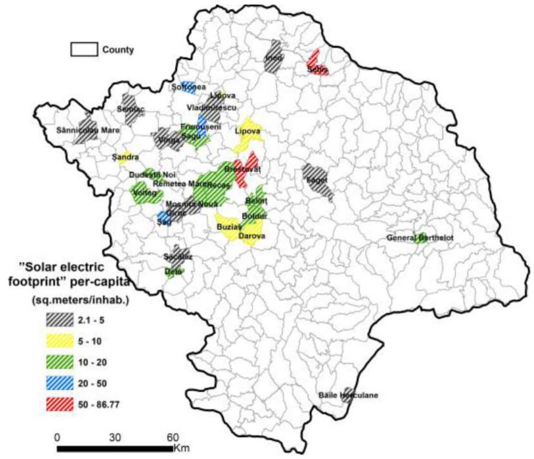

Figure 10. Distribution of solar electric footprint values in West Development Region

Compared to the WDR average solar electric footprint value of 12.5 sqm/inh., almost a half of PV parks had higher values. Some PV parks overcome the regional average to seven times (e.g. Brestovăț, Timiș County), five times (e.g. Sebiș, Arad County). Those photovoltaic farms are too large compared to the local needs and to the true economic and environmental loss of arable land covered by the solar panels.

This study revealed the positives and negatives of the PV parks installation and use in the West Development Region. However, the solar power has proved to be an important player of the national renewable energy system, with general positive effects on local economy. Thus, both at national and local levels, increasing the share of solar energy has been one of the main achievements in view of reaching the energy efficiency goals Romania has committed to.

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