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Land Use Conflicts Between Residential and Industry Sectors on One Side and Utility-Scale Photovoltaics on Another – A Missing Concept Gaining Importance

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Abstract
The purpose of this research note is to draw the attention of the researchers to the potential land use conflict that emerges during the energy transition. Namely, the competition between utility-scale photovoltaics (USPV) on one side and residential and industrial development on the other. This issue is an overlooked problem, even though other types of land use conflict have been raised in recent literature. The reason why this issue is unaddressed is probably because the described problem is not yet evident. However, population growth and industrialisation processes, together with increasing electricity demand, in particular the demand for renewable energy, are the main drivers of potential land use conflicts. The role of this paper is to shed light on the missing concept of land use conflict in the age of energy transition.

Keywords: *Land use conflicts, photovoltaic, residential areas, industrial areas, land requirements*.

1. Introduction

The development of photovoltaic power plants (PV) as power sources in energy systems has gained momentum in recent years. The objective of PV implementation is to minimise the adverse effects of electricity production on the environment. Especially PV can contribute to reducing greenhouse gas emissions [11, 26]. Particularly, employing utility-scale photovoltaics (USPV) has significant potential in many regions [3, 8, 27].

Nonetheless, the development of renewable energy generation units, including USPV, is associated with a change in land use [15]. Importantly, USPV requires larger amounts of land relative to conventional power plants, which is associated with a comparatively low energy density [16, 25]. This, in turn, undoubtedly leads to land use competition between USPV and other land use forms.

The literature describes some of the land use conflicts. For instance, USPV can compete with nature conservation forms, especially protected areas [1, 2]. The implementation of USPV can also threaten biodiversity [19], which is, in fact, an example of competition between habitat preservation measures and the industrial infrastructure in question. Interestingly, land use conflicts may also occur between PV and forests [23, 28]. In addition, PV can compete for land with other renewables [4]. Significantly, competition for land is well described between ground-mounted PV and agriculture [5], and agrivoltaics is a promising technology to mitigate it [24].

However, there is a research gap with respect to land use competition between USPV and housing or industry. Admittedly, there are works regarding the landscape impact of PV [12, 20, 29]. Nevertheless, this topic is associated more with the visual consequences associated with PV deployment, resulting in altering the perceived landscape than with strictly land competition.

This work aims to reveal that land use competition can be observed between housing, industry, and USPV, and although it may not be evident currently, this topic will probably gain importance in forthcoming years or maybe decades. This means that USPV is capable of competing for land sources with residential areas as well as with industry development. Importantly, although USPV is an industrial land use form, it can limit access to land for other industrial space uses, such as mining or manufacturing.

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2. Conceptual description of the research problem

2.1. USPV development

PV is one of the most promising technologies for reducing greenhouse gas emissions [13, 14]. Among the PV solutions, USPV is a type of system that is characterised by a high installed capacity. Despite USPVs have some environmental disadvantages in comparison to rooftop-mounted PV [21], the use of USPV allows for concentrating a large amount of power on one place and injecting it into a power system.

However, USPV development causes land use conflicts with other potential land use forms, described previously in the introduction section. At the same time, the growing energy demand is predicted. PV is said to play an increasingly important role in satisfying that demand worldwide [10].

Therefore, considering the necessity of USPV deployment, it is essential to draw attention to possible land use conflicts that may emerge in the near future. One of them, which is not yet addressed in the literature, is a competition between the installations in question on one side and housing and industry on the other.

2.2. USPV competition with housing

In recent decades, the human population has grown tremendously. Furthermore, the number of people worldwide is expected to increase significantly [17]. It is important to note that the human population will grow simultaneously with energy demand [22]. Therefore, the question arises of whether there will be enough land for both terrains, favourable for housing and energy infrastructure. In particular, considering the low energy density of USPV and its land requirements, the concern emerges that these land use forms will compete against each other. And this concern is justified by two observations. First, it is already observed that USPV leads to land conflicts with some specific land use forms. Second, the population that grows in numbers will need more space to live. Hence, the necessity of satisfying housing demand together with its auxiliary infrastructure both appear to be drivers of land use direction. While spatial management and land use policy for ensuring food security and energy security may be to some extent solved by employing agrivoltaics, the issue devoted to housing is, apparently, irreconcilable considering USPV.

To bring out this problem, it should be noted that there are already regions where USPV development is unsuitable, such as South Korea, where it is not feasible due to both a high urbanisation rate and a large forest area [18]. One more example is Switzerland, where the potential of USPV is limited due to already observed land competition [9].

It should be noted that the most suitable areas for development of USPV are those nearly potential grid connection point (and electricity consumption areas) since it allows to reduce costs for building cable routes to transmit energy from remote areas. Concurrently, this allows the reduction of energy transmission losses. Urban areas, on the other hand, consume a lot of energy. Hence, investors may seek lands in the vicinity of big cities to construct USPV. This, consequently, will limit the areas available for housing, especially in the suburbs, where the most intensive development of dwellings may occur.

Even considering the countryside, the subject issue persists. Implementing USPV in agricultural areas limits the potential area available not only for culture, but also favourable for residential purposes. This is a prominent problem, especially when USPV is located close to existing dwellings, making it impossible to construct new houses close to them. Hence, improperly planned USPV can cause fragmentation of areas intended for residential purposes, limiting land accessible for housing areas in the countryside.

In light of the issue addressed here, it appears that more attention should be drawn to the land conflict between USPV development and housing in future research. This is a great research gap that should not be missed. Indeed, in terms of sustainable development, especially sustainable spatial management, the problem that emerges is crucial to satisfying both residential needs and land requirements for USPV.

2.3. USPV competition with industrial areas development

Although USPV is indeed an industrial form of land use, it can compete with other industrial activities. Significantly, potential mining areas and storage or production facilities seem to be most affected.

Since USPV requires a large amount of land, it can limit mining activity. Importantly, mining is one of the most important industrial activities. As Max Planck put it: *Mining is not everything, but without mining, everything is nothing* [7]. Indeed, mining activity provides materials for global economies and is a foundation for, among others, civil engineering, transportation, and renewables. All usable deposits are important for the growth of the civilisation, starting with sand and gravel and ending with metal deposits. Importantly, open-cast mining is an essential type of mining activity. Nonetheless, deploying USPV within relatively large areas makes it impossible to run deposit exploitation afterwards. Considering this issue, it should be noted that USPV development shall be preceded by a geological survey in order not to decrease the available natural resources in the form of minerals. However, a poorly planned USPV spatial distribution may eventually lead to limited access to the deposits for the economy. Thus, there is a great need for proper spatial planning using all available data. The land use conflict between mining, especially open pit mining, and USPV may be most notable in smaller countries or in regions where the quantity of domestic deposits is limited. However, this problem shall not be missed in economic development strategies, and thus, access to geological data is crucial for planning purposes.

On the other hand, the economy, besides access to energy facilities, needs the development of industrial areas for, among other things, storage and production terrains, whereas the rapid development of USPV decreases available land. In particular, a problem similar to that one related to housing development arises, perhaps even more significant. Namely, production areas can be located close to urban areas to ease the transport for a larger number of employees. This is especially feasible by designing special economic zones. In addition, locations in the mentioned areas can facilitate further distribution of goods. Nevertheless, prospective areas intended for industrial activities prospectively may also be favourable for USPV. Hence, land use competition can emerge.

It should be noted that renewables are sometimes said to be developed close to existing industrial areas to limit their environmental impact. An example of that thinking is included in the RED III EU Directive (Directive (EU) 2023/2413 [6] of the European Parliament and of the Council of 18 October 2023 Amending Directive (EU) 2018/2001, Regulation (EU) 2018/1999 and Directive 98/70/EC as Regards the Promotion of Energy from Renewable Sources, and Repealing Council Directive (EU) 2015/652, 2023). That act of law indicates that renewable acceleration areas shall be designed giving priority to, among others, industrial sites. Nevertheless, these areas, specifically their neighbours, may be especially suitable for the development of industrial facilities, like storage and manufacturing. USPV, as it takes large amounts of terrain, will in fact limit other industrial forms of land use. In this term, USPV has a great potential to hinder the growth of the industry sector. Therefore, in the further industrialization process, attention should be paid to whether USPV is well planned in terms of its potential effect on the industrial environment.

3. Conclusions

Considering the issues addressed, it is desired to design and execute research that will reveal the intensity of competition between USPV and other land use forms highlighted in this paper. In particular, there is a need to carry out a spatial analysis taking into account, especially, future land demand for housing, industry (including access to deposits for mining activity), and USPV. This analysis would result in indicating overlapping areas for them.

In this short conceptual work, the phenomenon of potential land use conflicts between USPV and selected land use forms, yet not been raised in the literature, is conceptually described. The objective of this paper is to draw the attention of researchers to the potential land competition that may arise under energy transition conditions.

The problem addressed in this paper should not be missed, as a better understanding of land use conflicts leads to more effective policy making at both the regional and local levels. Importantly, we can observe that the natural environment and agriculture may not be the only components of the human surrounding that may be affected by USPV.

The conception of land use conflicts between USPV and housing or industrial areas is not addressed in the literature. However, it is important to pay attention to this potential issue, since the observed human population growth together with the increased demand for industrial products are crucial factors leading to potential land use conflicts.

In summary, this work emphasises the importance of research in the field of land use conflicts focused on USPV by defining a conceptual issue that is missing in the current research. This problem should not be overlooked as it appears it can not be avoided, especially in the future.

It should be added that nowadays, during energy transition, land use policy and urban planning gains importance like never before. Thus, science must provide answers to potential issues in advance, which is a challenging matter.

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