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Winds blowing strong: wind power expansion in Aragón

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Resumen:

The unstoppable increase in the installation of renewable energies for environmental and geopolitics reasons is one of the necessary components to achieve the energy transition. We are witnessing a global increase in the use of these types of energy sources, with wind being the main source of renewable energy production. Understanding the process of renewable energy installation from a territorial perspective is one of the current academic challenges that this paper proposes to analyse.

The energy transition is a complex process, being directly affected by technological, economic, social and environmental aspects (Blazquez et al., 2020). In addition, the energy transition has been conceived as a spatiotemporal process in which the territorial distribution of renewable and non-renewable energy sources is not spatially randomly allocated. In short, the energy transition can be considered as a spatially dependent process (Bridge et al., 2013a).

Recently, some authors aimed to build a theoretical framework on the concept of energy geography (Calvert, 2016; Pasqualetti & Brown, 2014), the geography of the energy transition (Bridge & Gailing, 2020) or the link between geography and renewable energies expansion (Fadly & Fontes, 2019), giving a spatial and territorial character to the processes under discussion. However, little empirical evidence exists in this area, highlighting the need to empirically address the energy transition process from both a spatial and temporal perspective. Only a few recent works considered spatial aspects (Balta-Ozkan et al., 2015, 2021; Schaffer & Brun, 2015; Zhang et al., 2023) and a few others incorporated both the spatial and temporal dimensions simultaneously (Olivier & Del Lo, 2022; Xu et al., 2022). Due to the absence of spatial scale data and the rapid

energy transformation that has occurred in the 21st century and will continue in the future, understanding this spatiotemporal process is thus one of the greatest academic challenges of our day (Bridge et al., 2013b).

In parallel, at the beginning of the 21st century, the theoretical body of Environmental Economic Geography (EEG) was also born, incorporating environmental factors into economic geography aspects (Bridge, 2008; Gibbs, 2006; Hayter, 2008). More precisely, from a spatial or regional perspective, EEG explores how economic activities can reduce environmental damage through institutional evolution and technological innovation (Boschma et al., 2017).

Theoretically, this branch of the EEG investigates the broader concept of the “green” transition in general as a dynamic process where innovation and institutional considerations play a key role (He et al., 2022). Sustainable transition in space, in a broad sense, is also discussed (Köhler et al., 2019; Murphy, 2015). Understanding the energy transition process from the perspective of economic geography is fundamental for designing and implementing effective public policies under varied regional framework conditions. This process is unstoppable, so designing future-adapted public policies is essential to minimising the territorial costs of the transition and maximising its potential benefits across space. Understanding the process of energy transition from this perspective is key to achieving it in a just way (Wang & Lo, 2021), especially in a spatially just way (Garvey et al., 2022).

Specifically, the process of expansion of wind energy in Aragon will be analysed. Aragon is one of the largest renewable energy producing regions in Spain and at the European level, consolidating in recent years as a leader in the installation of wind energy.

This paper analyses the development of wind energy in Aragon, among which its stages and potential factors that explain its installation in this territory. Understanding the process of expansion of this technology in space and time is key, given that the lack of land-use planning linked to these infrastructures is leading to a series of territorial conflicts. Understanding the historical evolution of Aragon as an energy producer and multilevel political management will help to understand this disorderly increase in wind energy.

Even more so, looking at the possible installation scenarios to be achieved in the coming years, doubling the current power in a short period. Therefore, this paper links concepts of the new Energy Geography, defining the energy transition process as a spatial-temporal process, all within a framework of a just energy transition.

From the methodological point of view, in addition to reviewing the historical energy evolution of Aragon, both renewable and non-renewable, its energy balances are analysed, as well as the multilevel decision-making between the state, the autonomous community and the municipality vis-à-vis decisions to install wind energy. In addition, spatial techniques such as point pattern analysis and Standard deviation ellipse method are used to analyse how wind energy has been installed based on temporal and geo-referenced data. Aragon currently produces 9% of the total Spanish energy, being also the autonomous community with the highest percentage of renewable generation (82%). Among the renewable energies, wind power generation (54%) and solar photovoltaic generation (17.4%) stand out. In addition, Aragon is the second autonomous community with the second highest installed wind power capacity (after Castilla y Leon) and the third in installed solar photovoltaic capacity (after Extremadura and Castilla y la Mancha). In short, Aragon is one of the most important territories in renewable energy generation in Spain and the renewable sector is very important in its energy mix. Not only that, the trajectory of expansion of renewable energies in Aragon is not comparable in any European region, since in the last years it has installed more wind energy power than any other NUTS 2 region in Europe (García-Riazuelo et al., 2025).

The results show that Aragon already produces more electricity, thanks to renewable sources, than it consumes. This makes the autonomous community a net exporter of electricity. The lack of territorial planning and horizontal integration between public administrations at all territorial levels explains this uncontrolled increase. This process has tended to be concentrated in space, and the installation of wind farms is not homogeneous over time. Moreover, this agglomeration pattern, surprisingly, has not changed over time, revealing important spillover effects in the diffusion process of this technology. Specifically, wind energy installation has tended to be concentrated in a small area of Aragonese territory, in the centre-west of the region. All this happens in a small space, as 90% of the wind farms are concentrated in a radius of 100 kilometres. Moreover, the presence of a spatial spillover is quantified within a radius of 90 km. Finally, the expansion of wind energy over time has been analysed, showing that despite large increases in installed capacity, it has always been concentrated in the same places and in the same direction.

In short, understanding and characterising the process of installing wind energy as a spatio-temporal process, in which institutions play a relevant role, is key to the formulation of land-use planning policies, in order to meet more just environmental and

energy objectives, taking into account the territory, thus minimising the possible conflicts that may arise. It can be concluded that the lack of institutional planning is one of the causes of this lack of planning in the installation and spatial concentration of wind farms. It is important to take this into account, since, as already mentioned, the forecast of the Government of Aragon is to double the installed capacity of wind energy in the next few years. Without the necessary planning instruments and the current disorder, as has been demonstrated, this has led to a social fracture with regard to the acceptance of the installation of wind farms in the territory. Continuing with the energy peripheralisation of Aragon does not seem to be the most appropriate way to reduce this social fracture (O'Sullivan et al., 2020). Without planning, the only thing that can happen is that the energy transition will not be completed (Rodríguez-Pose & Bartalucci, 2023). In short, in order to complete the energy transition, planning and territorial organisation must be taken into account to achieve a spatially fair energy transition.

Palabras clave: Wind Energy; agglomeration effects; spatial planning.

Área temática: Medio ambiente, sostenibilidad, energías renovables y Evaluación de políticas y planes estratégicos.

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