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Understanding the challenge of our era: The wickedness of land allocation for energy transition

André Alves
Centre of Geographical Studies and Associate Laboratory TERRA, Institute of Geography and Spatial Planning, University of Lisbon, Portugal
andrejoelalves@edu.ulisboa.pt

The energy transition from fossil fuels to renewable technologies is advanced as a response to pressing global issues, such as climate change, biodiversity crisis, environmental pollution, and resource depletion. Despite the widely recognised benefits of the decarbonisation of energy systems, the spatial implications of large-scale renewable energy deployment may introduce significant challenges for land-use planning. This paper applies the concept of wicked problems in planning as an analytical framework for examining renewable energy development. The paper argues that land-use planning processes associated with renewable energy infrastructure exhibit several characteristics that are commonly attributed to wicked problems and thus highlight the governance complexities involved in managing land for energy transition, as well as contributing to ongoing debates pertaining to the spatial dimension of energy production within planning theory.

Keywords: planning dilemmas, wicked problems, energy transition, renewable energy planning, spatial planning

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Introduction

Contemporary society faces interconnected challenges; notably, climate change and the transition from fossil-based energy production to low-carbon and renewable technologies. Both require integrated policy responses. While existent energy transition discourse typically focuses on technological and economic aspects, a less prominent aspect is the anticipated transformation of land to meet renewable energy targets (Kaza & Curtis, 2014). Planning often involves decisions which require practical judgments that navigate spatial, temporal, and social complexities (Khakee, 2020). In particular, land-use decisions are inherently complex. This is because they involve balancing multiple, and often conflicting, environmental, economic, and social objectives; each shaped by diverse stakeholder priorities and uncertainties (Bateman et al., 2024). These features resonate with the concept of wicked problems, which this paper advances as a central framework to understand the challenges pertaining to siting renewable energy infrastructure.

The environmental rationale for an accelerated shift away from fossil fuels has dominated the quest for new renewables since the late 1980s (Smil, 2015). According to the Intergovernmental Panel on Climate Change (IPCC) Special Report on Global Warming of 1.5°C, the decade 2020–2030 is crucial for achieving emission reductions in the energy sector (IPCC, 2018). The development of renewable energy systems such as wind parks and solar power plants, to both ensure universal access to electricity, heat and transport, and mitigate climate change, is one of the most pressing challenges facing humans today (Hernandez, R. R., Hoffacker, M. K., & Field, C. B., 2015). Given that renewables have a power density (W/m^2) that is orders of magnitude lower than fossil energy sources (van Zalk & Behrens, 2018), competition for land between energy infrastructure and other functions such as agriculture, forestry, and nature conservation areas is expected (Cunningham & Seidman, 2024).

Renewable energy infrastructure can involve highly contested spaces. Land cover changes and potential environmental impacts on protected areas (Alves et al., 2026), land value depreciation (Elmallah et al., 2023), and ecological effects on wildlife and native vegetation (Dhar et al., 2020), together with other social and environmental consequences (Dunlap et al., 2024), are prominent sources of opposition to new developments, and often fuel “not-in-my-backyard” sentiments (Batel et al., 2013; Susskind et al., 2022). Nevertheless, existent literature also highlights potential positive outcomes provided that appropriate planning and management strategies are adopted. For instance, solar power plants can increase bird diversity in agricultural landscapes (Jarčuška et al., 2024), enhance pollinator biodiversity (Blaydes et al., 2021), and, when combined with crop production through agrivoltaics, provide benefits across the food–energy–water nexus (Barron-Gafford et al., 2019).

The planning of energy production is entering a new phase due to the development of renewable energy. Unlike the localised impact of fossil fuel-based electricity generation infrastructure – natural gas-fired power plants -, renewable energy sources demand extensive land areas. Even though the relationship between land use and renewable energy has a long-standing history (Walker, 1995), the siting of renewable energy infrastructure, and particularly the challenge of balancing increased energy production whilst avoiding land-use conflicts, has received limited attention in planning studies. Nevertheless, the pursuit of more sustainable energy transitions has increasingly shifted attention towards spatial considerations, contributing to a growing interest in a spatial turn in energy planning (Guo et al., 2020; Osorio-Aravena et al., 2020; Stoeglehner et al., 2011; Stremke and Koh, 2010).

This paper examines the planning of renewable energy infrastructure through the lens of wicked problems. Although the spatial dimension of energy production involves multiple interrelated factors, the focus here is specifically on how planners should deal with the complex challenges that arise from land-use planning for renewable energy infrastructure within the broader context of the energy transition.

Methodology

This paper adopts an argumentative review design grounded in conceptual analysis. Accordingly, it employs a theory-driven interpretative approach to examine land-use planning for renewable energy infrastructure through the lens of wicked problems. The ten characteristics of wicked problems originally articulated by Horst Rittel and Melvin Webber (1973) were used deductively as organising categories to structure the examination of contemporary literature on land-use planning for the energy transition.

The literature reviewed was selected through iterative searches in major academic databases and focused on peer-reviewed publications which address renewable energy siting, land-use conflicts, spatial planning, environmental governance, and socio-technical transitions. Seminal works on wicked problems and planning theory were included to establish the conceptual foundation, while recent interdisciplinary studies were incorporated to reflect current debates.

The analytical process involved mapping empirical and theoretical insights from the reviewed literature against each of the ten wicked problem characteristics. This deductive-conceptual matching enabled the identification of structural parallels, tensions, and governance implications. As an argumentative review, the paper does not claim systematic coverage of all existing literature. Rather, its contribution lies in conceptual synthesis and theoretical reframing and seeks to stimulate further debate within planning scholarship regarding the spatial dimension of energy production.

Defining wicked problems

Wicked problems are complex and multifaceted issues which are characterised by ambiguity that resist straightforward or universally accepted solutions. They refer to a class of social system problems which are ill-formulated; where information is confusing; where there are many clients and decision makers with conflicting values; and where the ramifications for the whole system are thoroughly puzzling (Churchman, 1967). These issues do, however, extend beyond social systems, with Rittel and Weber (1973) having identified features that distinguish wicked problems from so-called “tame problems”. These complex and systemic problems typically provoke divergent views about the very nature of the issues, their relative importance, and the appropriate responses needed given the cognitive and sociocultural differences which exist in society (Alford & Head, 2017). Considered solutions to wicked problems frequently result in suboptimal policy outcomes. These may be partial or counterproductive and are often a consequence of limited comprehension of the problem or the constraints of scientific expertise in informing effective policy responses (Head, 2019). Additionally, policy-relevant knowledge remains inherently pluralistic rather than unitary, and this underscores the fact that various stakeholders in different contexts possess distinct perspectives on identical issues that cannot be “tamed” or addressed through conventional approaches, which are dependent on rational-analytic models of planning and decision-making (Rittel & Weber, 1973).

As described by Rittel and Webber (1973), wicked problems have 10 important characteristics:

1. They do not have a definitive formulation.

2. They do not have a stopping rule. In other words, these problems lack an inherent logic that signals when they are solved.

3. Their solutions are not true or false, only good or bad.

4. There is no way to test the solution to a wicked problem.

5. They cannot be studied through trial and error, meaning every trial counts.

6. There is no end to the number of solutions or approaches to a wicked problem.

7. All wicked problems are essentially unique.

8. Wicked problems can always be described as the symptoms of other problems.

9. The way a wicked problem is described determines its possible solutions.

10. Planners, that is, those who present solutions to these problems, have no right to be wrong. Unlike mathematicians, "planners are liable for the consequences of the solutions they generate; the effects can matter a great deal to the people who are touched by those actions" (Rittel & Weber, 1973, p. 167).

In summary, wicked problems encompass complex challenges that cannot be addressed through simple or definitive solutions. Moreover, the term conveys a sense of persistence and intractability, which often defies resolution due to the differences that exist between stakeholders and decision-makers that impede progress. The concept of wicked problems has been employed in research to underscore the limitations of reductionist approaches when it comes to addressing intricate societal and environmental challenges (Xiang, 2013). However, the term is also criticised for its ambiguity and perceived use as scientific jargon, and for the fact that it is predominantly used rhetorically rather than for analytical purposes (Noordegraaf et al., 2019; Peters & Tarpey, 2019). This study uses the concept as a descriptive tool to describe some aspects of the challenges involved in allocating land for renewable energy infrastructure.

Land-use planning and renewable energy infrastructure: a wicked problem?

In this section, the arguments for each of the points articulated by Rittel and Weber (1973) characterising wicked problems are developed. This is achieved by bridging connections with other references from various interdisciplinary fields to enhance understanding of the issue at hand and how planners should approach the challenge.

No definitive formulation

According to Rittel and Webber (1973), the information required to understand a wicked problem is contingent upon the proposed solutions. It follows, that accurately describing a wicked problem first requires a thorough inventory of possible solutions to be established. With regards to the siting of renewable energy infrastructure, no singular, definitive solution exists; rather, the optimal approach (for a given scenario) varies according to factors such as geographic characteristics, local ecosystems, and community preferences. Information requirements are, accordingly, influenced by the envisioned solution: for example, determining whether to prioritise optimal proximity to the electrical grid, minimise ecological impacts, or allow the conversion of agricultural areas for solar power plants. Without a clear problem definition—and particularly one that addresses the given spatial dimensions involved—achieving a satisfactory solution remains challenging, as no finalised solution concept can be applied. Given this, scenario development, which involves simulating the effects of specific decisions on land zoning and subsequent land-use changes (Gomes, 2026; Kim et al., 2022; Levin et al., 2023), offers a foundational method for designing better solutions.

No stopping rule

While would-be planners can always try to do better (Rittel & Webber, 1973), in reality, wicked problems tend to lead to sub-optimal solutions because it is difficult to assume that the (given) problem has been solved. In the case of land-use planning for renewable energy, establishing a clear endpoint is particularly challenging because new developments can always prompt further refinements or alternative approaches; solutions remain provisional. Factors such as technological advancements, shifting energy demands, and evolving environmental priorities render the planning process dynamic and ongoing. The emergence of new and unexpected situations may also lead to strains on existent energy systems and important policy changes (Tsangas et al., 2023). In addition, a land-use planning pathway that is deemed appropriate for today may soon become obsolete as a consequence of the emergence of new clean technologies or because societal priorities pivot towards alternative objectives. This evolving nature highlights the complex and uncertain characteristics of wicked problems; the search for solutions never stops. Furthermore, as long-term strategic policies drive the land-use planning instruments intended to ensure land availability for renewable energy, their sensitivity to changes in political priorities further complicates this process.

Good or bad solutions

Land-use planning for renewable energy infrastructure extends beyond a binary judgement of a solution's validity; it involves determining the relative "value" of an approach according to diverse, often subjective, criteria, including environmental sustainability, economic feasibility, and social acceptance. For example, the siting of a facility may be regarded positively for its contribution to renewable energy capacity but may also raise concerns regarding its effects on agricultural land, local food security, and biodiversity (Ariza-Montobbio & Farrell, 2012; Delicado et al., 2016; Susskind et al., 2022). Rittel and Webber (1973) argue that solutions to wicked problems inherently produce a cascade of consequences over prolonged, and frequently indeterminate, timeframes; complicating efforts to anticipate their full implications. Stakeholders such as developers and government agencies may prioritise accelerating the energy transition, potentially at the expense of adequate spatial planning, to maximise renewable energy outputs. At the same time, civil society and environmental organisations placing emphasis on ecosystem and biodiversity conservation may contribute to increased bureaucratic complexity and longer permitting processes; potentially constraining project development. Both positions are valid, but neither may offer an unequivocal solution, as each may yield repercussions that are difficult to predict. This inherent uncertainty supports the adoption of constructivist approaches in planning, which prioritise dialogue, mutual learning, and the inclusion of diverse perspectives over inflexible, predetermined solutions (Chermack & van der Merwe, 2003). Planning processes consistently involve reconciling diverse and frequently competing objectives and economic priorities within frameworks that are both political and technical (Grant, 2022).

This brings us to the root of the issue: the existence of divergent views on land use. As Head (2019, p. 182) observed, “by their nature, values cannot be adjudicated and settled by positivist science and ‘more data’; rather, value differences need to be managed through broad processes of argumentation and conflict resolution among stakeholders”. Disagreements arise because stakeholders hold fundamentally different assumptions, values, interests, and capacities on the ways that land should be used. Furthermore, there is no clear answer to what the best model might be, and planners should ground potential solutions in stakeholder consensus-building.

No immediate or ultimate test

The implications of land-use decisions for renewable energy development are extensive and may require considerable time to become fully evident, thereby illustrating the complexities of balancing immediate benefits with long-term sustainability. Kiesecker and Naugle (2017) suggest that the energy transition has the potential to precipitate a crisis of land use change. Assessing the effectiveness of a particular approach is not instantaneous, and long-term effects can lead to unexpected challenges. For example, while converting agricultural areas into energy production infrastructure may appear justifiable when neither land scarcity nor soil productivity are immediate concerns, such actions may compromise food security in future decades if fertile land faces competition from other land uses, such as urbanisation or timber production. Likewise, the disruption of natural areas by energy production infrastructure and transmission lines may not show immediate adverse effects but may cause prolonged and cumulative damage to wildlife habitats and severely impact biodiversity over time (Dunlap, 2023). It follows, that the complexity of these land-use decisions highlights the need for comprehensive and integrated strategies that consider the potential long-term consequences that may not be fully perceptible at the time of decision-making or implementation (Delafield et al., 2023).

One-shot operation

The idea of a one-shot operation highlights the substantial commitment and enduring consequences that are associated with land-use planning and infrastructure development. As stressed by Rittel and Webber (1973), there is limited opportunity to learn through trial and error; making it essential to exercise caution during decision-making processes. Decision reversal is often complex and costly. For instance, converting agricultural land into energy production sites can result in loss of soil productivity and health, while development of the same in sensitive ecosystems can lead to lasting damage to biodiversity (Dhar et al., 2020; Hernandez, R. R., Hoffacker, M. K., Murphy-Mariscal et al., 2015). Due to a range of cumulative factors, it is often challenging or impractical to reverse such impacts or repurpose the land effectively. It follows, that without many opportunities for iterative learning, land-use planning for the energy transition must be accompanied by comprehensive evaluations of potential outcomes and strategies to minimise adverse externalities, while also ensuring that the selected approach aligns with long-term sustainability objectives.

No exhaustive set of solutions

There are no universally accepted strategies or prescriptions; instead, planners must navigate a complex array of options; each carries unique implications and trade-offs. Unlike structured fields such as mathematics or chess, where rules and outcomes are clearly defined, land-use planning for renewable energy infrastructure is fluid and subject to continuous change. New technologies, shifts in energy demands, and evolving environmental considerations frequently emerge; necessitating ongoing exploration of viable solutions. For instance, innovative approaches such as agrivoltaics (Barron-Gafford et al., 2019), ecovoltaics (Tölgyesi et al., 2023), and pollinator-friendly photovoltaics (Dolezal et al., 2021) have gained increased attention as alternatives to conventional utility-scale solar installations. If these solutions deliver such impressive benefits, including mitigating some of the impacts typically associated with large solar infrastructure and optimising land-use efficiency, and may also benefit from higher public acceptance by communities (Pascaris et al., 2022), why are they still a niche? The answer may lie in a set of socio-technical barriers (Sovacool, 2009), with insufficiently supportive regulatory frameworks and policy incentives acting as constraints to its mass adoption (Carrausse & Arnauld de Sartre, 2023; Pascaris, 2021; Wagner et al., 2024). The necessity for informed judgment, the capacity to assess unconventional ideas, and the degree of trust and credibility between planners and communities are critical factors which influence the feasibility and acceptance of proposed solutions.

Essentially unique

The seventh characteristic of wicked problems, that all wicked problems are essentially unique, holds particular significance in the context of spatial planning. Each region presents distinct considerations with regard to land-use planning because variations in geography, climate, and the type of energy consumers imply that solutions which are effective in one location may be questionable in another. For instance, a wind park may coexist successfully with agricultural practices in one area but could face strong opposition elsewhere due to concerns about biodiversity or local property values. Although certain commonalities exist with other complex issues, solutions cannot be uniformly applied across all regulatory levels or countries. Each region encounters specific challenges aligned with its unique developmental priorities. As Kiesecker et al. (2024) highlight, some countries can meet their energy land requirements in low-conflict areas, while others face significant trade-offs. As a result, national responses vary: some countries, such as Italy and the Netherlands, prioritise the preservation of agricultural lands by imposing restrictions on converting these areas into solar energy infrastructure (Clarke, 2023; Matalucci, 2024), while others focus more on conserving natural landscapes or forested regions (Weber et al., 2023). This inherent uniqueness necessitates tailored approaches that consider the distinctive characteristics of each landscape and align with context-specific socioeconomic objectives. As a result, solutions must be adapted to local contexts, limiting the applicability of universal planning strategies.

Symptom of another problem

Every wicked problem can be viewed as a symptom of another problem. As described by Ackoff (1974), wicked problems interact with other wicked problems, forming a system of interrelated challenges. It follows, that addressing one problem may reveal additional issues or even generate new ones. In planning renewable energy infrastructure, this complexity is closely linked to broader concerns such as increasing energy demand, environmental sustainability, and prevailing economic growth models. For example, as global energy consumption rises, the demand for more land dedicated to energy production increases. Van de Ven et al. (2021) estimate that achieving renewable energy targets could require solar panels to occupy up to 2.8 % of the EU's land area by 2050—excluding additional land demands for mining essential materials, often referred to as "green sacrifice zones" (Canelas & Carvalho, 2023). This scenario is symptomatic of deeper systemic dependencies, and particularly the global economy's reliance on sustained energy consumption. Given this, society faces a dilemma: we are emotionally attached to the landscape we have, but we are equally attached to our consumption patterns (Kramer, 2017). Although some countries have managed to decouple economic growth from energy use, per capita energy consumption continues to increase in many regions (Our World in Data, 2023). This trend reflects an economic model centred on growth and consumption, which has been historically supported by fossil fuels with a comparatively low land footprint relative to renewable sources. This issue is also connected to wider ecological impacts. Some researchers argue that we are in the Anthropocene, a period in which human activities exert a dominant influence over the planet, and often surpass natural processes (Crutzen, 2006). Rising global energy demand is just one manifestation of this larger dynamic. In this context, the need to allocate more land to renewable energy production transcends a mere technical or spatial challenge. Rather, it reflects inefficient consumption patterns developed by fossil fuel dependence. The interconnected nature of these issues suggests, given the land-intensive nature of renewable energy infrastructure, that a transition to renewable energy with minimal land use conflict would necessitate substantial shifts in consumption habits and behavioural change.

Framing and solution dependency

In contemporary planning discourse, the way in which issues are framed significantly impacts stakeholder engagement and decision-making processes. The framing of a problem not only shapes perceptions but also influences the potential solutions considered. Problem framing not only shapes perceptions but also affects the range of potential solutions considered. Given the absence of definitive criteria to establish the "correct" explanation, diverse perspectives emerge. When a problem is narrowly defined, for instance, as a technical challenge with regard to integrating renewable energy infrastructure within existing landscapes, solutions tend to concentrate on optimising site selection based on specific criteria. Alternatively, if the issue is framed as part of a holistic challenge encompassing environmental sustainability, economic development, and community wellbeing, distinct approaches emerge.

Moreover, the language used in describing the (given) problem can reflect and shape stakeholder perceptions and priorities. Different stakeholders, such as government officials, environmental groups, landowners, and energy companies may, due to distinct concerns regarding economic growth, environmental conservation, or energy security, frame the challenges of renewable energy deployment through different lenses (Alves & Simoes, 2026), This multiplicity of perspectives influences the complexity of land-use decision-making; no single framing can fully capture the trade-offs inherent in renewable energy deployment (Khakee, 2020).

A well-rounded description that considers technical, social, economic, and environmental dimensions should facilitate the development of comprehensive strategies that not only advance renewable energy objectives but also ensure sustainable land-use practices, community participation, and ecological preservation. By acknowledging the complexity of the issue, planners can foster more effective and equitable solutions.

Accountability in planning solutions

Rittel and Webber (1973) argued that the planner has no right to be wrong; emphasising the weight of accountability. Unlike mathematicians, who can propose and discard hypotheses, planners must make complex decisions with tangible, real-world consequences. In land management, this dilemma is well-documented (Hartmann & Spit, 2015): active land policies can be both effective and efficient but may also risk potential conflicts between public and private interests; a passive system reliant on democratic procedures can lead to the separation of planning decisions and plan implementation. There is no clear best approach, and decision-making should be guided by the best possible information. However, limitations inherent in the concept of bounded rationality affect planning outcomes due to constraints on information availability, time, and cognitive capacity (Sager, 1999). Planning where to locate energy production infrastructure can result in plans that appear optimal in a theoretical context but fail to address the complexities of practical implementation. The EU, for instance, has introduced significant policy shifts to address the twin challenges of climate change and energy security, such as the revised Renewable Energy Directive III 2023/2413 (European Parliament & Council of the European Union, 2023. This document encourages member states to make full use of overriding public interest and thus enables renewable projects to bypass conservation restrictions such as those that exist under the Natura 2000 Network. This change exemplifies how attempts to expedite projects may generate tensions within processes pertaining to stakeholder consensus-building and illustrates the existence of a structural trade-off between acceleration and legitimacy. In addition, government assessment of public interest may diverge from community perspectives, and especially so with regard to impacts on landscape, ecosystems, and biodiversity.

Alongside these new permitting specifications, the REPowerEU package (European Commission, 2022), justified by the war in Ukraine and energy security concerns (Lambert et al., 2022), introduced the concept of “Renewables Acceleration Areas”, which are places designated for the rapid expansion of renewables with minimal anticipated environmental conflicts. While intended for expedited licensing by exempting projects from environmental impact assessments, the methodology for designating these low-conflict areas remains contested, as it must balance social, ecological, and economic trade-offs (Bolonio et al., 2024). In what follows, these recent EU policy developments are not assessed as policy failures but mobilised as analytical examples of how institutional acceleration can intensify the wicked characteristics of land-use planning for renewable energy. The discussion, therefore, focuses on the structural trade-offs between acceleration of deployment, coordination across governance levels, and the perceived legitimacy of planning outcomes that they illustrate.

The integration of advanced geospatial technologies, artificial intelligence algorithms, and the increasing availability of open-access geographic information may contribute to enhancing the aforementioned analytical process. However, the extent to which planning decisions can be solely supported by computer-generated outputs and algorithms—the functioning of which remains opaque—warrants examination. Furthermore, the degree to which planning authorities have access to the necessary information to enlighten land zoning decisions, while accounting for the potential implications and consequences for spatial planning, remains a critical consideration.

The consequences of spatial planning decisions are challenging to foresee, with feedback loops and trade-offs often resulting in suboptimal outcomes. For instance, administrative land-use decisions can significantly influence property values and provoke land speculation (Epstein, 1995). Designating parcels as having a comparative advantage of low conflict potential for renewable energy infrastructure may invite market speculation. Since the location of renewable energy infrastructure depends on variations in land and transmission costs (Basu et al., 2021), rising land prices within these designated areas could inadvertently push developers away, and thereby potentially undermine the intended acceleration of renewable deployment. Moreover, it could lead to projects outside these areas being delegitimised by local communities since they are located outside the alleged low-conflict areas. This example illustrates a broader structural trade-off between acceleration and legitimacy in planning processes.

These considerations point to the ethical responsibilities that planners should have. However, accountability has political dimensions. Spatial planning processes are ultimately administrative and precede political decision-making. Although planners may recommend specific actions based on the best information available and state-of-the-art techniques, it is the subsequent political decisions that determine implementation. Consequently, the success of a planner’s proposed strategy is largely contingent upon the political context and decision-making that follows.

Discussion

Renewable energy planning as a wicked spatial problem

Transitioning to renewable energy sources constitutes a key policy objective, and its implementation must be accelerated. Nevertheless, the spatial dimension of energy planning represents a critical challenge regarding the land use requirements of clean energy technologies such as wind and solar. The wicked problems framework provides a useful lens for exploring the critical dimensions of land-use planning within the energy transition. While the term “wicked problem” has been used in different rhetorical contexts, this paper does not engage with the ontological distinction between wicked and tame problems (Lönngren & van Poeck, 2021). Instead, the wicked problems framework is considered as an analytical lens for examining the spatial challenges associated with renewable energy production, while contributing to further consideration of the role of spatial planning in energy transition debates.

While this review mobilises the full set of ten characteristics proposed by Rittel and Webber (1973), not all of them are equally expressed in every context of renewable energy siting. In practice, some dimensions, such as the absence of a clear stopping rule or the distribution of accountability, tend to become more salient when conflicts over land use intensify or when political priorities shift rapidly. This means that wickedness should be understood as a matter of degree rather than as a fixed category, with the configuration of planning institutions, legal frameworks and stakeholder relations making some land allocation situations more wicked than others. In some planning settings, strong institutions and stable governance arrangements partially constrain the expression of certain wicked characteristics, whereas in more fragmented contexts these same characteristics may be amplified.

Land-use planning for renewable energy infrastructure exemplifies how different perspectives on problems and solutions are rooted in contrasting value systems. The deployment of renewable energy infrastructure presents a range of impacts and spatial constraints, making it a significant concern in contemporary spatial planning (Alves & Simoes, 2026). The urgency of the energy transition further necessitates adaptations in land-use planning, as traditional planning methods have been shown to be inadequate with regard to addressing the complexity and scale required for renewable energy development (Farinós-Dasí, 2022; Koelman et al., 2018).

In several contexts, attempts to accelerate project implementation appear to have been accompanied by legal and regulatory adjustments that have sought to increase procedural flexibility within planning systems. Such developments may resemble a neo-liberal non-planning governance arrangement characterised by market-centred coordination mechanisms rather than forms of territorially designed order. According to Schubert (2019), planning approaches which are strongly oriented towards market institutions have historically been associated with a range of governance failures as well as processes of environmental degradation. Despite recognition of these challenges in academic discourse, discussions within planning practice have insufficiently addressed the dimension and urgency of integrated approaches to reconciling competing land-use perspectives.

Existing research broadly recognises that multidimensional spatial energy planning requires the simultaneous consideration of diverse dimensions. These commonly include resource potential, environmental protection, biodiversity conservation, wildlife management, public participation, collaborative planning, and landscape experience (Codemo et al., 2023; Enserink et al., 2023; Josimović et al., 2024; Mostegl et al., 2017; Zardo et al., 2023). However, the progressive incorporation of additional analytical dimensions may also increase the methodological and institutional difficulties associated with operationalising planning frameworks capable of integrating such considerations in practice.

The analysis developed in this paper suggests that the adaptation of planning approaches to the spatial requirements of renewable energy must incorporate an explicit recognition of potential unintended consequences. The identification of a single optimal planning model remains unlikely given the plurality of interests, values, and territorial contexts involved. Nevertheless, this indeterminacy does not diminish the importance of sustained analytical and policy debate. In view of the wicked character frequently attributed to planning challenges within the energy transition, the present review contributes to ongoing discussions regarding the relevance of planning theory when it comes to addressing complex global transformations such as the transition towards low-carbon energy systems.

In this respect, the analysis highlights how the wicked problems framework provides a structured way to interpret the tensions that arise between policy urgency, spatial constraints, and plural societal values in renewable energy planning. Instead of treating land allocation as a purely technical optimisation problem, the framework emphasises the institutional and political dimensions that shape planning outcomes. This perspective helps clarify why attempts to accelerate renewable energy deployment frequently generate new governance challenges, especially with regard to legitimacy, coordination across planning levels, and the management of competing land-use priorities.

Implications for planning practice

In light of the preceding arguments, there are several domains in which planners may require stronger engagement in order to address wicked problems. It is important to note that these domains do not “solve” the wickedness or tame the problem, but they can make land-use planning decisions less wicked by reducing uncertainty, conflict, and institutional fragmentation.

The first domain concerns the expansion of planning practice beyond its traditional sectoral boundaries through stronger integration of energy within spatial planning frameworks. The territorial implications associated with renewable energy systems suggest an increasing relevance of approaches aligned with the concept of spatial energy planning (Osorio-Aravena et al., 2020), in which planning instruments play a central role in translating energy transition objectives into territorially explicit policy frameworks. In particular, knowledge generated within works for RAA designation may provide an important evidence base for identifying spatial constraints and informing the delineation of areas where development should be restricted. The establishment of clearly defined no-go areas may, therefore, constitute an important planning tool based on land use and nature conservation objectives. In contexts where such spatial energy planning instruments are well established, land allocation for renewables is expected to be less wicked, as clearer rules and shared expectations limit the range of disputes that may arise ex post.

A second domain relates to the integration of technological solutions capable of facilitating the reconciliation of competing land-use interests. A growing body of empirical evidence suggests that specific technological configurations may contribute to reducing environmental pressures or social conflicts associated with renewable energy infrastructure. For example, radar-assisted shutdown-on-demand protocols have proven effective in reconciling wind energy production with the conservation of soaring birds (Tomé et al., 2017). Furthermore, agrivoltaics have shown to have promising benefits related to the food-energy-water nexus, namely improving agricultural yields through crop protection and enhanced animal welfare (Widmer et al., 2024), and seem to have higher social acceptance than conventional ground-mounted solar power plants (Torma & Aschemann-Witzel, 2023). However, the adoption of such solutions generally remains contingent upon voluntary decisions by project developers. From a planning and regulatory perspective, the institutionalisation and formal incorporation of evidence-based measures within planning, decision-making, and permitting procedures may therefore warrant greater attention.

A third domain concerns the strengthening of analytical and modelling capacities within spatial planning processes. From a zoning and land allocation perspective, increasing complexity surrounding renewable energy deployment suggests a potential role for more systematic quantitative modelling approaches that simulate dynamic interactions between actors, spatial constraints, and policy interventions. Scenario-based and multi-agent systems modelling approaches may support the exploration of alternative spatial configurations and the comparative evaluation of policy options (Bosch & Kienmoser, 2024; Calvert & Jahns, 2021; Wu et al., 2020).

A fourth domain concerns the systematic monitoring of impacts. The absence of standardised indicators for several environmental, social, and territorial impacts continues to represent a limitation in existing evaluation frameworks (Cagle et al., 2023). At the same time, it is common to find divergent empirical results within existent literature with regard to some of the impacts of renewable energy infrastructure on the environment, as well as heterogeneous or contradictory results across contexts (Virah-Sawmy & Sturmberg, 2025). Given this, it is also important to engage with technological tools capable of capturing data at appropriate spatial and temporal scales in post-implementation evaluation (Hamada et al., 2026).

A fifth domain concerns governance arrangements and stakeholder engagement within spatial planning processes. Work in energy social sciences argues that transitions must be socially shaped, inclusive and just, not merely technologically efficient (Chilvers et al., 2021). Transitions are also multi-actor, multi-level, and long-term processes which involve the co-evolution of technologies, institutions, markets, culture and civil society (Geels, 2012). Dealing with multiple actors with divergent interests, values, and perceptions of acceptable land use requires participatory and collaborative approaches (Codemo et al., 2024; Enserink et al., 2023). From this perspective, strengthened participatory mechanisms within land-use planning processes may contribute to improving legitimacy as well as addressing conflicts and uncertainties. Where participatory mechanisms are routinised and perceived as legitimate, disputes over renewable energy projects may still occur, but they are more likely to be channelled through known procedures and negotiated compromises. In such cases, land allocation resembles a “less-wicked” problem, even if underlying value conflicts do not disappear entirely.

Conclusion

The transition towards renewable energy systems is widely recognised as a central policy objective within climate mitigation strategies. However, the spatial implications associated with large-scale renewable energy deployment introduce a set of planning challenges that extend beyond conventional sectoral approaches to land-use governance. The analysis developed in this paper suggests that the expansion of renewable energy infrastructure may be understood as a complex land-use planning issue that is characterised by competing interests, institutional uncertainty, and the coexistence of contrasting value systems.

Within this context, the analytical framework of Wicked Problems provides a useful conceptual lens through which to interpret the multidimensional character of these challenges. The concept emphasises the presence of problem definitions shaped by divergent normative positions and incomplete knowledge. Rather than implying the existence of an optimal and one-size-fits-all solution, such a perspective foregrounds the relevance of adaptive and context-sensitive planning approaches capable of accommodating the plurality of perspectives embedded in spatial decision-making processes.

Building on this perspective, planners should engage more actively with the integration of energy policy considerations within spatial planning frameworks. In particular, greater attention should be directed towards strengthening participatory governance arrangements, the development of monitoring mechanisms on the land use implications of the energy transition, and the use of evidence-based technological solutions to minimise trade-offs. This implies the need for stronger engagement with methodological approaches that combine spatial modelling and participatory knowledge integration to support context-sensitive planning strategies, which can help to minimise land-use conflicts associated with renewable energy infrastructure. By explicitly mapping the ten wicked characteristics to land-use planning challenges, this paper has not only enriched theoretical debates on spatial energy planning but also equipped practitioners with a framework for navigating trade-offs in the design of planning instruments, permitting procedures, and decision-making processes.

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