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Planning for the Future of Onshore Wind Farms through Adopting a Broader Temporal Approach

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ABSTRACT

Onshore wind farms are reaching the end of their operational or consent life and we need to consider how to plan for the future. This paper draws upon detailed empirical data from four UK case studies to understand the range and impact of changes that occur over the life of operational wind farms, including economic, policy, landscape and community changes and how these changes impact decisions regarding the future. In doing so it reveals the challenges of using time-limited consents without adequate consideration of the future. It also demonstrates the benefits for planning of adopting a multiple temporalities approach.

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Introduction

Unlike other forms of infrastructure, in the UK, wind farms have typically been granted 'temporary' 25-year planning consents with the requirement to decommission after this period. Sites have now started to reach the end of this consent period (see Windemer, 2019). Elsewhere across Europe and beyond, onshore wind farms are starting to reach the end of their operational or consent life and thus decisions are starting to be made regarding their future. When wind farms reach end-of-life the site owners currently have three key options i) to repower (remove the infrastructure and replace with new, often more efficient, infrastructure) ii) to life-extend (increase the planning consent for the existing infrastructure) or iii) to decommission (remove the infrastructure from the site). Upgrading infrastructure and increasing energy generation from sites could provide an important contribution to addressing climate change, however decision making is not straightforward as sites are likely to have changed over time in numerous ways. As more sites reach the end-of-life stage there is an increasing need to consider how decisions should be made about their future. This is an increasingly pressing issue for spatial planning as planners will have to make judgements regarding the future of sites that may have been originally time limited. Planners may also have to make judgements regarding the costs and benefits of replacing existing turbines with larger infrastructure. If sites are not repowered or life-extended then planners may also have to regulate the decommissioning of sites. So far few planners have faced these decisions, however the occurrence of such applications is expected to rise substantially over the next 5–10 years (Windemer, 2019).

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The challenge can be usefully addressed by not interpreting a wind farm as a fixed entity. While it is fixed in location, often for a certain duration, other elements of the site and its' context are likely to evolve and change over time. Such changes may include changes in policy, social changes, and physical changes to the equipment, site and the surrounding area. Each of these changes are likely to occur over a different timespan, potentially impacting decisions regarding the duration of the infrastructure in situ and the future use of the site. Currently, little consideration has been given to such changes or how they may impact how we plan for the future. This is significant as potential sites for onshore renewables are finite and the repowering of wind farms has been identified as a key way to increase renewable energy output (Doukas et al., 2022). There are also potential challenges associated with ageing onshore wind sites such as potential infrastructure abandonment (Windemer & Cowell, 2021), making understanding the factors that may lead to different end-of-life outcomes even more important.

In response to the lack of research on end-of-life decision making for wind farms, this paper adopts a multiple temporalities approach inspired by the work of Adam (1994, 1995, 1998, 2004) to explore how existing wind farms have changed over time and how this impacts end-of-life decision making. Adopting such an aproach facilitates an exploration of the multiple changes that occur over the operational life of wind farms, the impact of such changes, and how they influence the opinions and strategies of different actors. In doing so the challenges and opportunities facing existing sites are revealed, providing useful insights for planners and policymakers.

This paper draws upon detailed empirical data from four onshore wind farm case studies to investigate the range and impact of changes that have occurred over their operational life, including the different temporalities of the changes and the range of actors involved and impacted by the changes. Through doing so the paper makes two key contributions to planning theory and practice. Firstly, it provides one of the first investigations into how onshore wind farms change over their consent life, highlighting the significance of changes that have not been widely considered by academia or practice. Significantly, the paper demonstrates how such changes impact end-of-life decision making, highlighting challenges including that of using time-limited planning consents without adequate consideration of the future and providing important insights for planning. Secondly, through using the example of onshore wind farms, this paper demonstrates the value of adopting a multiple temporalities approach when planning for the future of existing infrastructure sites, and provides a framework for doing so. In doing so it responds to the call for more spatial planning research that highlights time and temporality (Hutter & Wiechmann, 2022).

The following section provides an overview of the limited social science literature on end-of-life decision making for onshore wind as well as the literature on considerations of time in planning that has influenced this work. The research methods are then discussed before a framework for exploring infrastructure temporality is presented. This framework is then used to discuss the range of changes occurring over time for wind farms. The paper then discusses how different temporalities are brought together to influence end-of-life decision making before concluding with recommendations for both policy and academia.

Long Term Experiences and End-of-Life Considerations for Wind Farms

Considerations of the long-term experiences and end-of-life decision making for onshore wind farms is limited as much existing academic literature focuses on wind farms at the point of granting planning permission. However, there is an emerging, yet patchy, body of literature on wind farm repowering, life-extension and decommissioning. The need to understand considerations surrounding repowering and life-extension has been identified as necessary due to the tendency for the best-located sites (e.g., the sites with high-levels of wind) to already be occupied by older, less efficient technology (Hulshorst, 2008; Unnewehr et al., 2021, Del Río et al., 2011), the shortage of other suitable sites (Serri et al., 2018) and due to the potential importance of repowering to meeting renewable energy targets (Meyerhoff et al., 2010). Studies have also highlighted the environmental benefits of repowering (see, for example, Martínez et al., 2018). Meanwhile studies on decommissioning have largely focused on the waste materials (Tota-Maharaj & McMahon, 2021).

Much literature on repowering and life-extension has focused on technical and economic considerations (Abadie & Goicoechea, 2021; Lacal-Arántegui et al., 2020; Nivedh et al., 2013; Prabu & Kottayil, 2015; Ziegler et al., 2018). Del Río et al. (2011) undertook an analysis of instruments and design options to support the repowering of onshore wind farms. In doing so they also provided an overview of the key barriers, drivers and benefits of repowering. Meanwhile, Serri et al. (2018) undertook an evaluation of onshore wind repowering potential in Italy focusing on the technical-economic aspects. In doing so they recognised the potential for the study to be built upon through the consideration of environmental, landscape and public acceptance issues. Existing studies thus provide useful insights for repowering potential but lack consideration of other aspects of the end-of-life decision making process, particularly consideration of the planning decision making process or how communities may be involved in such decision making. These studies also often have a linear bias, focusing on a snapshot in time, rather than providing a longer-term consideration of how sites may have developed over time and the different temporalities that may influence end-of-life decision making.

Unnewehr et al. (2021) discussed an important change that has occurred over time, that is expected to impact future repowering potential; changes in spatial exclusion criteria for wind turbines. Their study of German wind farms identified that approximately half of the existing German wind farms are now located in restricted areas due to the development of exclusion criteria. They explain that repowering under the current criteria could thus result in a reduction in installed capacity. While they did not investigate the impact of other criteria, they note that other criteria such as settlement development, local acceptance, landowners and use of land for agriculture could cause further potential challenges for repowering, identifying the need for consideration of these aspects. Grau et al. (2021) similarly suggest that the potential for the repowering of existing onshore wind turbines in Germany will be significantly impacted by 'geographical restrictions'. These studies demonstrate the impacts of one aspect of change over time (land use policy) and through doing so reveal the significance of such temporal investigations.

There have been a small number of studies that have looked beyond land use, technical and economic considerations of repowering and life-extension. There has been some consideration of the visual impacts of repowering with larger turbines (Meyerhoff et al., 2010; Möller, 2010) and of the factors driving repowering from developer's perspectives (Kitzing et al., 2020). Research has also considered the development and impact of end-of-life policy (Windemer, 2019; Windemer & Cowell, 2021) and policy instruments to support repowering (Del Río et al., 2011). Exploring support for repowering, Frantál (2015) undertook survey research with local governments and communities in the Czech Republic. The research found that almost half of public respondents and the majority of government representatives would support either repowering or new turbines in their municipality, with the findings suggesting that meeting expectations of the economic benefits of existing projects will have a significant impact on acceptance of future development. However, there has been a lack of wider consideration of what has changed over the operational life of wind farms and how this impacts the range of potential end-of-life decisions.

The potential for existing wind farms to be decommissioned (removed) or potentially abandoned has also been given limited consideration in existing literature. Most literature considering decommissioning focuses on waste materials (Invernizzi et al., 2020) and options for reuse of materials from a circular economy perspective (Cherrington et al., 2012; Jensen & Skelton, 2018). Much of the decommissioning literature is currently based on hypothetical cases (Windemer & Cowell, 2021) and as with literature on the other potential end-of-life options there is an absence of literature exploring how decisions regarding decommissioning are made.

Consideration of the Multiple Temporalities of Planning

The literature on end-of-life of wind energy infrastructure is particularly limited in its treatment of time, largely ignoring consideration of time beyond treating it as a series of atomistic time-specific moments within a linear concept of time. Here it is useful to turn to insights from literature on the multiple temporalities of planning in order to open up possibilities for taking a broader temporal approach to studying energy infrastructure.

Questions have emerged regarding how time is conceptualised and treated within planning due to a recognition of the multitude of stakeholders and associated temporal connections (Madanipour, 2010). The linear focus of time within planning practice has become subject to critique for having a restricted, bounded notion of both time and space and for divorcing concepts of time from concepts of space (see, for example, Davoudi, 2012; Graham & Healey, 1999a; Madanipour, 2010). From this perspective, planning can be seen as a type of governmental technology that imposes a particular temporal ordering on a more complex world and that fails to emphasise the multiple conflicting temporalities (Abram, 2014), instead focusing on spatial ordering. Graham and Healey (1999) critique considerations of time within planning theory and practice as either wholly neglected or treated as a container for linear events. They argue that planning theory and practice need to consider relational non-linear notions of time that reflect the changes that occur within the contemporary world and that there needs to be an understanding of how the process and effects of planning relate to multiple space-times. Elsewhere, it has been recognised that the way in which time is conceptualised can influence the focus of planning as well as how it treats and considers the future population (Moffatt, 2014).

Planning researchers have begun to build on the idea that time is not linear to explore how planning needs to understand multiple aspects of time (Del Río et al., 2011). Literature looking beyond linear time has developed ideas of time as something that is experienced rather than measured (Hicks, 2016). From such a perspective, it has been recognised that planning practices are influenced by and influence a range of conflicting temporal processes such as different envisioned futures within planning documents, changes occurring outside planning such as demographic and ecological changes and the temporal cycles of producing planning documents, but that these have been little considered (Abram, 2014; Van Der Knaap & Davidse, 2010). Meanwhile, the opinions of actors may also be changing over time (De Roo & Silva, 2010).

Laurian and Inch (2019) suggest that adopting a multiple temporalities approach can help to improve the discipline through helping to reveal the complexities of planning practice as well as through providing opportunities for planning interventions. Walter (2006) explored the multiple temporalities of landscapes, identifying that landscape representations may remain fixed while the actual landscape is changing and in constant flux. Degen (2018) argues for the need to explore the multiple temporalities that influence urban change, demonstrating how exploring the intersecting multiple temporalities of the environment, planning and everyday life can help to reveal the power relations that exist in the experience and making of urban spaces. Significantly, Raco et al's (2018) as its talking about their study of the temporalities of urban planning and the politics of time identified how developers and investors can use the temporalities of planning strategically through actions such as slowing down the development process.

There has been some limited research that has tentatively begun to apply these notions of time to renewable energy development. Windemer (2019) explored the multiple temporalities associated with end-of-life decision making for onshore wind farms in Great Britain, through policy analysis and an analysis of planning applications for repowered and life-extended wind farms. Doing so provided an initial exploration of the physical and social changes occurring over the operational life of wind farms, revealing the challenge created by the multitude of temporal changes. This paper builds upon this earlier work through providing in-depth case study evidence.

The multiple temporal approach taken in this paper draws on Barbara Adam's (1998, 1995) work on the multiplicities of time. Adam (1995, 1998) argues that linear considerations of time transform complexity into a fixed enclosed object when in reality time is less tangible as it is constructed through interactions. She argues that we need to move beyond clock time in order to understand how time is embedded in knowledge, interactions, practices, and the environment and thus to make the diverse experiences (particularly lived experience) and conceptions of time visible, especially in relation to environmental problems (Adam, 1995). Adam (1998) introduced the concept of 'timescape' to portray the multiple dimensions of time and the complex temporalities of changes to the landscape. This perspective argues that we cannot embrace considerations of time without simultaneously its embodiment in a specific context, including the spatial material and contextual influences on how we are considering time. This paper later develops a framework influenced by Adam's argument that we need to make the diverse experiences and conceptions of time visible.

Methodology

A Multiple Temporalities Approach

The research design aimed to facilitate an exploration of the multiple temporalities (see Adam, 1998, 1995; and Laurian & Inch, 2019) impacting wind farms over time and the associated impacts on end-of-life decision making. Drawing upon Adam's argument of the need to consider the spatial, material and contextual influences on how we are considering time, this research involved exploring the multitude of changes that have impacted the physical and social landscapes in which the wind farms are situated as well as changes to the wind farms themselves. The research did not seek to explore particular changes, but rather used policy documents and interviews to understand what changes had occurred over time. The research aimed to then explore the impact of these changes, how they have influenced the context of the site, how they have been considered by the various actors involved and how they impacted end-of-life decision making.

In-Depth Case Study Research

This paper is based on in-depth case-study research undertaken from 2017–2019 at four onshore wind farms in the UK. The purpose of the research was to investigate experiences of end-of-life decision making for onshore wind farms from the perspectives of all groups involved or impacted by each case. Multiple case studies were explored in order to identify common themes and changes occurring over the operational life of sites.

The research firstly involved textual analysis of renewable energy and planning policies at national (England, Scotland, Wales) and local level (43 documents in total). The planning files for the original and any end-of-life (repowering or life-extension) applications were then reviewed for each case. The planning files were also used to identify interviewees. In-depth, semi-structured interviews were then undertaken with developers, local authorities, planners, communities and opposition groups in each case (24 interviews in total). The interviews aimed to explore considerations of how the site had changed over time and decision making or opinions about the future of the site.

Both the textual data and interview transcripts were subjected to thematic coding using the software package NVivo. The codes used for analysis were identified through an inductive process of progressively narrowing the focus to identify key themes and patterns and using a codebook to develop the codes. One set of codes included the broad range of changes occurring at/impacting sites over time.

Case Study Selection

The cases were purposively chosen to reflect some of the oldest wind farms across England, Wales and Scotland with different local responses to repowering or life-extension and different policy contexts (see Table 1). Initial quantitative research using UK Government data provided information regarding the characteristics, age, and life stage of all wind farms in Great Britain, providing a basis for selecting cases. The cases were chosen to be similar in several dimensions including size, proximity to a settlement, and willingness of both the developer and Local Authority to participate in the research. All cases were owned by developers as community-owned cases form a small minority of older wind schemes. The cases were chosen to consist of at least five turbines in order to limit the number of variables influencing the research and to ensure that all sites were in an open and diversely claimed space.

The cases were selected to be different based on three main criteria, listed in order of importance:

1. Life stage (to explore the potential that key moments matter).
2. Local response to repowering/life-extension (to explore how and why responses and decision making differ).
3. Policy context (to explore how policies may influence decision making).

A summary of the cases and their key characteristics are outlined in the table below.

Table 1. Case studies.

Name and location	Original permission	Repowering permission	Public response to repowering	Other info
St Breock. Cornwall, England	11 x 53.5 m turbines operational in 1994 (operated for 18 years). Total installed capacity of original site: 4.95 MW.	5 x 100 m turbines granted planning permission in 2012, operational in 2015. Total installed capacity of repowered site: 10 MW.	Local public support for repowering. 95 public communications of support and 7 objections.	Located within a Special Landscape Area and Site of Importance for Nature Conservation as designated by the Local Development Plan.
Taff Ely. Rhondda Cynon Taff, Wales	20 x 53.5 m turbines operational in 1993. Total installed capacity of site: 9 MW.	7 x 110 m turbines granted planning permission in 2012. Permission not implemented. Proposed installed capacity of repowered site: 17.5 MW.	Mixed response to repowering application (greater levels of support than opposition).	No time limit on the planning consent for the original turbines.
Windy Standard (Brockloch Rig). Dumfries and Galloway, Scotland	Phase 1 of the wind farm, 36 x 53.5 m turbines operational in 1996. Total installed capacity of site: 21.6 MW.	Life-extension permission to extend the life of phase 1 for an additional 6.5 years, granted 2018.		Phase 2 of the wind farm comprising 30 x 100–120 m turbines, operational in 2017. Phase 3 20 x 125–177.5 m turbines granted permission in 2021.
Kirkby Moor. Cumbria, England	12 x45m turbines became operational in 1993. Total installed capacity of site: 4.8 MW.	6 x 115 m turbine repowering scheme refused in November 2015. Life-extension for 8 years, refused by the Local Planning Authority in 2017 then granted at planning appeal in 2019. Total installed capacity of proposed repowered site: 12–18 MW.	High levels of local opposition to the original application, repowering and life-extension applications.	

The Impact of Multiple Changes Occurring over the Operational Life of Wind Farms

Undertaking in-depth research at four windfarms revealed a number of changes occurring over the operational life of the sites. These changes are outlined in Table 2 and can be categorised as changes impacting the setting of sites, impacting the infrastructure and impacting the institutional context. The following section of the paper introduces the framework of infrastructure temporality that was developed from this research. The framework presents the range of changes occurring over time impacting the future of sites. The impacts of these changes on end-of-life decision making are then discussed. The paper then discusses the conditions that lead to specific temporalities dominating and the wider consequences of how the temporalities of renewable energy infrastructure are regulated. In doing so it reveals the benefit of adopting a multiple temporalities approach.

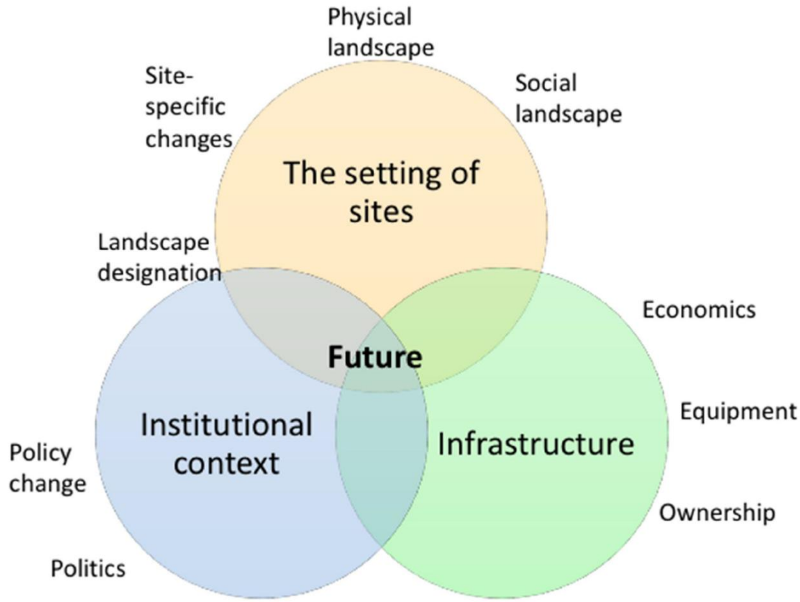

Figure 1. Framework of infrastructure temporalities.

Framework of Infrastructure Temporalities

The framework of infrastructure temporalities (Figure 1) emerged from the analysis of the textual and interview data from the case studies. One set of codes that emerged from the data included the range of changes occurring at/impacting sites over time. Informed by the literature on multiple temporalities the impact of these changes on end-of-life decision making in each case study was explored. The changes shown in the diagram could be seen to occur in different ways across all four case studies. The framework provides a way of organising the changes occurring over time impacting the setting of sites, the institutional context and the infrastructure itself, and how these changes come together to shape the future of the site. The centre of the diagram represents decision making regarding the future of the site and the elements surrounding it reflect the range of changes that may be occurring. The framework provides a way for future researchers to consider both the range and impact of changes occurring over the operational life of infrastructure, as well as for decision makers when considering the future of sites. The following section describes each of these changes in more detail in the context of the cases explored in this research.

Infrastructure Temporalities

Economics

Economic factors can be seen to directly influence end-of-life decision making for wind farm developers and site owners. For these groups, temporal decisions are linked to the economics of energy generation regarding a net balance of gains and costs over time, with assessments of tipping points when this falls one way or another. These tipping points are influenced by various non-linear temporalities, such as energy prices, policy, and subsidy regimes (as identified by Ziegler et al., 2018). Other economic dimensions of the infrastructure can also influence developer strategies such as production efficiency and asset value. Economic factors can also influence the timing of decisions, for example, a developer explained that end-of-life decisions are usually made when the infrastructure is 15–18 years old so that the existing machines can be sold.

Changes in subsidy regimes appear to have been a major influence on developer strategies across cases, directly influencing the timing of decision making. These are in turn linked to political concerns as well as underpinning legislative commitments. Many UK wind farms have a subsidy attached to their consent as part of the Renewables Obligation Scheme, which was introduced in 2002, requiring electricity suppliers to purchase a set amount of energy from renewable sources. As part of this scheme, Renewables Obligation Certificates (ROC's) were given to renewable energy firms for each megawatt-hour of electricity produced, the certificates would then be sold to electricity suppliers. Reflecting a political move away from onshore wind in England, this scheme ended for new onshore wind farms in 2017, the same year that the government prevented onshore wind from participating in the Contracts for Difference scheme (a scheme of price auctions to acquire new renewable energy at the lowest cost). Subsidies are attached to the original project as consented; the subsidy could thus continue if a site is life-extended (developers state that they could continue to benefit until 2027), but subsidies are not transferable to a (new) repowered scheme.

As subsidies are no longer available for new onshore wind projects, developers are faced with the decision of whether it is more viable to extend the life of an existing scheme (and thus continue to benefit from the existing subsidy) or to repower with more efficient turbines that will produce larger energy output but without subsidy.

> The question is then do you want to repower today, or do we want to continue to operate the existing site for the meantime … as a generalisation you start looking at the commercial and operational realities of continuing to run the existing site versus repowering, and in fiscal terms all of those older sites continue to be eligible for ROC until March 2027. (Wind Farm Developer, A)

The ending of the existing subsidy may create a tipping point in the future that makes repowering or life-extension more favourable. Developers explained that life-extension provides a lower-risk, cheaper, and easier option than repowering as the infrastructure is already in place. Emphasising the significance of subsidy changes, one developer identified that the removal of subsidy changed their strategy:

> because quite clearly the existing turbines have to some extent a greater income. (Wind Farm developer B)

Similarly, another developer explained that life-extension applications are likely to coincide with the end of ROCs in 2027 and that there will then be a time when it is more profitable to repower.

The variability of economic changes can also influence strategies regarding the physical attributes of sites, for example, developers described how the removal of subsidies has led to a situation in which taller turbines are necessary for viability. The increasing need for taller turbines to make schemes viable was recognised across cases. Economic considerations are also starting to change the consent durations sought. Developers are now pushing for longer periods in planning applications, identifying 30 years as the operational life of wind farms (relating to when parts will wear out). Changes in taxation can also influence decisions between new machinery and existing assets. Economics and equipment materialities have different time signatures, but these are the factors that matter most to developers' internal calculations.

Overall, while it is often developers and site owners who are dominating the temporal decision making on wind farms, their decisions are made within economic frameworks that have their own unique temporalities. These temporalities can influence decisions regarding the materiality of the infrastructure such as size of turbines, consent durations as well as timings. These various economic temporalities with their various tipping points provide the constraints and stimulants that shape developers' end-of-life strategies.

Equipment

Across the cases, end-of-life decisions have been influenced by the perceived useful life of the infrastructure in both a physical and economic sense, such changes can occur over a long time period and are not always easily known. The lifespan of equipment and availability of replacement parts to repair the infrastructure can influence end-of-life strategies for developers and site owners. This includes certification and warranties as after a certain period there is a need to do more screening and turbine components may wear more quickly in turbulent sites. Such elements are also closely tied to the economics of considering the cost of replacement and productivity. If replacement equipment is unavailable then repowering the site with new infrastructure may be the only option for continuing energy generation.

Ownership

Changes in the ownership of sites can lead to a change in end-of-life strategy due to the different priorities of site owners. A change in site ownership may also lead to a change in community-developer relations which can impact how a community may respond to an end-of-life application, particularly if there is a lack of relationship or trust between the community and developer. This could be seen to have occurred in Kirkby Moor where many community members complained that they did not know who the developer was.

The Setting of Sites

Site-Specific

There are a wide range of site-specific factors, with different temporalities, that can impact both the spatial and material elements of the site, impacting decision making for developers and site owners. For example, while repowering can increase output, it depends on grid capacity, so if there is no more grid capacity available then life-extension provides a fall-back option. Grid capacity depends on what other forms of energy infrastructure may have been developed in the area over time. The duration of the original consent may influence decision making as some older sites without time-limited consents may continue to operate through replacing parts. Changes that have occurred over time, such as the development of new buildings and infrastructure in the nearby area may also influence end-of-life options, such as through changing people's opinions of what may be suitable for the area. One example of this is in Kirkby Moor where some community members expressed a preference for offshore wind in the area (a technology that was not available at the time that the original wind farm was developed.) New built development may also impact the ability for larger turbines to be brought to a site through decreasing the amount of open space available. Change in landownership may also have an impact as new landowners may not be willing to extend the lease.

Physical Landscape Changes

Visual impacts have long been identified as a critical factor shaping wind energy consent decisions (Wolsink, 2007a) and this remains the case for repowering, as evidenced in interviews with both Local Planning Authorities (LPA), developers, and community members. The entanglement of technologies with landscapes can be seen to impact end-of-life decisions in numerous ways. Landscapes are not fixed or stable (Walter, 2006), characteristics of landscapes can alter significantly over the lifespan of renewable energy developments. The landscapes of energy infrastructure may change over the 25 year consent life of a wind farm, changing the context in which decisions are made. In many cases, further development, particularly of other wind farms, has occurred in proximity to sites. Physical changes in the surrounding area can be seen to form barriers that influence temporal strategies, for example, one developer explained that when it comes to end-of-life applications, site constraints have often become greater and the developable area is often a lot smaller due to encroachment by development.

Visual impact on the landscape is one of the central considerations for assessing applications to increase the duration of sites through repowering or life-extension. Due to wider landscape shifts, it is not as simple as judging whether the application, in its narrow dimensional terms, creates an acceptable net change in visibility. Due to technological changes and the need for larger turbines in order to be profitable, repowering often involves significantly larger turbines. UK Government data on granted repowering applications revealed an average height increase of 98.8%. LPA decision makers revealed that assessing the impacts of the visual change upon the landscape was particularly difficult in terms of deciding if a smaller number of larger turbines or a larger number of smaller turbines was visually preferable. Existing industry research asserted that a smaller number of larger turbines is usually preferred (Sustainable Energy Ireland, 2003). However, the findings of this research revealed that this assumption is not always born out. Thus, the context of the site, including changing perceptions of the suitability of the turbines on the landscape, is significant, and the perceived suitability of energy infrastructure in the landscape is important (see also Hirsh & Sovacool, 2013; Otto & Leibenath, 2014). These findings reflect the arguments of Wolsink (2018) who identified that as a concept visual impact is often misunderstood, arguing that it is not purely an assessment of the aesthetics of the infrastructure itself, but of wider landscape concerns such as (but not limited to) a person's assessment of the landscape, the change in the character of the landscape, and a person's attachment to place (which may also change over time).

Perhaps the most significant element of landscape consideration in end-of-life decision making is what is considered as the baseline upon which repowering or life-extension applications are judged. This baseline reflects a preference for a specific point in time and opinions of the correct baseline may change over time. In some cases, the baseline has been considered as the site in its previous condition without the wind farm in place. For example, in Kirkby Moor the baseline was considered to be the site pre-wind farm development, this was then pivotal to the controversies faced by successive applications. In other cases the presence of the wind farm is considered to be the baseline from which to judge subsequent applications. For example, in the life-extension for phase 1 of Windy Standard it was considered that as the principle of development was established, it was only necessary to consider the acceptability of any material changes, rather than reconsidering the merits of the original proposal. Accepting that the physical landscape has 'become a wind farm' is the main dividing line, shaping the dynamics of public and regulatory responses. These earlier decisions thus set precedents for the future. Significantly, such considerations of sites having become wind farms has begun to influence policy, with Scottish Policy explicitly classifying the current use of a site (as a wind farm) as a material consideration.

Another important temporal dimension to such considerations are changes in perceptions of how the land is used. Longer-term perceptions of the physical landscape can be seen to impact how a wind farm is perceived, particularly influencing the responses of communities and in some instances, the approach of Local Planning Authorities. For example, in Cornwall (England) there is a long-established tradition of working on the land and thus viewing the land as a resource, for example, now an energy resource and this is reflected in Cornwall's positive approach to wind energy and in community members saying that they view the land in such a way.

Changes in Landscape Designations

In some cases, land designations (such as World Heritage Site status for the adjacent Lake District National Park in the case of Kirkby Moor wind farm) have occurred, providing additional development constraints. A change in landscape designation forms a key moment of change and can create particular challenges for developers and LPA decision makers in terms of assessing if the wind farm is still suitable in the landscape. These changes can also prove useful for opposition groups arguing against the continuation of a wind farm. So far, the experience of the oldest wind farms (those aged 20 years or over) in the UK shows this trend flowing one way in terms of increasing constraints over time, rather than in terms of any loosening of landscape constraints or restrictions.

Social Landscape Changes

The research revealed the importance of communities being able to recognise the benefits of a wind farm over time in order to support the continued use of the site, reflecting existing literature identifying the importance of community benefits in acceptance or opposition to onshore wind (Ellis et al., 2009). Taking a longer temporal perspective also revealed that experiences of community benefits over time can play an important role in responses to end-of-life applications. Either the provision or lack of community benefits was a common element of discussion by communities in all of the cases. The perception of community benefits appeared to vary across cases with support for the continuation of a site being reflected where people recognise the benefits that their community has gained from the existing site. Such recognition of the importance of community benefits was particularly notable in the expression of support for repowering in St Breock and Taff Ely as reflected in the quote below:

> because we're such a small community if there wasn't any benefits they would soon know about it too, you know as well, I mean we're not pushovers you know. (Community respondent, A)

Over time the provision of community benefits appears to foster positive public response; however, in some instances the impact may diminish over time if the demands for such a fund diminish. Such diminishing value can be seen to have occurred in the case of Windy Standard where, due to the volume of wind farms in the area compared to the relatively small local community, some members of the community identified that they are running out of projects to spend the funds on and thus attribute less value to their benefit. This reflects existing literature identifying communities varying capacities to make use of community benefits and the challenges and opportunities associated with such payments (Aitken, 2010b; Bristow et al., 2012; Cowell et al., 2011; Munday, Bristow, & Cowell et al., 2011). Meanwhile, in the case of Kirkby

Moor, the perceived lack of community benefits from the existing wind farm was a key argument of opponents. In this case, while there had been community benefits available, many respondents stated that they had not been aware of the fund. This perceived lack of identifiable benefit led such community members to oppose the repowering and life-extension.

Social history is also important, temporalities are not just background landscape changes but also made by the actors involved. People's relationships with the landscape and perceptions of the suitability of the windfarm on the landscape and its perceived fit (see Bailey et al., 2016) can be seen to change over time. The communities living close to energy infrastructure may change over the lifespan of the infrastructure both in terms of the composition of the community and how they consider the infrastructure, site and the duration of its various impacts. Generational differences can potentially influence responses due to how the temporal dimension of land use is perceived, for example, in certain locations older community members may have negative memories of previous forms of energy extraction such as coal mining (Cowell, 2010). A range of temporal factors can influence community considerations of the suitable duration of the infrastructure including the history of how the land was used before the wind farm (e.g., the history of using land as a resource in St Breock and Taff Ely, compared to the protected National Park landscape in Kirkby Moor).

How the original scheme was considered and perceptions of the existing site also appear to influence responses to end-of-life applications. For example, the original Kirkby Moor wind farm faced high levels of opposition and the LPA described how people "felt as if it had been imposed for no good reason" (LPA A), rejecting the reasons that had been provided. In such emotive cases, memory of resistance can endure over decades, sustained in local narratives. Meanwhile, sites with less opposition to end-of-life decisions appear to have often (but not always) been less controversial originally.

Familiarity is a temporally-infused process that the research found was often invoked in end-of-life decisions. There is a perception amongst industry and LPA planners that familiarity or acceptance is likely to occur over time amongst communities living with infrastructure, reducing opposition to end of life applications. Such a perspective suggests that wind farms will become a familiar part of the landscape, as reflected in quotes such as:

> if they've been there 25 years, people will have, you know, they are such a custom feature in the landscape that people probably pass them without even noticing that they're there. (LPA B)

> I would have thought there would be an element that after a project's been there for a set period of time, even if there has been objection to that, initially people get used to things and potentially start to see things in a different light. (Planning consultant)

This perspective reflects existing literature suggesting that those living close to wind turbines become more supportive or at least less active in their objection or opposition to them after installation (Damborg & Krohn, 1999; Warren et al., 2005; Wolsink, 2007b). Such perceptions of familiarity are reflected in developer confidence that people will not object to life-extension applications, as reflected in the following quote:

> those turbines have been there for nearly 25 years, they're used to being part of the landscape, people would be perfectly happy for them to remain for another 5–10 years. (Developer C)

Expectations of local familiarity and acceptance have shaped developer strategies for end-of-life applications, particularly in terms of the timing of applications. However, familiarity will not always lead to a change in community perspectives over time or an increase in support for an existing wind farm or end-of-life application (Windemer, 2023). An assumption of the positive effect of familiarity ignores the significance of influential factors that may change over the operational life of a wind farm, impacting experiences and perceptions of the infrastructure.

The social history developed over time between communities and developers/operators can influence community reactions to end-of-life applications. Relations can improve over time through communities recognising the value of community benefits and through good communication and the establishment of trust with the developer. This reflects existing literature that identified the importance of trust on responses to renewable energy schemes (Aitken, 2010a; Friedl & Reichl, 2016; Ricci et al., 2010; Walker et al., 2010; Wolsink, 2007b). In other cases, relations may worsen over time, negatively impacting perceptions of the site and its duration. In cases where poor relations are formed between the community and developer, end-of-life applications provide an opportunity for the community to oppose or renegotiate, raising issues that have long been of concern and exploiting the shifts and inconsistencies of developers' positions over time – in the UK, the attempted continuation of initial temporary permissions – as part of their case against. However, while this is a common strategy of opposition groups, only in exceptional cases does it gain traction.

Compared to the other temporalities discussed, currently in the UK social temporalities, i.e., changes in local community perceptions do not appear to have a significant influence on end-of-life decisions. Existing research identified that community responses often do not influence the outcome of end-of-life applications (Windemer, 2019) and in the context of the case studies explored in this paper, community perceptions did not influence developers' decisions to submit an end-of-life application. In the case of the proposed Kirkby Moor repowering, there were five main reasons for refusal and while visual impact was one of the reasons, impact on the local community was not listed as a reason. However, the reasons for refusal for the life-extension application in Kirkby Moor included 'adverse impacts on the local economy' with the decision note identifying the substantial number of objections from the local community, thus social temporalities can have some impact. The influence of community preferences could also change in the future depending on the weight given to community support in planning policy (changes to policy could potentially affect the balance of power between actors).

Institutional Context

Politics and Policy Changes

Politics and policy changes can be seen to occur as a partial state response to the temporalities discussed above, but also have their own unique time signatures that impact the context of end-of-life decision making. A change in political leadership and the preferences of political leaders over time can have a significant impact on end-of-life decision making for both developers and local authorities through altering the economic and policy support for onshore wind. This is most evident in England where, in 2015, the UK government removed financial support mechanisms and introduced strict planning regulations on onshore wind as a result of a group of over 100 Conservative MP's writing to the government to call for an end to the support mechanisms for onshore wind farms. This was despite high levels of public support for onshore wind. The impact of this change in planning policy and financial support in England was an effective end to the building of new onshore wind farms, consequently enhancing the need to focus on existing sites.

Policymakers at both central government and local authority level have a potentially important influence on the decision making of both developers and planning authorities through

Table 2. Temporalities impacting the future of onshore wind farms.

Type of temporality / temporal change	Examples
Affecting the infrastructure	
Economic Economic changes can: • Make repowering unviable and potentially make life-extension or closure (decommissioning) more viable alternatives. • If positive, economic changes can remove constraints making repowering viable.	Variations in: • Subsidies. • Investment strategies. • Taxation. • Viability calculations. • Levelised energy costs. • Asset values. • Production efficiency.
Equipment • A lack of availability of machinery and parts can reduce the potential options for sites. • However, the development of new technology can open up different possibilities.	Tendencies for: • Parts of equipment wearing out. • Changes to ability to replace or maintain parts. • Change in size / type of turbines or solar panels available.
Changes in ownership • A change in ownership may offer a range of future options for a site. • A change in ownership may impact community-developer relations and trust.	Manifested in: • Sale of sites. • Changes in structure or priorities of site owners.
Affecting the institutional context	
Policy changes • If restrictive, changes may prevent some end-of-life applications from being submitted or granted. • If supportive of repowering / life-extension, can increase the likelihood of successful applications.	Changes to: • National approach to renewable energy expansion. • Spatial steering or zoning of onshore wind. • National end-of-life policies. • Local level policies. • Decisions that form precedents.
Political changes • Can change the focus and level of support for renewable energy.	Political changes at a national, regional and local level.
Affecting the setting of sites	
Social landscape changes • Perceptions change over time. • Negative changes can lead to opposition to end-of-life applications. • If perceptions of the site become more positive over time then people are likely to be open to the continuation of the use.	Changes in: • Familiarity with the infrastructure. • Perceptions of the landscape and the presence of the windfarm within the landscape. • Community-developer relations. • Perceptions of community benefits. • Composition of the local community.
Physical landscape changes • Changes in the surrounding area can create a physical or regulatory restriction on future development.	Development of: • Nearby windfarms. • Landscape designations (national and local level). • Houses or other built development in surrounding area.
Other site-specific factors • Site specific factors can create barriers to certain forms or compositions of development.	• Site access. • Grid availability. • Position of landowner.

policy development, most clearly through the delivery of systems of market support that can alter the decision making context. National-level planning policy can influence end-of-life decision making in terms of the overall approach, requirements and spatial steering for onshore wind as well as considerations of repowering and life-extension. Changes or development of end-of-life policy over time has had a significant impact on decision making for both developers and LPA decision-makers. The cases explored in this research revealed that an unclear policy context can create difficulties and consequent decision making delays for developers when deciding what end-of-life strategy to pursue. Developers explained that in the context of an uncertain policy they may wait until the policy changes to provide more certainty for end-of-life applications. For example, a developer in England expressed that:

> without more clarity on the change in government policy, it's pretty hard, …, it's hard to envisage much repowering happening in the UK. (Developer C)

Similarly, LPA officers in England and Wales identified that despite the policy changes to support repowering and life-extension, they have faced challenges in making decisions due to the lack of guidance regarding how applications should be assessed. Comparatively, in Scotland there is greater policy clarity for decision makers regarding how end-of-life applications should be treated. For example, Scotland set out a clear position in support of repowering in their 2017 onshore wind policy statement, including explaining why repowering is needed. The development of greater clarity in planning policy can potentially increase speed and confidence at the LPA decision making level. There have thus been calls for the rest of the UK to follow the more detailed supportive policy approach to repowering and life-extension in Scotland.

Local-level policies on wind energy have developed over time in numerous areas, providing additional guidance on the siting of new onshore wind farms. However, there is little evidence of emerging local-level policy consideration of end-of-life issues. Such planning policy change could provide greater clarity for LPA decision makers, an opportunity for greater levels of community involvement, and either more clarity or potentially more constraints for developers. Additionally, while some local authority planners have increased their experience and knowledge of assessing wind farm planning applications over time, this has not occurred in all areas. Thus, there is a perceived lack of uniformity in planning officers' experience, creating challenges in decision making for both developers and LPAs.

The Multiple Temporalities of Infrastructure Planning

Through adopting a multiple temporalities approach inspired by the work of Adam (1995, 1998, 2004) and Laurian and Inch (2019), this paper has shown how wind farms do not simply comprise the infrastructure itself, rather they comprise interlacing flows of multiple temporalities that are temporally and spatially sensitive and that come together in episodic fragmented ways. These temporalities are dynamic, changing over time and can be seen to provide both constraints and opportunities for future decision making. Such temporalities should not just be considered on their own, but rather together in the context of the site as they are interconnected and overlap. From this perspective, wind farms should be considered as complex spaces comprising various uses and human and non-human aspects that change over time (see Bonta & Protevi, 2004). As the various temporalities are in flux so too are the characteristics of sites, shaping end-of-life decisions. The different changes occurring along different temporal pathways are brought together in end-of-life decision making, with some obtaining more influence than others, to influence the direction in which change takes place and thus form regulatory-economic-physical fixes. As such, end-of-life decisions themselves go beyond a linear conception of time. There is no one end-of-life decision and the limited range of end-of-life options that we see now may increase over time as different technologies and options become available. Moreover, these decisions do not occur at one point in time, the timing is influenced by a range of factors.

While cases vary in outcomes and the influence of particular temporalities, this research found certain temporal elements dominating, largely reflecting the preferences of developers over other actors. These often include economic temporalities promulgated and acted upon by owners and developers. Economic subsidies, the levelized cost of energy, and consequently how long a project needs to run to be profitable without support, appear to be the most significant influence on developers' strategies. Due to the complicated range of factors, developers' strategies often change over time. The relationship between this change and temporal fixes is particularly interesting. Due to the subsidies attached to the oldest wind farms in Great Britain, it appears that developers are often pursuing a strategy of life-extension (a cheaper and lower-risk option than repowering) with the intention of repowering in the future if it appears more financially beneficial to do so. However, while developers' financial and investment strategies form one critical dimension of time, they cannot wholly align the future around their economic interests and site-specific constraints, including changes in the surrounding land use, can have a significant influence on the future development of the site. Moreover, planning policy can also play a significant role in shaping the future of existing sites as a supportive planning policy can provide the certainty needed for developers to submit end-of-life applications. Comparatively, communities and their preferences appear to have had little influence on the outcome of end-of-life applications. There are wider consequences to consider here regarding communities who were assured that the infrastructure would be removed after 25 years as well as impacts on overall energy generation.

Planning processes for end-of-life decisions are a mediating arena in which the various temporalities are brought together and – to different degrees – acted on. Nevertheless, planning has its own temporal assumptions and norms which shape how decisions are constructed and justified. In Great Britain and particularly in England, planning policy for onshore wind can be seen as strategically selective, focusing on regulating consents and lacking consideration of broader impacts that may change over time, what may happen to the infrastructure at the end of its consent period and how communities may influence such decisions, reflecting a deferral of certain aspects. It appears that developers coordinate while planners regulate time. The regulatory function of Local Planning Authorities occurs through the use of the time-limited consents, meaning that there is a regulatory end point in which planners will need to become involved (if an end-of-life application has not already been submitted). Meanwhile, developers coordinate when to submit the end-of-life applications based on the multiple temporalities influencing the site, which may not always align with the end of the consent life. 25-year consents reflect a very linear, divisible, conceptualisation of time focusing on regulation and lacking consideration of the longer-term future. The use of these consents for onshore wind farms, without adequate end-of-life policies, demonstrates how multiplicity is rendered linear for the purposes of regulation, with consequences for elements left outside of regulation i.e., considerations of how end-of-life decisions should be made. While this form of linear regulation has provided the benefit of creating a set point for revisiting original siting decisions, the lack of consideration of 'what next' raises potential difficulties. The cases discussed in this paper reveal how a lack of detailed end-of-life policy has created challenges for LPA decision makers as well as for developers.

This research has furthered existing literature such as Abram (2014), De Roo and Silva (2010), Degen (2018), Del Río et al. (2011), Graham and Healey (1999), and Moffatt (2014), that suggests that planning needs to explore multiple aspects of time, evidencing the need for expanding such an approach to planning regulation rather than just plan-making. Beyond the regulation of energy infrastructure, this research demonstrates how consideration of multiple temporalities provides useful insights for planning through enabling an exploration of the multiplicity of changes occurring over the lifespan of developments, impacting the context in which decisions are made. Considerations of time can be seen to impact sustainable and equitable outcomes through influencing what is considered, in what level of depth, and what is left outside regulation. Such an approach as outlined in the framework of infrastructure temporality (Figure 1) is expected to also prove useful if applied to considering future decision making for other forms of infrastructure and built development.

Conclusion

Internationally, wind farms are starting to reach the end of their operational or consent life. This research revealed the multiple changes that occur over time influencing wind farm sites, revealing how planning acts selectively on them, with distributive consequences. In doing so it exposed consequences for the regulation of energy infrastructure as well as wider insights for planning regulation. It revealed that end-of-life decision making for onshore wind farms will not be straight forward due to the range of changes that occur over the operational life of sites, changing the context in which these decisions will be made. It also revealed the challenges that may arise when the future is not considered, for example, where temporary planning consents are used without consideration of the future. Given the potential impact of end-of-life applications on renewable energy output there is a need to give greater academic and policy consideration to how end-of-life decisions will be made. While this paper focused on Great Britain, the changes explored here are likely to be experienced internationally. For example, land use changes are expected to have an even more significant impact across Europe where many existing wind farm sites have been designated as Natura 2000 sites or have been subject to other forms of spatial exclusion criteria (see, for example, the case of Germany, Grau et al., 2021; Unnewehr et al., 2021).

This paper has demonstrated the benefits of looking beyond the linear notion of time to consider multiple temporalities. The particular value of this approach is that it recognises not only the range of factors that are changing over time, but also the different rates that these changes occur i.e., their unique temporal pathways. The framework of infrastructure temporalities (see Figure 1) provides a way of understanding how these changes come together to influence spatial planning decision making. Sites are not static and in order to plan for the future of a site it is important to understand how the site and the surrounding area has changed over time. The framework facilitates an exploration of the range of changes, occurring over different timescales, that impact the setting of sites, the institutional context and the infrastructure itself, and how together these changes can shape the future. Adopting such an approach enables an exploration of what temporalities appear to be dominating decision making and whose interests are consequently being reflected. Through doing so it facilitates consideration of representation in planning, enabling us to consider if changes need to be made in order to ensure that other voices are heard. This approach has proved useful when making sense of the interface between planning and energy, but beyond this there is a need for wider thinking about the multiplicities of time impacting planning. It is thus suggested that future researchers contribute to the further development of the framework.

Beyond academia, this research provides recommendations for planning policy and practice. It raises the need to potentially reconsider the use of 25-year planning consents for wind farms, particularly as turbines are considered to often be capable of working for longer periods. Time-limited consents were originally used for wind farms as a way of regulating the impact of a new technology. This can be seen in the planning decision documents for some of the oldest wind farms which describe them as a trial. Time-limited consents do provide the benefit of flexibility and a chance to revisit a site, so one solution would be to keep a time-limited consent requirement but for a longer period than 25 years to reflect the operational life of the turbines. An alternative option would be to use conditions based on the operational life of wind farms (i.e., they should be removed once they fail to operate for a set period), rather than using a fixed time-limit. A challenge here would be the need for enforcement action from Local Planning Authorities, however such consents could also involve a review after a set period of time.

The paper also reveals the challenges of using time-limited consents without adequate consideration of the future of onshore wind farms, suggesting that policymakers need to give greater consideration to planning the future of these sites. If existing sites are not repowered then overall energy output from wind energy could decrease, however end-of-life decision making is not straightforward. This paper demonstrates the need for an end-of-life policy for onshore wind in order to increase certainty for both those submitting applications and those assessing planning applications. Such a policy needs to enable planners to take into consideration how sites may have changed over time and also provide an opportunity for local communities to input into the decision making process. More widely, the paper emphasises the need for the planning system to adopt a broader temporal approach to considering the future through being prepared and adaptable to the new forms of energy and other infrastructure that we are likely to see in the context of addressing climate change. The case of onshore wind demonstrates that a lack of planning policy can create uncertainty for both developers and decision makers. The planning system thus needs to be quick to react to new forms of applications that may arise.

Disclosure Statement

The author reports there are no competing interests to declare.

Notes on Contributor

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