



Original research article

Recycling energy landscapes as Britain's coal plants close: What are the directions, drivers and justice implications of site re-use?

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ABSTRACT

Global research interest in coal phase-out has focused mostly on the consequences for energy decarbonisation, to the relative neglect of the spaces affected by facility closure, with a particular research gap on the fate of coal-fired power station sites. Yet tracing processes of post-closure landscape recycling of these spaces can enhance our understanding of the dynamics and justice implications of energy transitions. This paper pursues these issues, applying assemblage thinking to examine what has happened to the sites of the Britain's last coal-fired power stations. It draws on media data, planning files and interviews, to analyse what these sites are becoming, which futures are being effaced, and how. Our assemblage approach revealed the differential power of alternative development trajectories: on some sites, hierarchical and closely-coupled market-policy relations produce powerful drivers for housing projects; for those envisioned as future energy centres, we observe struggles to construct coherence from the shifting, heterogeneous elements at work. Large-scale solar PV is an exception, with projects exploiting the grid connection but not the brownfield land. Elements of power station spaces that might constrain development trajectories – foregrounding existing heritage, ecological and social values – have been readily smoothed aside. Drawing on these findings, our assessment identifies a range of factors creating difficult real-world contexts for realising ‘place-based just transitions’: the protracted, uncertain processes of building future uses, the elite-level and fragmented decision-making processes, and the significant re-scaling of energy assemblages that facility closure can trigger.

1. Introduction: coal phase out - what comes next?

Making careful use of the land resource has long been integral to sustainability thinking [1], with clear relevance to how societies address the land-use legacies of our energy systems. As Pasqualetti and Smardon [2] argue, there is a strong case for ‘recycling’ energy landscapes, for ‘future use and long-term value’, (p1), an agenda which combines ‘prudence, intergenerational equity, precaution’ and ‘responsibility’ (p.2). The concept of ‘energy landscape recycling’ has captured growing research interest [2–4], providing a frame of reference extending beyond ‘re-use’ to emphasise a ‘circular economy’ approach to land resources, and the containment of long-term risks. Within the energy domain, few sectors are more pertinent subjects for landscape recycling than those produced by our long-standing reliance on coal, given its scale, impacts and pervasive decline.

In many countries around the world, coal-powered electricity generation is diminishing. Key drivers of decline include environmental

legislation, actions to address climate change, and the falling costs of more sustainable energy alternatives [5]. At a global level, member nations of the Powering Past Coal Alliance [6] pledged to phase out coal: by 2030 among OECD/EU members and by 2040 elsewhere. In some countries, the final period of phase out has been relatively swift. Back in 2014, coal was the UK's largest single source of electricity generation [7] (see Fig. 1), but the subsequent downturn saw the last coal-fired power station, Ratcliffe-on-Soar, ceasing generation on 30th September 2024. This provides a timely moment to reflect on how these power plant landscapes may be recycled in some form.

The phase-out of coal power is a pivotal and polyvalent component of wider energy transitions and yet, as Johnstone and others have discussed [8,9], a large share of the research response has focused on the acontextual effects on decarbonisation and energy supplies. A smaller subset of transitions researchers has examined the impacts on local spaces, communities and workers involved in the mining, processing, transportation, combustion and waste-disposal processes that coal

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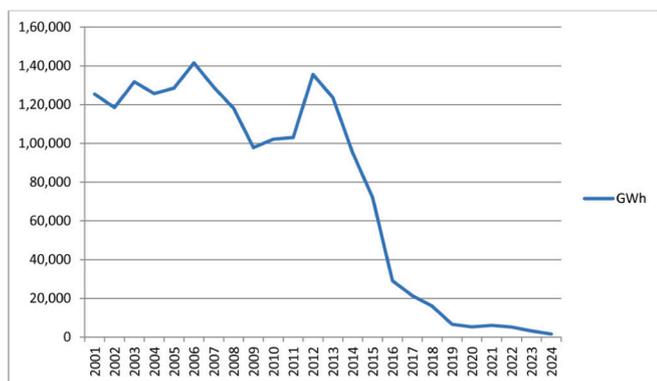


Fig. 1. The decline of coal power in Britain, 2001–2024. Electricity supplied (gross) per annum, in GWh, using DUKES Table 5.6 [7].

power entails (e.g. [8,9]). Fewer still have examined what has happened and what *should* happen to former power station sites (see [10–12]). This omission is consequential, given that arguments for ensuring that coal's energy landscapes are appropriately 'recycled' [2] intertwine with those for 'just transitions' [13], for the places and communities affected. Plus, the land legacy of coal-fired electricity generation is considerable. Since the world's first electricity generating station sparked into life in London in 1882 [14], England alone has been home to over 160 coal power sites, with the largest exceeding 300 ha.

This paper focuses on the 'recycling of energy landscapes' [3] for the last coal-fired power stations operating in Britain (England, Scotland and Wales). Its main objective is to trace what has happened to these sites since coal-based electricity generation ceased, and to use this data to address the following questions. *What explains the subsequent directions of development that emerge? How is the agency to drive change processes pulled together, distributed and mobilised? How are other candidate future pathways for coal power sites set aside and dismissed and, along with them, other communities of interest?*

Beyond the distinctive empirical contribution of this analysis, examining how former coal power station sites evolve also illuminate key justice dimensions of energy transition. Energy landscape recycling mobilises a sense of 'restorative justice' [15], but there are vital yet under-examined justice dimensions to how this recycling is achieved, the processes involved and the outcomes that emerge [4]. Thus, we draw on the three, widely-rehearsed fundamental dimensions of justice (after Schlosberg [16]): *distributive* (concerned with fairness in the distribution of goods and bads); *procedural* (addressing the inclusiveness of decision-making processes) and *recognition* (concerned with which identities, interests and knowledges get considered). In particular, we use our analysis to engage with emerging agendas that link the achievement of justice in decarbonisation and energy transitions to careful attention to place (see [17–19]). This agenda has emerged in the context of industrial decarbonisation, and has been captured in the Place-Based Just Transition Framework of Lai et al [17], which seeks to guide fair decarbonisation through sensitivity to place-specific needs, genuine community engagement and localised benefits (Ibid. p.4). The challenges of applying such frameworks, we argue, are ontological, especially the prevailing tendency in research and policy to defer to intuitive spatial categories like 'sites', 'host communities' or 'community engagement' (see discussion in [20]). Given that places are continually being remade, not least by energy transitions processes, understanding the scope for 'just transitions' requires more critical investigation of their spatial dynamics, following Walzer's famous contention that 'community is itself a good - conceivably the most important good - that gets distributed' [21], p.29).

To address these concerns, the analysis presented here explores the insights of assemblage concepts, as developed by Deleuze and Guattari [22]. Assemblage thinking provides a way of grasping the dynamic,

messy, processual nature of change, thus helping to link otherwise 'abstract analytical frameworks' of just transitions to 'lived realities' ([23] p.2). As our analysis will show, dealing justly with the 'communities' and 'places' affected by the recycling of fossil power energy landscapes means negotiating the shifting development assemblages, and thus also of the relevant community. The next section of the paper expands on our theoretical approach, followed by an outline of the research methodology. Key patterns of change across the power station sites are then analysed, first mapping what these sites are becoming, and which futures are being effaced, then explaining the relative power of different development assemblages. The conclusions summarise key findings, and reflect on the implications for theory and justice in energy transition research.

2. Theoretical approach: power station sites as complex spaces

Our starting proposition is that the key issues under investigation here – tracing landscape recycling processes, understanding the drivers of change and the justice implications – would all benefit from the insights of less essentialist spatial ontologies. Dominant approaches to land use change research, adopting simple categories like 'site' or 'land use', with fixed categories and properties, inadequately grasp what is happening in a space [24,25].

This paper deploys Deleuze and Guattari's geophilosophy, particularly notions of assemblage [22]. Assemblages are entanglements of heterogeneous entities that are both social and material, and can embrace technologies, substances, social practices and discourses. Assemblages are dynamic rather than static, giving them an emergent quality, wherein shifts in the constituent entities and the relations between them can change patterns of interaction and thus their configuration, without necessarily cohering into seamless wholes [26]. Following from this, rather than conceiving of a world composed of fully-formed objects with fixed essences ('beings'), we should conceive of these objects as continually in the process of becoming something else ('becomings') [27]. Assemblage thus provide a perspective that is attuned to tracing the relationship between stability and fragility in transition processes, including spatial change, helping to understand how spatial forms are held together, fall apart, or are reassembled [26].

The concept of assemblage can be applied at a variety of scales, depending on the analytical purpose. At the systemic level, grid networks can be viewed as assemblages [28]. Assemblage concepts have also been applied to the construction and evolution of energy projects and facilities [29,30]. Thus coal-fired power stations are nodal elements in wider, centralised fossil fuel assemblages but can also be viewed as assemblages in their own right - the perspective adopted here. For all their apparent obduracy and coherence, the 'coal power plant assemblage' is a composite of multiple interlocking uses, with differentiated spatial relationships to other places. There are the functional requirements of the supply and combustion of fossil fuel, the operation of generators and the supply and export of electrical power, requiring rail networks, coal storage areas, ash disposal systems, transmission lines and substations, as well as boiler houses, generator halls and cooling systems. Pollution control equipment like Flue-Gas Desulphurisation (FGD) add their own infrastructures and material flows: inputs of limestone, outputs of gypsum. Often, fossil energy use has reproduced itself over time, with sites hosting successive generations of coal-fired plants (often referred to as 'A', 'B', 'C' etc. stations) and, latterly, gas-fired generators [10]. Labour is required to operate and maintain all these elements. At the same time, the social and environmental obligations placed on the energy industry from the post-war period meant that many sites incorporated social amenities, including nature reserves, and sports facilities [31,32].

One can see the potential value of this perspective in helping to extend 'energy landscape recycling' research beyond comparing 'before' and 'after' land use categories [2,3], towards seeing recycling as multi-stranded change processes. Some elements of the previous assemblage

may get repurposed, others demolished and replaced, while others persist, as assets or liabilities. Recomposition processes can be affected by elements within the site but also by exterior material or discursive relations to elements beyond the site, such as multiple and shifting state agendas. These may confer stability but, equally, different agendas can be associated with their own particular governance lines – formed of rationalities and policies – that connect parcels of land to different social and economic goals, hampering coherent territorial development [33].

Assemblage thinking has been used previously in energy social science (see [23,29]), but not without criticism. The emphasis on multiple relations and description has been deemed to hide ‘power differentials, and especially the decisive influence of dominant actors’ ([23], p.4), and fall short of providing a basis for critical, evaluative judgement [26,30]. Such criticisms are misplaced. Tracing change processes can show how and why certain assemblages ‘win out’ to ultimately territorialise themselves in the landscape, as new places, and which places struggle to be built and ultimately ‘flicker out of existence’ ([34] p.91). This reveals power and agency ‘in actu’ [35] as, after Murdoch [36,p.370], tracing the shifting constellations of assemblages ‘is akin to tracing the topology of power for whoever succeeds in defining the order of priorities succeeds in defining the connections which give rise to the spatialities and temporalities that compose our world’. Researchers have also begun using assemblage thinking to interpret justice in energy transitions, not as abstract principles but as rooted in practices, contextually embedded in assemblages [23]. Pertinent to the following analysis, Chezel and Nadai [29] noted how manifestations of fairness shift as wind farm assemblages upscaled from smaller, locally-developed projects to embrace larger projects.

In summary, rather than using concepts like ‘site’, ‘land use’ or ‘place’ as our ontological foundation, we approach our subject using an assemblage approach. This entails conceiving the world in terms of dynamic relations between heterogeneous human, natural and material elements, which are continually in the process of becoming. Rather than focusing analysis around ultimate outcomes, our assemblage approach is processual, focused on explaining the construction of new stable relations. The merits of this approach become clear as we turn towards our primary subject. The end of coal-powered electricity generation marks a moment when site assemblages are potentially opened up, allowing new entities and people to enter ([29], p.1005).

3. Methodology

This research focused on Britain's last twelve coal-fired power stations, which ceased generating electricity from coal over the period 2015–2024 (see Table 1). This period is marked by the 2015 Paris Agreement on Climate Change and, linked to that, the UK Government's announcement that coal power would be phased out by 2025, a deadline subsequently brought forward to 2024 [37]. Though high profile, the government's announcement was substantially symbolic, in cementing phase-out trends already largely accepted by the sector [38]. The data set encompasses an array of land recycling pathways and is, therefore, sufficient for the purposes of this analysis.

The plants covered have particular qualities that affected the change processes that emerge. They are mostly gigawatt-scale power stations, commissioned in the 1960s–1980s. The planning, design and siting choices were led by the nationalised Central Electricity Generating Board (1958–2001), with central government endorsement i.e. they are ‘nationally-determined spaces.’ They also represent the apotheosis of energy ‘de-localisation’ ([11], p.117), facilitated by expanding grid networks and driven by economies of scale towards larger plants needing considerable space. The majority were built in rural locations, mostly with no prior energy production uses, to become monumental features in new ‘landscapes of power’ [39]. Consequently, many proved controversial, with opposition to the landscape impacts reinforcing environmentalists' critique of pollution [40].

To operationalise the assemblage approach discussed above, entails

Table 1

The last twelve coal-fired power stations in Britain.

NAME (Location)	Installed capacity (MWe)	Commenced generation	Date ceased coal-fired electricity generation
Ironbridge (Shropshire Council, Telford & Wrekin Council, England)	1000	1969	2015 20th November
Lynemouth (Northumberland, England)	420	1972	2015
Ferrybridge C (Wakefield City Council, Yorkshire, England)	2000	1966	2016 31st March
Longannet (Fife Council, Scotland)	2400	1969	2016 24 th March
Rugeley B (Cannock Chase District Council, Lichfield District Council, Staffordshire, England)	1000	1970	2016 8th June
Eggborough (Selby District Council (up to 2023), North Yorkshire Council (from 2023), England)	1960	1967	2018 23rd March
Cottam (Bassetlaw District Council, Nottinghamshire, England)	2000	1968	2019 30th September
Aberthaw (Vale of Glamorgan Council, Wales)	1555	1971	2020 31st March
Fiddlers Ferry (Warrington and Halton Borough Councils, Cheshire, England)	1989	1971	2021 31st March
Drax (Selby District Council, North Yorkshire, England)	3960	1974 (expansion opened 1986)	2021 (31st) March
West Burton A (Bassetlaw District Council, Nottinghamshire, England)	2000	1967	2023 31st March
Ratcliffe-on-Soar (Rushcliffe Borough Council, Nottinghamshire, England)	2000	1967	2024 30th September

mapping the shifting assemblages that constitute power station spaces, over time [24], and using this to help explain what these sites have become, looking at which elements are reproduced, which are repurposed though new relationships, which are effaced, and why. This requires data that can capture the processual nature of change, with a longitudinal dimension [23]. Three main sources have been used:

1.) *Media data.* The ‘Nexis Advance UK’ database was searched for items on each power station, using power station name as an exact search term (e.g. ‘Fiddlers Ferry power station’). This database covers national and local newspapers, specialist energy publications, and transcripts from TV news coverage. The search time-frame was set from 01.01.2012 to 27.06.2025. Media data was used to construct timelines of events for each power station, and access ‘official’ and contending arguments about change.

2.) *Planning application data.* Planning applications were searched and analysed for each power station location, using online databases. Each significant application from 01.01.2012 to 07.07.2025 was examined, seeking information on prospective changes to parcels of land within power station sites; developers' intentions, plans, and supporting impact studies; consultation responses from statutory bodies, NGOs and publics, as well as decisions and justifications. (The definition of ‘significant’ here excluded applications discharging conditions, for minor structural changes, and fuel ash handling). In planning arenas, we can observe which discourses ultimately proved authoritative in legitimising decisions.

3) *Semi-structured interviews.* To supplement the documentary data,

we conducted eleven interviews with key actors involved in or affected by decisions about the future uses of power station sites from: energy companies and their consultants; planning authorities and public sector agencies; strategic grid network bodies; and voluntary sector groups. Table 2 provides a list and the citation scheme. The accent was on those individuals that could elucidate the reasoning behind decisions, including explaining why certain pathways were not pursued, which might be less visible from ‘public facing’ media and planning sources. Interviews were undertaken between November 2024 and May 2025; lasted 30–60 min, and each was recorded and transcribed. We include a sample interview schedule as Supplementary Information but, because the interviews targeted a range of actors, and pursued specific areas of information and clarification, each interview was somewhat bespoke.

In terms of analysis, the three data sources were processed and analysed manually. The first analytical task was process tracing, to identify and sequence key change events and major actors. Here, the two documentary data sources are complementary, by corroborating events but also accessing different voices. People expressing views in newspaper articles may not necessarily participate in planning processes; not all proposals for future development become formal planning applications but may yet attract media attention [10]. Following from this, the data was subject to thematic coding [41], structured around the key justifications for changes; why proposals were deemed necessary and acceptable, socially, economically and environmentally; the various elements involved (actors, intentions, policies, infrastructures etc), and the causal effects these exerted. The analysis was used to identify the dominant assemblages emerging through coal power sites, and what has been dismantled or recomposed, as reported in Section 4. It then informs Section 5, where we explain why particular assemblages have proven dominant and others more fragile.

4. Results: what are power station sites becoming?

What are coal power sites becoming? The results are summarised in Table 3, from which one can distil a number of patterns in the emerging assemblages.

4.1. Becoming new energy assemblages

Coal power station sites represent assemblages of elements conducive to future intensive energy use. There is the physical infrastructure of major grid capacity for using or exporting significant flows of electricity, the level ground, and road and rail access. There are supportive social and institutional elements, too, especially planning policies, which underscore presumptions in favour of perpetuating energy uses [10]. For example, the following policy applied to ‘Land at Ferrybridge Power

Table 2
Interviewees.

Interviewee category	Linked to which coal power plant (if any)	Code (for referencing interviewee material)
Developer/consultant	Fiddlers Ferry, Ferrybridge	Developer1
Developer/consultant	Rugeley	Developer2
Developer/consultant	West Burton	Developer3
Planning authority/ public sector agency	Fiddlers Ferry	Public body1
Planning authority/ public sector agency	Longannet	Public body2
Planning authority/ public sector agency	Ratcliffe-on-Soar	Public body3
Planning authority/ public sector agency	West Burton and Cottam	Public body4
Grid network body	(non-specific)	Grid1
Grid network body	(non-specific)	Grid2
NGO	Rugeley	NGO1
NGO	(non-specific)	NGO2

Table 3

The shifting development assemblages of Britain’s last coal power sites, 01.01.2012 to 07.07.2025.

Station name	Date of closure (demolition complete)	Size of site (hectares)	Becoming new energy uses	Becoming non-energy use
Ironbridge	2015 (Sept 2021)	139 ha	Biomass , application for plant to enable 100% biomass combustion; consented 2012; not pursued. Substation , to serve new housing development; consented 2021.	Development comprising up to 1000 houses , retirement village, land for employment development , retail, allotments, sports pitches, schools etc.; outline consent granted 2022. General Industrial, Storage and Distribution (‘Mountpark’); consented 2024
Ferrybridge C	2016 (March 2022)	283 ha	Energy from Waste (EfW) plant (‘Multifuel 1’), 68Mwe; consented before research period in 2011. EfW (‘Multifuel 2’), 90 Mwe; consented 2015 CCGT : 2200 MW + 299 MW ‘peaking plant’ (‘Ferrybridge D’); explored 2018–2019; scheme dropped. Battery storage : 150 MW; consented 2021. CCS facility linked to EfW plants; in pre-application (Press announcement 2023). Hydrogen/nature gas-fired power station , 1.2GW, EIA scoping opinion sought 2024.	
Longannet	2016 (Dec. 2021)	229 ha	No applications formally submitted.	Business, industrial and storage units , received outline consent 2020; prime potential client was a train manufacturer; project dropped 2025.
Rugeley B	2016 (June 2021)	139 ha	Biomass conversion infrastructure; consented 2013; scheme dropped. Battery storage , 45 MW; consented 2017.	Mixed-use development, comprising up to 2300 houses, plus employment land , schools, accessible public/ green space; also

(continued on next page)

Table 3 (continued)

Station name	Date of closure (demolition complete)	Size of site (hectares)	Becoming new energy uses	Becoming non-energy use
			Renewable energy component incorporated within new housing development (see adjacent cell)	retains existing 132 and 400 kV substations; application covers whole site; consented 2021
Lynemouth	2015 (NA)	50 ha (est.)	Biomass conversion consented before research period, 2011. Bioenergy with Carbon Capture and Storage (BECCS) , early-stage assessment with/by UK Government, 2023.	No
Eggborough	2018 (July 2022)	162 ha (ash disposal was offsite at Gale Common, 150 ha)	Biomass conversion , consented 2012, but not pursued. Battery storage : approved (as Permitted Development) in 2017; scheme did not progress. CCGT: up to 2500 MW, plus 299 MW peaking capacity plant; consented 2019; yet to receive Final Investment Decision. Cryogenic storage scheme : 49.9 MW ('Highview Power'); replaces battery project; received EIA screening decision 2019; application did not progress. Battery storage : 500 MW; consented 2023.	Employment and logistics units ('Core 62' development) : hybrid application including power station demolition and employment units (53.5 ha); consented 2020.
Cottam	2019 (started Aug. 2023; not complete)	348 ha	CCGT power station, 440 MW, on adjacent site (commissioned before research period in 1999) Battery storage , 50 MW; consented 2018	No formal applications yet. Local Plan 2020–2038 identifies site as 'Cottam Priority Regeneration Area', allocated for 'mixed use regeneration',

Table 3 (continued)

Station name	Date of closure (demolition complete)	Size of site (hectares)	Becoming new energy uses	Becoming non-energy use
Aberthaw	2020 (started October 2024, not complete)	198 ha	Biomass combustion project, assessed for EIA screening by LPA, 28.03.2012. Carbon Capture demonstration project; given temporary (5-year) approval 2023, later extended. 'Green energy park' ; project proposed 2022; aiming to attract and cultivate 'zero carbon' manufacturing, to include battery storage and green hydrogen. No formal planning application submitted yet.	to come forward after 2038. Note that Green energy park proposal includes goals for attracting manufacturing.
Fiddlers Ferry	2021 (started December 2023; not complete)	324 ha	Additional biomass processing equipment, application made 2012 but withdrawn. 132 kV substation , consented 2013 Battery storage , 150 MW; consented 2023	Industrial and warehouse storage units , plus ancillary offices; application made 2023; not determined at time of writing. Development Framework Agreement for the whole site; provides for 860 houses and 101 ha for industrial land & housing; approved 2025. None
Drax	2021 (NA)	331 ha (including 160 ha for adjacent Barlow ash mound)	Biomass conversion: biomass co-firing preceded start of the study period; full conversion of three additional generating units (latterly a fourth) to biomass required handling facilities; consented 2012 Carbon Capture and Storage (CCS) ; 'White Rose Project', involving a coal power plant	

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Table 3 (continued)

Station name	Date of closure (demolition complete)	Size of site (hectares)	Becoming new energy uses	Becoming non-energy use
			(448 MW) plus CCS and carbon transport pipeline; dropped by 2015 for funding reasons; consent denied 2016 for same reason. Gas conversion of existing coal-fired units, plus battery storage ('Drax Re-Power'), totalling up to 3800 MW; consented 2019; gas conversion element dropped 2021. Battery storage: up to 49 MW; EIA screening request issued by 2020; further progress uncertain; 100 MW scheme operating since April 2025 BECCS , requiring additional infrastructure to be applied to two existing biomass generating units; consented 2024. Battery storage , 49 MW; consented 2016; commissioned June 2018 Battery Storage , 500 MW scheme; consented 2024; note, site overlaps with OCGT below, so cannot proceed with both. Open-cycle gas turbine (OCGT) , 299 MW peaking plant ('West Burton C'), consented 2021; not progressed yet. Prototype nuclear fusion reactor ('STEP – Spherical Tokamak for Energy	
West Burton A	2023 (demolition started November 2024, not completed)	200 ha (note - ash disposal is off-site at Bole Ings)		None

Table 3 (continued)

Station name	Date of closure (demolition complete)	Size of site (hectares)	Becoming new energy uses	Becoming non-energy use
Ratcliffe-on-Soar	2024 (demolition yet to begin)	265 ha	Production'); site choice confirmed by government 2022; first (temporary) buildings consented 2024. Energy-from-Waste project (EMERGE), 49.9 MW; <i>potential</i> CHP; consented 2021; project not progressed yet. 'Energy generation and storage' (Ratcliffe Redevelopment Local Development Order); approved 2023; to potentially include hydrogen production, battery storage, solar power.	Ratcliffe Redevelopment Local Development Order project (see cell left) may also include gigafactories, data centres, logistics, R & D facilities.

Note: see table included as Supplementary Information for more details on consenting body, areas, land uses occupied, and dates.

Station':

'Within this zone permissible development proposals will be restricted to employment generation directly associated with power generation and related infrastructure, including the generation of renewable electricity' ([42], policy EZ18).

Previous research would also predict supportive societal expectations among local publics based around place identity, continuity and 'fit' [25], a narrative picked up by prospective energy developers, as discussed below. Furthermore, scenarios for energy transition indicate significant demand for energy facility sites, notably for dispatchable power that can balance increased renewable energy capacity. Scenarios for the UK project demand for up to 51GW of energy storage capacity (batteries and long-duration storage), and up to 10GW of low-carbon dispatchable power (biomass with Carbon Capture and Storage (CCS), and hydrogen) by 2050 [43], which all need locating. Consequently, one might expect interest in future energy-related uses.

The findings reveal a more fragmentary reality. Components of the coal power assemblage have been reutilised for centralised energy provision. This can be seen in the gas-fired thermal power plants already in place within or adjacent to these sites (Cottam, West Burton). Almost all coal power sites have seen the development, or proposal, of battery storage plants. Such projects encountered few planning problems. Some battery projects benefited from 'permitted development rights', because they were '(d)velopment by statutory undertakers for the generation, transmission, distribution or supply of electricity for the purposes of their undertaking' (Application 2017/0893/ CPP, Eggborough, determined by Selby District Council). This means that normal planning application process were reduced to a simpler 'prior notification' procedure, with restricted consultation and the role of the local planning authority reduced to approving details of layout etc. However, most only

occupied a fraction of the former coal power site. Grid connections and substations were always retained although, as part of the closure process, these assets were formally separated and passed to National Grid.

Beyond batteries, the construction of new concentrated power assemblages has been more hesitant. Applications for new, unabated gas-fired power projects made since 2012 were all approved – there were no major impediments in the consenting process – but Drax and Ferrybridge schemes were subsequently dropped by site owners, with Eggborough being downscaled at the time of writing (July 2025). Back in 2012, many remaining coal-power plants were being put forward for enhanced biomass co-firing or conversion – a pathway which makes considerable use of existing generation infrastructure - but only two were successful: Lynemouth and Drax. These import biomass in the form of wood pellets, mostly from North America [44]. To date, Drax has been the main location at which facility owners have been able to build connections to prospective large-scale lower-carbon thermal power pathways, by pursuing CCS projects. This has been a long, episodic process, however (see Table 3), with earlier projects being abandoned and the current BECCS scheme not scheduled to begin construction until 2027 [45].

Other sites illustrate the challenges of constructing new, durable assemblages around lower carbon energy. At Ratcliffe-on-Soar, long-established working relations between the local planning authority and the site owner meant that – relatively unusually – planning actions to steer future development preceded closure by some years, beginning in 2018. The parties collaborated to construct a future development vision centred on ‘advanced manufacturing ... technology needed to transition to net zero, green and low-carbon energy generation, and energy storage’ [46]. To help de-risk this pathway, the council developed a Local Development Order for the site, which extended permitted development rights to simplify downstream planning consenting processes for developers. The aim was to ‘lock in future uses of the site in the quickest way possible’ and ‘a bit of control’ (public body3). But with demolition not scheduled to be complete until 2030–2031, plans are at an early stage.

Elsewhere, at Aberthaw, the site was purchased in 2022 by the Cardiff Capital Region (a regional body formed from local councils in south-east Wales). Media announcements immediately touted ‘master plans’ and ‘visions’ that had green energy at their centre, yet no such plans had emerged formally in the public realm by the time of writing. For West Burton, securing the Spherical Tokamak for Energy Production (STEP) nuclear fusion scheme project has underpinned the proposal of a ‘Trent Clean Energy Supercluster’, spanning ex-coal power sites at West Burton and Cottam (and High Marnham, which closed in 2003). The proponents’ goal is to ‘embrace clean energy and innovation’ across these spaces, including hydrogen production [47]. Yet, as with Ratcliffe, progress is contingent on site-owner buy in, which is not guaranteed: “they’re basically open to multiple opportunities for the sites ... they’ve not given a strong fixed sense of ‘this is what we want to do’” (public body4).

One trend emerges strongly from the data: major energy projects are coming forward and clustering across extensive areas *surrounding* ex-coal sites, especially solar PV (at Cottam, Drax and West Burton), high-voltage grid interconnectors (at Drax) and battery storage (at Ironbridge, Ferrybridge, Rugeley, Cottam, Drax and Ratcliffe). These schemes all exploit one specific element of the coal power assemblage – their high-capacity grid connections – and create new assemblages with dramatically recast spatial geometries, as discussed below.

4.2. *Becoming housing, warehousing and light industry*

Almost half of ex-coal power sites have seen the total or partial dismantling of energy generation assemblages to become more conventional urban land uses - housing and industrial-warehousing facilities (Table 3). These pathways exploit the road access bequeathed from the centralised energy production assemblage, and the institutional and societal presumptions promoting redevelopment of brownfield sites.

However, it also sees these spaces reformulated into a different assemblage, in which key elements are market pressure for housing intertwined with supportive, cross-scalar government planning policy for house-building.

Characteristic strands of the ‘becoming housing’ pathway can be observed at Fiddlers Ferry, sited on edge of Warrington in north-west England. For the local planning authority, Warrington Borough Council (WBC), policy for the site was shaped by wider contestation around the local development plan. WBC had long struggled to accommodate sufficient land for new home construction to meet their housing requirements and faced continual pressure to release green belt land to do so (public body1). Early consultation drafts of their local plan released in 2017 saw WBC proposing to site 7000 homes/employment land on greenfield sites, with the then still-operational Fiddlers Ferry site only treated as a ‘contingency employment site’ (public body1). This met concerted protest through the local press, from some local politicians, all concerned to ‘minimise’ the loss of green belt land [48]. However, the closure announcement of Fiddlers Ferry triggered a sequence of discussions and policy shifts that ended with the (2021) adopted plan allocating 860 houses and 101 ha of employment land to this site, reducing the need for green belt land releases elsewhere in the Borough.

From the site owner’s perspective, the decision to sell the Fiddlers Ferry site asset was based on judgements about the prospective financial returns, and that the site was deemed too distant from, too lacking in ready access to, potential CCS and storage infrastructures in the wider region to be repurposed for decarbonised thermal power. The owners entered close, collaborative working relations with the local planning authority about future uses, which led ultimately to the development planning framework for the site [49]. Bar a few hectares for a battery storage facility, and the retained National Grid substation, the site was to have no further role in centralised energy production.

Similar planning rationalities, linking housing development targets, the brownfield status of power station sites, and greenfield development resistance, can be observed driving pressures for housing development re-use elsewhere, even on more deeply rural sites such as Ironbridge.

For other sites, it is less clear that any singular assemblage is becoming dominant, with these spaces becoming more hybrid in nature, combining energy functions with other uses, arising from piecemeal, incremental site redevelopment. Housing developments juxtaposed with batteries and major grid substations are already on the cards. At Ferrybridge, warehousing and logistics schemes will co-exist with Energy-from-waste (EfW) plants. In these developments, we observe a shift from energy production as a major, centralised and spatially-sequestered operation in rural settings, which aligns the diverse elements of the assemblage and its surroundings towards its singular main function, towards energy production becoming more physically-modest elements within new ‘peri-urban complexes’ ([50], p.35).

4.3. *Not becoming protected, as heritage or wildlife sites*

The construction of future energy, housing and warehousing assemblages all depended substantially on other elements of the coal power assemblage becoming effaced, or at least reconstituted in forms that did not impede dominant development agendas.

The first of these elements concerns former coal power stations not becoming heritage. This requires some explanation given that, over their fifty-year existence, these facilities had accumulated multiple layers of meaning that could inform memorialisation and heritage actions: as local landmarks; as ‘architectural gems’ [51]; as sites of protest, from the 1984–85 miners’ strike to climate change activism; and as places of work (and play, see below). This intertwining of built form, machinery and social relations evidently cultivated strong attachments. Demolition attracted national as well as local news coverage, providing affective moments of memory. As an employee put it, as the end neared for Ratcliffe-on-Soar, ‘it’s in my blood. You cut me, I bleed Ratcliffe’ [52].

Despite this, arguments for conservation exerted minimal effect on

landscape recycling processes. There have been efforts to assert the heritage and architectural value of these facilities, especially the cooling towers, with the Twentieth Century Society calling for at least some of these structures to be preserved by listing designation (NGO1, [53]). Such calls had attained little success by the time of writing. The formal case against conservation was aired at a number of sites, with planning officers citing 'lack of architectural interest' (the 'standard designs'); 'lack of technological interest' (no major technical innovations) and lack of 'rarity' (cooling towers being 'relatively common types') (e.g. Lichfield District Council (Application 19/00753/OUTMEI), Planning Committee Report 27.07.2020, para 3.37). Opportunities for discussing the merits of conservation were further constrained by the fact that the planning system treats demolition as permitted development (GPDO (England) 2015) with local planning authority oversight restricted to 'prior approval' of details of safety and process. In addition, proponents of development – both the site owners and the planning authority – were almost invariably resistant to seeing redevelopment opportunities restricted by major, conservation requirements.

Consequently, the effacement of the power station structures as material, in situ heritage has proceeded largely unhindered to date. With few exceptions, demolition has seen all previous built structures removed down to 'slab level'. Instead, conservation interests were addressed through placing planning conditions on owners/developers to document the structures prior to demolition, and make those reports available on-line (e.g. [54]). Information value is conserved, but in de-territorialised, non-material forms. One could interpret these actions as a form of justice as recognition [16], in that there are legitimate interests attached to the former coal power assemblage that require attention in the change process. However, they are granted a subservient status, which legitimises the renegotiation of their existing material form into some acceptable substitute.

In addition to heritage, such processes of recognition and renegotiation can be observed with other interests, attached to social and ecological elements of coal power spaces. Various researchers [31,32] have explained how the environmental 'amenity clause' (Section 37 of the 1957 Electricity Act) and other duties encouraged the nationalised energy industry to create 'welfare landscapes'. These embraced nature reserves and field studies facilities within power station sites; the housing of sports facilities like pavilions, football fields, cricket pitches and golf courses; and social clubs from which many other interest groups benefited. Many of these facilities persisted into the privatised era, receiving considerable active use right up to plant closure. With wildlife habitats, while some elements were kept and incorporated into the landscaping schemes of subsequent developments, we observed several post-closure processes that granted developers considerable flexibility to efface and reassemble those ecological interests. The first mobilised the classic *site-based approach* to managing change: that any visual or ecological features within power station sites were not designated, and thus regarded as lower value, and able to be traded off for the economic gains of development. Second, are arguments of *aggregation*: i.e. the fact that there may be wildlife features or areas of green space within the sites did not prevent them from being regarded, in aggregate planning terms, as 'previously developed land', for which re-use should be a priority. In some cases, this stretched to embracing open greenfield space within the power station operators' ownership, some of it in agricultural use, where incorporating it would help ensure viability of remediation (public body1). Thirdly, any environmental features – whether non-designed habitat features or protected species - were deemed to have their interests *more than adequately substituted* by the retention and creation of new environmental features and landscaping within the sites' new development schemes (e.g. [55], para 6.5).

Negotiating trade-offs between development priorities and extant social and ecological interests through planning processes never generated sufficient controversy to deflect site redevelopment trajectories. Nevertheless, substitution processes could be intricate, protracted and consequential. For some activities, decisions were directed by

policies requiring equivalent replacement facilities e.g. for sports pitches, facilities and 'open space' [56], which developers then needed to deliver. However, many social activities lacked policy recognition, leaving their prospects contingent on how site owners balanced commercial imperatives against dealing fairly with community legacy issues. One example is large-scale railway modelling; a hobby that has strong affinities with the engineering culture of the energy sector, with a subset of coal stations hosting extensive track, gratis, within their sites. At Rugeley, there is the prospect of space being afforded to the model club within the park-space of the new housing development, but only after initially being given notice to quit, returning under short-term licenses, with hopes of secure long-term arrangements dependent on the shifting priorities of changing landowners. Hence for them:

'uncertainty is the overriding thing', 'we don't know where we'll end up'; 'it's a ... situation which has probably been influential in some of our members not renewing' (NGO2).

5. Analysis

The findings section above has charted what coal power spaces are becoming as fossil fuel assemblages are dismantled and the sites are recycled into other uses. But what of our other research questions? What explains these directions of development, and what does this reveal about how the agency to drive change and the implications for place-based just transitions?

5.1. The differential power of housing and energy development assemblages

The start point for explaining change is the recognition that the energy companies owning coal power facilities that close are pursuing profit from their assets, including land and, as landowner, have considerable agency in determining subsequent pathways. Beyond this basic position, recycling coal power sites was rarely swift, but has proved simpler to realise for some pathways than others, and this can be attributed to the heterogenous elements that needed aligning.

Across the sites, one can observe the powerful, reinforcing effects of the various elements of housing development assemblages. Here, the combination of market opportunity and pro-delivery, target-centred housing planning policy created *consistent and pervasive* incentives for private and public sector actors to allocate ex-coal power sites for housing, especially in England. The housing development assemblage operates a more-or-less hierarchical logic which – although varying in detail over time – mobilises a 'national-to-local' strategic line, which links national policy and more local delivery objectives, represented by new house completion numbers, through to requirements to allocate sufficient sites in development plans [57]. Comparable policy and market elements also combine to generate pressures for ex-coal power sites to become 'employment land'.

Importantly, the assemblages that foster housing or warehousing development on ex-coal power sites also incorporate planning policy presumptions in favour of brownfield land re-use, reinforced further by pressure from publics and their political representatives against developing greenfield sites. These pressures are especially intense where the rural and suburban locations of coal-fired power stations are in areas where land acceptable for housing development is scarce, as at Fiddlers Ferry. Such pressures to re-use brownfield sites 'trumped' concerns about the externalities of major new housing development in rural and thinly-serviced locations as at Ironbridge (discussed below).

The dynamics of the housing development assemblage can be contrasted with the persistent fragility and protracted nascency of new energy assemblages, especially for forms of dispatchable thermal power. As noted earlier, intuitively, coal power sites offered significant notional advantages for such re-use, including grid access, and sharing the

presumption in favour of brownfield redevelopment with the housing assemblage. The research also found development interests constructing discourses of ‘place continuity’ in energy activities, as a basis for social acceptance of the new proposals [10,19]. For example, Bassetlaw’s 2040 vision:

‘to become the greenest, most sustainable district in which to live and work’, involved ‘building on its legacy of energy production, manufacturing and logistics to power the net zero economy’ [58].

However, to date, sites positioned to become new energy assemblages have struggled to translate fully into stable, durable investable opportunities. One critical element here – and a contrast with the housing sector – has been persistent instability in national energy policies, markets and corporate factors, which problematise the construction of remunerative projects. These uncertainties affect a range of technological pathways; notably hydrogen [59], as well as CCS, and often also reflect continuing contestation of environmental sustainability claims. Even though biomass conversion was realised at Lynemouth and Drax, the economic, environmental and ‘low carbon’ merits of this technology have been the subject of persistent critique and, come 2025, the government significantly reduced financial support for unabated biomass. Similarly, the cessation of coal generation altered the benchmarks for judging Energy-from-Waste plants, since exposed as ‘the UK’s dirtiest form of power’ [60].

Site value is relative, too, and itself reflective of the unfolding spatial formation of future decarbonised energy assemblages. As the owners of the Fiddlers Ferry site intimated (developer1), many ex-coal power station sites can be relatively distant from the centres of prospective industrial decarbonisation clusters, making releasing them for non-energy uses a surer source of financial returns. Distance from these emerging and fluid low carbon energy assemblages may well problematise the energy-centred redevelopment plans at other sites, with the exception of Drax. Given all this, the relative cohesion of the housing development assemblage, as a route to delivering profitable and locally-desired development, could further destabilise nascent energy-related assemblages. At Ratcliffe, promoting an energy-centred vision faced push-back: ‘at times we’ve been swimming against the tide’ (public body3), with competing regional elite visions ‘creating a lot of noise about housing’ (ibid.). Data centres, as major energy consumers, may also present economic opportunities to site owners that trump power projects [e.g. [61]].

Consequently, propitious corporate circumstances are required to construct major energy assemblages on ex-coal power sites, to incentivise company decisions ‘not to sell and divest our high-carbon assets and hold on to them and manage those through the transition’ (developer2). Such circumstances come and go. The Zero Carbon Rugeley project [62] had ambitious aims to use redevelopment of the power station site to catalyse innovative, smart local energy systems for the whole town. This vision ascended while it could be promoted by a site owner with commercial interests spanning regeneration, housing, and energy services. However, it crumbled as more short-term corporate restructuring, ‘wanting to raise cash out of the business’ (developer2), meant selling off the energy services business, thus dismantling the long-term value proposition.

5.2. Agency in shaping what coal power spaces become

What then of our questions about agency? Who drives choices around coal power site recycling, and what does this say about the justice dimensions of transition processes, especially procedural fairness? As noted above, the key actors in change processes were the large corporate owners of the sites, whose powers to construct new development assemblages reflected their panoply of powers, rooted in ownership and control of the land and financial resources. Where there were early ‘public discussions’ about future development opportunities of

coal-power sites, these tended to be ‘at a high level’ (public body3), involving senior corporate and council leaders, often behind the curtain of commercial confidentiality. The position of local publics shows history repeating itself, with the very scale of the sites delimiting publics’ engagement in the assemblage construction process. When these large-scale coal-fired power stations were being planned in the 1950s and 60s, their ‘exceptional scale’ and ‘strategic significance’ meant that consent decisions were taken centrally, by government ministers. During their redevelopment, again the large scale of these sites is used to justify their treatment as ‘exceptional opportunities’, for which elite-level collaboration sets the direction (see also [18,63]).

These high-level discussions about future strategic development were themselves permeated by power differentials. Local and regional government bodies could be assiduous in deploying their statutory powers as planning authority and their interests in regeneration to work with site owners, and many moved swiftly to adjust land-use planning policies previously favouring continued power generation to more flexible accommodating policies (observed at Cottam, Longannet, Fiddlers Ferry, Ferrybridge, Ratcliffe and West Burton). Yet officers realised that the greater powers of site owners meant that they had little choice but to be accommodating towards owners’ redevelopment decisions (public body3). As interviewees expressed it:

‘I’m a pragmatist if I am nothing. And experience tells me that it’s great having policy. It’s great having ... local plans, but if you can’t find an economically viable route to develop it’s never going to happen’. (public body2)’.

Across the twelve cases, public responses to what coal power station sites were becoming were patchy in their focus and extent, with limited substantive effect on the directions of site redevelopment. Where new projects had minimal local impacts (for example on the landscape), then responses from *local* publics were usually minimal, as observable from the planning files on battery projects and biomass conversion schemes. Nor did the press analysis or the planning application files, reveal any major public upwelling of resistance to power station demolition. However, the wider sustainability and decarbonisation credentials of energy-from-waste schemes, biomass projects, new gas projects or CCS did come under intense challenge, but mostly from environmental NGOs and campaign groups, rather than residents. This included Biofuelwatch, ClientEarth and the Yorkshire Wildlife Trust with Drax’s gas conversion project, and Biofuelwatch, Friends of the Earth, Extinction Rebellion and the Green Party UK with Drax’s BECCS scheme (see Table 3). NGO criticism of Drax’s gas conversion proposal led planning inspectors to recommend rejection on climate change grounds, only for this recommendation to be overturned by the Secretary of State.

Large-scale resistance from local publics and politicians was most observable around schemes involving housing, in two dimensions. In a more direct sense, as at Ironbridge, the conversion of the power station site to a new village of up to 1000 homes fomented considerable opposition from pre-existing rural communities, which focused on the potential spillover effects of extra traffic and demand pressure on local amenities [64]. But public and local political concerns also exercise more pervasive, indirect effects: by resisting new development on greenfield sites in their area, they reinforce siting policies favouring brownfield sites, like ex-power stations, despite the externalities. This was observable at Fiddlers Ferry, Ironbridge and Ratcliffe-on-Soar.

5.3. The terrain for place-based just transitions

Using assemblage thinking to chart what ex-coal power sites are becoming, and the messy, processual nature of change, offers useful insights into the contextual conditions for realising ‘just transitions’ in general, and place-based just transitions in particular. Such change processes are shown to be procedurally, spatially and temporally complex, in ways that matter.

Looking first at 'on-site' decision-making procedures, the research reveals the highly fragmented, piecemeal opportunity structures around 'future use' decisions. Many categories of development enjoyed permitted development rights (PDR), meaning that the principle of the development could not be questioned, and the scope of consultation was much reduced. Decisions around demolition also enjoyed PDRs, and were usually taken prior to and separately from decisions about future uses. Planning file analysis also revealed the fluid baselines against which the acceptability of new projects was judged. Battery schemes at Fidders Ferry were assessed as 'small ... in relation to the power station buildings' (Application 18/00249/FUL, Officer's Report 17.04.2018); the EfW scheme at Ratcliffe, 'would be smaller than the other infrastructure and buildings already on site' (Application 20/01826/CTY, Officer's Report 19.04.2021, para 47); yet in each case existing buildings were destined for removal. Altogether, the institutionalised incrementalism and fragmentation of decision-making processes make it difficult for publics or external stakeholders to view the transformation of sites as a whole.

Second, an assemblage perspective also helped to show how ex-coal power spaces are re-scaled through the closure and recycling process, with a recomposition of the relationship between elements *within* and *beyond* the site. Within 'new housing development assemblages' and 'energy-development' visions, one can see new hybrid spaces emerging, where energy infrastructures – instead of the spatially-sequestered coal-power behemoths of the 1960s - are inserted between others uses: batteries-with-houses-with-warehouses-with-EfW plants etc. One legacy may be increased potential for conflict, as new energy infrastructure projects vie for access to grid connection points whilst navigating other, incompatible land uses. Substation owners, NGET (National Grid Energy Transmission), have limited ability to orchestrate land market and planning decisions:

'we will explain to' (owner of the coal power site that is selling the land that) 'it would be beneficial to leave another route in for more connection customers in the future, but they're absolutely under no obligation' (Grid1).

Sites thus become 'complex spaces', with multiple assemblages all operating in the same space [24], without overall ordering logic or agency.

Further beyond the site perimeter, one of the most dramatic re-scaling processes involves the proliferation of large solar power and battery storage schemes. These projects all exploit one element of the coal-power assemblage – their nodal, high-capacity grid connections – but not the brownfield land vacated. The prospective capacity and spatial extent of some of the solar PV schemes is considerable, as illustrated in Table 4. Developers' narrowly-framed discourses of continuity, that such schemes 'replace ... former generation capacity' of coal-fired power [65], have not quelled public opposition to the spatially-dispersed impacts across wider rural areas [66]. Such re-scaling –

Table 4
Major new renewable energy projects linking into ex-coal power substations.

Coal power site	Connecting projects	Capacity, Area and furthest distance from substation
Cottam	Cottam Solar Project	600 MW, 1270 ha, 18 km
	Tillbridge Solar	500 MW, 1214 ha, 18.5 km
West Burton	Gate Burton Energy Park	500 MW, 824 ha, 8 km
	Steeple Renewables (Solar) Project	400 MW, 888 ha, 5.5 km
	West Burton Solar	c480MW, 886 ha, 14.5 km
Drax	East Yorkshire Solar Farm	400 MW, 1277 ha, 15 km
	Helios Renewable Energy (Solar) Farm	190 MW, 476 ha, 11 km

Note: data focuses on the twelve coal power sites considered in this study, and on renewables projects classified as 'Nationally Significant Infrastructure Projects' (i.e. over 50 MW).

driven by multiple developers, without a tangible spatial plan or vision - creates a challenging basis on which to operationalise notions of 'just transition'.

This spatial flux intertwines with the extended temporality of change, as coal power landscape recycling is shown to be a long, ongoing process of becoming, not a point in time, involving processes that begin before and extend beyond any notional moment of closure [17]. 'Before', the data reveals 'closure' to be a punctuated, episodic process of retrenchment. Within the overarching temporal framework of EU and UK environmental legislation [37], the fate of individual power stations was affected by corporate judgements about profit opportunities from evolving 'political markets' for peaking capacity and biomass conversion; faltering political willingness to fund life-extending but under-proven CCS technologies [38]; accidents like fire (hastening closure at Ironbridge and Ferrybridge), as well as the ageing, depreciated nature of the assets themselves. Levels of direct employment fell in concert, from typically 750 in the days of peak capacity, to around 150 at the point of final closure.

Events post-closure are similarly protracted, with the careful treatment of hazardous and valuable materials preceding a staged demolition exercise. Nowhere have decommissioning and demolition been completed less than four years after electricity generation ceased (Table 3). Some processes related to coal power are anticipated to extend into the future; at several sites, the continued extraction of fly ash for use in construction materials may persist until mid-century [49]. And while some sites are being actively redeveloped for housing, for those earmarked for energy-related pathways, time-frames look more uncertain. For example, options on the West Burton site have been secured for the STEP nuclear fusion project, but this is an incremental, long-term project, with a demonstration fusion reactor currently estimated to 'begin operations early 2040s' (developer3). Consequently, while the scheme offers significant scope for new employment, place-continuity discourses about 'replacing the jobs Nottinghamshire lost from the end of coal mining' [67] are largely symbolic: most previous workers have moved on, retired or passed away. Energy companies often reported success in re-deploying ex coal plant employees to posts elsewhere in their business, but one can observe temporal and spatial dislocation between job losses, job gains and the places and communities affected.

6. Conclusions

Now that all the coal-fired power stations in the UK have closed, it is important to understand what is happening to these large, iconic spaces. This agenda has saliency as well for the 2400 coal plants still operating globally that will face the same fate [68], a number that underlines the importance of appropriate landscape recycling. While in operation, the complex social and material elements of the coal power generation assemblage were given cohesion by the core functions of electricity production and revenue generation. These sites constituted controlled and tightly-securitised spaces [50], in which powerful hierarchical relations dominated their operational life. Through closure processes, however, an array of potential futures opens up.

The main objective of this paper was to address a knowledge gap, by tracing what had happened to the sites of Britain's last twelve coal-fired power stations since coal-based generation ceased and, using an assemblage approach, to explain the directions of development that are emerging. This revealed coal power sites becoming a variety of things: housing and warehouses predominate on three sites; two have converted to burn biomass; with the remainder being positioned – with various degrees of provisionality - as sites for future energy-related investment. For some of these spaces one can observe a shift from neatly demarcated, coal-centred energy sites standing apart in rural landscapes, towards new hybrid spaces, in which energy uses remain on or adjacent to sections of the vacated site but now in sharp propinquity with new residential and workplace neighbours. This has implications for coordination and, potentially, for place identity. The research also

traced how other social and ecological relations to these sites – centred on heritage, social clubs or nature conservation – became effaced in the pursuit of comprehensive site redevelopment: smoothed aside in their current material form and substituted by new, development-compatible forms.

The assemblage perspective has proven valuable in a number of regards. First, by conceptualising coal plant spaces as assemblages of heterogeneous elements it has opened up the multi-stranded processes of change at work in energy landscape recycling. Rather than viewing recycling in terms of fixed, essentialist categories of sites or land-use categories which describe the picture ‘before’ and ‘after’, assemblage approaches open up the processual nature of change and the partiality of recycling (some elements are repurposed and some not), thus linking landscape recycling research to Eadson and Van Veelen’s call for more focus on ‘negotiation, struggle, inclusion and exclusion in path development processes’ ([13] p.218).

This connects to our second research question, which seeks to explain the directions of development emerging on coal power spaces, by examining the agency to drive change. Here, too, an assemblage approach proved useful. Rather than viewing power and agency as structurally determined, one can observe how agency is pulled together, distributed and mobilised, and revealed – in actu [35] – through tracing the elements that come together to enable new development assemblages to form (or not). Taking this approach has shown the considerable agency of site owners, but also the differential power of alternative development assemblages. There are those where hierarchically-structured and closely-coupled market and policy relations proved strongly supportive of particular development outcomes, as with new housing development, which is materialising. These can be compared to the comparative fragility of policy-technology-market assemblages around energy projects on these ex-coal-power sites, which reflect the greater difficulties of orchestrating the multiplicity of relations at work..

Our analysis suggests fruitful avenues for future energy transitions research. Tracing what fossil-fuel and energy generation spaces actually become, offers a valuable and distinctive lens on the wider contingencies of constructing new energy systems – the surprises, setbacks and struggles that emerge - and thus what ‘affected communities’ actually experience during energy transitions. Furthermore, our research also shows the contribution that assemblage approaches, and longitudinal research designs in general, can make to justice debates [23]. The processes of becoming that unfold over time – where the multiple, lengthy temporalities of post-closure change intertwines with the spatial fluidity of these re-scaling energy spaces - evidently create challenges for the practical mobilisation of ‘just transitions’, especially as a place-based construct. It is hard to specify the relevant ‘affected’ or ‘host communities’ as these shifting assemblages reconstruct which communities are implicated and how. Workforces ebb away in the count-down to closure. Other social networks also change, such as the ageing membership of railway model clubs - ‘every club ... around the country when we talk to them, it’s a dying out hobby’ (NGO1). Simultaneously, the research has revealed that decisions about ‘what should this space become?’ are not singular, but fragmented across multiple decisions, which vary in their openness to wider public engagement and never encompass a ‘whole picture’ of change. Strategic vision-making for power station *sites* risks ignoring the spontaneous accretion of major new solar projects expanding apace around them, but which only re-use the grid connection.

This study has its limitations. It focuses on just twelve coal power sites and a time-limited data-gathering period. Further research examining more sites, including older power stations and extending further into the future would broaden the picture of what coal-power sites can become. However, to see this research subject as ‘more knowable’ simply through ‘more data’ is to ignore a core insight from the assemblage perspective - that phasing out coal-power generation is inevitably an open-ended, episodic and contingent process of ‘becoming’ something else. Consequently, landscape recycling and the prospects for

place-based just transitions *both* look very different as one moves from simple ontologies to perspectives that recognise the multiple, open processes at work. The implications for ‘just transitions’ are more profound than previously recognised. Simple notions of ‘engaging communities’ in energy transition, tied to specific places and decisions – assumed to be static and singular – confront real world situations in which successive decisions and the changes they precipitate affect the identities of relevant persons [69], and (re)construct the potentially relevant public [70]. Addressing these challenges requires justice research that attends to the concrete experiences of the actual un-making and re-making of energy spaces [23], recognising that the spaces that actually emerge are unlikely to be, in total, a product of coherent over-arching intent.

CRediT authorship contribution statement

Richard Cowell: Writing – review & editing, Writing – original draft, Validation, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Martin J. Pasqualetti:** Writing – review & editing, Writing – original draft, Conceptualization.

Declaration of competing interest

The authors of this paper are aware of no conflicts of interest that could have influenced this work.

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Appendix A. Supplementary data

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Data availability

The authors do not have permission to share data.

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