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PROVOCATION

Decommissioning: another critical challenge for energy transitions

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To achieve the dual goals of minimising global pollution and meeting diverse demands for environmental justice, energy transitions need to involve not only a shift to renewable energy sources but also the safe decommissioning of older energy infrastructures and management of their toxic legacies. While the global scale of the decommissioning challenge is yet to be accurately quantified, the climate impacts are significant: each year, more than an estimated 29 million abandoned oil and gas wells around the world emit 2.5 million tons of methane, a potent greenhouse gas. In the US alone, at least 14 million people live within a mile of an abandoned oil or gas well, creating pollution that is concentrated among low-income areas and communities of colour. The costs involved in decommissioning projects are significant, raising urgent questions about responsibility and whether companies who have profited from the sale of extracted resources will be held liable for clean-up, remediation and management costs. Recognising these political goals and policy challenges, this article invites further research, scrutiny and debate on what would constitute the successful and safe decommissioning of sites affected by fossil fuel operations – with a particular focus on accountability, environmental inequality, the temporality of energy transitions, and strategies for phasing out or phasing down fossil fuel extraction.

Key words energy transitions • decommissioning • environmental justice • corporate accountability • fossil fuel phase-out

Key messages:

- Toxic effects of fossil fuel infrastructures extend beyond the end of their productive life.
- Decommissioning is vital for meeting environmental justice demands and achieving just transition objectives.
- Decommissioning challenges highlight how ‘transitions’ require historical reckoning as well as future planning.
- Clarity and accountability will continue to be central to developing effective frameworks for decommissioning.

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Decommissioning, scale and transitions thinking

It is not known how many oil and gas wells have been drilled around the world. While companies continue to extract from millions of active wells, many more have reached the end of their productive life and are currently sitting idle, unused or abandoned by their former operators. One rough calculation estimates more than 29 million abandoned oil and gas wells exist globally (Groom, 2020). The many environmental, social and climate-related impacts of disused energy infrastructures present a number of challenges for different countries and communities in designing, demanding and implementing distinct forms of energy transition.

Abandoned oil and gas wells have a range of toxic impacts. Often they leak methane, which exacerbates global climate change, as well as hazardous chemicals that contaminate air and water supplies at local scales – effects that most commonly and acutely destroy the lives of marginalised communities (AWA, 2021; Townsend-Small and Hoschouer, 2021; Costley, 2022). A clear imperative for just energy transitions, then, is the safe decommissioning of energy infrastructures that are no longer in use, coupled with the ongoing monitoring and management of their toxic impacts. These are vital steps for achieving the dual goals of minimising global pollution and meeting diverse demands for environmental justice.

In this *Provocations* article, we discuss how decommissioning presents critical challenges for energy transitions both pragmatically and analytically. We highlight specific issues and concerns to invite further research and debate on decommissioning processes more broadly. These issues include: (1) the importance of corporate accountability; (2) the different effects and shortcomings of some extant decommissioning funding models and (3) addressing a lack of clarity in the knowledge used to establish the scale of decommissioning challenges.

We also engage with oil and gas decommissioning as a way to expand critical analyses of energy transitions. Much of the literature on (energy) transitions maintains a temporal focus on the future and an analytical focus on the promise of different 'solutions' – often obscuring past or ongoing struggles for environmental justice and transformative social change (Escobar, 2015; Curley, 2023). This is the case even while much energy transitions research has expanded to address climate justice, land and labour exploitation, ongoing colonial histories, and other intersecting inequalities through community-engaged research (Powell, 2018; Blair et al, 2022; Boyle, 2023). One such alternative, which roots the need for transitions in struggles for systemic change, frames energy transitions as broader projects of social and ecological transformation (rather than merely the substitution of some energy sources for others), emphasising how much it matters who calls for, leads, works on and contributes to such processes (Partridge, 2022). Here, we also argue for expanding the temporal frame of analysis in work on energy transitions to disrupt the assumed linearity of much analytical transitions work. This means analysing how 'transitions' require not only future planning but also historical reckoning – identifying how current conditions for change are differentially constrained by previous energy and economic projects, impositions, constructions and decisions.

The standard focus in energy policy on metrics (such as renewable energy output or greenhouse gas concentrations in the atmosphere) tends to obscure what historians of energy have repeatedly shown: that energy transitions past and present are rarely final or complete, as societies always tend to use more of everything (Partridge, 2022). A standard policy focus also risks obscuring the ongoing forms of toxicity that affected communities endure at and around now-disused or abandoned sites of fossil fuel extraction. Prior energy systems do not simply or neatly come to an 'end'. Many energy-related injustices are routinely overlooked by decision makers when those injustices 'fall outside the formal remit' of environmental impact assessments, occur in places that are disconnected from active sites of combustion and consumption, or occur on timescales that are longer or more unpredictable than commonly recognised energy impacts (Healy et al, 2019: 220). We suggest a more complete range of the justice-oriented goals of energy transitions will only be achieved when authorities *also* enforce comprehensive frameworks for safe, just and effective fossil fuel decommissioning.

Our focus on oil and gas decommissioning serves to highlight the environmental justice and climate justice dimensions of these forms of infrastructure and their typically toxic 'afterlives'. Doing so complements scholarship that pursues an analytical perspective on infrastructure, decay, repair and infrastructural change more broadly – particularly work that emphasises repair not only to material infrastructures but also, simultaneously, repair to damaged practices of cultural, economic and political self-determination, or 'social infrastructures' (Berlant, 2016; Wallsgrove, 2022). The afterlives of (fossil fuel and other forms of) infrastructure also influence how we understand and theorise 'transitions' that take shape unevenly across unequal global contexts:

> In many, if not most, cases we live and work among various kinds of ruined or faltering infrastructure. Many of the past projects and assurances of modernity have degenerated. We now see decay and breakdown where there once was grandeur and optimism … In the Global North, the Keynesian era had a surfeit of growth-oriented projects and emphasized multiplying infrastructures and employing human labor in the service of bettered conditions … Decades later, after a proliferation of neoliberal policies in which governmental provision of public goods and infrastructures has been reduced, many of us who reside in the Global North live among the remnants: infrastructures that have been neglected, abandoned, and left to deteriorate … deterioration as such is intimately tied to northern neoliberal forms of governance and experience; in much of the Global South a high-functioning Keynesian infrastructural apparatus never existed. It is important that we distinguish between infrastructure that has gone to ruin and infrastructure that never was. In some parts of the world, persistent infrastructural breakdown, or total absence, is the norm. (Howe et al, 2016: 550)

Thus the imperatives and objectives of transitions vary enormously in relation to temporal, social and economic conditions. In areas of high fossil fuel production such as those discussed later, decommissioning might play a central (but often still neglected role) in achieving transition goals. Meanwhile in areas of persistent or total infrastructural breakdown or absence, transitions might instead seek to advance the provision of basic needs and – with regard to energy – a shift toward fulfilling access and sufficiency needs (Yaka, 2019; Burke, 2020; Bouzarovski, 2022). Diverse approaches to energy transition(s) also connect to place-specific concerns about land-use change, labour and livelihoods that demand equally place-specific (and responsive) forms of change (Partridge, 2020). These differences further underline how dominant narratives of 'urgency' in relation to climate mitigation can obscure other needs, such as addressing the 'urgency' of infrastructural inequalities.

Desired transitions might also include movement towards transformed political-economic systems, particularly modes of organising and relating that reflect post-structuralist, postcolonial and decolonial critiques of globalisation and neoliberalism (López-Castellano et al, 2022). These are movements for change that stem from diverse experiences and struggles across the Global South – throughout centuries of colonialism and in particular since the 1990s during which time such grounded critiques have been an increasingly visible and explicitly stated component of international networks of resistance (López-Castellano et al, 2022). Such transformative transitions seek to change not only the different energy sources that constitute national and global energy matrices but also the socio-economic relations that enable or prioritise certain forms of energy extraction, generation and consumption. These are movements that recognise and scrutinise the many ways in which 'energy infrastructure, including renewable energy infrastructure, furthers (neo)colonial social and political power imbalances' (Allan et al, 2022: 44). In many contexts, this means mobilising for a transition away from 'extractivism' – understood as the 'appropriation of Nature to feed economic growth and the idea of development understood as an ongoing, linear process of material progress' (Gudynas, 2013: 165) and the overexploitation of natural resources destined primarily to global export markets (Hamouchene, 2019; Partridge, 2022).

These differing views on transition(s) connect, in different ways and to differing degrees, to our argument here: that past forms of industrial activity (and the inequalities they exacerbate or have sought to address) limit the potential for positive contemporary change and development – which is to say that the safe and effective decommissioning of fossil fuel infrastructures is vital for enabling the future construction of more just and healthy energy systems.

Corporate accountability, clean-up costs and offloading

To date, the decommissioning of coal infrastructure has received more attention than that related to gas or oil, not least because reducing coal use and combustion has been prioritised as a way for countries to meet their climate policy and emissions reductions goals. Global targets have been set: 'an average of 60 GW [of active coal power] must come offline in OECD countries each year to meet their 2030 coal phaseout deadline, and for non-OECD countries, 91 GW each year for their 2040 deadline' (GEM, 2023: 5). While the international community is pledging aid to support some countries in moving away from coal – for example the 2022 international Just Energy Transition Partnership pledged US$20 billion to Indonesia, one of the world's largest coal producers and consumers (GEM, 2023) – meeting these global targets will require an overall rate of coal retirement and decommissioning nearly five times faster than what was witnessed during 2022 (Codexverde, 2023). Here, however, we focus on oil and gas as these industries are headed in the other direction, continuing to grow rather than withdraw in most countries, despite the fact that United Nations' Intergovernmental Panel on Climate Change (IPCC) is clear on its guidance across all fossil fuel industries: 'the Paris climate goals could move out of reach unless there are dedicated efforts to early decommissioning, reduced utilization of existing fossil fuel installations, [and] cancellation of plans for new fossil fuel infrastructures' (IPCC, 2022: 2.7.2). Clearly, global decommissioning efforts cannot be limited to coal.

Throughout this *Provocations* article, we focus primarily on the US oil industry – a collection of private companies that, together, pose one of the most serious threats to achieving global climate targets. The US is the world's largest producer (and consumer) of oil, accounting for approximately 20 per cent of global production (EIA, 2022a). Yet while the *scale* of decommissioning challenges in the US may exceed that in other countries, the underlying issues of disruption, accountability, funding and incomplete knowledge exist in multiple contexts. Likewise, the containment of risk and increasingly stark global and local inequalities in exposure to environmental harms. Multinational oil corporations in Equatorial Guinea, for example, have built 'infrastructure-rich enclaves with all of the comforts of elite modern life' in another example of 'infrastructural poverty and privilege [where] corporate sponsored development abuts urban areas that are bereft of basic infrastructural capacities (Appel, 2012)' (Howe et al, 2016: 551). Delayed decommissioning projects place exposed communities at even greater risk, further deepening infrastructural inequalities.

Both within the US and elsewhere, the number of idle, abandoned and orphaned oil wells continues to grow – not only because new wells (which will eventually fall out of productivity) continue to be permitted and drilled but also because the identification of old wells is a process marred by uncertainty and opacity (Riddick et al, 2019; Joselow, 2022). This means that the costs involved in decommissioning projects will also continue to grow, raising urgent questions about responsibility, accountability and whether companies who have profited from the sale of extracted resources will be held liable for clean-up, remediation and management costs.

Drawing on recent research and data sources, we note how decommissioning also presents policy challenges that are exacerbated due to a range of gaps in regulatory and reporting systems. To take one illustrative case, as pointed out by researchers at the think tank True Transition, in the US there is no 'uniform nomenclature' or agreed definition of key decommissioning terms, no national or shared database of well locations, nor any systems for tracking or monitoring decommissioned wells (AWA, 2021). At the same time, corporate practices designed to evade liability for clean-up costs are prevalent.

California is one oil-producing state where bonding measures and regulations have been more assertive than most – and yet despite (or because of) this, corporate practices of evasion continue. For example in 2022, Aera Energy (which is a joint venture between Shell and ExxonMobil and accounts for about a quarter of California's oil and gas production) sold more than 23,000 wells across California to a German asset management group called IKAV for an estimated $4 billion (Olalde, 2022). This sale has been described as putting IKAV in charge of 'a living relic of California's early oil and gas production' (Valle, 2022a: n.). It is one of many recent sell-offs whereby ownership of ageing wells is transferred between corporations such that lines of liability and responsibility between (current) owners and (historic) operators become blurred. Despite regulatory efforts in California to hold operating companies accountable for the wells they have drilled, operated and profited from – including surety bonds and special measures to call on former operators to contribute to clean-up costs – it is not always clear who is liable nor how those operators will be held to account (Partridge et al, 2020). Different corporate practices of 'offloading' liabilities – together with complex corporate structuring, shell company registrations and efforts to exploit legal loopholes around bankruptcy – only exacerbate this problem.

The Aera Energy case is one illustration of the gap between bonds in place and actual decommissioning costs. The California Council on Science and Technology calculates that the state-wide average cost to plug an onshore orphan well is $68,000 (CCST, 2018). This figure does not include additional surface reclamation costs that may be required, nor does it capture some of the significant cost variations across the state. In densely populated areas of the Los Angeles urban oil field, for example, costs are about three times higher; meanwhile in inland regions – where most of the Aera wells are to be found – the average cost is slightly lower at $47,000 (CCST, 2018). Based on these figures, ProPublica estimates a total cost to California of $1.1 billion to clean up 23,000 wells – the bonds currently posted by Aera Energy ($3 million) cover less than half a percentage point of that figure (Olalde, 2022). Bearing in mind that this is just one section of one company's operations in one state in one country, it becomes clear that taxpayers and the public sector face a future of huge decommissioning costs.

Dominant corporations in the energy sector are global operations. Practices and techniques that are used successfully in one region – be they technological, mechanical, financial or legal – are frequently then adapted for use, or imposition, elsewhere. Anticipated costly futures around oil and gas decommissioning are further informed by prior experiences with other extractive industries. For example, scrutiny of the demise of the coal industry and the costs of coal mine clean-up in West Virginia and other states, coupled with similar practices of corporate restructuring and avoidance, mean that taxpayers in affected states could face reclamation costs totalling hundreds of millions, or even billions, of dollars (Olalde, 2020). As tracked by energy scholar Emily Grubert, what has become an all-too-familiar pattern among US coal companies of bankruptcies, asset sell-offs and strategies for evading environmental liabilities is now also common in the oil industry – with the effect of creating even more extensive environmental damage and risk (Grubert, 2020). The pattern in the coal industry is not only now familiar, it is also widespread: 'Almost half of all the coal produced in the United States is mined by companies that have recently gone bankrupt' (Macey and Salovaara, 2019: 879). In the oil and gas sectors, bankruptcies in the US and Canada rose 50 per cent in 2019 alone (Groom, 2020).

Taken together, these dynamics characterise what Grubert refers to as the 'mid transition' phase of the energy transition process: when the inevitable decline of the fossil fuel industries is evident to everyone, including fossil fuel companies themselves and, in response, they find ways to shirk responsibilities by minimising their costs and liabilities. Since even rapid decarbonisation will probably take decades, this medium-term future of the 'mid-transition' will likely see the 'conventional, fossil-based energy system' coexist with a 'new, zero-carbon energy system', requiring 'explicit and coordinated plans not only for zero carbon phase-in, but for fossil carbon phase-out' (Grubert and Hastings-Simon, 2022: 1). The 'mid transition' concept evidently relies upon a linear understanding of transition and social change and also assumes that actual transformative (rather than merely additive) energy transitions are possible (if not already taking place). These are positions that we seek to unsettle. As noted earlier (and throughout), we argue that the growing challenge of decommissioning disrupts such linear assumptions and demands that we pay attention to how histories of extraction shape energy transitions. These histories are just as important, if not more, than the setting of targets for emissions reductions, renewables build-out and fossil fuel phase-out. Nonetheless, the 'mid transition' concept remains particularly valuable for the ways in which it exposes corporate misdirection and malpractice throughout changes to global energy systems.

Grubert highlights how Exxon have been deploying evasion tactics within the global oil industry (Grubert and Hastings-Simon, 2022). In addition to their role in the massive sale of wells in California to IKAV, already mentioned, the company recently engaged in wide ranging sell-offs across a number of sites. In 2022 alone, Exxon also sold: assets in the Barnett shale in Texas and in the Montney shale, Duvernay shale and elsewhere in Alberta, Canada (Khan, 2022); pipelines, processing properties and assets in Arkansas, including around 4,100 wells not currently in operation (Valle, 2022b); and all operations in Chad and Cameroon, while also preparing to cease operations in Equatorial Guinea and to sell $1.28 billion of shares in their Nigerian unit (Valle, 2022c). In California, also in late 2022, ExxonMobil announced the sale of wells, pipelines, processing facilities and offshore oil platforms that make up its Santa Ynez Unit, where production has been halted since the 2015 Refugio oil pipeline blowout. This deal is striking (not least because it also involves up to a $2 billion loss for the company): assets will be sold to a newly formed merger called Sable Offshore Corporation, in which ExxonMobil holds a 50 per cent share, for a purchase price of $643 million – most of it ($623 million) financed by a loan from ExxonMobil (Magnoli, 2022). Meanwhile the deal contains a 'reassignment option' which will see ownership revert to ExxonMobil, without cost, if oil production is not successfully restarted by 1 January 2026 (Magnoli, 2022). The 'mid-transition' era is both volatile and opaque.

Corporate accountability is also an issue for the vital work of monitoring and enforcement. Analysts behind the proposed US Abandoned Well Administration and the related Abandoned Well Act – which would work with federal, state, local and tribal governments to manage an expanding decommissioning programme – emphasise both how central clean-up operations are to energy transitions and how decommissioning involves long-term processes rather than time-bounded events (AWA, 2021). Cement is typically used to plug abandoned wells. However, plugging measures can be expected to fail or become ineffective over time due to the deterioration of well casings and cement, with well integrity failure often occurring within a decade of well decommissioning (Bishop, 2013; Boothroyd et al, 2016). Studies repeatedly underline the importance of ongoing monitoring processes for leak detection and enforcement of repair regulations, especially as leaks from idle and abandoned wells can be a source of methane, polluted water, hydrogen sulphide and other hazardous chemicals (Townsend-Small and Hoschouer, 2021). For decommissioning to be effective, then, further processes are required to ensure that wells are subsequently inspected and repaired when needed (Boothroyd et al, 2016: 462). Decommissioning is a challenge that requires long-term and strategic responses in order to support any form of meaningful (energy) transition, especially with regard to corporate accountability.

Funding models: initial steps and unanticipated impacts

The opacity of the mid-transition era refers to complex and evasive corporate practices as well as to ambiguity regarding the scale of the challenge. Federal funds for fossil fuel decommissioning projects in the US are now available as part of the Biden Administration's $1 trillion infrastructure plan, which includes $11.3 billion earmarked for the abandoned mine lands programme over the next 15 years (Raby, 2022). In February 2022, the US Department of the Interior (DOI) announced that this funding would include nearly $725 million for the fiscal year, available to 22 states and the Navajo Nation for reclamation and clean-up of abandoned coal mines and sites (Raby, 2022). While accessing and administering these funds demand particular forms of community engagement with discriminatory legal and regulatory systems – and reclamation plans deepen colonial impositions regarding land-use change and political sovereignty thus undermining the touted justice objectives (Curley, 2023) – the same plan includes $1.15 billion from the DOI for capping abandoned oil and gas wells across the country, which Interior Secretary Deb Haaland described as a way to 'confront the legacy pollution and long-standing environmental injustices that for too long have plagued underrepresented communities' (Costley, 2022). That funding comes directly from the bipartisan infrastructure bill that includes $4.7 billion to create a federal programme for addressing orphaned wells across the US (DOI, 2022a). Although these are significant sums of money earmarked specifically for decommissioning work, the number of documented and undocumented wells in need of attention are so significant that these spending figures appear to shrink in size and effectiveness.

Official figures vary across sources, but a widely cited 2022 report from the US Environmental Protection Agency (EPA) states that: 'The US population of abandoned oil and gas wells (including orphaned wells and other non-producing wells) is around 3.7 million' (EPA, 2022: 3/108). Taking these figures at face value – $4.7 billion for plugging 3.7 million abandoned wells across the country – results in a total of just $1,271 per well. This is clearly nowhere near the actual anticipated costs which, as noted, currently average $47,000 per well in California. The national average will of course vary further in light of factors like well depth, the quality of well records and how long the well has been out of operation (HWS, 2020). Nevertheless, one West Virginia company specialising in well plugging reported that most of their decommissioning operations cost $40,000 to $60,000 per well (HWS, 2020). Federal funds therefore appear to make only a minor contribution to the anticipated total costs for well decommissioning across the US; that said, a primary effect of this funding appears to be kick-starting efforts to identify wells in need of proper plugging.

The scale of these funding initiatives in the US is not only unprecedented, it has also led to perhaps unanticipated exposure of the scale of the challenge. The availability of federal funds for decommissioning has led many state governments to suddenly 'find' (or register for the first time) large numbers of abandoned and orphaned wells which were previously not reported in official records. This shift is revealing; it suggests that there are cases where the scale of the decommissioning challenge has, for decades, been denied, ignored or obscured. Only when federal funding is on the table are attempts made to reverse some of those trends.

Researchers at the Environmental Defense Fund and McGill University have been mapping abandoned and orphaned wells in the US and tracking them over time. One of their key findings, in addition to the environmental impacts of these wells, has been that many states reported greater numbers of orphaned wells in 2022, after federal funding was released, than in 2021 (Peltz et al, 2022). For instance, Ohio reported just 891 orphaned wells in 2021 compared with 20,439 in 2022; Pennsylvania reported 8,840 in 2021 compared with 18,471 in 2022 (Joselow, 2022). The term 'orphaned wells' refers to wells whose owners have gone bankrupt, have vanished or were never properly recorded, with the effect that these wells remain unsealed, creating environmental harm, and that no company is officially registered as responsible for clean-up costs (Menon, 2022). Orphaned wells vary enormously in their relative state of disrepair or damage. Many are known to leak toxic substances such as arsenic, formaldehyde or benzene, creating both air pollution and water contamination and, through methane leaks, exacerbating climate change (Joselow, 2022). Addressing these environmental harms, in the absence of funding supplied by responsible or solvent companies, places the financial burden onto states and taxpayers. As a result, progress towards proper plugging has been slow: for example in West Virginia, of more than 6,300 documented orphaned wells, just three were plugged from 2018 to 2020 (Menon, 2022: n). Amid such conditions of uncertainty and opacity, establishing the scale of the problem is itself a challenge – further complicated by knowledge gaps and a lack of clarity across available data sources.

Knowledge gaps and the growing challenge of finding wells

The case of the oil and gas wells in the US is illustrative because it exposes neglect (on the part of both industry operators and regulatory actors) towards directly tackling the 'post-productive' hazards posed by these wells. Even when some states have made extensive extractive industry records available publicly, the depth, accuracy and reliability of those data is not consistent, thus making the challenge of designing decommissioning strategies more difficult still. Under-reporting and inconsistencies in regulatory enforcement, both between and within states, have created unreliable records that now make the national situation difficult to determine with any degree of clarity or precision. For example, the DOI has cited the EPA report mentioned earlier, clarifying that the figure of 3.7 million abandoned wells nationwide includes plugged [~39 per cent], orphaned and inactive wells – and yet that same DOI report cites multiple sources that cast doubt on these figures, noting that some states are 'likely underestimating well counts by a factor of ten' (DOI, 2022b: 13). Reporting, record-keeping and regulatory oversight all remain critical factors in determining the scale of the decommission challenge. While the examples mentioned next draw on cases from the US, similar challenges emerge in all of the world's extractive economies and take shape according to each specific political, geographical and economic context.

As Kang et al (2016) note, Pennsylvania has the longest history of commercial oil extraction in what is now the US, with early wells dating back to the mid-1800s. Addressing contemporary issues of methane emissions from abandoned oil and gas wells, that same research team update official 2015 figures from the state Department of Environmental Protection: those records show only 31,676 abandoned oil and gas wells across the state, yet the authors calculate that a more accurate figure would be between 470,000 up to 750,000 (Kang et al, 2016: 13636–7). This discrepancy is explained in part by changing regulations and reporting requirements over time, with legacy wells presenting particular problems: 'Pennsylvania only began permitting new oil and gas wells in 1957; retroactive registration of older, previously undocumented wells was not required until the 1980s. As a result, the record of wells drilled prior to 1957 is known to be incomplete' (Dilmore et al, 2015: 12017). Kang et al also note that official state figures are largely based on 'either incomplete databases or qualitative expert opinion' and so their team instead base calculations on synthesised data from multiple institutional databases, analysis of historical documents, field investigations and the inclusion of 'additional wells drilled for enhanced recovery purposes' (Kang et al, 2016: 13637). These specific findings reflect a general challenge for current decommissioning efforts, including in places with relatively shorter histories of oil (and gas) extraction: incomplete records and an unreliable knowledge base undermine efforts both to locate wells and to prioritise those that present more serious environmental threats.

Similarly unreliable records exist in other states. While what is today the state of West Virginia is known as a major producer of coal, second only to Wyoming (EIA, 2022b), it has also had significant gas and oil production. The West Virginia State Department of Environmental Protection had records in 2016 for 11,000 unplugged and 58,000 plugged abandoned gas and oil wells, but more recent estimates – based on a comprehensive review of records and new calculations for historical drilling activity – put the number of abandoned wells somewhere between 60,000 and a staggering 760,000 wells (Riddick et al, 2019: 1850/5). Archival work here is supremely important. A more thorough review of historical documents beyond departmental records – including, for example, historical maps and written accounts of extractive industry operations – suggests the number of wells in need of decommissioning is far higher than has yet been counted. Intensive drilling practices at multiple sites across the state have not been accounted for: 'early 20th century USGS maps of other oil mining towns in [West Virginia] … show many more sites of former oil and gas wells than there are plugged wells' (Riddick et al, 2019: 1855). Extractive histories thus influence and constrain the possibility of realising energy transitions in different places. Furthermore, these examples of opacity and knowledge gaps across the energy sector show how even establishing starting points from which to build future-focused transition plans presents its own challenges. Effective practices for decommissioning planning, implementation, enforcement and monitoring are vital for beginning and enabling meaningful transitions.

Conclusion

The goals and methods of different transitions are tied to the social, economic, political and geographical dynamics of diverse global contexts. Here, through a critical focus on the challenge(s) of fossil fuel decommissioning, we have argued that understanding and analysing specific historical dynamics – particularly the impacts of histories of extraction – are also vital for understanding how diverse transitions are designed, imagined, enacted and delivered. Without genuine (and enforced) corporate accountability, the ongoing (and often worsening) toxic legacies of prior extraction will continue to undermine the conditions of possibility for building meaningful transitions. Corporate practices of evasion and misdirection further undermine these efforts. With regard to funding, we have highlighted both how limited global access to such resources remains and how, even when such funds are made available, accessing them often involves multiple forms of compromise for marginalised communities expected to engage with highly discriminatory legal, judicial and political systems.

Histories of extraction, exploitation and inequality are thus replicated and perpetuated within many transition/decommissioning projects. With regard to knowledge and data, we have highlighted how difficult it is to accurately establish baseline standards and starting points for transition projects when so much information about energy systems – particularly their presence and ongoing environmental impacts – remains opaque, partial and incomplete, including in global contexts where such sources of information are nominally maintained and made available.

Thus many questions remain. The vast problem of fossil fuel decommissioning only continues to grow. As we have seen, planning and protective measures (including bonding requirements and regulations) have yet to catch up, which means we should anticipate more climate and environmental damage to result from disused wells: 'infrastructures, paradoxically, both mitigate and magnify precarity … [and] the more these infrastructures are taken for granted, the more difficult it is to prepare for and anticipate their failure' (Howe et al, 2016: 555–6). Recent estimates in the US locate 14 million people as living within one mile of an orphaned well, a figure that includes 1.3 million adults with asthma (Joselow, 2022). Also in the US, approximately three out of every five oil and gas wells that have ever been drilled are currently inactive and barely half of these have been plugged (Kang et al, 2021). Add to this approximately 2.6 million miles of fossil fuel pipelines that will, eventually, no longer be in use (Calma, 2020). And, as already noted, no one knows how many oil and gas wells there are around the world – so establishing the global scale of decommissioning challenges remains a daunting task. Climate activists rightly call for an immediate end to investment in, subsidising of and construction of fossil fuel infrastructures. But long-term plans for this transition are also required. Abandoned infrastructures do not simply come to a stop, they continue to have a toxic presence in landscapes and communities – an afterlife of destruction that continues long after the end of their apparent and inequitably distributed economic utility.

Without responsible fossil fuel decommissioning there is no 'just transition' nor even, in practice, a transition of any kind. Since the Industrial Revolution began, societies have always consumed more of everything: more wood, coal, oil or gas, even as one source displaced another for supremacy (Jones, 2014; Malm, 2016). Large-scale, intentional fossil fuel decommissioning is thus a vast geographic and temporal problem, and also unprecedented. Although the timelines, priorities and implementation of decommissioning vary significantly across global contexts – particularly as many countries continue to expand their fossil fuel operations – some of this work has already begun. Never before have industrialists or governments invested in closure on a large scale. Unlike building and permitting, there is no regulatory playbook for fossil fuel decommissioning, presenting both challenge and opportunity. What can decommissioning learn from 50 years of environmental policy? How can transitions thinking accommodate toxic presents into the future? What must we do today to ensure accountability immediately and in a generation's time? Clearly, information, mapping and data must be collected and shared; but what else? Temporal thinking about transitions has to shift focus away from a strictly future-oriented set of ideas and initiatives to include the past and present. An effective and just energy transition cannot assume a 'moving on' from fossil fuels but must instead confront the troubling dynamics that have brought us to the current moment (Escobar, 2015). Imagining alternative futures is valuable to such efforts, but reckoning with extractive histories and confronting fossil fuel decommissioning is essential.

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Conflict of interest

The authors declare that there is no conflict of interest.

References

Allan, J., Lemaadel, M. and Lakhal, H. (2022) Oppressive energopolitics in Africa's last colony: energy, subjectivities, and resistance, *Antipode*, 54(1): 44–63. doi: 10.1111/anti.12765

Appel, H.C. (2012) Walls and white elephants: oil extraction, responsibility, and infrastructural violence in Equatorial Guinea, *Ethnography*, 13(4): 439–65. doi: 10.1177/1466138111435741

AWA (Abandoned Well Administration) (2021) The Abandoned Well Act, True Transition, https://www.truetransition.org/_files/ugd/0ad80c_1c0e9182c8ae4b01b078a0ec96744733.pdf.

Berlant, L. (2016) The commons: infrastructures for troubling times, *Environment and Planning D: Society and Space*, 34(3): 393–419. doi: 10.1177/0263775816645989

Bishop, R.E. (2013) Historical analysis of oil and gas well plugging in New York: is the regulatory system working?, *New Solutions: A Journal of Environmental and Occupational Health Policy*, 23(1): 103–16. doi: 10.2190/NS.23.1.g

Blair, J.J.A., Balcázar, R.M., Barandiarán, J. and Maxwell, A. (2022) *Exhausted: How We Can Stop Lithium Mining from Depleting Water Resources, Draining Wetlands, and Harming Communities in South America, R: 21-10-A*, New York: Natural Resources Defense Council.

Boothroyd, I.M., Almond, S., Qassim, S.M., Worrall, F. and Davies, R.J. (2016) Fugitive emissions of methane from abandoned, decommissioned oil and gas wells, *Science of The Total Environment*, 547: 461–9. doi: 10.1016/j.scitotenv.2015.12.096

Bouzarovski, S. (2022) Just transitions: a political ecology critique, *Antipode*, 54(4): 1003–20. doi: 10.1111/anti.12823

Boyle, E. (2023) Rethinking energy studies: equity, energy and Ivan Illich (1926–2002), *Energy Research & Social Science*, 95: art 102903, doi: 10.1016/j.erss.2022.102903.

Burke, M.J. (2020) Energy-sufficiency for a just transition: a systematic review, *Energies*, 13(10): art 2444, doi: 10.3390/en13102444.

Calma, J. (2020) Even if oil and gas disappear, pipelines are here to stay, The Verge, 6 August, https://www.theverge.com/21356423/oil-gas-pipelines-abandoned-enbridge-line-3.

CCST (California Council on Science and Technology) (2018) *Orphan Wells in California: An Initial Assessment of the State's Potential Liabilities to Plug and Decommission Orphan Oil and Gas Wells*, Sacramento: CCST.

Codexverde (2023) Informe internacional advierte que retiro de centrales a carbón debe avanzar casi cinco veces más rápido para cumplir objetivos climáticos, Codexverde, 10 April, https://codexverde.cl/informe-internacional-advierte-que-retiro-de-centrales-a-carbon-debe-avanzar-casi-cinco-veces-mas-rapido-para-cumplir-objetivos-climaticos/.

Costley, D. (2022) Interior department approves $1B to clean up abandoned wells, *AP News*, 1 February, https://apnews.com/article/science-business-environment-pollution-water-pollution-cc3ec8bdaf84f57077fe115595793f4f.

Curley, A. (2023) *Carbon Sovereignty: Coal, Development, and Energy Transition in the Navajo Nation*, Tucson: University of Arizona Press.

Dilmore, R.M., Sams, J.I. III, Glosser, D., Carter, K.M. and Bain, D.J. (2015) Spatial and temporal characteristics of historical oil and gas wells in Pennsylvania: implications for new shale gas resources, *Environmental Science & Technology*, 49(20): 12015–23. doi: 10.1021/acs.est.5b00820

DOI (Department of the Interior) (2022a) *Biden-Harris Administration releases final guidance on new orphaned well program, press release, 12 April*, Washington, DC: DOI.

DOI (Department of the Interior) (2022b) *Assessing Methane Emissions from Orphaned Wells to Meet Reporting Requirements of the 2021 Infrastructure Investment and Jobs Act (BIL): Federal Program Guidelines*, 11 April, Washington, DC: DOI, https://www.doi.gov/sites/doi.gov/files/federal-orphaned-wells-methane-measurement-guidelines-final-for-posting-v2.pdf.

EIA (Energy Information Administration) (2022a) Total oil (petroleum and other liquids) production, as of December 8, international energy statistics, U.S. Energy Information Administration, https://www.eia.gov/tools/faqs/faq.php?id=709&t=6.

EIA (Energy Information Administration) (2022b) *Annual Coal Report 2021*, Washington, DC: EIA.

EPA (Environmental Protection Agency) (2022) *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2020*, Washington, DC: EPA, https://www.epa.gov/system/files/documents/2022-04/us-ghg-inventory-2022-main-text.pdf.

Escobar, A. (2015) Degrowth, postdevelopment, and transitions: a preliminary conversation, *Sustainability Science*, 10(3): 451–62. doi: 10.1007/s11625-015-0297-5

GEM (Global Energy Monitor), CREA, E3G, Reclaim Finance, Sierra Club, SFOC, Kiko Network, CAN Europe, Bangladesh Groups, ACJCE and Chile Sustentable (2023) *Boom and Bust Coal 2023: Tracking the Global Coal Plant Pipeline*, April, Covina, CA: GEM, https://globalenergymonitor.org/report/boom-and-bust-coal-2023/.

Groom, N. (2020) Special report: millions of abandoned oil wells are leaking methane, a climate menace, Reuters, 16 June, https://www.reuters.com/news/picture/special-report-millions-of-abandoned-oil-idUSKBN23N1NL.

Grubert, E. (2020) Fossil electricity retirement deadlines for a just transition, *Science*, 370(6521): 1171–3. doi: 10.1126/science.abe0375

Grubert, E. and Hastings-Simon, S. (2022) Designing the mid-transition: a review of medium-term challenges for coordinated decarbonization in the United States, *WIREs Climate Change*, 13(3): art e768, doi: 10.1002/wcc.768.

Gudynas, E. (2013) Transitions to post-extractivism: directions, options, areas of action, in M. Lang and D. Mokrani (eds) *Beyond Development: Alternative Visions from Latin America*, Quito: Transnational Institute, pp 165–88.

Hamouchene, H. (2019) *Extractivism and Resistance in North Africa*, Amsterdam: Transnational Institute.

Healy, N., Stephens, J.C. and Malin, S.A. (2019) Embodied energy injustices: unveiling and politicizing the transboundary harms of fossil fuel extractivism and fossil fuel supply chains, *Energy Research & Social Science*, 48: 219–34.

Howe, C., Lockrem, J., Appel, H., Hackett, E., Boyer, D., Hall, R., Schneider-Mayerson, M., Pope, A., Gupta, A., Rodwell, E. et al. (2016) Paradoxical infrastructures: ruins, retrofit, and risk, *Science, Technology, & Human Values*, 41(3): 547–65.

HWS (Hydrocarbon Well Services) (2020) How much does it cost to plug an oil and gas well?, Hydrocarbon Well Services, https://hydrocarbonwell.com/how-much-does-it-cost-to-plug-an-oil-and-gas-well/.

IPCC (Intergovernmental Panel on Climate Change) (2022) *Climate Change 2022: Mitigation of Climate Change (Working Group III Contribution to the WGIII Sixth Assessment Report of the Intergovernmental Panel on Climate Change)*, Geneva: IPCC, https://www.ipcc.ch/report/sixth-assessment-report-working-group-3/.

Jones, C.F. (2014) *Routes of Power: Energy and Modern America*, Cambridge, MA: Harvard University Press.

Joselow, M. (2022) With money on the table, states identify 120,000 leak-prone oil wells, *Washington Post*, 2 December, https://www.washingtonpost.com/politics/2022/12/02/us-has-more-than-120000-abandoned-oil-wells-research-shows/.

Kang, M., Brandt, A.R., Zheng, Z., Boutot, J., Yung, C., Peltz, A.S. and Jackson, R.B. (2021) Orphaned oil and gas well stimulus: maximizing economic and environmental benefits, *Elementa: Science of the Anthropocene*, 9(1): art 00161, doi: 10.1525/elementa.2020.20.00161.

Kang, M., Christian, S., Celia, M.A., Mauzerall, D.L., Bill, M., Miller, A.R., Chen, Y., Conrad, M.E., Darrah, T.H. and Jackson, R.B. (2016) Identification and characterization of high methane-emitting abandoned oil and gas wells, *Proceedings of the National Academy of Sciences*, 113(48): 13636–41. doi: 10.1073/pnas.1605913113

Khan, S. (2022) Exxon, Imperial to sell Canada shale assets to Whitecap for $1.5 billion, Reuters, 28 June, https://www.reuters.com/markets/us/exxon-imperial-sell-canada-assets-whitecap-15-billion-2022-06-28/.

López-Castellano, F., Lizárraga, C. and Manzanera-Ruiz, R. (eds) (2022) *Neoliberalism and Unequal Development: Alternatives and Transitions in Europe, Latin America and Sub-Saharan Africa*, Abingdon: Routledge.

Macey, J. and Salovaara, J. (2019) Bankruptcy as bailout: coal company insolvency and the erosion of federal law, *Stanford Law Review*, 71: 879–962.

Magnoli, G. (2022) ExxonMobil selling Santa Ynez unit offshore oil platforms, Las Flores Canyon processing facility, Noozhawk, 16 November, https://www.noozhawk.com/exxonmobil_selling_santa_ynez_unit_offshore_oil_platforms_processing/.

Malm, A. (2016) *Fossil Capital: The Rise of Steam Power and the Roots of Global Warming*, London: Verso.

Menon, S. (2022) Finally, a plan – and money – to stop pollution from tens of thousands of abandoned oil and gas wells, Environmental Defense Fund, 21 March, https://www.edf.org/article/orphan-wells.

Olalde, M. (2020) Exposed: West Virginia and other states relying on 'House of Cards' to pay for coal mine cleanup, DeSmog, 25 June, https://www.desmog.com/2020/06/25/coal-surety-bond-pools-liabilities-mine-cleanup/.

Olalde, M. (2022) Big oil companies are selling their wells. Some worry taxpayers will pay to clean them up, ProPublica, 27 October, https://www.propublica.org/article/california-oil-wells-shell-exxonmobil.

Partridge, T. (2020) 'Power farmers' in north India and new energy producers around the world: three critical fields for multiscalar research, *Energy Research & Social Science*, 69: art 101575, doi: 10.1016/j.erss.2020.101575.

Partridge, T. (2022) *Energy and Environmental Justice: Movements, Solidarities, and Critical Connections*, Cham: Palgrave Macmillan.

Partridge, T., Barandiaran, J., Walsh, C., Bakardzhieva, K., Bronstein, L. and Hernandez, M. (2020) California oil: bridging the gaps between local decision-making and state-level climate action, *The Extractive Industries and Society*, 7(4): 1354–9. doi: 10.1016/j.exis.2020.07.020

Peltz, A., Kang, M. and Boutot, J. (2022) Plugging orphan wells across the United States, Environmental Defense Fund, https://www.edf.org/orphanwellmap.

Powell, D.E. (2018) *Landscapes of Power: Politics of Energy in the Navajo Nation*, Durham, NC: Duke University Press.

Raby, J. (2022) Biden plan to spend $725M to clean up abandoned coal mines, AP News, 7 February, https://apnews.com/article/joe-biden-business-environment-and-nature-environment-wildlife-b8f19a6ca9f84adc0b0320b40e4f394f.

Riddick, S.N., Mauzerall, D.L., Celia, M.A., Kang, M., Bressler, K., Chu, C. and Gum, C.D. (2019) Measuring methane emissions from abandoned and active oil and gas wells in West Virginia, *Science of The Total Environment*, 651(2): 1849–56. doi: 10.1016/j.scitotenv.2018.10.082

Townsend-Small, A. and Hoschouer, J. (2021) Direct measurements from shut-in and other abandoned wells in the Permian Basin of Texas indicate some wells are a major source of methane emissions and produced water, *Environmental Research Letters*, 16(5): art 054081, https://iopscience.iop.org/article/10.1088/1748-9326/abf06f. doi: 10.1088/1748-9326/abf06f

Valle, S. (2022a) Exxon, Shell sell California oil assets for $4 billion to IKAV, Reuters, 1 December, https://www.reuters.com/business/energy/exxon-shell-sell-california-oil-joint-venture-asset-manager-ikav-2022-09-01/.

Valle, S. (2022b) Exxon to sell Arkansas shale gas assets to Flywheel Energy, Reuters, 27 August, https://www.reuters.com/business/energy/exclusive-exxon-sell-arkansas-shale-gas-assets-flywheel-energy-2022-08-27/.

Valle, S. (2022c) Exxon completes sale of Chad, Cameroon operations for $407 million, Reuters, 9 December, https://www.reuters.com/business/energy/exxon-completes-sale-chad-cameroon-operations-407-million-2022-12-09/.

Wallsgrove, R.J. (2022) Restorative energy justice, *UCLA Journal of Environmental Law and Policy*, 40(2): 133–83. doi: 10.5070/L540257928

Yaka, Ö. (2019) Rethinking justice: struggles for environmental commons and the notion of socio-ecological justice, *Antipode*, 51(1): 353–72. doi: 10.1111/anti.12422