

RESEARCH ARTICLE

The UK Ministry of Defence and the transition to ‘low-carbon warfare’: A multilevel perspective on military change

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Abstract

Retaining operational effectiveness in a low-carbon world will require military innovation and change. Indeed, there has been growing acknowledgement within some defence ministries that as the world decarbonises a military energy transition is essential. In this paper, we illustrate how calls for a military energy transition have gained renewed traction within the UK Ministry of Defence (MoD) since 2018. Empirically, we draw on semi-structured interviews with 46 officials and armed forces personnel, conducted by the authors between June and October 2023. To structure our analysis, we adopt a multilevel perspective (MLP) from the field of Sustainability Transitions. Combining the MLP with insights from the literature on military innovation, we shed light on the ways proponents of ‘low-carbon warfare’ have challenged the ‘high-carbon’ sociotechnical regime that currently dominates the MoD. We also explain why more rapid and disruptive change has been stymied. By centring attention on the extent of ‘alignment’ between internal and external sources of change, our MLP makes a valuable contribution to understanding why the struggle for military change often unfolds in non-linear ways.

Keywords: climate change; energy; low-carbon warfare; military innovation; multilevel perspective; sustainability transitions

Introduction

There is growing acknowledgement within some defence ministries that as the rest of the world transitions away from oil, coal, and gas, keeping militaries tethered to fossil fuels will become increasingly untenable.¹ As NATO’s Strategic Foresight Analysis (2023) made clear, ‘adaptation of military concepts and capabilities to green energy sources and EDTs [emerging disruptive technologies] is crucial.’² This followed earlier remarks by NATO Secretary General Jens Stoltenberg:

I’m absolutely confident that in the future, the most effective, the best planes, the best ships, the best military vehicles, they will be fuelled by something different than fossil fuels. They will not emit.³

¹Duncan Depledge ‘Low-carbon warfare: Climate change, net zero and military operations’, *International Affairs*, 99:2 (2023), pp. 667–85.

²NATO, ‘Allied Command Strategic Foresight Analysis’ (2023), available at: https://www.act.nato.int/wp-content/uploads/2024/05/SFA2023_rev2.pdf, p. 10.

³NATO, ‘Remarks by NATO Secretary General Jens Stoltenberg at the high-level roundtable “Climate, Peace and Stability: Weathering Risk Through COP and Beyond” in Glasgow, UK, 2 November 2021, available at: https://www.nato.int/cps/fr/natohq/opinions_188262.htm).

These statements suggest that at least some NATO allies are beginning to anticipate and prepare for a future of ‘low-carbon warfare’.⁴ Some have gone as far as to suggest the scale of change required could amount to a ‘Revolution in Military Affairs’.⁵ And yet, amid the return of industrial-scale warfare to the edge of Europe, soaring violence in the Middle East, and tensions in the Indo-Pacific, many still find it unfathomable that NATO allies could be contemplating major changes to something as fundamental as the energy systems used by their military forces. Nevertheless, we think it is vital that scholars of security, strategy, and war take the prospect of low-carbon warfare seriously and recognise that militaries are inescapably entangled with global environmental change and the unfolding energy transition.⁶

Retaining operational effectiveness in a low-carbon world will require military innovation and change.⁷ However, despite earlier attempts to grapple with these kinds of questions, the possibility of a military energy transition in the coming decades remains stubbornly absent from major studies and handbooks on future war.⁸ Our study aims to reinvigorate discussions of this important gap.

Our interest in the prospect of a military energy transition is not about ‘climate-proofing’ militarism as others might suggest.⁹ Our view is that avoiding discussion of a military energy transition and simply demanding emissions reductions is more likely to encourage greater climate policy obstructionism from a powerful actor.¹⁰ Militaries not only have their own complex relationship with the climate crisis (as both problem and solution), but they also remain very much in demand for dealing with other kinds of existential threats, as Russia’s ongoing assault on Ukraine illustrates all too well.¹¹ While we might all share a desire to see a more peaceful world as part of a green and just transition, pragmatically, we should be alert to the likelihood that a low-carbon future is not necessarily going to be a more peaceful one.

To begin addressing the general lack of attention to the military energy transition by scholars of security, strategy, and war, we examine how proponents of ‘low-carbon warfare’ within the UK Ministry of Defence (MoD) are seeking to challenge the armed forces’ long-standing operational dependence on fossil fuels. As a leading power within NATO, which aspires ‘to set a pragmatic

⁴Depledge, ‘Low-carbon warfare’; see also Richard Milburn, ‘Carbon warriors: Enhancing NATO’s response to climate change’, *The RUSI Journal*, 168:4 (2023), pp. 30–9.

⁵Constantine Samaras, William J. Nuttall, and Morgan Bazilian, ‘Energy and the military: Convergence of security, economic, and environmental decision-making’, *Energy Strategy Reviews* (2019), available at https://www.act.nato.int/wp-content/uploads/2024/05/SFA2023_rev2.pdf; p. 100409.

⁶For a recent review, see Anselm Vogler, ‘On (in-)secure grounds: How military forces interact with global environmental change’, *Journal of Global Security Studies*, 9:1 (2024), p. ogad026.

⁷We define military change as ‘change in the goals, actual strategies, and/or structure of a military organization’ (including material and technological aspects) but exclusive of ‘changes in operational means and methods (technologies and tactics) that have no implications for organizational strategy or structure’. See Theo Farrell and Terry Terriff, ‘The sources of military change’, in Theo Farrell and Terry Terriff (eds), *The Sources of Military Change* (Boulder, CO: Lynne Rienner, 2002), pp. 3–20 [p. 5]). As these scholars go on to explain, innovation, like adaptation and emulation, are pathways for getting there.

⁸See, for example, Clive Murgatroyd, ‘Defence in a changed climate’, *The RUSI Journal*, 153:5 (2008), pp. 28–33 (p. 2833); Clive Murgatroyd, ‘Sustainability in defence acquisition’, *The RUSI Journal*, 157:2 (2012), pp. 12–16; Michael Brzoska, ‘Climate change as a driver of security policy’, in Jürgen Scheffran et al. (eds), *Climate Change, Human Security and Violent Conflict* (Heidelberg: Springer, 2012), pp. 165–84; Michael Brzoska, ‘Climate change and military planning’, *International Journal of Climate Change Strategies and Management*, 7:2 (2015), pp. 172–90; Stacy Closson, ‘The military and energy: Moving the United States beyond oil’, *Energy Policy*, 61 (2013), pp. 306–16; Daniel Fiott, ‘Reducing the environmental footprint? Competition and regulation in the greening of Europe’s defense sector’, In Jürgen Scheffran, Michael Brzoska, Hans Gunter Brauch, et al. (eds), *Organization & Environment*, 27:3 (2014), pp. 263–78.

⁹Benjamin Neimark, Oliver Belcher, Kirsti Ashworth, and Reuben Larbi, ‘Concrete impacts: Blast walls, wartime emissions, and the US occupation of Iraq’, *Antipode*, 56:3 (2024), pp. 983–1005.

¹⁰Oliver Belcher et al., ‘Hidden carbon cost of the “everywhere war”: Logistics, geopolitical ecology, and the carbon footprint of the US military’, *Transactions of the Institute of British Geographers*, 45:1 (2020), pp. 65–80; Neta Crawford, *The Pentagon, Climate Change, and War: Charting the Rise and Fall of U.S. Military Emissions* (Cambridge, MA: The MIT Press, 2022); Andrew K. Jorgenson, Brett Clark, Ryan P. Thombs et al., ‘Guns versus climate: How militarization amplifies the effect of economic growth on carbon emissions’, *American Sociological Review*, 88:3 (2023), pp. 418–53.

¹¹Vogler, ‘On (in-)secure grounds’.

but stretching bar for allies' and partners' ambition' in response to the climate crisis, we believe the UK case also has relevance for the broader alliance.¹² Empirically, we show that beginning in the late 2010s, proponents of 'low-carbon warfare' made inroads towards changing the way the MoD engages with climate change and energy issues. This accelerated the institutionalisation of novel approaches to energy in new posts and organisational structures, material investments in research programmes, technological experimentation and trials, and the discursive embedding of 'low-carbon warfare' in the organisation's strategic ambitions. All this was facilitated and supported by developments in the wider landscape within which the MoD operates. However, despite the inroads that have been made, more recent events nationally and internationally have conspired with sources of institutional inertia to resist more rapid and disruptive progress, at least for now.

Our study of the UK MoD also makes two important theoretical contributions to the study of military innovation and change. By applying a 'Multi-Level Perspective' (MLP), adopted from the field of Sustainability Transitions (ST), we shift the focus of investigation away from the military itself and instead take the sociotechnical system of defence as our unit of analysis. By analysing 'systems' rather than 'organisations', the MLP provides a framework for situating military organisations within the wider context in which they operate, without simply 'adding on' or subordinating one aspect of military change (factors internal to military organisations) to the other (external factors). In this way, we found the MLP offers a useful way to navigate what Terriff and Farrell called the 'kludge' that is likely to arise when trying to synthesise internally and externally focused explanations of military change.¹³ Second, our study demonstrates how 'temporal alignment' between internal and external events is crucial for creating 'windows of opportunity', which communities of interest can exploit to accelerate the pursuit of change. By emphasising this temporal dimension, and how it enables and restricts the pace and scale of change, our paper also advances scholarly understanding of why processes of military change often unfold in non-linear ways.

The remainder of the article unfolds as follows. In the next section, we situate our interest in low-carbon warfare in the context of the scholarly literature on the sources of military change. We then explain how the MLP we adopt from the field of ST provides us with a framework for thinking about defence as a 'sociotechnical system', and how it foregrounds the crucial importance of 'temporal' alignment between internal and external factors for helping to explain why military change occurs when it does, why it runs into friction, and how this leads to non-linear outcomes. In the section that follows, we illustrate these theoretical insights with empirical findings from our study of the UK MoD. We conclude by considering both the empirical and theoretical implications of our findings.

The sources of military change

One of the most critical questions addressed by scholarship on security, strategy, and war concerns why and how militaries change. In his seminal work on *The Sources of Military Doctrine*, Barry Posen argued that military change was primarily driven by civilian interventions arising in response to events in the international system.¹⁴ Stephen Rosen challenged this view by arguing that what matters most is whether the pursuit of change aligns with organisational interests.¹⁵ However, Rosen also pointed out that organisational interests are far from clear-cut because militaries are 'complex political communities', within which there is constant ideological struggle revolving around the search for new theories of 'victory'.¹⁶ Other studies similarly stressed the importance of

¹²UK Ministry of Defence, 'Climate Change and Sustainability: Strategic Approach' (2021), available at: {https://assets.publishing.service.gov.uk/media/605ddb8e8fa8f5047d3a851e/20210326_Climate_Change_Sust_Strategy_v1.pdf}, p. 17.

¹³Terry Terriff and Theo Farrell, 'Military change in the new millennium', in Theo Farrell and Terry Terriff (eds), *The Sources of Military Change* (Boulder, CO: Lynne Rienner, 2002), pp. 265–78 (p. 275).

¹⁴Barry Posen, *The Sources of Military Doctrine: France, Britain, and Germany between the World Wars* (Ithaca, NY: Cornell University Press, 1986).

¹⁵Stephen P. Rosen, *Winning the Next War: Innovation and the Modern Military* (Ithaca, NY: Cornell University Press, 1994).

¹⁶Rosen, *Winning the Next War*, pp. 19–20.

internal struggle, albeit with greater attention to the influence exerted by, for instance, institutional structures, the availability of organisational and financial capital, strategic culture, cognitive styles, and professional debates.¹⁷ Like Rosen, these works all returned a degree of agency back to the military. However, for scholars such as Kier and Avant, internal struggles were still influenced and shaped by civilian intervention from the outside, whether through culture or institutions, even if only indirectly.¹⁸ Unlike Posen though, their argument was that civilians do so primarily in response to domestic political struggles, rather than events in the international system.

Ultimately, what unites many critics of Posen's work is a shared understanding of the inner workings of military organisations as being more mutable than functionalist and neo-realist logics allow. For these scholars, military change always involves an internal political struggle between dominant and insurgent communities of interest, with the latter often led by visionary military thinkers. Adamsky similarly argued that 'norm entrepreneurs' or 'epistemic agents' from inside the military were the chief enablers of change.¹⁹ Organisational structure, Jensen argued, matters too, as these 'visionaries' needed safe spaces (or 'incubators') in which to operate, as well as the support of 'advocacy networks' to champion and diffuse innovative ideas across the wider community.²⁰ Jensen's broader point was that it is possible to organise militaries in ways that make them more innovative and more open to change.²¹

From our perspective, a striking feature of these studies is how they almost always locate the sources of military change in events, ideas, institutions, and cultures. Broadly speaking, they share a collective scepticism that technology might exhibit a decisive influence. Nevertheless, they do acknowledge that military change often involves some combination of both technological and organisational change. Even then, though, organisational matters are still given primacy, as political, institutional, social, and cultural factors are seen to 'interpret' or 'imbue' technology with certain meanings and understandings, which determined how it was to be taken up and converted into capabilities.

This is not to say scholars of military innovation and change are inattentive to the material world. As several studies remind us, while innovation may begin in the realm of ideas and imagination, and be fought over through political, ideological, and cultural struggle, sooner or later emerging ideas will have to confront and adapt to the realities of the environment in which 'real operational units' are being developed and must operate.²² Horowitz was also mindful of the material domain, stressing the importance of human, organisational, and financial capital, 'rather than viewing capabilities as totally fungible depending on state strategy.'²³ These works show that the need to grapple

¹⁷ Elizabeth Kier, *Imagining War: French and British Military Doctrine between the Wars* (Princeton, NJ: Princeton University Press, 1997); Dima Adamsky, *The Culture of Military Innovation: The Impact of Cultural Factors on the Revolution in Military Affairs* (Stanford, CA: Stanford University Press, 2010); Michael C. Horowitz, *The Diffusion of Military Power: Causes and Consequences for International Politics* (Princeton, NJ: Princeton University Press, 2010); Benjamin M. Jensen, *Forging the Sword: Doctrinal Change in the U.S. Army* (Stanford, CA: Stanford University Press, 2016); David Morgan-Owen, Aimee Fox, and Alex Gould, 'Sources of military change: Emulation, politics, and concept development in UK defence', *The British Journal of Politics and International Relations*, 26:3 (2024), pp. 864–85; Alex Neads, Theo Farrell, and David J. Galbreath, 'Evolving towards military innovation: AI and the Australian army', *Journal of Strategic Studies*, 47:5 (2023), pp. 1–30.

¹⁸ Kier, *Imagining War*; Deborah Avant, *Political Institutions and Military Change* (Ithaca, NY: Cornell University Press, 1994).

¹⁹ Adamsky, *The Culture of Military Innovation*.

²⁰ Jensen, *Forging the Sword*.

²¹ See also Avant, *Political Institutions and Military Change*; Williamson R. Murray, 'Innovation: Past and future', in Williamson Murray and Allan R. Millett (eds), *Military Innovation in the Interwar Period* (Cambridge: Cambridge University Press, 1996), pp. 300–28.

²² Allan R. Millett, 'Patterns of military innovation in the interwar period', in Williamson Murray and Allan R. Millett (eds), *Military Innovation in the Interwar Period* (Cambridge: Cambridge University Press, 1996), pp. 329–68 (p. 349). See also Dima Adamsky and Kjell Inge Bjerga (eds), *Contemporary Military Innovation: Between Anticipation and Adaptation* (London: Routledge, 2012).

²³ Horowitz, *The Diffusion of Military Power*, p. 9.

with different material-strategic realities is not easily ignored. Indeed, many scholars have suggested that the prospects of military change are deeply connected to whether it is being pursued in peacetime or wartime.²⁴ This is striking but also somewhat problematic given growing questioning, in the wider academic literature, of whether peace and war are so easily distinguishable, particularly if, as Mark Leonard has argued, we have entered an age of ‘unpeace.’²⁵

Yet the distinction between peacetime and wartime is not the only problematic dichotomy to emerge in the literature on military innovation and change. Indeed, as this review has alluded to, many of the key debates rest on dichotomies (and trichotomies) that draw hard divisions between internal and external worlds, between civilian and military realms, between top-down and bottom-up drivers, and between culture, technology, and institutions, with a view to isolating the independent variable that drives military innovation and change. There are important exceptions, though. Murray and Millett’s edited collection on *Military Innovation in the Interwar Period* is particularly noteworthy for being produced by historians who shied away from trying to produce generalisable theory and instead tried to embrace the ‘complexities and ambiguities inherent in innovation.’²⁶ These more historicised and holistic accounts also suggested that military innovation only produces revolutionary change in exceptional cases. More often, innovation is found to follow an evolutionary pathway, challenging the conventional wisdom that innovation is always sudden, disruptive, and ferociously fought over.²⁷

Importantly, conceptualising innovation as a process that unfolds over time rather than a sudden, disruptive event also helps scholars to clarify whether it is the process or the outcome that they are most interested in. As Horowitz and Pindyck observe, too often there has been a lack of clarity about this point.²⁸ Building on interest in innovation as process, several scholars have attempted to draw up models of change that try to capture how new visions emerge, how they are supported, how they are implemented, and how they spread across borders. As Horowitz and Pindyck argue, this kind of common framework is necessary for demonstrating variance across cases and for making non-conforming cases ‘easier to locate, compare and investigate further.’²⁹ However, as we will go on to show, we find that the models developed so far remain somewhat limited when it comes to demonstrating how the possibilities of innovation change over time because of the complex interplay between strategic, organisational, cultural, material, and political factors. Part of the problem, we suggest, is the tendency to conceptualise the military as a discrete actor, rather than treating it as part of a wider sociotechnical system of defence. Moreover, while a growing number of scholars recognise that military change rarely unfolds in a linear way, non-linearity remains poorly captured in their models. To address this, we found it useful to turn to the framework provided by the MLP that is widely used in the field of ST.

A multilevel perspective on military change: Attending to temporality

Like Military Innovation Studies (MIS), the field of ST is broadly interested in questions about how and why change occurs, albeit with a particular focus on ‘large-scale’ sociotechnical transitions, and a normative interest in addressing grand societal challenges relating to the environment.³⁰ Notably, studies of the military have been largely absent in the field of ST, although recent work

²⁴ Posen, *The Sources of Military Doctrine*; Rosen, *Winning the Next War*; Murray, ‘Innovation: Past and future’; Adamsky and Bjerga, *Contemporary Military Innovation*.

²⁵ Mark Leonard, *The Age of Unpeace: How Connectivity Causes Conflict* (London: Bantam Press, 2021).

²⁶ Williamson Murray and Allan R. Millett, ‘Introduction’, in Williamson Murray and Allan R. Millett (eds), *Military Innovation in the Interwar Period* (Cambridge: Cambridge University Press, 1996), pp. 1–5 (p. 4).

²⁷ Murray, ‘Innovation: Past and future’; Neads et al., ‘Evolving towards military innovation’.

²⁸ Michael C. Horowitz and Shira Pindyck, ‘What is military innovation and why it matters’, *Journal of Strategic Studies*, 46:1 (2023), pp. 85–114.

²⁹ *Ibid.*, p. 103.

³⁰ Jonathan Köhler, Frank W. Geels, Florian Kern et al., ‘An agenda for sustainability transitions research: State of the art and future directions’, *Environmental Innovation and Societal Transitions*, 31 (2019), pp. 1–32.

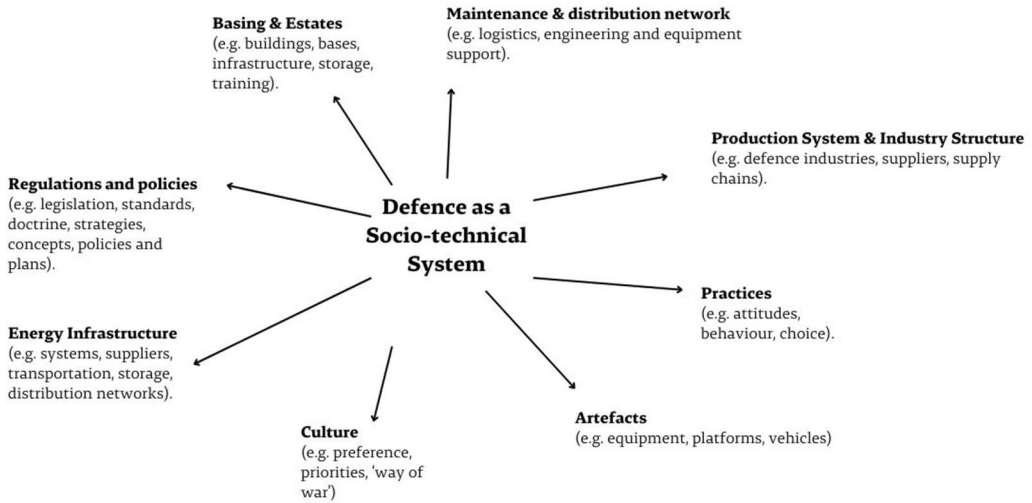


Figure 1. Defence as a 'sociotechnical system'. Modified from Geels et al., 'The socio-technical dynamics of low-carbon transitions'.

on the security dimensions of sustainability transitions, and the effects of wars on sociotechnical transitions in energy, food, and transport, has started to redress this.³¹ To escape debates about whether what happens at the 'macro' level or the 'micro' level is more important, some ST scholars prefer to focus on developments at the 'meso' level, but within an MLP. Crucially, though, what distinguishes this approach is that it is combined with a focus on 'sociotechnical systems' as the primary unit of analysis.³² At the same time, ST's MLP stresses that the temporal alignment of forces of change (or resistance) within and between different analytical levels is the most important factor determining the scale and pace of change that can occur across a system.³³

In the ST literature, sociotechnical systems refer to the assemblages that develop around the delivery of specific societal functions. ST research is mainly interested in conceptualising and explaining how changes can occur in the way these functions are fulfilled.³⁴ For our purposes, the societal function of interest is 'defence'. In the past, MIS scholars have depicted the military as the principal organisation responsible for the delivery of the defence function. However, as Figure 1 depicts, the military is only one part of the 'sociotechnical system' that actually delivers defence. Ever since navies transitioned from sail to steam, armies abandoned horses for internal combustion engines, and air forces took to the skies, this system has been configured for 'high-carbon warfare'. Abandoning this system will require more than an adjustment of policy, the development of low-carbon technology, and the procurement of new capabilities. A significant transition will only occur when multiple elements (military, civilian, industrial, infrastructural, organisational, cultural, technological, societal) across the system have been reconfigured to deliver the core function in a new way.

³¹ Phil Johnstone and Caitriona McLeish, 'World wars and sociotechnical change in energy, food and transport: A deep transitions perspective', *Technological Forecasting and Social Change*, 174 (2022), p. 121206; Paula Kivimaa and Marja H. Sivonen, 'Interplay between low-carbon energy transitions and national security: An analysis of policy integration and coherence in Estonia, Finland and Scotland', *Energy Research & Social Science*, 75 (2021), p. 102024; Paula Kivimaa, Marie Claire Brisbois, Dhanasree Jayaram et al., 'A socio-technical lens on security in sustainability transitions: Future expectations for positive and negative security', *Futures*, 141 (2022), p. 102971.

³² Köhler et al., 'An agenda for sustainability transitions research'.

³³ Frank W. Geels, Benjamin J. Sovacool, Tim Schwanen, and Steve Sorrel, 'The socio-technical dynamics of low-carbon transitions', *Joule*, 1:3 (2017), pp. 463–79.

³⁴ Köhler et al., 'An agenda for sustainability transitions research'.

But what produces a sociotechnical transition? Why do some sociotechnical systems change, while others do not? Why are some transformations sudden and disruptive, while others may take decades or more to unfold? According to ST scholars, transitions are ‘non-linear processes’ that ‘result from the interplay of developments at three analytical levels: *niches* (the locus for radical innovations), socio-technical *regimes* (the locus of established practices and associated rules that stabilize existing systems), and an exogenous socio-technical *landscape*’.³⁵ The idea of ‘niches’ is similar to Jensen’s ‘incubators’, albeit they are just as likely to emerge as informal assemblages as from dedicated organisational structures.³⁶ Regimes represent the dominant institutions, cultures, and cognitive styles within an organisation and their reinforcement by material artefacts, infrastructures, and resources. In line with the expectations of many MIS scholars, these incumbent regimes are important because they attempt to mediate the way their organisation engages with the ‘outside world’. The landscape represents this ‘outside world’, in which events (social, political, and material) occur that regimes have limited if any control over.

Thus, the MLP describes both the internal dynamics of a given sociotechnical system (i.e. how much room there is to be innovative, which actors, technologies, cultures, and institutions are involved in the struggle between the innovating niche and incumbent regime, and what organisational and material resources are being mobilised in support of one side or the other), as well as how these dynamics are entangled with what is happening in the wider sociotechnical landscape (domestically and internationally). In the ideal type, transitions come about when an emerging niche, in alignment with a wider landscape of change, destabilises and overcomes the incumbent regime and establishes a new way of operating (see Figure 2). Conversely, change is likely to be stymied when events in the wider landscape conspire with the institutional status quo to reinforce the incumbent regime. As such the possibilities of change are inherently dynamic, and this helps to explain why change sometimes occurs suddenly and disruptively, while at other times it is more evolutionary and incremental.

In capturing these dynamics, the MLP provides a framework for situating military organisations within the wider sociotechnical system that they are entangled with, without falling into the trap described by Terriff and Farrell of ‘adding on’ or subordinating one aspect of military change (e.g. internal factors) to another (e.g. external factors).³⁷ By stressing the importance of alignment between internal and external forces of change, the MLP resists the temptation to blame either external events or internal structures for successes and failures of military innovation.³⁸ In this way, the MLP also offers a way out of many of the other conceptual cul-de-sacs that have been created by military innovation scholars trying to portray processes of change in overly reductionist ways. As noted earlier, such work often relies on all kinds of problematic dichotomies (and trichotomies) that locate the sources of military change in either the internal or external environment (including whether occurring in conditions of peace or war), in technology, culture, or institutional organisation, and in civilian or military affairs, among others. By contrast, ST’s sociotechnical systems perspective makes room for the complex interaction of all these different factors and more.

Essentially then, the MLP provides a common framework that can be applied across cases to help identify what factors seem to be exerting the most influence within a given system, how these are interacting with each other, whether this is leading to stabilisation or destabilisation around a core function, and where interventions might be possible to promote greater alignment and, ultimately, support what Posen described as the end goal of military innovation: closer integration of strategic ends and military means.³⁹ The MLP is diagnostic, not prognostic. It does not predetermine which

³⁵ Frank W. Geels, ‘The multi-level perspective on sustainability transitions: Responses to seven criticisms’, *Environmental Innovation and Societal Transitions*, 1:1 (2011), pp. 24–40 (p. 26, emphasis added).

³⁶ Jensen, *Forging the Sword*.

³⁷ Terriff and Farrell, ‘Military change in the new millennium’.

³⁸ Stuart Griffin, ‘Military innovation studies: Multidisciplinary or lacking discipline?’, *Journal of Strategic Studies*, 40:1–2 (2017), pp. 196–224.

³⁹ Posen, *The Sources of Military Doctrine*.

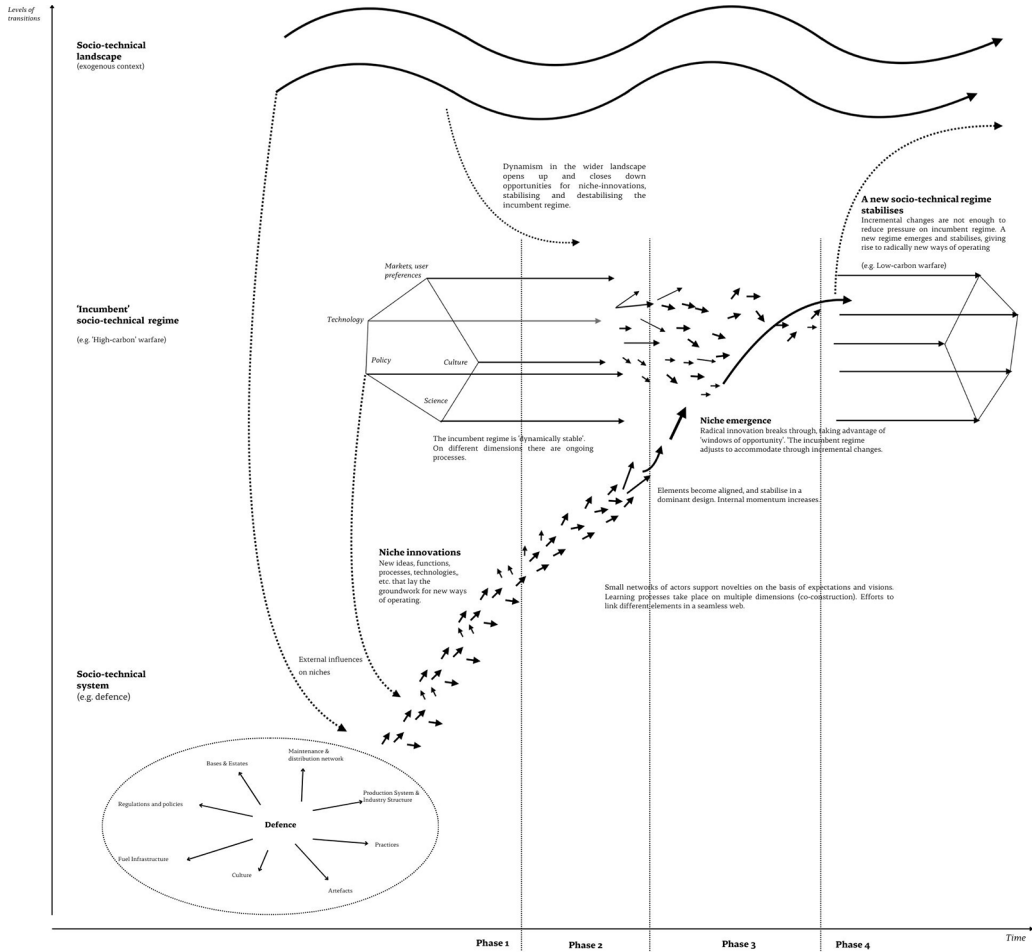


Figure 2. A multilevel perspective on ‘sociotechnical transitions system’. Modified from Geels et al., ‘The socio-technical dynamics of low-carbon transitions’.

factors and what interactions are likely to be the most important in any given case. In fact, by taking sociotechnical systems as its unit of analysis, the MLP is truly agnostic with regards to whether the civilian realm is more important than the military, the internal is more important than the external, the cultural is more important than the technological, and whether change is more likely to occur in peacetime or wartime (or even times of ‘unpeace’). In this way, the MLP provides a useful framework for also looking comparatively across cases and extrapolating broader lessons about when military change is most likely to occur. At the same time, the MLP also remains alive to the fact that processes of military change are unlikely to ever unfold the same way twice.

In the remainder of this article, we illustrate the value of the MLP as a framework for investigating the extent to which, between 2018 and 2024, internal debates within the MoD aligned with developments in the wider landscape to challenge the incumbent sociotechnical regime of ‘high-carbon’ defence. First, we explain how we approached our study. Then we demonstrate how changes in the wider landscape facilitated and supported a period of niche expansion during which proponents of change began to mount a challenge to the incumbent regime by rhetorically and materially contesting the way the sociotechnical system of defence is configured for military operations. Lastly, we reflect on the limits of what has been achieved during this period of progress and

Table 1. Interview participants

Participant affiliations	# of interviews (interviewees)
UK Ministry of Defence (MoD) – Head Office	6 (6)
UK MoD enabling organisations	13 (15)
UK frontline commands	23 (24)
Other organisations within MOD*	1 (1)

Total number of interviews (interviewees): 43 (46).

*Further details on other organisations have not been disclosed to protect the anonymity of a participant who did not want their affiliation to be published.

why, in part because of ongoing change in the wider landscape, the incumbent regime has so far been able to resist more radical transformation.

Researching the UK MoD and the military energy transition

To better understand what lies behind the MoD's recent interest in possible futures of 'low-carbon warfare', between June and October 2023, we conducted 43 semi-structured interviews with 46 MoD officials and armed forces personnel. All interviews took place on MS Teams to maximise flexibility with regards to participant participation, as well as to reduce costs and environmental impacts associated with travel. Two of the interviews had more than one participant. Our initial sampling was purposive. We used our existing networks within the MoD and armed forces to draw up an initial set of 10 interview targets who could illuminate the extent to which the prospect of a military energy transition was being taken seriously across the organisation, and why. We then asked our initial recruits to recommend further participants for our study (commonly known as 'snowballing'). Given the federated structure of the MoD, we made a concerted effort to reach as many different branches as possible (see Table 1). This enabled us to better evaluate how far the emerging niche had reached, what progress has been made to date, and what still needs to change. Since only some interviewees consented to be quoted by name, we decided to anonymise all participants.

Mindful of the diversity of opinion across the MoD, every effort was made to reach individuals who might be more resistant to the idea that a military energy transition is needed. Notably though, we generally encountered greater disagreement among MoD and armed forces personnel over the extent of progress so far than over the overall direction of travel. The willingness of MoD personnel to talk to us may also reflect what Griffin described as 'a natural tendency for military organisations to pay the most attention to the dynamics of innovation when they either perceive themselves ill-prepared for an imminent threat or ill-suited to cope with an existing one'.⁴⁰ Indeed, that so many MoD personnel, as well as many who do not work directly on 'energy' and 'sustainability' were willing to engage with us may suggest that the kinds of questions we are raising in our research have also been preoccupying our participants.⁴¹

However, we also recognise that our findings may have been skewed by self-selection and social desirability biases. This reflects a long-recognised issue with navigating access to defence communities, despite the growing openness of Western militaries to academic scrutiny.⁴² Given the demands on their time, personnel who were antipathetic to our research may have simply been less willing to engage with us. As a result, we do not claim our sample is representative of the entirety of the UK MoD. Significantly though, that there must be a diversity of opinion is reflected in our

⁴⁰ Griffin, 'Military innovation studies', p. 198.

⁴¹ Over half our interviews (25/46) did not occupy climate change and sustainability 'posts'.

⁴² Delphine Deschaux-Beaume, 'Investigating the military field: Qualitative research strategy and interviewing in defence networks', *Current Sociology*, 60:1 (2012), pp. 101–17; see also Griffin, 'Military innovation studies'.

understanding that an emerging ‘low-carbon’ niche is facing a struggle to overcome an incumbent ‘high-carbon’ regime. We are therefore confident that our empirical findings are sufficiently robust to demonstrate both the emergence of a ‘low-carbon’ niche within the UK MoD and the contours of the struggle it is facing to overcome an incumbent ‘high-carbon’ regime amid a broader landscape of change. In this way, we also affirm the utility of the MLP that we have adopted from ST for examining how military change is enacted and resisted.

To produce a detailed analysis of our dataset, we approached our interview transcripts in two ways. One author conducted a thematic qualitative analysis based on Braun and Clarke, using an inductive approach to identify explicit themes arising.⁴³ The other author used Atlas.ti’s ‘concepts’ function to auto-generate codes from the most significant noun phrases (e.g. climate change and sustainability, operational advantage, etc.) in the dataset.⁴⁴ These were then counted and clustered to create topics that could then be aligned with the themes identified by the first author.⁴⁵ By doing so, we were able to significantly speed up the process of identifying, locating, and counting references to our different themes in over 50+ hours of transcripts. We then progressed to interpreting the significance of what we had found, using our MLP to structure our analysis.

Low-carbon warfare: A niche gains momentum

In 2021, the MoD committed to reducing its dependency on fossil fuels and playing a full part in helping the rest of Government achieve its legal commitment to reach net zero greenhouse gas emissions by 2050.⁴⁶ The work that underpinned this decision had begun several years earlier, when Lieutenant General Richard Nugee was charged with preparing a report on the implications of climate change for defence. One of his key conclusions was that ‘if the right decisions were made, the MoD could reach net zero (scope 1 and 2 greenhouse gas emissions) by 2050 while making military operations more resilient, self-sufficient and efficient’.⁴⁷ Crucially though, his report also emphasised the need to act immediately, since it would be the decisions taken out to 2025 that would determine the success or otherwise of this transformation.⁴⁸

Significantly, this was not the first time that the MoD had considered the need to address its dependence on fossil fuels. Between the late 2000s and early 2010s, the UK and its NATO allies had engaged in a concerted effort to rethink their operational reliance on fossil fuels. As Depledge discussed, the experience of significant losses incurred transporting supplies to the frontline in Afghanistan and Iraq, combined with record oil prices at the time, were significant motivators.⁴⁹ Domestically, following the 2008 Climate Change Act, the UK MoD had been committed by Government to address its estate emissions. Notably, the MoD’s 2011 Sustainable Development Strategy also set an objective to reduce operational reliance on fossil fuels by 2030.⁵⁰ Nevertheless, the MoD’s initiatives soon showed signs of stalling.⁵¹ By 2015, oil prices were falling, David Cameron’s Conservative Government (2015–16) was backsliding on its ‘green’ policies, and the

⁴³ Virginia Braun and Victoria Clarke, ‘Using thematic analysis in psychology’, *Qualitative Research in Psychology*, 3:2 (2006), pp. 77–101.

⁴⁴ This tool is based on topic modelling, a technique that uses natural language processing (NLP) and machine learning and which is used widely to analyse large textual datasets. The purpose is to give the user quicker insights and a more agile understanding of the data. It also increases the robustness of the data analysis and its validity through replicability. See also Marissa D. Abram, Karen T. Mancini, and R. David Parker (2020). Methods to Integrate Natural Language Processing Into Qualitative Research. *International Journal of Qualitative Methods*, 19, available at: <https://doi.org/10.1177/1609406920984608>.

⁴⁵ Atlas.ti, ‘Find concepts and auto-code’, *Atlas.ti 22 Mac – User Manual*, available at: <https://doc.atlasti.com/ManualMac.v22/SearchAndCode/SearchAndCodeFindConcepts.html>.

⁴⁶ UK Ministry of Defence, ‘Climate Change and Sustainability: Strategic Approach’.

⁴⁷ Interview with a senior adviser to the Ministry of Defence, June 2023 [#2].

⁴⁸ Interview [#2].

⁴⁹ Depledge, ‘Low-carbon warfare’.

⁵⁰ UK Ministry of Defence, ‘Sustainable Development Strategy’ (2011), available at: <https://assets.publishing.service.gov.uk/media/5a7966d5e5274a2acd18c8a7/20110527SDStrategyPUBLISHED.pdf>.

⁵¹ Murgatroyd, ‘Sustainability in defence acquisition’.

MoD was prioritising other strategic and financial challenges. Reflecting a broader shift within NATO, concerns were also moving from expeditionary warfare back to conventional deterrence, with its implicit reliance on high-carbon capabilities.⁵²

Through the prism of the MLP, we can immediately see how the waxing and waning of the MoD's interest in 'low-carbon warfare' was entangled with events in the wider landscape. A brief window of opportunity emerged as internal and external imperatives to change aligned. However, it closed again before the incumbent regime could be destabilised. The collapse of this earlier 'niche' raises important questions for our study: why did the Nugee report have the impact that it did? How has a new niche been able to emerge, and is it destabilising the incumbent regime? In what ways does this latest struggle appear to be entangled with a wider landscape of change? Put more simply, in what ways have developments at different levels of the MLP aligned in recent years to bring about an acceleration of 'low-carbon' innovation within the MoD?

The MoD's renewed interest in possible futures of 'low-carbon warfare' since the Nugee Review was disseminated is easy to trace. Over the past six years (2018–24), the MoD has stated openly that it now regards the global transition away from fossil fuels as a threat to capability and readiness levels.⁵³ A spate of high-level papers have been published stressing the MoD's renewed ambition to markedly reduce the armed forces' operational reliance on fossil fuels.⁵⁴ This included the publication of the first Defence Operational Energy Strategy, which charts out how the MoD intends to harness the unfolding energy transition to maintain advantage over its adversaries. In 2019, then Chief of the General Staff, General Sir Mark Carleton-Smith, suggested that the current generation of military equipment would 'be possibly the last to be dependent on fossil fuel engines.'⁵⁵ In 2021, the Chief of the Air Staff, Air Chief Marshal Sir Mike Wigston, announced the Royal Air Force (RAF) was setting itself the goal of being 'net zero' by 2040.⁵⁶ That same year, the MoD established a new directorate for Climate Change and Sustainability within Head Office to act as a change agent.⁵⁷

Meanwhile, the British Army, the Royal Navy and the RAF all embarked on projects to demonstrate new ways of thinking about how operational capabilities – and not just estates – might be powered in the future. For the British Army, this included experimenting with hybrid and

⁵²Katarina Kertysova, 'Towards a greener alliance: NATO's energy efficiency and mitigation efforts', in Louise van Schaik, Pierre Laboue, Katarina Kertysova et al. (eds), 'The World Climate and Security Report 2022: Decarbonized defense – the need for clean military power in an age of climate change', *International Military Council on Climate and Security*, available at: <https://imccs.org/wp-content/uploads/2022/06/Decarbonized-Defense-World-Climate-and-Security-Report-2022-Vol.-I.pdf>. See Fiott, 'Reducing the environmental footprint?' for a parallel discussion of the limited progress made in the EU context around this period.

⁵³House of Commons Defence Committee, 'Defence and Climate Change: Eighth Report of Session 2022–23 (HC 179)', available at: <https://committees.parliament.uk/publications/41129/documents/200843/default/>.

⁵⁴UK Ministry of Defence, 'Climate Change and Sustainability Strategic Approach'; UK Ministry of Defence, 'Integrated operating concept', available at: https://assets.publishing.service.gov.uk/media/612f91b28fa8f50328e2c8f5/Integrated_Operating_Concept_2025.pdf; UK Ministry of Defence, 'Sustainable Support Strategy', available at: https://assets.publishing.service.gov.uk/media/6364e700d3bf7f388ba7dc55/Sustainable_Support_Strategy_2022.pdf; UK Ministry of Defence 'The Defence Capability Framework', available at: https://assets.publishing.service.gov.uk/media/62d7d1668fa8f50c0a8a4029/MOD_Defence_Capability_Framework_Accessible_Jul22.pdf; UK Ministry of Defence, 'Defence's response to a more contested and volatile world', available at: https://assets.publishing.service.gov.uk/media/64b55dd30ea2cb000d15e3fe/Defence_Command_Paper_2023_Defence_s_response_to_a_more_contested_and_volatile_world.pdf; UK Ministry of Defence, 'Defence Aviation Net Zero Strategy 2023', available at: https://assets.publishing.service.gov.uk/media/64abc18112104000cee6540/Defence_Aviation_Net_Zero_Strategy.pdf; UK Ministry of Defence, 'Defence Operational Energy Strategy', available at: https://assets.publishing.service.gov.uk/media/6570b223809bc300133081cc/Defence_Operational_Energy_Strategy_2023.pdf.

⁵⁵Kim Sengupta, 'British Army says it must get green to protect environment and maintain recruitment', *The Independent* (12 September 2019), available at: <https://www.independent.co.uk/climate-change/news/dsei-british-army-green-environment-climate-change-mark-carleton-smith-a9103096.html>.

⁵⁶GOV.UK 'CAS RAF NetZero ambition' (24 November 2021), available at: <https://www.gov.uk/government/speeches/cas-raf-netzero-ambition>.

⁵⁷Now the Climate Change and Environment Directorate.

fully electric light vehicles as part of a Battlefield Electrification Plan.⁵⁸ The RAF started trialling sustainable aviation fuel and light electric aircraft and committed to delivering a ‘net zero capable’ sixth-generation fighter jet.⁵⁹ Although the Royal Navy has remained uncertain about what energy sources it will be reliant on in the future, it has been exploring how a broader shift towards modularity in the design of the new Multi-Role Support and Fleet Solid Support ships could be exploited to make it easier to change how vessels are powered over the course of their service lives, especially as alternative fuels and technologies mature.⁶⁰ In addition, each of the front-line services now has a 2* senior military officer with a supporting team to champion change across their service, and each enabling organisation has also built its own climate change and sustainability team. A 3* Lieutenant General was appointed to oversee the delivery of the new Defence Operational Energy Strategy. Moreover, various parts of the MoD are also working with defence industry and allies to explore and develop ways to make military equipment that is less carbon-intensive.⁶¹

All this activity confirms the (re-)emergence of a niche within the MoD prepared to challenge the prevailing wisdom that operational effectiveness in the 21st century will continue to require the support of a high-carbon energy system. However, in contrast to earlier periods of interest in ‘low-carbon warfare’, the emerging niche has this time made notable inroads into capstone documents, including the Integrated Operating Concept (described by the Government as ‘the most significant change in UK military thought in several generations’⁶²), UK Defence Doctrine (6th edition), and the MoD’s Refreshed Command Paper, which claimed ‘contributing to achieving Net Zero and being more effective – are not mutually exclusive.’⁶³ Rhetorically at least, the MoD’s strategic ambition to move away from fossil fuels has never been higher.

Our interviews were revealing of the ways in which – in line with many of the insights we have drawn from the literature on military innovation and change, as well as the MLP that we have adopted for this study – the developments outlined involved a complex interplay of internal developments and exogenous events. Notably, most of our interviews ($n = 23$) suggested the work undertaken by the MoD between 2018 and 2021, starting with the Nugee Review, was critical for building recognition internally that climate change and the net zero energy transition were creating imperatives for change. This work reportedly proved instrumental for opening up discussion around a ‘new theory of victory’ markedly less reliant on fossil fuels, as well for developing an advocacy network inclusive of senior military officers that would encourage others from across the MoD to be part of the emerging niche. Meanwhile, the commitment to explore the potential and possibilities of ‘low-carbon warfare’ was institutionalised and embodied by the creation of new posts and organisational structures, materialised through investments in research programmes, technological experimentation, and trials, and discursively embedded in the organisation’s strategic ambitions.

⁵⁸ Alistair Beard and Sarah Ashbridge, ‘Greening defence: The British Army’s bet on electrification’, *Royal United Services Institute* (23 March 2022), available at {<https://rusi.org/explore-our-research/publications/commentary/greening-defence-british-armys-bet-electrification>}.

⁵⁹ Alistair Beard and Sarah Ashbridge, ‘Greening defence: RAF ambitions in search of jet zero’, *Royal United Services Institute* (28 June 2022), available at: {<https://rusi.org/explore-our-research/publications/commentary/greening-defence-raf-ambitions-search-jet-zero>}; UK Ministry of Defence, ‘FCAS sustainability strategy’, available at: {<https://www.raf.mod.uk/what-we-do/team-tempest/documents/strategy-brochure/>}.

⁶⁰ Sarah Ashbridge and Alistair Beard, ‘Greening defence: Transforming the Royal Navy for a climate-affected world’ (30 May 2022), available at: {<https://rusi.org/explore-our-research/publications/commentary/greening-defence-transforming-royal-navy-climate-affected-world>}.

⁶¹ House of Commons Defence Committee, ‘Oral evidence: Defence and climate change’ (21 March 2023), available at: {<https://committees.parliament.uk/oralevidence/12870/pdf/>}.

⁶² GOV.UK, ‘Integrated Operating Concept’ (26 October 2022), available at: {<https://www.gov.uk/government/publications/the-integrated-operating-concept-2025>}.

⁶³ UK Ministry of Defence ‘Integrated Operating Concept’; UK Ministry of Defence ‘Joint publication 0–01 UK Defence Doctrine’ (6th edition, 2022); UK Ministry of Defence ‘Defence’s response’, p. 35.

However, our interviewees also made clear that these developments were closely entangled with a wider landscape of change, which was posing questions that exposed the limitations of the incumbent ‘high-carbon’ regime. This in turn was creating demand for a ‘new theory of victory’. One important shift identified in many of our interviews ($n = 12$) was that international and domestic emissions targets had been tightened, especially since the signing of the Paris Agreement in 2015 which committed all 196 signatories to pursue efforts to limit average global temperature rise this century to 1.5°C. In 2019, the UK became the first country to sign a net zero by 2050 target into law. This increasingly stringent legislative context reportedly increased the pressure on the MoD to raise its own level of ambition. Although the resulting emission targets for the MoD were most clearly defined in relation to the defence estate and white vehicle fleet, there was recognition among our interviewees that the department would still need to do everything it could to reduce military emissions as well.

Moreover, it was stressed in many of our interviews ($n = 16$) that UK legislation was not the only driver of concern – even without emissions targets, the armed forces would not necessarily be exempt from having to adapt as the global energy transition unfolds, especially if more stringent legislation was brought in elsewhere in the world. In several of our interviews ($n = 10$), participants also questioned whether just because the MoD’s operational emissions had so far remained largely exempt from reporting requirements, binding reduction targets, carbon budgets, etc., that they would remain so in the future (except in the most extreme cases).

A second landscape shift identified in almost half of our interviewees was that the MoD also had to contend with growing societal concerns about the climate crisis. Many of our interviews ($n = 20$) noted that during the late 2010s and early 2020s, there had been a notable change in the political and societal ‘zeitgeist’, both in the UK and elsewhere, which had led to greater public support for action to address the climate crisis. Even without tougher legislation on military emissions, most of these interviews ($n = 18$) suggested that this awareness was translating into a growing sense of public pressure on the MoD to change. In several of our interviews, participants thought this was already having a bearing on recruitment ($n = 9$). Looking to the future, many of our interviews ($n = 12$) anticipated that society’s willingness (nationally and internationally) to absorb the economic, environmental, and moral costs associated with maintaining a ‘high-carbon’ sociotechnical system of defence based on fossil fuels would continue to be tested as the climate crisis intensified, and that this could eventually erode the MoD’s societal licence to operate (at least in some scenarios) as well as its ability to recruit the best talent. As one interviewee remarked, ‘as the sad realities of climate change start to impact our personal lives, the imperatives to act will grow very, very quickly.’⁶⁴ Or as another warned, ‘you can’t be a horrendous carbon offender as an organisation and blame everyone else when you’re trying to deal with the security consequences of climate change.’⁶⁵

A third landscape factor identified in our interviews was that even if emissions from military operations remained exempt in legislation, defence’s industrial base, the infrastructure that it relies on, and wider society would not be. Indeed, in many of our interviews, participants took the view that, irrespective of any nationally binding operational emissions targets, the MoD was still going to face an increasingly costly, complex, and constrained operating environment as the legal ($n = 18$), financial ($n = 14$), and societal costs ($n = 12$) of ignoring the need for a military energy transition were only likely to grow. This would seriously impact on the armed forces’ freedom of operations. Without changes, participants in some of our interviews ($n = 6$) also stressed that opportunities to exploit opportunities for technological and operational innovation could be missed, further compounding the cost of remaining tethered to fossil fuels. As one interviewee put it:

We’re currently seeing the global energy and aviation transitions happening around the world, and the UK military is incredibly dependent on its interoperability with global energy and

⁶⁴Interview with a senior military officer in the Ministry of Defence, June 2023 [#3].

⁶⁵Interview with retired British Army officer, June 2023 [#5].

global airport infrastructure. If we don't change with that, we would actually see ourselves constrained in terms of the places we could fly in and out of, which then reduces our operational freedom.⁶⁶

Although the landscape shifts discussed by our interviewees have only really become evident over the past 5–10 years, the broader expectation was that if the MoD did not respond now, these trends would intensify and become more costly to navigate in the future. Chiming with Adamsky and Bjerga's work, our findings suggest that anticipation of future change, in a landscape that it has little capacity to influence, is a powerful motivation for the MoD to acknowledge and explore the opportunities of 'low-carbon warfare' as an alternative 'theory of victory' for operating in a climate-changed world.⁶⁷ Because it takes so long to design and procure new capabilities – which are then expected to remain in service for decades – there is a real risk that militaries will lock themselves into relying on the maintenance of a high-carbon energy system for the foreseeable future, even as that very same system is displaced by changes occurring in the wider sociotechnical landscape. Addressing this lock-in is likely to become more expensive the longer it takes for defence organisations to respond. As one interviewee put it, 'the world around us is changing, and so if we don't change, then we'll be too late, and we'll lose our strategic advantage.'⁶⁸ Or as the Defence Operational Energy Strategy concluded, 'the MOD cannot afford to adopt a reactive stance. It needs a proactive strategy to ensure it can respond better than its adversaries to the energy transition.'⁶⁹ Our finding that 'anticipated' landscape changes are just as important to consider as 'actual' ones, also speaks to growing interest in understanding how sociotechnical imaginaries contribute to our understanding of the multidimensionality, temporality, and political nature of sustainability transitions⁷⁰ and military innovation.⁷¹

Our discussion of how the broader landscape within which militaries operate has changed – and is anticipated to change – is not intended to downplay the significance of the internal dynamics within the UK MoD and its armed forces. Our point rather is to emphasise that the (re-)emergence of a low-carbon niche has been entangled with a wider landscape of (anticipated) change – comprising developments that the MoD has little control over. The alignment of internal and external forces of change subsequently combined to expose weaknesses and destabilise parts of the incumbent 'high-carbon' regime. The incumbent 'high-carbon' regime's inability to respond to emerging and anticipated landscape pressures proved to be a critical factor in creating space for low-carbon innovators within the MoD to drive forward innovative ideas about how defence needs to be delivered differently as the world decarbonises. The emerging niche effectively seized this window of opportunity to start making institutional, material, and rhetorical inroads.

The regime fights back

Within the MoD and armed forces, there is now clearly greater acknowledgement that bending defence towards 'low-carbon' military operations is, over the long term at least, both a requirement and an opportunity. Yet, for many observers, it may seem like little has changed. For now, defence in the UK continues to be delivered through a high-carbon sociotechnical system. While the emerging niche has made notable inroads into the incumbent regime, there has not yet been the kind of breakthrough that will upend the high-carbon sociotechnical system underpinning defence. None of our interviewees contradicted this claim: as one proponent of change remarked,

⁶⁶ Interview with a Royal Air Force officer, June 2023 [#10].

⁶⁷ Adamsky and Bjerga, *Contemporary Military Innovation*.

⁶⁸ Interview with civil servant in the Ministry of Defence, September 2023 [#42].

⁶⁹ UK Ministry of Defence, 'Defence Operational Energy Strategy', p. 13.

⁷⁰ Silke Beck, Sheila Jasanoff, Andy Stirling, and Christine Polzin. 'The governance of sociotechnical transformations to sustainability', *Current Opinion in Environmental Sustainability*, 49 (2021), pp. 143–52.

⁷¹ Sofie van der Maarel, Desiree Verweij, Eric-Hans Kramer, and Tine Molendijk. 'Imaginaries, expectations and disillusionment in a Dutch military innovation hub', *Science, Technology & Human Values* (2023), pp. 1–22.

'You know, you can't point to a whole bunch of new capabilities that Defence has procured in the last 12–18 months that show that sort of leap towards large-scale sustainable technology employment.'⁷² Indeed, there was widespread recognition across everyone we interviewed that while the thinking, the planning, and the level of strategic ambition to go after low-carbon innovation had advanced in significant ways, the fundamentally 'high-carbon' character of military operations so far remains largely unchanged.

To explain the limits of change to date, the MLP directs our attention towards two important factors: (1) the difficulty of destabilising the incumbent regime that is essentially reluctant to change the existing sociotechnical system of defence; (2) ongoing developments in the wider sociotechnical landscape that frustrate opportunities for further innovation and support the reassertion of the old regime. In this way, the MLP also captures insights from the wider literature on military innovation and change, which emphasise the path dependencies established through the way military institutions have been organised and structured, the grand strategies determined by civilian decision-makers, organisational culture, and material 'lock-in'.

The first of these issues – regarding the difficulty of destabilising the incumbent regime – was reflected in an array of challenges identified by our interviewees as the principal reasons why, despite the strategic ambition set out in key capstone documents, change is not happening faster. These revolved around culture, capability, and concepts. First, the need for cultural change also came up in many of our interviews ($n = 14$), with some ($n = 6$) suggesting that the door to this was already opening, at least in some parts of the MoD. Nevertheless, several blockers were identified including an ongoing lack of incentives (related, for instance, to promotion), top-down support, and enablement of bottom-up initiatives. Yet even if these blockers could be overcome, in some of our interviews ($n = 6$) participants also stressed that cultural change alone would not be enough to make much difference: it needed to be undertaken alongside more practical, material, and financial considerations. This again reflects the usefulness of the MLP for capturing the ways in which multiple sources of change are entangled with one another, rather than treating cultural, technological, and organisational factors as discrete variables.

Regarding capability, a second issue identified in most of our interviews ($n = 25$) concerns the material constraints that seriously limit the MoD's ability to quickly replace the material 'high-carbon' elements of the system with 'low-carbon' alternatives. In many of our interviews ($n = 12$), participants highlighted the challenges of replacing existing equipment and overcoming historical investment decisions that are currently too expensive (financially, organisationally, and politically) to unpick. This includes the most recent round of recapitalisation that led to the procurement of the Queen Elizabeth class aircraft carriers and the F35-B Lightning fighter jets, both of which are examples of 'high-carbon' capabilities that the MoD plans to keep in service well beyond 2050. The sunk costs involved, and the limited resources available to design and procure alternative capabilities, make it extremely difficult for either civilian leaders or the MoD to make rapid and disruptive material changes to the existing sociotechnical system of defence. While the incorporation of emerging technology into these capabilities might enable some incremental improvements, the MoD's ongoing commitment to these and other platforms means that the pathway for low-carbon innovation has been narrowed to mostly focus on technologies that can either be 'dropped in' (i.e. 'sustainable' fuels) or retrofitted within the existing sociotechnical system. Even with breakthrough advances in low-carbon technology and rising operational costs for 'high-carbon' forces, the time and the resources required to overcome this material 'lock-in' increases the incumbent regime's reluctance to accommodate change in the short term. The reality, though, suggested by many of our interviews ($n = 15$), is that many of the technological solutions needed simply do not exist yet, or if they do, there are still issues around how you turn it into an operationally effective and affordable capability. Even then, procurement processes take time, and the opportunities to recapitalise and replace do not come around very often ($n = 7$). Several interviews ($n = 11$) also highlighted the need for wider material changes to the infrastructure, supply chains, and industrial base that

⁷²Interview [#3].

defence relies on. Others ($n = 5$) expressed concern about the countervailing risks that the uptake of new technologies might create, while it was also mentioned that for certain capabilities, it might be that fossil fuels would still be the best answer, even if the costs involved were much greater. Clearly then, from a sociotechnical systems perspective, the struggle between the niche and the incumbent regime cannot be disentangled from the capacities of the material and technological artefacts that the MoD has at its disposal, both now and in the future.

Third, across most of our interviews ($n = 25$) there was a broad view that the MoD's knowledge and understanding of the depth and scale of change required to develop the concepts necessary to move away from a high-carbon sociotechnical system of defence still needs to mature. The challenges ranged from a lack of appropriate baselines and measurements from which to plan ($n = 10$), to the need for a stronger evidence base around what is possible, how it can be delivered (without relying on promissory technology), and for a sound business case to be put behind it ($n = 11$), to a requirement for fundamental changes across the defence operational model to embed energy, climate, and broader sustainability considerations into mainstream organisational processes ($n = 18$). Notably, these findings also speak to Rosen's claim that innovation often requires new strategic measures of effectiveness and new forms of data intelligence.⁷³ So far, low-carbon innovators have been able to articulate the risks of persisting with a high-carbon system, as well as persuading senior leaders of the strategic necessity of a military energy transition over the long term. However, they have only just begun to develop the evidence base required to establish a viable pathway for the MoD to undertake such a transition without undermining core outputs by exposing the department to new (and perhaps unanticipated) risks that outweigh those associated with remaining on the current trajectory. Notably, the MoD's own action plan anticipates that this will take more time, with work to significantly reduce operational emissions not expected to begin until 2026 at the earliest.⁷⁴ As one of our interviewees put it:

we know it's one of our policy priorities. We just don't know how to prioritise it. If you can't cost it or if you can't understand the operational impact, it is very hard to really factor it into our capability priority decisions.⁷⁵

All this speaks to the fact that without clearer concepts of how to operationalise 'low-carbon warfare' supported by a firmer evidence base, changes to defence management processes, and new strategic measures of effectiveness, the emerging niche will struggle to make more radical changes to the incumbent sociotechnical system.

Overarching the need for changes to culture and capabilities, our interviews also found that unless senior civilian ($n = 14$) and military ($n = 4$) decision-makers allocated greater prioritisation to these tasks, and with it more resource, there would be little more than incremental advances towards low-carbon warfare. Indeed, across most of our interviews ($n = 27$) we heard that despite signs of strategic ambition to markedly reduce defence's reliance on fossil fuels, there was still a lack of clarity over what the MoD was actually being mandated to do ($n = 6$) and where accountability lay ($n = 8$). There was also uncertainty around to what extent the pursuit of 'low-carbon warfare' should be prioritised relative to other tasks and drivers ($n = 9$), and how much resource should be put against it ($n = 16$). Without a stronger mandate and the provision of additional resources to deliver it, senior personnel have found it harder to change key decision-making structures in ways that allow the 'costs' and 'risks' of remaining dependent on fossil fuels to be more accurately factored into calculations regarding the most effective and most efficient ways to deliver defence outputs. As one interviewee explained:

it's not codified in our planning guidance and the operational planning scenarios we use for development, and so it's not baked into the things we routinely test our planned force against.

⁷³Rosen, *Winning the Next War*.

⁷⁴UK Ministry of Defence, 'Climate Change and Sustainability: Strategic Approach'.

⁷⁵Interview with civil servant in the Ministry of Defence, July 2023 [#28].

Until it is, we won't understand the operational risks, and we won't be able to respond within our capability and financial planning processes effectively.⁷⁶

Thus, for all the progress that the low-carbon niche has made, the widely held view among our interviewees was that it was yet to significantly alter what the MoD values when it makes decisions about how to structure and fund future force and capability development. In line with Avant, part of the explanation for the lack of mandate is that it has not yet been a major priority for civilian leaders.⁷⁷ Indeed, contrary to Kier, who argued that civilian intervention could be a source of frustration for the military, in our case, there appeared to be frustration within the MoD (at least among those people that we spoke to) at the *lack* of civilian intervention to help accelerate change.⁷⁸ All this reinforces the importance of seeing the way defence is delivered as a function of a wider sociotechnical system that involves more than the military. Simply making inroads within the MoD and armed forces is not enough to bring about military change.

Again, our MLP has proven useful for capturing a broad range of issues that reflect insights from the literature on military innovation and change, which are often taken in isolation. For our purposes, the issues regarding culture, capabilities, and concepts, and the way in which they intersect with civil–military relations, the possibilities inherent in existing and emerging technology, and the material resource base, illustrate why the sociotechnical system of defence is so difficult to change, and why the incumbent regime may be reluctant to make more than incremental adjustments, even when wider landscape conditions appear to favour low-carbon innovation. Given time, though, the low-carbon niche may be able to gather enough momentum to make a breakthrough and bring about more radical transformation, especially if events in the wider landscape favour it as well.

Maintaining the momentum for change

Notably though, many of our interviewees expressed concern that there were already signs that the momentum for change was being lost due to a series of further development in the wider landscape, which were making it harder for niche innovators to challenge the incumbent regime. The most pronounced of these ($n = 15$) was Russia's full-scale invasion of Ukraine in February 2022. Indeed, the need to respond in the short term to the return of major interstate warfare to the edges of Europe has inevitably diverted resources and the attention of senior decision-makers away from innovating for low-carbon warfare. It has also exacerbated the issue of material lock-in, as the UK and its allies turned their attention to recapitalising their forces using tried-and-tested capabilities despite the long-term 'carbon' risks that they embody. With growing tension in the Indo-Pacific ($n = 7$) also encouraging the MoD to prioritise actions that reinforce a high-carbon approach to defence in the short term, there has been diminishing headroom to invest in a military energy transition.

Another change in the wider landscape identified in several of our interviews ($n = 8$) was what participants saw as faltering societal and political support for the low-carbon energy transition, at least in the short term, even as many of our interviews also predicted that demand for a military energy transition would grow over the long term (as discussed earlier). This was being driven by short-term pressures (such as the UK's 'cost of living' crisis) deflecting the attention of politicians and the wider public away from the need to address climate change and accelerate the energy transition. Within this context, civilian leaders are perhaps even less likely to be forthcoming with a mandate for the MoD to embark on a major energy transition. More generally, the last Conservative government's (2022–4) lack of commitment to its own net zero strategy and the diversion of public attention may have also reduced some of the concerns internally within the MoD about impending

⁷⁶Interview with civil servant in the Ministry of Defence, July 2023 [#28].

⁷⁷Avant, *Political Institutes and Military Change*.

⁷⁸Kier, *Imagining War*.

legal and societal pressure on the incumbent regime of defence to be more responsive to the need for a military energy transition, at least for a short time. As one interviewee concluded:

political will, public will, is kind of critical because we can only go so far at a certain pace. If you've got a headwind against you politically, then ... you're just not going to get there ... irrespective of our ambition.⁷⁹

Even in the absence of an explicit attempt by Government to direct the MoD away from decarbonisation, uncertainty over the strength of political and societal support for net zero has still been damaging to the low-carbon niche because it reduces the external pressures on the incumbent regime to change. By impacting decisions around prioritisation and resources, it also delays the ability of the low-carbon niche to build the critical mass needed to overcome the incumbent regime. With the new Labour government (2024–) having just announced a major defence review, it remains to be seen whether the domestic landscape will once again shift to favour the low-carbon niche within the MoD, and what will be the strength of any new commitments.

These short examples again illustrate the value of adopting an MLP, as they show how military innovation may be resisted by developments in the wider sociotechnical landscapes that align with and reinforce the expectations and interests of the incumbent regime within defence. As we saw earlier, important shifts in the wider landscape opened windows of opportunity for low-carbon innovators of defence to drive forward with changes to the sociotechnical system of defence. More recent developments, though, have, at least in the short term, potentially turned the tide against low-carbon innovation and reinforced the status quo. This shows how tracking what is happening in the wider landscape – and the extent to which these events align with and favour one side or another in the struggle over what should be the dominant ‘theory of victory’ – is critical for understanding how far and how fast innovation can bring about military change.

Conclusions

This paper has found that since circa 2018, an emerging niche of UK MoD and armed forces personnel was able to make important inroads internally regarding the need to consider the strategic and operational potential of a military energy transition in a decarbonising world and develop an alternative theory of victory based on ‘low-carbon warfare’. The progress of this niche was institutionalised and embodied by the creation of new posts and organisational structures, materialised through investments in research programmes, technological experimentation, and trials, and discursively embedded at the very highest levels in the MoD’s strategic ambitions. While more recent developments in the wider landscape may have helped reinforce the dominance of the ‘high-carbon’ regime within the MoD and slowed the pace of change, they have not unpicked these institutional, material, and rhetorical achievements.

Up to now, the literature on military innovation and change – and security studies more broadly – has largely ignored the prospect of a military energy transition away from fossil fuels. The few exceptions mostly critique interest in ‘low-carbon warfare’ as an attempt to ‘climate-proof’ militarism. Nevertheless, several of our findings speak directly to the insights from key literature on military innovation and change. For instance, we have highlighted the emergence of a ‘maverick’ figure in the form of Lieutenant General Richard Nugee, who was instrumental in proposing a ‘new theory of victory’ and developing an advocacy network around it. We have demonstrated the importance of civilian leaders, and how an apparent lack of interest in the prospect of a military energy transition is stymieing efforts within the MoD to mobilise the resources necessary to bring about the change needed to deliver against the department’s strategic ambitions. We have

⁷⁹ Interview with civil servant in the Ministry of Defence, July 2023 [#16].

illustrated how events in the wider national and international landscape – whether political, societal, technological, or economic – have been crucial for encouraging militaries to reconsider their dependence on fossil fuels. As influential – if not more – have been the *anticipated* shifts in the *future* landscape and a sense of concern among those we spoke to that the MoD will not be able to adapt quickly enough if it does not begin to prepare now.

To all this, our MLP adds two important insights. The first is that all the above factors were relevant as constitutive parts of the sociotechnical system that delivers the societal function of defence. In this way, we escaped the dichotomous/trichotomous thinking that has dominated a lot of earlier work on military innovation. Second, our MLP demonstrated that a crucial dynamic enabling the emerging niche to make progress during the late 2010s and early 2020s was that these developments were all closely aligned. Indeed, it seems the alignment of internal and external sources of change compounded the pressure on the incumbent ‘high-carbon’ regime, creating a window of opportunity for the emerging niche to make its inroads. Significantly though, by the end of the period in question, as the same dynamics shifted in favour of the status quo and stabilised the incumbent regime, more rapid and disruptive progress has been harder to achieve. By centring attention on alignment, we find that the MLP makes a significant contribution to understanding why innovation processes unfold in non-linear ways, as well as why sometimes the change these processes bring about is sudden and disruptive, while at other times it occurs incrementally. In this way, rather than seeing military change as unfolding either in a revolutionary or evolutionary way, we find the potential for both forms of change to be part of the same process.

We are reluctant to make further theoretical claims at this stage. Like others, our aim is not to ‘draw firm lines or locate single source explanations.’⁸⁰ It is also a notable limitation of this study that we have only addressed a single case to illustrate the utility of the MLP. Comparative studies, including both NATO and non-NATO countries, therefore represent a crucial direction for future research. Here, we would note not just other national contexts, but also the importance of considering whether and how sub-state armed groups might also be seeking to take advantage of ‘low-carbon’ technologies. We also encourage the extension of the MLP approach to analyse other cases of military innovation, past and present. Only then will it be possible to confirm the utility of the MLP across multiple cases.

Beyond comparative research, a more detailed investigation of the wider sociotechnical system underpinning the delivery of defence is still needed. ST scholars using the MLP stress the need for alignment not only between different analytical levels but also within them. This study has very much addressed the former. Investigating the latter will help to clarify where the main points of friction are between the military and other parts of the sociotechnical system of defence, where controversies need to be addressed, and where more resources are likely to be needed. While our study has offered insights based on perspectives from inside the MoD, an investigation of the wider system is required to more thoroughly corroborate their diagnosis of how the external landscape is changing.

To close, it is important to stress that innovation can and will continue to progress outside of windows of opportunity, only it is more likely to be incremental and evolutionary. That said, neither a lack of resources nor a lack of alignment should be seen as a barrier to innovation per se. As Rosen argued, while bringing innovation to fruition may be difficult and expensive, initiating it and creating strategically useful options can be done relatively cheaply.⁸¹ Moreover, as Neads et al. showed, one of the reasons for doing this is to encourage professional debate, as this can help build consensus around what the next ‘theory of victory’ should look like.⁸² Related to this, simulation and experimentation remain powerful tools for thinking about the future. While the construction of new systems may need to be deferred for the time being to avoid countervailing risks associated with uncertainties around low-carbon sociotechnical futures, there is still value in doing

⁸⁰Watts and Murray, ‘Military innovation in peacetime’, p. 381.

⁸¹Rosen, *Winning the Next War*.

⁸²Neads et al., ‘Evolving towards military innovation’.

everything that can be done to prepare for the rapid construction of a new system of ‘low-carbon warfare’.⁸³ Indeed, if militaries are to remain operationally effective in a decarbonising world, then it is essential that even in the absence of more favourable landscape conditions, incremental efforts to ‘redefine strategic measures of effectiveness and to collect and analyze the information relevant to creating new capabilities’ for low-carbon warfare continue to be encouraged.⁸⁴

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⁸³Murray, ‘Innovation: Past and future’.

⁸⁴Rosen, *Winning the Next War*, p. 261.