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Industrial Strategy and the Low Carbon Supply Chain Challenge

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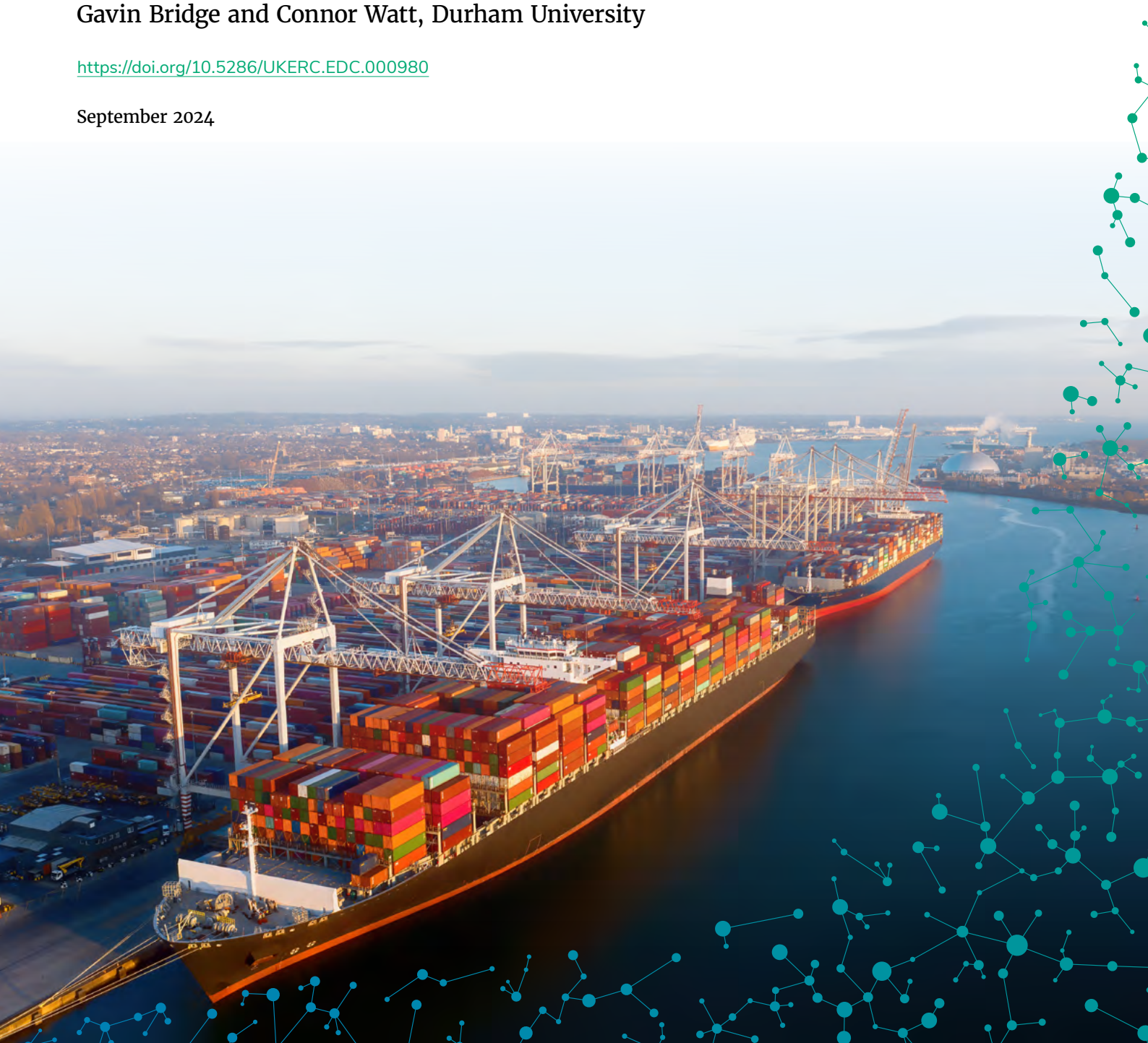

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Summary

This Briefing Paper integrates research from Phase 4 of the UK Energy Research Centre (UKERC) and brings it into conversation with contemporary concerns about the role of industrial strategy and low carbon supply chains in the energy transition. It draws on conversations with UKERC theme leads, and with selected organisations beyond UKERC who sit at the nexus of industrial strategy and low carbon supply chains. The research was completed prior to the announcement of a UK General Election and a change in government at Westminster.

The next phase of the energy transition will be manufacturing intensive. Manufacturing and industrial processes are central to the build out of low carbon technologies and infrastructures, and to the development of a circular economy of low carbon materials. These industrial aspects of energy transition – i.e., transforming manufacturing for a low carbon economy – raise questions for research and policy that are different to the challenge of emissions reduction.

Decarbonisation is creating a new economic terrain. There are substantial socio-economic benefits to be had from the energy transition if the UK evolves its approach to decarbonisation from emission reduction to manufacturing transformation. Doing so requires a green industrial strategy that provides clarity, certainty, consistency and continuity in objectives, cross-sectoral coordination, and distinguishes between short and long-term priorities.

Industrial strategy is back internationally in a big way, but not yet in the UK. The US Inflation Reduction Act and the EU's Green Deal have set a bar for governmental engagement with the low carbon transition. The absence of a similar plan in the UK has made it an outlier on the global stage.

The previous government's reluctance to intervene in industrial matters was nothing new – the UK has historically preferred to adopt a case-by-case, sectoral approach to industrial policymaking. The incoming government has recognised the need for a comprehensive industrial strategy and has centred clean power and resilient supply chains within it. But it is early days: whether Labour's industrial strategy proves sufficient to the challenge of manufacturing transformation in an era of geoeconomic competition remains to be seen.

There are opportunities in the manufacturing aspects of energy transition to address the UK's chronic regional inequalities. The UK's manufacturing base is dispersed around the country, often in areas experiencing significant economic challenges over multiple decades. The industrial and manufacturing aspects of low carbon transition, if given adequate coordination, can be a powerful means of addressing these regional disparities.

1. Introduction

This Briefing Paper focuses on the manufacturing and supply chain aspects of decarbonisation in the UK. These industrial aspects of energy transition differ from the conventional concerns of energy policy with deploying energy technologies and infrastructures for emissions reduction. They involve flows of goods and materials that stretch far beyond UK borders, have objectives and timeframes not limited to net zero, and raise different questions for research and policy.

By focusing on the manufacturing and supply chain aspects of energy transition, this Briefing Paper foregrounds connections between the UK's national energy transition and the wider global context. It highlights, for example, how delivery of the UK's decarbonisation targets relies on international supply chains; and how the significance of decarbonisation for the UK extends beyond emissions reduction to the prosperity, sustainability, and competitiveness of the country's economy. It shows too how the industrial aspects of energy transition are eroding globalisation and driving a structural transformation of the world economy, creating a new geography of geopolitical competition and economic power linked to the location and/or control of net zero industry.

UKERC research focuses on the challenge of delivering the energy transition in the UK. This UKERC Briefing Paper summarises findings from a UKERC Phase 4 Integration Project on *UK Industrial Strategy and the Low Carbon Supply Chain Challenge*. It contributes to an evolving discussion within UKERC about these industrial and supply chain aspects of the energy transition and their implications for the UK. Its aims to bring these features of energy transition to the attention of other researchers within UKERC and beyond, and to highlight promising intersections between UKERC research and the broader research and policy community around industrial strategy and supply chains in the UK.

Our effort to link UKERC's research on energy transition with the question of industrial strategy and supply chains is motivated by four general observations:

First, the energy transition is a manufacturing and materials problem. Transitioning from a high to low carbon energy system requires expanding and modernising a host of infrastructures and systems – from transport mechanisms and fuel systems to electricity generation, energy storage and heating solutions – many of which "*need to be built from the ground up.*"[1] Manufacturing and industrial processes are central to the modernisation and replacement of capital stock, so scaling the build out of renewable and other low carbon technologies and infrastructures is a manufacturing challenge. The electrification of mobility, for example, involves replacing a significant portion of the global ICE vehicle fleet with EVs; and ending the use of gas boilers requires the manufacture and installation of heat pumps at scale. At the same time, achieving net zero will also require reducing the quantity of materials required to deliver desired levels of consumption through whole system approaches to resource and energy efficiency. This includes materials innovation and substitution, materials stewardship and circularity (reuse and recycling so that materials are maintained in circulation at their highest value). Delivering the energy transition will also involve product reformulation (such as manufacturing lighter vehicles and more durable consumer goods) and increasing resource productivity through changes in social behaviour around materials and manufactured products (such as providing goods as a service).[2] [3]

Second, low carbon products are a new terrain of economic competition and prosperity. The materials, machines, and

infrastructures of the energy transition – wind turbines, photovoltaic panels, heat pumps, electrolysers and lithium-ion batteries – are a key source of innovation, economic value, and job creation. Annual investment in clean energy worldwide ($2 trillion) is now nearly twice that in fossil fuels ($1.1trillion).[4] Clean energy manufacturing, deployment and sales accounted for 10% of global GDP growth in 2023 and was substantially higher in China (one fifth) and the EU (one third).[5] In the UK, the Skidmore Review (Mission Net Zero) identified decarbonisation as the economic growth opportunity of the 21st century, with a potential global market worth more than £1 trillion in the period 2021-2030. The UK's net zero economy grew 9% in 2023, compared to 0.1% for the economy overall, while employment in the sector grew 8% in 2022.[6] The manufacturing and supply chain aspects of energy transition, then, align decarbonisation with some of the foundational objectives of government such as macro-economic growth, economic security, and employment and skills. For these reasons, decarbonisation is contributing to a "*renaissance of industrial policy among governments across the world as they seek to ensure their economies are at the forefront of the new global energy economy that is emerging*".[7] In the UK, a green industrial strategy focused on manufacturing transformation has the potential to address several headline economic problems, such as stagnant productivity, low growth, chronic under-investment, regional inequality and falling living standards.

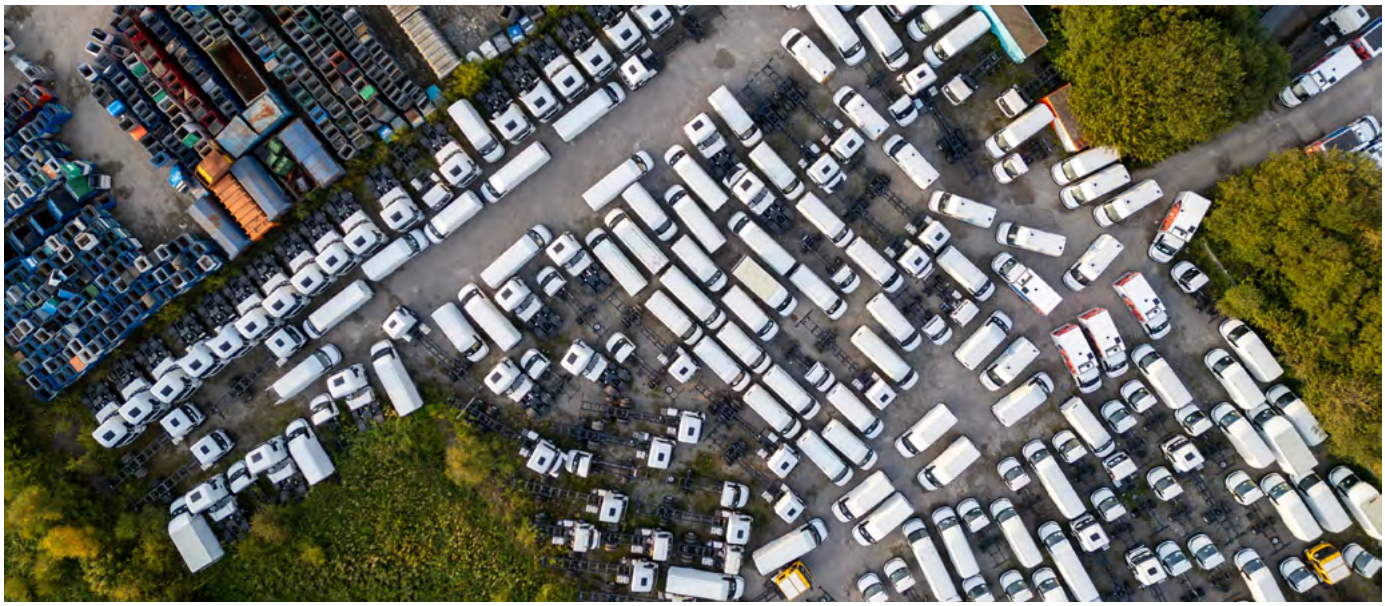
Third, new trade flows in clean technologies and materials means that the geopolitics of energy security is evolving. Decarbonisation puts access and control over technologies – rather than fuels – at the centre of the global energy landscape. Although fossil fuels remain a focal point of international energy politics, the trade flows and supply chains for low carbon energy technologies are diversifying and intensifying. Decarbonisation, then, "*supplements a geopolitical economy of energy founded on supply security concerns and resource rents with one founded on regulated trade, patenting/technology rents, and manufacturing capability.*"[8] Globally, huge additions have already been made to manufacturing capacity for the energy transition, notably in relation to batteries, EVs, and solar PV, and further capacity growth is expected.[9] [i] Yet much of this manufacturing capacity has been regionally concentrated – notably in China for batteries, EVs, solar PV and wind – raising concerns about geopolitical risk and the security and resilience of international supply chains.[ii] These concerns centre on access to and control over technologies, materials and minerals deemed 'critical' for industrial production – such as rare earths, cobalt and lithium – and their potential exposure to geopolitical disruptions and uncertainties. The geopolitical economy of energy, then, is "increasingly shaped by competition and strategy in relation to technology and manufacturing knowhow and the trade of goods" and less over time to the trade of fuels.[10] [iii]

Fourth, decarbonisation lays the ground for future circular economies of material recovery, recycling and re-manufacture. The build-up of installed capacity in renewables represents a growing domestic stock of materials, with opportunities for capturing and retaining

i Globally, investment in the energy sector has tilted decisively towards low carbon: nearly two dollars were invested in clean energy for every dollar invested in fossil fuels, and clean energy employment now accounts for over half of energy sector jobs worldwide. See IEA, 2023. Key findings – the state of clean technology manufacturing. Access here.

ii Other technologies (electrolysers, heat pumps) and materials (copper, nickel) have more diverse geographies. For ref to this point, see IEA, 2023. Key findings – the state of clean technology manufacturing. Access here.

iii Kuzemko et al. 2024 also note how manufactured goods are subject to WTO trade regulation in value-added activities in a way that fossil fuels are typically not.



value within national and regional economies via reuse, recycling or export as these assets age. Such opportunities are not typically available in fossil fuels. A strategy of re-use, however, depends in part on the availability of foundational industries – such as metals reprocessing – that are themselves subject to industrial decarbonisation. The circular economy potential of decarbonisation, then, highlights the value of including materials management and materials processing considerations within industrial strategy alongside conventional supply chain concerns. This extends, for example, to a comprehensive material strategy (beyond critical minerals) focused on resource efficiency, improvements in production processes and the facilities, infrastructures, material specifications and business models required to boost the use of secondary materials.[11]

The stakes are high. Many countries are designing and implementing green industrial strategies to capture the economic upsides of decarbonisation, and to leverage energy transition for geoeconomic and geopolitical advantage.[12] The US Inflation Reduction Act (IRA) commits large-scale and long-term government support to specific clean technologies and sectors; the EU's Green Deal Industrial Plan (and supporting legislation like the Net Zero Industry Act and Critical Raw Materials Act) aim to scale up Europe's manufacturing capacity for net zero technologies and products and enhance the competitiveness of Europe's net zero industry; and China is reaping the economic benefits of its 'Made in China 2025' policy, a national strategic plan and industrial policy to upgrade the country's manufacturing base in areas that include green tech and net zero.

Net zero and global decarbonisation present large growth opportunities for UK manufacturing. Capturing these opportunities in a context of intensifying geoeconomic competition will require an industrial strategy that has heft and durability as well as reckoning with openness of the UK economy to cross-border flows of trade and investment. An industrial strategy tailored to net zero must also balance twin goals: achieving rapid emissions reductions (which in some case may most efficaciously be achieved with imported technologies and materials) while nurturing home-grown innovation and supporting a domestic green industrial sector to grow and achieve export capacity. Finally, an industrial strategy focused on manufacturing transformation must recognise the role foundational (i.e. material processing) industries can play in material resource efficiency and supporting resilient manufacturing supply chains. The UK's industrial decarbonisation strategy focuses on emissions reduction in foundational industries like steel making and metal smelting. An important role for industrial strategy – yet to be achieved in the UK – is to connect industrial decarbonisation to a more comprehensive and expansive objective: transforming manufacturing and materials use in the UK to meet ambitious climate targets and secure a thriving and resilient low carbon economy.

Our approach

This Briefing Paper, *Industrial Strategy and the Low Carbon Supply Chain Challenge*, spotlights the manufacturing and supply chain aspects of energy transition and considers what they mean for the UK. It identifies the scope of the challenge, contextualises supply chain concerns around energy transition, and highlights key themes emerging from UKERC research. In common with other UKERC integration projects, the aim of this Briefing Paper is to synthesise accumulated knowledge from UKERC Phase 4 research and bring that knowledge into conversation with research conducted by other organisations. To compile this paper, we held research conversations with UKERC Theme Leads and with a handful of selected organisations working at the nexus of industrial strategy and low carbon supply chains (see Table 1).

Conversations aimed to bridge between in-depth domain expertise and the cross-cutting subject of UK low carbon supply chains and industrial strategy and were conducted over a period of six months (December 2023 – May 2024). Since most of UKERC's research in Phase 4 has centred on delivering transition – as distinct from the specific problem of manufacturing and supply chains – our objective was to tease out the implications of this research and draw connections to wider conversations about UK industrial strategy, manufacturing, and the net zero economy. We supplemented these conversations by reading a wide range of UKERC research output, and by consulting research reports and briefings produced by non-UKERC organisations. As a short integration project oriented towards synthesising existing findings, we did not conduct new formal research into industrial strategy and supply chains using value chain, production network or comparative policy analysis approaches (although we recommend future work in this area, see Section 5). Our research was governed by an ethical framework and all conversations with participants were conducted according to standard social science practices around informed consent, and with an undertaking not to quote or name individual persons.[13]

Table 1: UKERC themes and other organisations consulted for this briefing paper

UKERC Phase 4 Themes	Other Organisations
Geopolitical Economy of Energy System Transformation	Heat Pump Federation
Technology and Policy Assessment	Make UK
Industrial Decarbonisation	National Manufacturing Institute Scotland
Energy Systems for Heat	North East Battery Alliance
Mobility	North of Tyne Combined Authority
Energy, Environment and Landscapes	RenewableUK
Energy Infrastructure Transitions	UK Critical Minerals Intelligence Centre
	UKRI

The general election and labour's industrial strategy

Research for this Briefing Paper was completed in the first half of 2024. We drafted the report before the announcement of the 2024 General Election which saw Labour subsequently form a government in Westminster. The manufacturing and supply chain aspects of decarbonisation that we highlight in this paper are larger and more durable than changes in government. The paper's core messages – about the centrality of manufacturing and materials to the energy transition, how this has transformed low carbon technologies and infrastructures into a new terrain of geopolitical competition and economic power, and how industrial strategy needs to reckon with the potential of decarbonisation to transform the economic potential and strategic value of UK manufacturing assets – remain highly relevant. So too stands our assessment of the relevance of UKERC's record of work in Phase 4 to understanding the implications of energy transition for the formulation of industrial strategy; and how the manufacturing and material challenges of transition create new knowledge needs and opportunities for UKERC that complement its long-standing concern with emissions reduction.

However, there are some notable differences between the new government and the outgoing one in terms of industrial strategy. The standard critique of the previous government on industrial strategy – that it didn't have one – no longer holds. While in opposition, Labour developed the outlines of an industrial strategy (*Prosperity through Partnership*, 2023).[14] It diagnosed the need for an industrial strategy in the context of a climate emergency, technological change and renegotiation of relations with the EU, and noted weaknesses of previous iterations that echo the analysis in this paper. Labour's pre-election strategy document outlined four 'missions' that industrial strategy should seek to fulfil, with two of these – clean power and building more resilient supply chains – closely aligned with the central concerns of this Briefing Paper. The National Wealth Fund (NWF), a manifesto pledge, has allocated £7.3 billion in support of these missions and economic growth, and highlighted green steel, green hydrogen, industrial decarbonisation, gigafactories and ports as sectors where the NWF could spur private investment. In opposition, Labour proposed some actions that we recommend in this Briefing Paper, such as a cross-sectoral orientation to strategy and the importance of consistency across the political cycle. Labour have said, for example, they will retain Manufacturing Catapults, Challenge Funds and Local Skills Improvement Plans. A specific recommendation in this Briefing Paper – about reinstating the Industrial Strategy Council, a repeated ask of manufacturing organisations like MakeUK – was included in the King's Speech laying out the incoming government's legislative agenda.

The new government's embrace of industrial strategy is welcome. Its diagnosis of the problem and analysis of the functions industrial strategy needs to perform in relation to the energy transition broadly aligns with our own. That said, three general cautions are needed.

First, it is early days and the full shape and financial heft of Labour's industrial strategy have yet to emerge and be tested. The Autumn Statement may tell us more about the scale of support for British manufacturing, and many features of the strategy document remain to be implemented. Some, like a Cabinet Subcommittee on National Resilience, have got an early start in response to the first report of the Covid inquiry. Others – like a Supply Chain Task Force to review potential supply chain needs across critical sectors including energy and defence – have yet to be populated. Following through is going to be important. More fundamentally, a strategy whose ambition and scope are better than what came before should not be mistaken as a strategy that is sufficient to the challenges at hand. The scale of the financial resources dedicated to industrial transformation will be key to its success.

Second, the target sectors for the NWF – hydrogen, ports, gigafactories, industrial decarbonisation – are familiar as previous governments have focused initiatives and policies in these areas (even in the absence of an overall industrial strategy). There is accumulated experience with industrial policy in these areas that can be instructive for the new government going forward. The last previous outing of an industrial strategy worthy of the name – under Theresa May – created new sectoral partnerships (some of which have endured) but did not deliver transformative change. Some reasons for that were political, with the shift in the Conservative Party towards a less interventionist strain of government and the shelving of the strategy itself. But there are also lessons from the ambition and scope of the strategy itself. One of these is that industrial strategy needs to be cross-sectoral and, at the same time, intra-sectorally fine grained. The case of Britishvolt, the failed gigafactory development (see Box 2), highlights how industrial strategy needs to differentiate, for example, between the immediate needs of the energy transition (which require support for the operationalisation and implementation of technologies at high TRLs) and the longer-term process of building a resilient and prosperous low carbon economy (where support for research and development and lower TRLs is vital). The government's identification of target sectors is a reasonable place to begin. However, a key point we make in this Briefing Paper is that industrial strategy built around sectors needs be granular and tailored to differences within them. Not only muscular and durable, industrial strategy needs also to be smart.

Third, a strategy can be transformational in ambition and competently delivered but that does not mean it will be socially just. The government's formulation and implementation of industrial strategy should, of course, involve consultation with industry. There is much that can be improved about understanding the nature of the supply chain challenges for green industry and industrial decarbonisation through this consultative approach. Yet industry is a wider category than business alone. Industry is also the workforce, the places and communities in which people live and work, and the environments and ecologies that sustain our quality of life. The formulation of industrial strategy, then, should not be ceded to business alone if the goal is to achieve an energy transition that is socially just. The new government has offered a nod in this direction by casting industrial strategy broadly: its pre-election strategy document includes 'everyday economies' as part of industry. It has also declared, however, its intent to 'codesign policy with business' and to put business 'at the heart' of industrial strategy. Some of the recommendations we make in this Briefing Paper speak to this question about whose voices and interests will shape a new era of industrial policy in the UK. They include the need to ensure industrial strategies for the energy transition support biodiversity and environmental protection, and to understand how regional legacies shape inclusion in the new economies of decarbonisation. These are far from niceties: if energy transition is to be successful it needs to command popular support, which means it must clearly improve socio-economic conditions and people's quality of life. For the opportunities of transition to a low carbon economy to be fully grasped, then, it is vital that industrial strategy does not replicate a narrowly business or finance-focused agenda.

We have edited the Briefing Paper to acknowledge the change in government and, in some places, to highlight its recent actions or expressions of intent that are relevant to our findings and recommendations. The research underpinning the paper and its framing, however, reflect the situation prior to the General Election. An analysis of industrial strategy under Labour, and its contribution to addressing the manufacturing and supply chain challenges of the energy transition, requires the fullness of time.

Organisation of this briefing paper

There are four further sections in this Briefing Paper.

- Section 2 considers how focusing on manufacturing shifts the research and policy conversation around energy transition and puts UK industrial strategy into historical and geographical context.
- Section 3 characterises the nature of the UK's manufacturing and supply chain challenge in relation to the energy transition. It provides a snapshot of the current situation and provides some illustrative examples.
- Section 4 summarises seven key findings from the research. These speak to the gaps and forward implications of the convergence of energy transition and manufacturing in the UK.
- Section 5 offers a handful of recommendations for research and policy.

2. Shifting perspective: energy transition as a manufacturing and supply chain challenge

Approaching decarbonisation as a materials and manufacturing challenge, rather than as a matter of reducing territorial emissions of greenhouse gases, introduces a different perspective. Conventional accounts of the UK's low carbon transition are centred on the achieved national emissions reductions (against a 1990 baseline) and on pathways for further emission reduction to reach net zero by 2050.

They focus primarily on the UK's energy infrastructure, highlighting for example, shifts in the nation's installed capacity for electricity generation. UKERC research acknowledges how this 'national' transition has had international spillovers – for example, in the geography of gas trade, in growing electricity interconnectors, the leakage of carbon through international trade in goods, and the capacity of the UK to leverage its leadership position (Climate Change Act, net zero) on the international stage. Aside from these notable exceptions, however, decarbonisation has been understood largely as a *national* project of transition in which international relations and geopolitics are a background context.[iv]

When the energy transition is seen as a materials and manufacturing challenge, however, two other geographical contexts come to the fore. These supplement the national focus of conventional research and policy on decarbonisation and brings different challenges into view. The first is the cross-border, globally integrated character of the UK's manufacturing and materials processing industries. Many UK manufacturers occupy a mid-stream position within international supply chains: they are simultaneously importers and exporters of goods with their commercial fortunes tied closely to actors and events outside of the UK. The UK economy is distinctive in its openness to foreign investment. The country's manufacturing and energy sectors include major multinational firms, many of them headquartered outside the UK and some owned by foreign governments. More generally, from this perspective the challenge for the UK is not only how to rapidly reduce territorial emissions (including industrial emissions from its manufacturing and materials processing sector) but how to secure macro-economic growth and prosperity in the context of a rapidly changing international political and economic landscape. From this perspective, then, national strategies around decarbonisation are not "*merely attempts to deal with the…climate crisis (but)… are also part of the struggle for global dominance*".[15]

The second distinctive context is the regional dimensions of the UK's manufacturing economy. 'Regional' here draws attention to both the formal devolution of some key

iv This national framing is underpinned by systems of carbon accounting pursuant to UNFCCC and reproduces framings of climate change and energy transition as a 'clean energy race' (cf. 'global battery race' or "the global race for critical minerals" (UK BEIS. 2022. Resilience for the Future: The UK's Critical Minerals Strategy, foreword. Access here.). Its focus on action within – rather than across – state borders, however, falls victim to what Agnew (1994) has termed a 'territorial trap' in relation to international political economy (see also Lachapelle et al., 2017. The Political economy of decarbonisation. Access here.).

responsibilities to the nations and regions which produces a differentiated and multi-layered administrative landscape; and the regional distribution of manufacturing capabilities that, in turn, reflect legacies of investment and divestment arising from a broadly neoliberal economic policy. It highlights, for example, the spatial distribution of manufacturing capacities (such as the way manufacturing is much less geographically concentrated than financial services) and the unevenness of manufacturing investment and employment across the UK. These regional dimensions of manufacturing have been a focal point of socio-economic research in the UK for decades in the context of multiple waves of industrial restructuring and globalisation.

The regional legacies of coal in the UK highlight the risk in transitioning away from fossil fuels of creating 'stranded communities' associated with carbon-heavy work (such as steel, cement and petrochemicals).[16] [17] More recently, the 'levelling up' policy agenda and a concern for so-called 'left-behind' places has highlighted the potential of green industries to disrupt prevailing geographies of inequality in the UK. UKERC research has long recognised there are local and regional aspects of national energy transition. Attention to the material and manufacturing dimensions of decarbonisation affirms the importance of this perspective, and to the opportunities for research at this interface (including, for example, local energy planning to accelerate net zero).[18]

Eroding globalisation: the return of national industrial strategy

The global background to the UK's energy transition is a structural transformation of the world economy that is reconfiguring global supply chains. The causes of this transformation are complex, but geographies of production at the world scale are being reshaped in the wake of the Covid-19 pandemic, ongoing wars in Ukraine and Gaza, and intensifying geopolitical tensions between the US and China.[v] [19] The pandemic exposed the vulnerabilities of relying on international supply chains for vital healthcare products and appliances. Government-ordained work stoppages and port closures disrupted trade in goods and materials for the energy transition and highlighted a "*need to closely monitor security of supply for certain minerals… essential for the energy transition, including cobalt, nickel and copper*".[20] The crisis in semiconductor supply, in particular, exposed how an outsourcing paradigm of flexible manufacturing – "*focused on economies of scale, short-term efficiencies, and just-in-time production*" – was vulnerable to shocks and undermined national economic resilience.[21]

Russia's invasion of Ukraine, and the sanctions that followed, underscored the UK's integration in global energy markets. The subsequent spike in global gas prices revealed the UK's reliance on gas to be a strategic vulnerability, highlighting the potential of low carbon transition to align security, affordability, and decarbonisation objectives. Israel's war in Gaza and its wider regional impact on the Red Sea, which has driven a redirection of LNG trade away from the Suez Canal, has similarly disrupted global gas market integration (e.g., by redirecting Asia-bound LNG from the US to Europe). And growing geopolitical tensions between the US and China – both keen to restructure global energy systems in a way which foregrounds their own material interests and economic strengths – are driving

v Several different lens for understanding these changes, from ongoing debate about deglobalisation and regionalisation of world economy, notions of technological sovereignty and technological rivalry, and associated ideas about a Second Cold War challenging the an 'open door' US-led international order (Schindler et al. 2023. The Second Cold War. Access here.) and the 'Great Green Wall'.

a fragmentation of global networks as firms seek to derisk – or are required by government to decouple from – their China-based supply chains. The UK's energy transition, then – and the nature of its manufacturing and supply chain challenge – is strongly shaped by a global context in which the "*great powers currently vie to shape the composition and geography of [global production networks] that they anticipate will underpin geopolitical power in the 21st century.*"[22]

A symptom and cause of this structural transformation is the 'return'[vi] of industrial policy to national economic agendas after several decades of globalisation.[23] The roots of this return lie not in the demands of low carbon transition but in the contradictions and failures of a neoliberal economic model, although industrial policy has "*almost always done double duty*" in managing macro-economic conditions and political objectives.[vii 24] However, China's success in moving up global value chains (in green energy, in particular), combined with dramatic cost reductions for solar and wind and growing rivalry for technological leadership between the US, China and Europe, lies behind the rapid growth of green industrial policy.[viii 25]

The US Inflation Reduction Act, and the EU's Green Deal are key examples of industrial policies that target strategically important products associated with energy transition

vi A 'return' because since the 1980s "liberalising top-down sectoral support was largely abandoned in favour of horizontal reforms liberalizing markets and improving regulatory approaches to competition" (McCann et al. 2023:1. Rebalancing UK regional and industrial policy post-Brexit and post-Covid-19: lessons learned and priorities for the future. Access here. The 2017 Industrial Strategy "*appeared to represent a major shift in national economic policy thinking towards a strategic approach to economic development, which for four decades have been largely eschewed by the central government*" (ibid: 2). This proved, however, to be short-lived.

vii The financial crisis (2008/9) weakened faith in liberal economic orthodoxy, creating new space for state intervention in the economy and driving a reappraisal in OECD economies about the role of strategic industrial policy. Access here; Allan and Nahm. 2024. Access here.

viii The resulting green industrial policies are diverse and "do not map easily onto theories that posit national economic policymaking traditions or those that build on statist–liberal categories" Allan and Nahm. 2024. Access here.

– such as batteries, electric vehicles and green hydrogen.[26] [27] Geopolitical considerations about security of supply and national security are a driver of these industrial policies, but they also explicitly identify manufacturing for the energy transition as the basis of long-term economic security and prosperity. Political and economic objectives, then, converge in industrial strategies for decarbonisation in novel and hybrid ways. State industrial strategies for decarbonisation, and the reshaping of global production networks for technologies and materials associated with the low carbon economy, are integral to "*rise of contemporary state capitalism, with its characteristic fusion of (geo-) political and economic logics.*" [ix] [28]

These shifts have been interpreted in epic spatial terms as, for example, 'deglobalisation' as global offshoring is replaced by regional onshoring, or as the emergence of a Second Cold War premised on centrality within economic networks rather than the formation of territorial blocs. Such sweeping claims aside, international supply chains persist and most examples of national onshoring driven by state policies relate to certain strategically important product categories rather than whole production networks.[29] [30] Even US efforts to stimulate the build out of an EV supply chain "*stretching from mines to the factory floor*" – via the IRA and Biden's 100% tax on Chinese EVs – include side deals making battery metals from countries like Canada and Australia eligible for support by the Defence Production Act.[31] As one commentator has observed, "*a limiting factor for the erosion of globalization is that no country can now depend on a national supply chain*" as, even for the US and China, the "*interconnections are too deep and the cost to build national alternatives to foreign suppliers is too great.*"[32] [x] The renaissance of industrial strategy, then, is not driving a wholesale 'deglobalisation' of low carbon supply chains. It is, however, creating more complex, multi-scalar production networks "*in which global outsourcing, regional production clusters, and locally concentrated operations are closely interrelated*".[33] [xi]

ix Allen and Nahm offer an interesting insight into how state's role changes depending on whether the goal is to build a supply chain or to integrate into existing supply chains: "*when governments seek to actively build domestic supply chains, they play an important role in sector-level technological and financial decisions. This is because establishing a whole ecosystem entails coordination across multiple firms and regions. By contrast, when the goal is to foster competition among domestic firms to help the strongest firms integrate into global supply chains, such decisions can be more easily delegated to the private sector.*"

x And Chinese firms adjusting their investment strategies, accordingly, investing in production in third countries with pre-existing Free Trade Agreements with the US (e.g., Morocco, Mexico, and Korea) in a move similar to strategy around solar to bypass US solar tariffs by rerouting into Southeast Asia; something the US Treasury's Foreign Entity of Concern ruling is meant to address.

xi Alami et al. note that how geopolitics and security are not the only shapers of global production networks: "*while the international division of labour and geography of advanced industrial production is increasingly shaped by great powers, this does not always mean that capital accumulation is subordinated to national security imperatives. On the contrary, decoupling is unfolding as states assume roles of entrepreneur and owner of capital, in addition to regulator, at unprecedented scale and scope*" (Schindler et al. 2023. Citing Alami and Dixon. 2023. Uneven and combined state capitalism. Environment and Planning A: Economy and Space. 55(1). Access here.).

Uk industrial strategy: a return after years of indifference? [34]

The UK has been an outlier in the OECD as the only member without a formal industrial strategy. There is some consistency here, however, as the UK has for several decades had an aversion to active industrial policy (see Box 1). Its approach has been "*ad-hoc and haphazard*" and characterised by "*regular cycles of new policy announcements that are often prematurely changed or rolled back*".[35] Industrial policy returned to the UK national agenda in the wake of the financial crisis of 2007/8.[36] The period of economic austerity that followed the financial crisis exacerbated profound spatial inequalities in the UK. Economic recession, concern around an over-reliance on finance and retail, and a perceived need to 'rebalance' the economy through state support for manufacturing, renewed government's interest in industrial policy. The regional politics of the Brexit vote in 2016 suggested the capacity of manufacturing for 'levelling up', given its much greater regional distribution than finance and the way "*manufacturing happens in different places to services, and many of these places have seen fewer benefits from growth in recent decades*".[37]

From this perspective, the 2017 Industrial Strategy – developed by Greg Clark (Secretary of State at BEIS) during Theresa May's government – represented a "*core response to the disaffection*" that triggered the decision to leave the EU.[38] A highwater mark of industrial strategy in recent years, the 2017 document identified five cross-sectoral targets for industrial policy as 'foundations of productivity' (ideas, people, infrastructure, business environment, places) and established an independent Industrial Strategy Council, headed by Andy Haldane of the Bank of England. It positioned the low carbon economy as a prime target for industrial strategy, identifying four 'grand challenges' including clean growth and the future of mobility and transport systems.

However, when Boris Johnson succeeded Theresa May as Prime Minster, the 2017 Industrial Strategy was replaced – initially by a narrative of *Green Industrial Revolution* (2020)[39] and, in the wake of the pandemic, a *Plan for Growth* (2021)[40]. Aiming to both spur economic recovery by 'building back better' and realise opportunities from Brexit, the plan centred on three objectives: levelling up the whole of the UK via funding to regenerate towns, plus introduction of freeports; facilitating the transition to net zero, through investment in clean energy; and supporting a vision for 'Global Britain,' via international cooperation and free trade. The Plan diverged from May's sectoral approach and identified "*three core pillars for growth*" that cross-cut specific sectors – infrastructure (investment in broadband, transport, and other infrastructure), skills (apprenticeships, lifetime skills guarantee, technical education reform) and innovation ('creative ideas' and technologies, funding for start-ups and scale-ups, pension investment reform). However, the Plan remained reluctant to involve government in the actual content of industrial activity.

Significantly, Johnson's government disbanded the Industrial Strategy Council which was replaced with a looser and more opaque organisation (the Build Back Better Business

Council) which ultimately became 'the Prime Minister's Business Council'. The Council brought together a group of leading British business leaders to discuss the main issues of the day, but its discussions were largely behind closed doors and it did not have the same independent monitoring role as the Industrial Strategy Council.[41] Under Sunak, industrial policy shifted still further away from a formal, written strategy to a series of statements on funding for specific sectors and industries. The Sunak government's stance was characterised by the Earl of Minto (Minister of State, Department for Business and Trade) in a statement in June 2023, in which he said government preferred a more targeted plan than the overarching industrial strategy of 2017.[42] This approach garnered some stern assessments from architects of the 2017 Industrial Strategy. Giles Wilkes, a former business advisor under Theresa May, characterised industrial strategy under Sunak as "*furtive, apologetic, or maybe surreptitious*".[43]

Box 1: A brief history of UK industrial policy

The 1960s marked the high point of post-war UK industrial strategy: in 1961 the Treasury approached the Chancellor and Cabinet with a report titled *Economic Growth and National Efficiency* and a suite of policy recommendations for managing UK industry with a view to fostering high rates of employment across the country. The report led to foundation of the National Economic Development Council and sparked a period of 'indicative planning' characterised by tightly coordinated government, business, and union interaction around fostering growth through industrial policymaking.[44] In this era "*industrial strategy was associated with a governing philosophy sceptical of free markets… the public sector owned swathes of industry, used budgets to fine-tune aggregate demand, and orchestrated wage and price agreements in grand bargains struck in Downing Street*".[45]

By the late 1960s and early 1970s, however, the balance of payments crisis and a changed international situation meant industrial policy centred around propping-up failing industries, either via nationalisation or via subsidy. This was government not so much 'picking winners' as 'backing losers.' These negative experiences of state intervention prepared the ground for the privatisation of state industries and shrinking of the state during the Thatcher administration from 1979 onwards and engendered a deep opposition to industrial strategy within the Treasury. The government of John Major, with Michael Heseltine as Secretary of State for Trade and Industry, reintroduced a role for the state in industrial questions but failed to develop significant policies. Expectations for a robust new industrial strategy from the Labour Government after 1997 gave way to a focus on financial markets. Some low-level, market-failure style interventions, with direct focus on supporting aerospace and defence industries, were supplemented in the later years of the Labour administration – under Peter Mandelson as Secretary of State for Trade and Industry – with a more direct industrial strategy that focussed on areas of growth, rather than just on market failure alleviation. The Coalition government, in which Vince Cable was Secretary of State for Business, Innovation and Skills, developed a stronger industrial strategy focussed on sectoral intervention in 11 key sectors, and establishing both the Advanced Manufacturing Supply Chain Initiative, and the Catapult centres. The Cameron/Osbourne administration that followed, however, focussed on deficit reduction and, while they increased the number of catapult centres, they also disbanded Labour's Regional Development Agencies (RDAs) and replaced them with Local Enterprise Partnerships that, while more geographically focused than RDAs, lacked funding and were "*unable to establish local coordination on training and product development.*"[46]

3. Characterising the challenge of decarbonisation for industrial strategy

In this section we characterise the low carbon challenge for UK manufacturing and industrial strategy, as highlighted through our conversations with UKERC researchers and with other organisations working at the nexus of industrial strategy and low carbon supply chains (see Section 1, Table 1). We consider what kind of low carbon manufacturing landscape the UK's arms-length approach to industrial strategy has produced over time, and we offer a brief snapshot of contemporary manufacturing production networks and material supply chains associated with energy transition. Where the previous section provided some historical and geographical context, this section outlines key features of the current situation in the UK and provides brief illustrative examples. By characterising the contemporary low carbon challenge for industrial strategy, this section lays the ground for a more detailed, forward-facing analysis that follows in Section 4.

3.1 Starting points: building on UKERC research

We focused our conversations with UKERC Phase 4 research Theme Leads – and with selected research and manufacturing bodies in the UK – on industrial and manufacturing aspects of the low carbon transition. Through these conversations we aimed (i) to gain an integrated understanding of how UKERC's research on the challenges of delivering energy transition might inform industrial strategy and low carbon supply chains; and (ii) to identify where and how this research intersected with broad thematic concerns (beyond UKERC) about low carbon manufacturing, industrial strategy, and supply chains in the UK.

Table 2 summarises these conversations schematically and identifies key points of intersection. Columns A – C summarise the focus and outcomes of research activity in UKERC Phase 4 by individual UKERC theme. Column D highlights areas where UKERC Phase 4 research intersects with concerns about low carbon manufacturing, industrial strategy and supply chains that emerged in our conversations. The nine themes listed in column D describe diverse aspects of the decarbonisation challenge for manufacturing, as expressed to us during the research, and is illustrative rather than exhaustive.

Table 2: how UKERC research can inform industrial strategy

Phase 4 Theme	Focus of UKERC Thematic Research	Research Outcomes Relevant to Industrial Strategy and Low Carbon Supply Chains	Cross-Cutting Themes in Relation to Manufacturing, Industrial Strategy and Supply Chains								
			Onshoring, friendshoring and re-scaling cross- border supply chains	Scope and content of UK industrial strategy	Technological innovation and commercialisation	National prosperity, productivity and economic resilience	Place and region: diversity, legacies, authority & responsibility	Jobs, skills and social inclusion	Materials strategy (including circular economy)	Societal and environmental impacts of manufacturing	Ownership and control of key industrial assets
Geopolitical Economy of Energy System Transformation	• Geopolitical consequences of patterns of supply and demand • Emerging global production networks for low carbon energy technologies • Consequences of decarbonisation for fossil fuel producing economies • Modelling global energy futures	• New energy systems are central to emerging and ongoing geopolitical tensions • Decarbonisation pathways rely not on linear supply-chains and simple material flows, but on complex global production networks.	●		●	●			●	●	●
Technology and Policy Assessment	• Systematic, rapid evidence reviews of contentious energy issues • Techno-economic approach to a wide range of projects including energy innovation, deployment and international comparisons • Focus on specific technologies and pathways (e.g. heat pumps, biomass) and cross-cutting issues (e.g. demand-side response, green jobs)	• Impact of critical mineral supply and material innovation on pathways for decarbonisation • An industrial strategy focussed on heat pumps can bring both domestic manufacture and installation to an industrial scale • Huge potential scale and scope of 'green job' generation	●	●	●			●	●	●	
Industrial Decarbonisation	• Future industry decarbonisation strategies • Detailed analyses of technologies, product outputs, and trade patterns • Infrastructural capacity issues • Cost of emissions reduction pathways for key industrial sectors • A whole-systems approach to industrial energy use beyond the major energy intensive sectors	• Importance of an industrial strategy for measuring and comparing decarbonisation pathways • Cluster-focussed approach downplays decarbonisation needs of dispersed sites • Foundational industries must be given a role in transition plans • Limits on ability of supply chains to scale to meet demand	●	●	●		●				

Phase 4 Theme	Focus of UKERC Thematic Research	Research Outcomes Relevant to Industrial Strategy and Low Carbon Supply Chains	Cross-Cutting Themes in Relation to Manufacturing, Industrial Strategy and Supply Chains								
			Onshoring, friendshoring and re-scaling cross- border supply chains	Scope and content of UK industrial strategy	Technological innovation and commercialisation	National prosperity, productivity and economic resilience	Place and region: diversity, legacies, authority & responsibility	Jobs, skills and social inclusion	Materials strategy (including circular economy)	Societal and environmental impacts of manufacturing	Ownership and control of key industrial assets
Energy Systems for Heat	• Heat decarbonisation pathways. • Localised and district heating systems • Interfaces between heat and other energy vectors • Modelling of different heat scenarios on physical network constraints	• Extensive benefits of developing integrated heating systems and interfaces between heating and other energy vectors. • Scale of heating system changes brings governance challenges • Heating system relies on scaling physical infrastructure capacities	●	●	●		●			●	●
Mobility	• Readiness of the grid for EVs • Planning and governance of grid connections for new housing • Air quality and ecosystem impacts of transport electrification • Local energy and mobility transitions • Aviation and shipping transitions • Global battery and vehicle supply chains	• Introduction of new fuels has major implications for transmission infrastructure and supply chains • The health and environmental outcomes of transportation electrification need to be centred in development plans • Spatial patterns of EV uptake and impact on grid capacity require rigorous planning processes	●	●	●		●			●	
Energy, Environment and Landscapes	• Environmental impacts of renewable energy developments using ecosystem service and natural capital approaches • Spatial and economic modelling tools to help decision-makers take a whole-systems perspective on renewable planning issues	• Significant biodiversity and natural capital improvements can be gained at minimum cost with considered spatial planning • Environmental issues have been downgraded in policy documents in recent years • A 'narrow' approach to renewable development can generate myriad new problems					●			●	
Energy Infrastructure Transitions	• Infrastructural development challenges • Financial and regulatory aspects of infrastructural development • Public attitudes on heat decarbonisation • Energy price design – e.g. Locational Marginal Pricing • Impact of energy infrastructure changes on resilience of supply	• Lack of intergovernmental cohesion on infrastructural planning issues and systemic failures in attracting investment • International price differentials of industrial electricity and implications for UK manufacturing				●				●	●

Table 2 shows where existing UKERC research (which has been orientated, for the most part, towards the problem of emission reduction) can inform ongoing debates about the challenge of decarbonisation for manufacturing and industrial strategy. It also outlines some of the core issues a green industrial strategy needs to address. To build on this foundation, we highlight three features of the contemporary UK manufacturing and the industrial policy landscape that shape the space for a green industrial strategy: the scope of industrial policy; the structure of the manufacturing base; and the particularities of place. We briefly review each of these in turn as they provide a foundation for the analysis in Section 4.

The UK needs a comprehensive industrial strategy

Chop and change have long been a feature of industrial policy in the UK and something many respondents identified when we spoke to them. The dynamism of the industrial policy landscape in the UK, however, contrasts with the absence of comprehensive strategy. Multiple policies and periodic sources of funding have favoured sectoral initiatives or promoted specific interventions to support productivity or achieve emissions targets, but they have not added up to a comprehensive strategy. The formal yet fleeting return of strategy under Theresa May was not only short-lived but limited by its sectoral orientation. More recently, as Giles Wilkes observes, dissolution of the independent Industrial Strategy Council and the renaming of the Department of Business and Industrial Strategy highlights

the way comprehensive strategy has not been favoured by recent administrations. By and large strategy has been by default rather than design, an aggregate of narrowly constituted national policies and actions by devolved administrations.[xii]

The 'return' of industrial strategy elsewhere, however, ups the stakes. The scope, scale, and longevity of initiatives like the US IRA and EU Green Deal highlight the degree to which government intervention is restructuring global networks of production (examples include UK research and manufacturing businesses being enticed to relocate to Europe or the US). With its smaller economy, narrower manufacturing base and fiscal constraints, the UK cannot replicate these initiatives wholesale.[47] However, US and EU initiatives substantially increase the importance to the UK of having a comprehensive industrial strategy – i.e. one that goes beyond the scope of the UK's industrial decarbonisation strategy which aims to deliver net zero emissions from carbon-heavy industry. The UK also needs a green industrial strategy aimed at transforming manufacturing – i.e. creating an industrial base in the UK for a low carbon economy and, in the process, capturing the long-term opportunities of the energy transition. Moreover, the UK needs an overarching industrial strategy that informs and connects the specific project of industrial decarbonisation to the wider challenge of manufacturing transformation.

Reckoning with the structure of UK manufacturing

The UK's long history of manufacturing, and experience with multiple waves of deindustrialisation, means the country's manufacturing base is now concentrated in specific sectors, technologically specialised, and integrated into international supply chains through the outsourcing of materials and components, and via export of finished goods. Many UK manufacturers occupy a 'mid-supply chain' position, meaning they both import materials and components and export intermediate goods and final products. This exposes them to significant changes in the international trading environment, including the UK's exit from the EU and uncertainty around the international rules-based trading environment managed by the World Trade Organization. A mid-supply chain position also means that volatility and resilience in the supply chain has both import and export sides. This is important, because an industrial strategy based on 'onshoring' supply chains and decoupling from key external suppliers can have consequences for market access for finished products.

In terms of the technologies and infrastructures required to deliver the energy transition (e.g. offshore wind, battery energy storage, heat pumps), UK manufacturing presents a mixed picture. Research, development, and innovation (RD&I) capacities, for example, are greater in some areas of decarbonisation, but not in others. They are relatively strong in battery technology, for example, and aspects of offshore wind – such as floating wind, servicing, and blade technologies – but weaker in areas such as integrated heat and material circularity. And while the UK may have good RD&I in relation to electro-chemical energy storage, it has very limited bulk manufacturing capacity in areas like cathode production, cell manufacturing and battery assembly. Where there is bulk manufacturing capacity in the UK – such as around components of offshore wind and EVs – these manufacturing processes are foreign owned and/or externally controlled. Box 2 sketches how some of these issues have unfolded in relation to lithium-ion batteries in the UK.

xii While it is possible to read across multiple policy initiatives at national and regional level and discern an overall approach, this is not the same as an explicit strategy (see also *Box 3*). This form of industrial policy has been characterised as a choice between "industrial strategy by default or design" (Vince Cable quoted in Wilkes 2020:12. How to design a successful industrial strategy. Access here).

This differentiation by technological pathway stems, in part, from the lack of a systematic and coordinated approach to industrial policy over several decades. It relates also to the relative openness of the UK economy to cross-border flows of trade and investment; and to the reluctance of government to maintain a role for foundational industries in the economy as a whole. Since the privatisations of the 1980s, the UK state has not held large equity stakes in manufacturing but has, instead, preferred to adopt an arms-length relationship with manufacturers, allowing the market to determine technological trajectories and commercial outcomes. Many foundational industries have been 'let go' because of the availability of cheaper global supply chains. The capacity to refine metals in the UK, for example, has reduced markedly in the last twenty years with the closure, for example, of the last copper smelter (James Bridge in Walsall in 1999), last zinc smelter (Britannia at Avonmouth in 2002) and the Anglesey (2009) and Lynemouth (2012) aluminium smelters.[48] Closures in the UK steel industry offer a parallel example and one that is continuing to unfold.[49] The openness of the UK economy, and liberal rules around corporate control, mean that – after decades of neoliberal investment policy – much UK manufacturing capacity is foreign owned and externally controlled. Key decisions on capacity, strategy and the supply chain are often not made at the level of the UK. Some manufacturing facilities important to the energy transition have characteristics reminiscent of classic 'branch-plants:' strategic decisions are made outside the UK, technology and materials sourcing use global supply chains (for reasons of quality and cost), and they present limited opportunities for building UK supply chains.[50]

A range of crises – from the pandemic and the war in Ukraine to the prospect of losing mass market automotive production – have exposed the consequences of historic approaches to industrial strategy in the UK. These have produced a mixed landscape of technological development, a pattern of technological specialisation with limited capacities in bulk manufacturing and foundational industries, and ownership structures that mean many key assets for the low carbon economy are externally controlled. This is the state-of-play with which future industrial strategy for energy transition needs to come to terms.

The particularities of place are becoming increasingly important

This next phase of the energy transition – particularly around the 'deep decarbonisation' associated with heat and mobility – will require engaging the complex geographies of the UK more intensively than has been the case with the power sector. The turn to 'place-based' policy acknowledges the reality of spatial difference and the need, for example, to address regional disparities in wages, livelihood chances and employment rates. Place-based policy also focuses on the local determinants of macro-economic performance, and how particularities of place can be leveraged to drive better socio-economic outcomes. Recognising, responding to, and working effectively with the specificities of place in the context of decarbonisation has a range of implications. It will, for example, require flexibility in decarbonisation pathways and adapting strategy to spatial context. In relation to manufacturing, in particular, the diverse geographies of the UK also offer opportunities for innovation and novel solutions, and for collaborative combinations of regional advantage. Working effectively with these spatial differences requires coordinating action via a multi-scalar constellation of political institutions.

Box 2: Building the UK's lithium-ion battery supply chain[51]

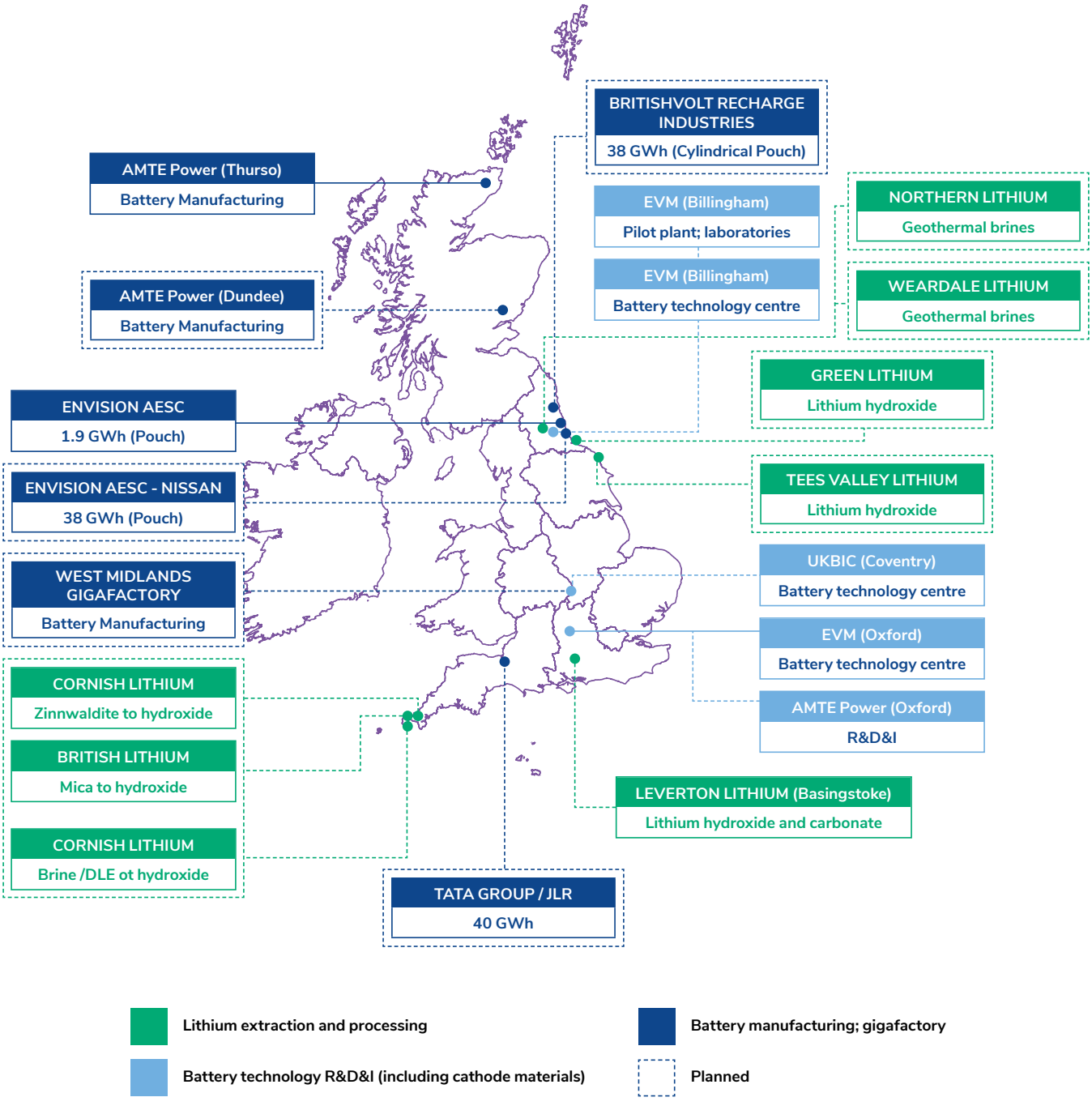
Like the US, EU and several other countries, the UK is seeking to develop a national battery supply chain. This is less about a global race to counter China, however, and more about securing the UK's role as an automobile manufacturing platform. The phase out of ICEs, and local content requirements embedded in the EU-UK Trade and Co-operation Agreement that followed Brexit, are driving a localisation of battery production along with much of the battery supply chain.[xiii] The UK has a history of battery R&D but, without bulk domestic battery production, car manufacturers may decide that producing EVs in the UK is not viable and relocate production to the EU.[52] Battery and automotive interests have argued vigorously for building gigafactories at speed in the UK. Tata's announcement (June 2023) of a large battery facility in Somerset, six months after the insolvency of Britishvolt, was welcomed by the UK car industry. At the same time, established 'home-grown' battery research – anchored in the UK's Universities, research organisations and long-standing battery technology developers – has had to reckon with the urgency of commercialising and scaling battery production for the automotive sector.

Policy efforts have focused on converging two distinct political economies and areas of policy – battery science and industrial manufacturing. The Faraday Battery Challenge is an example of how government has deployed elements of research policy and industrial policy in an effort to assemble discrete capacities into a national battery sector. These include battery manufacturing, battery research and development, and critical minerals expertise and finance. Launched in 2017 with a government investment of £330 million over 5 years, the FBC provides scientific, technology development and manufacturing scale-up capability with a goal of "*ensur[ing] the UK leads the world in the design, development and manufacture of batteries for the electrification of vehicles.*" [53]

Efforts to develop a domestic battery supply chain are, in practice, embedding the UK in wider geographies of lithium mining and refining, battery chemical production, technology development and finance (Figure 2). Thus, the UK's emerging supply chains for battery manufacturing are globally connected in ways that confound simplistic claims of 'onshoring' production or 'deglobalisation.' They span Australian hard rock lithium mining and refining, US finance capital, Saudi Arabian chemicals production, and Chinese-based battery producers. For example, the Envision Group – a privately-owned renewables energy firm registered in Shanghai – is central to the UK's efforts to grow battery manufacturing capacity (via its 80% stake in Envision-AESC). With a role in Nissan's Sunderland plant and reported involvement with Tata/JLR in Somerset, Envision-AESC will account for around 70 GW of UK production capacity – around 70% of the estimated demand from the UK car industry by 2030. The UK's battery manufacturing capacity, in other words, will be closely tied to the global strategy of this China-based company.

xiii This need is particularly acute, as the EU is pursuing its own "*active industrial policy when it comes to the EV supply chain, in an attempt to make the EU into one of the main EV production centres in the world*" (Bailey and Rajic 2022: 26. Manufacturing after Brexit. Access here.).

Figure 2: Key components of the UK's battery landscape



(Source: Bridge and Faigen, 2023a)

3.2 Defining the space for a green industrial strategy

The top-line objectives for a UK green industrial strategy should be:

- to transform the UK's manufacturing and materials sector by capturing the economic upsides of decarbonisation (within the UK and beyond), and developing the industrial base for a prosperous and resilient low carbon economy;
- to accelerate progress towards net zero by developing, making and deploying technologies and materials for decarbonisation at pace and scale, and by enhancing material circularity and resource efficiency;
- and to achieve these goals in the context of a rapidly changing international political and economic landscape in which established global supply chains are being disrupted, in part, by industrial policies adopted by economic rivals.

The UK has yet to rise to the challenge of structural transformation in the world economy and the economic opportunities of energy transition. Specifically, it has lacked the cross-sectoral coordination, short and long-term prioritisation, and continuity of support a strategy could provide. While the UK should not aim to match other national initiatives directly, cross-sectoral coordination and prioritisation are needed, based on an assessment of future economic opportunity, existing industrial capability, and supply chain considerations.[54] Cross-sectoral support is important because low carbon industries are fundamentally changing the nature of existing sectors: the shift to EVs in the auto industry, for example, is combining battery production and auto production in novel ways that sit uneasily with sector focussed forms of support.[55] [56] In this context, a goal of industrial strategy is to "*leverag[e]... diverse capabilities in new and innovative ways.*"[57] From this perspective, net zero represents "*a generational opportunity for the UK to rebuild the diversity of its manufacturing strengths while paving the way to a more sustainable era of prosperity.*"[58]

Recent analysis by the IPPR identifies the coordinating space – above and beyond specific policies – that an industrial strategy should occupy. It highlights the value of a "*pathfinder*" approach to green industrial strategy that recognises "*the constraints placed on our economy by path dependencies – our economic history and current productive capabilities (but...) also acknowledges that there are still many possible paths we could take for the future, depending on choices we make today.*" It identifies three immediate priority areas for UK manufacturing – heat pumps, wind and green transport – along with a need to "*retain and decarbonise foundational manufacturing*" such as steel and other metals, concrete and glass because "*retaining and greening these industries will minimise the emissions we import and maintain thousands of jobs in the UK*".[59]

Development of an industrial strategy for energy transition (see Box 3) needs also to recognise regional dynamics and address geographic inequalities in the UK. These regional dimensions are a prominent feature of the UK policy landscape, not least in relation to manufacturing and the legacies of deindustrialisation, which is tightly enmeshed with problems of regional inequality. The UK has some of the *highest interregional inequalities in productivity among major industrialised countries*.[60] Although emanating from a complex history, this can largely be attributed to decisions taken in the late 1970s and throughout the 1980s to shrink the industrial and manufacturing base, and focus instead on service and financial businesses located in London and the South East of England.

Policy interventions of late which have tried to tackle this issue of regional inequality have included a variety of approaches blending

industrial and regional policy. Prominent examples include the 'Levelling Up' agenda[61], the 'Northern Powerhouse' measures[62], the 'Midlands Engine'[63], Local Industrial Strategies[64], City Deals[65], and greater devolution to English regions through a raft of Regional and City mayors and Mayoral Combined Authorities.[66] While these policies recognise certain interfaces between industrial and regional policy, they often mistake correlation for causation or fail to explain how place-based industrial policy might alleviate regional inequalities.[67] This suite of regional interventions in the industrial policy sphere – many associated with the 2017 Industrial Strategy – were challenged at the time on a number of grounds,[xiv 68 69] and more recent analyses have found widespread failures in meeting intended outcomes.[70 71 72]

Box 3: Defining industrial strategy

Underlying discussions about an appropriate government approach to handling affairs of industry is the question of what actually constitutes industrial policy, and how this might be distinct from industrial strategy. Coyle and Muhtar propose a definition of industrial policy as follows: "*In the context of developed economies, industrial policies are often used with the intention to induce structural or industrial upgrading – that is, to enable and assist the creation of new value-generating activities and product spaces in the economy, as well as better and more efficient production techniques (by utilising relevant scientific and technological advancements).*"[73]

This definition is broad enough to encompass a wide variety of various UK governments' interventions in the industrial space. However, many would argue that the diverse iterations of industrial policy mentioned above do not constitute a strategy because they lack certain key elements – namely, a level of coordination between government and industry which would identify common concerns and goals, in the context of specific long-term economic targets, and the proposal of a set tools required to meet those goals.[74 75]

Various organisations that we spoke to as part of this research voiced similar concerns about the form and purpose of industrial strategy in the UK. MakeUK, for example, recently called for an industrial strategy which prioritises identifying and supporting a broad, cross-sectoral industrial vision, moving away from industrial policy of the past which primarily sought to prop-up industries facing economic difficulty – an industrial strategy foregrounding coordination, with an emphasis not on deficit, but on growth.[76] Similarly, the 2024 RenewableUK Manifesto[77], while calling for inter-governmental and inter-departmental coordination around renewable industrial development, also emphasised the importance of long-term targets around which industry could design and implement development plans.

In a similar vein, the IPPR provide a useful definition: "*Critically, industrial strategy must be more than just a collection of 'supply side' economic policies in areas such as infrastructure, skills, research and development, land use planning, competition, business taxation, regional economic development and export promotion. Industrial strategy must mean the overall coordination of these fields, aimed at a clear set of objectives or purposes.*"[78]

xiv Criticisms included lack of novelty in policy, insufficient funding to accompany the expected transformations, and centring on spaces (such as clusters) which were already relatively economically sound.

4. Key findings

This integration project reframes the low carbon transition as a manufacturing and materials challenge. Our research identifies several key findings about the UK manufacturing and industrial policy landscape from the perspective of furthering energy transition and capturing the economic upsides of low carbon economy. Some of these align with general critiques of UK industrial strategy and strategic support for manufacturing, although we focus here on particular intersections with energy transition. We identify seven areas of concern that speak to the ability of the UK to respond to new low carbon manufacturing demands.

4.1 Strategic response to decarbonisation requires a manufacturing transformation, not only industrial emissions reduction

The UK's approach to industrial decarbonisation misdiagnoses decarbonisation as a discrete problem of emissions reduction, rather than a systemic challenge of wholesale economic transformation. The UK's Industrial Decarbonisation Strategy[79] is an important tool for meeting the net zero objectives of the Sixth Carbon Budget, but is insufficient as a response to the manufacturing and supply chain challenge posed by decarbonisation.[xv] The absence of a comprehensive industrial strategy that understands how decarbonisation is changing the international 'rules of the game' and establishing a new international competitive terrain with significant geopolitical and strategic implications, has limited the ambition of UK industrial decarbonisation to reducing emissions from existing industries. Strategy has aimed to keep as much of the industrial make-up of the UK as intact as possible and aspired to a frictionless model of transition. What has been missing is wider consideration of how energy transition changes the economic potential or strategic value of existing assets, or how a more transformative approach to decarbonisation might encourage new arrangements of technology, finance, and infrastructure that enhance macro-economic performance.

Industrial decarbonisation lacks direction without an overarching industrial strategy. The macro-economic goals of industrial decarbonisation are unclear and efforts at decarbonising specific industrial clusters are disconnected from the broad industrial objectives of the UK in the context of geopolitical landscape and global production networks. For example, government agreed financial support for electric-arc furnaces to produce green steel but has given little indication of the role this steel will play within domestic demand (e.g. how it may use procurement and regulation to support a market for UK-made green steel) or the export potential of UK green steel (which will depend, in part, on the international standards agreed for low carbon steel). UKERC researchers have urged greater ambition from industrial strategy beyond decarbonising the UK's industrial clusters. This includes highlighting needs for research, development and demonstrating support around breakthrough technologies

xv Foundational industries represent around 14% of UK territorial emissions, of which 86% are from fuel combustion associated with high- and low-grade heat, drying/separation, space heating and on-site electricity generation (UKERC 2023. Review of Energy Policy). Access here.

and wider low carbon infrastructure, as well as and drawing attention to the importance of market creation for products made via low carbon production processes. [80] [81] The abandonment of May's Industrial Strategy and its replacement with the 'Plan for Growth' removed the former's limited efforts at inter-sectoral coordination and sense of future vision which showed, albeit in a constrained way, how industries might work towards specific goals.

As an example, an overarching green industrial strategy would encompass a national materials strategy that builds upon the UK Critical Minerals Strategy.[82] It would consider what material requirements the UK currently has, and how to source them or recycle them. Without such a strategy, many companies shy away from recycling and prefer to just sell-off scrap, much of which is exported. Around 40% of annual consumption of aluminium is exported as scrap, for example, despite a UK infrastructure for dealing with that material; and in steel there are opportunities to recycle/reuse without having to go through the heat-intensive recasting phase. New thinking is required to maintain value-added manufacturing and materials in the UK. A materials component of industrial strategy would, for example, assess the 'stock' of materials currently in use and the 'afterlives' of these materials when scrapped, the potential for retaining value-added materials in the UK via a circular economy of materials refurbishment and reprocessing, and the infrastructural requirements (reprocessing facilities, recycling logistics) needed for materials to re-enter supply chains.

For example, advanced manufacturing has been a target of UK industrial policy (e.g. the Plan for Growth) but not in a way that highlights its material synergies and dependencies on 'foundational' industries – such as steel, metals processing, ceramics and glass. Many of these foundational industries are a focus of industrial decarbonisation strategy given their dependence on high temperature processes, but this is largely separate from a consideration of their role in the (future) UK materials economy and the strategic value of maintaining material reprocessing capabilities in the UK. One context for the value of retaining domestic capabilities in this area is the government's plan to raise defence spending to 2.5% of GDP, and the physical security of having a national capacity to produce key materials (such as facilities for converting iron to steel).[xvi] [83] Developing a more robust materials recycling sector would retain added value (from initial mining, refining and processing) in the UK and improve the UK's position on Rules of Origin requirements. However, this requires coordination and a cross-sectoral view that considers, for example, materials for aerospace, automotive, construction etc.[84] Organising circular battery flows, for example, is complex: the specificity of batteries to different EV producers, IP protections around battery technology, low value components, limited end-of-life supply (to date), and logistical issues associated with battery collection make realising circularity challenging. A clear materials strategy would support circularity, most likely in collaboration with a large material processor with the capacity to manage multiple sources of supply and extensive market networks, and with chemicals manufacturers able to handle battery materials (like electrolytes) which cannot currently be recycled.

A green industrial strategy would establish key timeframes, identify decision points and enable continuity of objectives geared to the challenge of manufacturing transformation

xvi Closure of the UK's remaining blast furnaces (Scunthorpe and Port Talbot) has raised concern that it leaves the UK without facilities for converting iron to steel (and reportedly the only country in the G7 without such capacity). These strategic concerns are in play around the choice of decarbonisation pathway for steel: proposed investments in electric arc furnaces fed by scrap steel, versus the alternative pathway of direct reduction of iron using hydrogen.

(as distinct from emissions reduction from existing facilities). For the most part, low carbon industry targets are derived from net zero legislation and carbon budgets, some of which are relatively short-term. UK targets for offshore wind, hydrogen, and Scottish onshore wind, for example, only run up until 2030.[85] An industrial strategy that considers decarbonisation in the round – as a source of macro-economic opportunity and manufacturing renewal – would recognise how time horizons for achieving manufacturing transformation (i.e. development of net zero manufacturing with export potential) are different to those for emission reduction (derived from net zero legislation and carbon budgets). Their goal is to provide the clarity, certainty, consistency and continuity of policy required to unlock investment; to enable long-term skills development for the green economy via education and training; and to support planning and construction of necessary manufacturing infrastructure.[86] The Skidmore Review, for example, recommended a long-term R&D and technology roadmap and 10-year demonstrator projects (i.e. running beyond 2030 decarbonisation targets). The benefit of extended timescales is already evident in the research community, for example, with the goal of realising benefits beyond the immediate goals of policy. A green industrial strategy needs to accommodate these longer term horizons for manufacturing transformation, alongside more immediate national goals for emission reduction and the build-out of renewable infrastructure.

4.2 Decarbonisation's twin challenges require 'make or buy' decisions

A central insight from this project is that decarbonisation presents a twin manufacturing challenge for the UK. On the one hand, the need to deliver at pace on the country's net zero commitments requires scaling the deployment of technologies and materials across a wide range of sectors, from mobility and heating to transport and infrastructure. On the other, decarbonisation is changing the rules of the game around international economic competition in ways that are potentially transformative for UK manufacturing. There are tensions and trade-offs between these two objectives that a comprehensive industrial strategy will need to address. For example, The CCC has indicated the UK is off-track to meeting its medium-term targets under the Climate Change Act and advised that it "*push forward strongly with new low carbon industries.*"[87] But delivering at pace on decarbonisation may require importing finished products and materials rather than the more protracted and uncertain process of developing domestic sources of supply. Conversely, nurturing future areas with export potential by supporting domestic producers (e.g. by requiring locally produced goods and materials in supply chains) may increase costs of decarbonisation.[88] Both routes have geopolitical implications. A rapid delivery plan based on imported materials and technologies at lowest cost would require an accommodation with China (as a key source of supply) that is likely to fall foul of US policies.

A strong stance on building domestic capability and requiring local content via a 'Buy British' procurement policy could run up against WTO rules and spur retaliatory restrictions in key export markets for the UK.[89]

Industrial strategy for decarbonisation, then, confronts a national version of the 'make or buy' decision familiar to most manufacturing firms – i.e. whether to manufacture a product domestically or outsource production to (international) supply chains. The long-term strategic value of green manufacturing to the UK means these decisions are not purely about a comparison of the costs of emission reduction in the short term, but need also to take account of future potential, the possibilities for innovation and recombination of existing capacities, and the strategic value of industrial assets.

Strategy should aim to 'make' materials and goods where the UK has high ability to compete internationally, and where manufacturers can build themselves into future global supply chains as significant contributors to global decarbonisation. In some cases this will already be evident, but strategic analysis will also be required to identify specialised areas of UK manufacturing that can be nurtured over time to build net zero capabilities. For example, a make-or-buy analysis conducted by RenewableUK for offshore wind indicates competitive capabilities in the manufacture of blades, industrial foundations, composite towers, turbine drive trains and offshore export cables. A strategic decision to 'buy,' on the other hand, applies to areas of low domestic manufacturing capability, as well as goods and materials with low market value (so there is limited lost value from importing) – in the wind sector this includes areas like nacelle assembly and turbine electrical systems. Additionally, it may be strategic to protect areas of manufacturing that have an ability to compete internationality but where (currently) there is low market opportunity, or where assets perform key roles in enabling other parts of the supply chain. Examples in wind include monopile foundation manufacturing and wind turbine installation equipment.[90]

'Make-or-buy' highlights a key tension arising from the twin challenges of decarbonisation that UK industrial strategy must navigate. Practice is far muddier, however, than the coolly calculative decision the phrase suggests. For example, a 'make' decision must contend with structural challenges around UK manufacturing that extend well beyond net zero. The long-standing problem of under-investment in UK manufacturing (exacerbated by a flight of investment from equities), the dominance of finance in the economy, high energy costs (see 4.6), and barriers and costs associated with EU-UK trade and Cooperation agreement following Brexit, are substantial complications to the transformation of manufacturing. There are also challenges around the infamous 'valley of death' associated with technology commercialisation. The UK has a long-standing record of technological innovation in several low carbon areas – notably in relation to batteries and wind – and recent rounds of industrial policy have secured investment in testing and demonstration facilities (e.g. at Blyth and OREC for wind, and in the UK Battery Industrialisation Centre).[xvii] Yet the UK continues to struggle to nurture technologies from early TRLs through to development, demonstration and qualification – and "*further action is required to ensure there is the long-term conversion of British intellectual property into globally deployed innovations.*"[91]

xvii Technological development and commercialisation can both reduce supply chain risk in domestic markets and open future export potential, such as UK research and development around the manufacture of permanent magnets (for use in wind turbines) that do not use rare earth elements.

4.3 Supply chains are evolving as they scale, introducing new risks and challenges

The next phase of energy transition requires rapidly scaling up deployment of low carbon technologies and infrastructures for heating and mobility, as well as further build out of renewables in the power sector. Scaling deployment has focussed concern on the capacity of supply chains to provide the materials and manufactured goods required for different energy transition pathways, and on the dependence of the UK on cross-border flows. This has drawn attention to questions of 'supply chain security' around the availability of materials and potential supply bottlenecks, such as important assessments of 'criticality' in relation to particular minerals. UKERC research shows the supply chain challenge is broader than narrow questions of security of supply and reflects wider dynamics in global production networks, such as strategies of innovation, competition and control. Research highlights, for example, questions of technological risk, carbon leakage, ESG concerns, and ownership and control.

Technologies (rather than fuels) are central to decarbonisation and there are risks associated with rapid technological change. In the battery sector, for example, there have been significant shifts in battery chemistries over short time scales. UKERC research highlights the risks associated with rapid technological change. In the early 2010s numerous studies of energy futures predicted that thin-film solar PV based on cadmium-telluride technology would form an increasingly significant proportion of emerging solar energy systems – some estimates suggested cadmium-telluride based solar PV could make up 30-40% of the PV market by 2020. This led to concerns amongst resource analysts that tellurium supply and production would fall far short of demand and undermine the development of this emerging technology. In the proceeding years, however, huge cost efficiencies in crystalline-silicon PV have led to its dominance as a solar technology, with cadmium-telluride thin-film PV only occupying a 5% (and falling) share of the market.[92]

Cross border supply chains are increasingly structured by relative energy and carbon costs, in addition to long-standing considerations of the cost of labour. The uneven pace of decarbonisation globally means that countries and regions who are decarbonising face the risk of 'carbon leakage' via their material supply chains. This risk arises because domestic industries facing stringent emissions regulations have a cost incentive to shift carbon-intensive parts of the supply chain to countries with weaker climate policies (often in combination with other cost factors, such as energy prices and labour costs). Carbon tariffs – like the Carbon Border Adjustment Mechanism legislated as part of the European Green Deal and taking effect from 2026 – are a way to protect domestic industries and reduce carbon leakage from carbon intensive imports. The proposed UK Carbon Levy similarly intends to target carbon-intensive industrial goods imported to the UK in sectors like aluminium, cement, ceramics, fertiliser, iron and steel. There is an important role here for analytical methods to research and track embodied carbon, such as UK research capacities around carbon footprints and environmentally extended input-output modelling.

An insight from UKERC work is that scaling up is not a simple market pull, in which a linear supply chain expands in scale and locations. Rather, the supply chain is transforming as it scales introducing new risks and challenges. In relation to lithium-ion batteries, for example, the scaling up of EV production is associated with a convergence of battery production with automobile manufacturing, vertical integration along the battery mineral material chain, and efforts by states to converge battery R&D and industrial policy.[93] As battery production scales, therefore, the 'supply chain' is evolving into a production network – an organisational and geographical structure linking actors in different regional and national economies, who compete and cooperate for a share of value creation, transformation, and capture. These organisational structures increasingly shape the UK's ability to transform its manufacturing capacity. An example is the ownership of UK manufacturing assets and the way these assets are incorporated into international corporate and financial networks of production and control. The relatively open nature of the UK economy means that, after decades of neoliberal investment policy, much UK manufacturing capacity is externally owned and controlled and of the 'branch-plant' type. The UK state has not taken an equity stake in manufacturing but has, instead, preferred to adopt an arms-length relationship with manufacturers and allowed the market to determine technological trajectories and commercial outcomes. As a consequence, key decisions on capacity and strategy are often not made at the level of the UK.

4.4 Scaling decarbonisation requires plural technological pathways tailored to place

A green industrial strategy needs to allow for a diversity of decarbonisation pathways if it is to accelerate the next phase of decarbonisation and capture macro-economic benefit from the low carbon economy. A plurality of pathways enables solutions to be tailored to the demands of place in ways not possible when policy favours single technological solutions. Different geographies also present varied techno-economic opportunities for innovation and development and may require novel arrangements of research, finance, and infrastructure – i.e. they can generate potential upsides to decarbonisation that are occluded when policy promotes a single national solution. Devolving responsibility for decarbonisation pathways can help identify solutions that speak to regional industrial legacies and the requirements of place. Importantly, however, there remains a central role for strategic coordination to identify commonalities and shared goals, prevent

duplication (e.g. around technology trials), and navigate and resolve broader structural challenges.

UKERC research on energy systems for heat, for example, underlines the need for new low carbon energy systems to take account of already existing regional infrastructures. This may mean, for example, that in high-density urban areas district heating systems offer the most appropriate and efficient solution, while areas that host heavy industrial activity can make use of waste heat or share electricity generation capacities. Similarly, UKERC research on energy mobility shows how, by adopting a plurality of interventions rather than a single solution, transport systems can be designed to reflect local needs. For example, electrified public transport serves high population urban areas but can be supplemented by developing EV charging infrastructures and providing support for active travel.

UKERC's industrial decarbonisation research spotlights the role for plural decarbonisation pathways. It shows how a policy focus on industrial clusters ends up sidelining the 50% of industrial emissions associated with smaller, dispersed industrial sites located all around the country (something considered – albeit in a piecemeal fashion – by the recent Local Industrial Decarbonisation Plans competition, which provides support for industrial manufacturers not located within the UK's existing industrial clusters). The UK's industrial decarbonisation strategy expects industrial facilities within industrial clusters to convert to hydrogen as a fuel source and sequester carbon via CCS. Targeting hydrogen and CCS as the primary national pathway for industrial decarbonisation makes most sense in a future where there is growing demand for hydrogen outside of industrial applications – e.g. in domestic heating systems and as a fuel for transport. The focus on hydrogen, however, has tended to under-represent the complexity of decarbonising industry beyond the clusters. Decarbonisation pathways for non-clustered sites remain vague by comparison, and piped links from dispersed sites to cluster-based hydrogen and CCS facilities could be prohibitively costly in many cases. Moreover, the limited policy attention and funding given to alternatives potentially forecloses solutions that may be more tailored to place and which, over time, open avenues for technological specialisation and transformation. Rather than a single pathway, UKERC research shows that decarbonisation of industrial sectors is likely to require a "*combination of bespoke technologies that rely on electrification, fuel switching to hydrogen and biomass, carbon capture and storage (CCS) technologies, novel processes, and resources and energy efficiency options.*"[94] [95]

4.5 Regional diversity is a national asset, but realising its full potential requires strategy by design rather than default

Manufacturing in the UK has a broad regional expression – a legacy of multiple previous waves of industrialisation – and is much less geographically concentrated than financial services, which are dominated by London and the southeast of England. Although manufacturing employment in the UK's post-industrial regions has declined, areas like the Midlands and the northeast of England continue to be "*the most manufacturing-intensive regions today in terms of economic activity and still have a much higher share of manufacturing jobs than the national average.*"[96] Green manufacturing strengths are spread around the country. Recent research by IPPR[97] shows areas with the highest green growth potential (based on regional clustering of firms related to green manufacturing) include Manchester, Newcastle, Warrington, Wigan, Leeds and Glasgow, Falkirk and Motherwell.[98] This potential is a reflection, in part, of infrastructural legacies (such as

port and rail links, underutilised grid capacity and vacant industrial space), accumulated investments in research, development and manufacturing capacities (e.g. regional catapults), and workforce skills and experience.

Historically important industrial and manufacturing regions – such as the Midlands, northeast England – already have leading roles in the UK's decarbonising economy as sites of green manufacturing and materials processing. Other regions identify net zero as key areas for growth. The regional diversity of UK manufacturing is a national asset. The absence of a coherent industrial strategy at national level, however, means in practice much of the delivery of industrial policy is effectively devolved to the regions. Central government has "*devolve[ed] the hard parts of delivery, without commensurate resources or institutionalised powers*".[99] Regional authorities grapple with a diverse range of reindustrialisation processes – coordination of public and private development plans, land-management and planning issues, and provision skills and training. Several regional authorities designed local industrial strategies as part of the 2017 UK-wide Industrial Strategy, however these were generally shelved when the national strategy was scrapped. Many regions are now actively developing new industrial strategies with substantial green manufacturing elements taking centre stage (e.g. the North East Combined Authority). For the most part, however, actions at the regional level to capture the economic upsides of decarbonisation have not been mirrored at a national level.

As a result, the UK has acquired an industrial strategy by default, rather than by design. Strategy is, in effect, the aggregate of these regional initiatives rather than a coordinated process of optimising regional strengths and developing synergies from regional diversity. Reserved powers around macro-economic decisions have not been used by central government to optimise the regional potential of low carbon industrial development as part of a strategic effort to transform manufacturing. Batteries are an illustrative example: in the absence of an industrial strategy, battery manufacturing in the UK is likely to be characterised by 'balkanisation' as regions compete to attract a limited pool of

external investment and independently seek to develop industrial pathways. The experience of Britishvolt – touted as being key to the future of UK automotive, but which developed neither a proven product nor confirmed customers and went into administration in 2023 – highlights an important point: industrial strategy needs to be able to distinguish between development of a globally competitive 'cradle-to-grave' battery ecosystem over time, and an immediate need to mass produce batteries to retain automotive sector jobs. It also highlights how poor choices around key assets, and inter-regional competition for external investment, can lead to regional assets being stranded.

The challenge, then, is around coordinating these dispersed regional elements into a coherent industrial response to the energy transition. This is distinct from the current approach of marketing discrete regional elements to companies seeking branch-plant style investment. In some respect this is an industrial optimisation challenge: while regional industrial strategies ensure some manufacturing development, the absence of national-scale coordination diminishes their potential combined macro-economic impact. Recognising this challenge, organisations like RenewableUK have called for a 'Four Nations Taskforce' to coordinate renewables development. A coherent manufacturing vision of energy transition can facilitate a just labour transition. Coherent and stable industrial goals – such as clarity on long-term technological pathways like hydrogen[xviii] – are needed to make credible workforce transition plans and design skills development strategies as a long-term practice. Recruitment is an example: several of our non-UKERC respondents observed how the lack of a clear vision of an industrial, low carbon future makes it very difficult to market careers in renewable manufacturing to young people.

Coordination implies several things beyond better communication of central government policies and initiatives, although this too can be improved. The bulk of manufacturers in the UK are SMEs, and considerable resource

xviii The Heat Pump Federation, for example, noted failure to call time on hydrogen for home heating is undermining the country's electrification goals.

is spent keeping up to date with the rapid flux of departments, personnel, and policies (MakeUK estimates, for example, that the average lifespan of economic initiatives is 2 years). Coordination also concerns the multi-actor nature of the problem, which requires a new degree of coordination between industry, government (at various levels), energy users and supply chains across multiple sectors. An embedded approach to industrial policy making can support this goal by providing "*institutionalised channels for the continual negotiation and renegotiation of goals and policies*," and may be further enhanced by a place-based focus on specific regions[100] (see also 4.6). The regional diversity associated with dispersed manufacturing capacities does not necessarily present ready-made solutions – many regional elements require investment and adaptation – but this diversity allows for policy experimentation, technological innovation (around the particularities of place) and creative inter-regional combination.

4.6 Enabling conditions are fundamental: network infrastructure and electricity prices

For the UK to achieve its ambitious decarbonisation goals and capture a manufacturing upside from net zero, some fundamental enabling conditions must be in place. The nature of these enabling conditions will vary for different decarbonisation pathways and industries. They include logistical infrastructures (like deep-water port access or increased rail capacity), communications networks and digital infrastructure, and access to grid electricity and low carbon fuels (a function of both physical connection and price). The last of these is key for most sectors. From green manufacturing and industrial decarbonisation to low carbon mobility and heating, grid access and affordable electricity are a prime enabler for a host of decarbonisation and manufacturing developments.

The scaling up, geographical expansion and reinforcing of electricity networks will be central to the transformation of manufacturing. A significant increase in electrical generation is required to meet the UK's 2035 electricity decarbonisation goal (an additional 16GW each year of new generation), which must be paired with massively increased transmission capacity.[101] Pace is key: while some underutilised network capacity can be incorporated into these plans, especially in areas that have experienced significant deindustrialisation, major investments in new network capacity are needed quickly. A lack of basic enabling infrastructure is already hampering the ability to meet decarbonisation targets in areas like heating, transport and industrial decarbonisation.

Several respondents noted the poor uptake in heat pump technology in the UK – which at the current rate will fall far short of the aim for 600,000 installations per year by 2028.[102] A range of factors explain the slow effort to transform home heating – limited policy ambition, uncertainty around hydrogen's role, and shifting subsidy programmes – but a significant contributor is the need for comprehensive grid improvements which have not yet materialised. Grid connectivity is also key to electrification solutions for emission reduction in the industrial sector (see 4.4). While hydrogen and CCS projects may meet the decarbonisation needs of the main industrial clusters, these technological pathways are not available for dispersed manufacturing sites outside the clusters. While electrification offers a viable alternative decarbonisation pathway for dispersed sites, grid connection is a substantial barrier. Reported wait times for new grid-connections are, in some cases, over 15 years.[103] This leaves SMEs with little option but to continue to rely on gas for power and heating needs until a more appropriate solution becomes apparent.[104]

A focus on electrical infrastructure spotlights two areas for reform. Historically network expansion has been incremental and adopted a 'cautious approach' in which companies must prove the existing system cannot meet their needs before being granted approval to develop. Large, rapid increases in network capacity need a different approach, including changes to the planning regime to allow network capacity to be built more quickly. The National Energy System Operator will be crucial to assessing sectoral and regional energy demand and advising on which major transmission projects to accelerate. An objective of the NESO's Strategic Spatial Energy Plan is to link "*link policy, consenting and regulatory approval*" so as to "*help compress the timeframe from options assessment to commissioning of projects*". Electricity market reform is also key to this process, given large falls in the cost of renewable energy, the growing volume of low carbon, low cost power generation in the UK, and the way current market arrangements reflect the economic characteristics of fossil fuels.[105] The Review of Electricity Market Arrangements (REMA) process – focused on changes to achieve decarbonisation of electricity system by 2035 – considered ways to manage bottlenecks and capacity issues, and how to pass the value of a renewables-based system through to consumers. It rejected (as of March 2024) delinking fossil and renewable electricity markets through structures like a green power pool and a split market, focusing instead on retaining and adapting marginal pricing across the wholesale market so that (unabated) gas-fired electricity generation settles the marginal price in the market for shorter periods of time (anticipating prolonged periods in the future where low-cost renewables set the marginal price).[106]

The oversight, planning and integration functions of the NESO are a positive development and suggest the value of a coordinated approach. The infrastructural piece of transition is a key enabling condition and efforts can be bolstered by an industrial strategy that adopts a similarly comprehensive objective. A comprehensive overview of the fundamental requirements of industry has been lacking, particularly in past formulations of industry policy where the common, underpinning needs of manufacturing transformation fell through the gaps of a sector-by-sector treatment.

4.7 Industrial strategy needs to support biodiversity and environmental protection on the way to net zero

A narrow focus on industrial strategy to achieve net zero and boost economic growth may exacerbate environmental crises beyond climate change. To avoid "*exchanging the climate crisis for alternate environmental crises*,"[107] there is a need to actively manage multiple environmental objectives and maximise co-benefits of manufacturing and other low carbon infrastructures. UKERC research in the *Energy, Environment and Landscapes*[108] theme highlights the implications of low carbon transition for land use and ecosystems[109], and how relatively small shifts to increase environmental protection can have large biodiversity gains. Work in the ADVENT project[110], for example, assigned value to natural capital alongside financial markers in renewable development models, and found that a small shift towards consideration of environmental protection measures could lead to vast gain in biodiversity levels. One localised example of this is 'biodiversity net gain' policies administered by local planning departments which require construction projects to show observably higher levels of species biodiversity on completion of work.

Embedding environmental protections within industrial strategy and policy is necessary, and complementary to an approach focused on the macro-economic potential of low

carbon transition. UK industrial policies have over time recognised this point, with plans for widespread low carbon build-out complemented by strong statements on environmental protection and improvement. For instance, the 2017 Industrial Strategy spoke of working "*not just to preserve, but to enhance our natural capital – the air, water, soil and ecosystems that support all forms of life – since this is an essential basis for economic growth and productivity over the long term.*"[111] And the *Clean Growth Strategy* published in 2017[112] placed improvements in the natural environment and natural capital at the heart of plans for renewable development. However, such statements have been diluted in more recent iterations of industrial policy. The 'Plan for Growth,' which replaced the 2017 Industrial Strategy, speaks of environmental 'considerations', suggesting improvements to natural environments are an optional extra rather than a key concern of strategy. Rather than a language of avoiding environmental damage caused through renewable development, industrial policy now refers to compensation for landscape renewal.

The more expansive point here, emerging from UKERC research, is a need to view objectives around industrial strategy and the low carbon supply chain holistically. UKERC research on delivering energy transition highlights the importance of keeping social and environmental values (quality of life, environmental integrity) in view, rather than approaching industrial policy for net zero as a narrow set of objectives without consideration of its wider social and environmental consequences. This observation aligns with the point we make in 4.1, about the need to see the wider upside of energy system transformation but extends it to consider the economic and ecological value of biodiversity and environmental protection. There are formal methodological approaches for doing this (some of which are utilised in UKERC) but there are also more procedural elements, such as how formulation of a low carbon industrial strategy can be embedded in discussions about just transition, quality of work, and remedying regional inequality.

5. Recommendations

This Briefing Paper aims to contribute to an evolving discussion, within UKERC and beyond, about the industrial and supply chain aspects of energy transition and their implications for the UK. It seeks to bring these aspects of energy transition to the attention of other researchers, and to highlight promising intersections between UKERC research and the broader research and policy community around industrial strategy and supply chains in the UK. Our effort to link UKERC's research on energy transition with the question of industrial strategy and supply chains leads to five broad recommendations for policy and three recommendations for research.

5.1 Recommendations for policy

- **Focus the strategic response to decarbonisation on manufacturing transformation.** Strategy should start from the premise that energy transition changes the economic potential and/or strategic value of existing UK assets; and should encourage new arrangements of technology, finance, infrastructure and materials around low carbon that create prosperity. The reorientation here is towards embracing and steering transformation to realise its macro-economic potential, rather than treating industrial policy as a tool to address deficiencies or offset costs of decarbonisation.

- **Provide strategic coordination and policy durability beyond the political cycle by reinstating the Industrial Strategy Council**. Our diagnosis of the manufacturing and supply chain challenge for the UK (Section 3) highlights a need for coordinated action and durable objectives, which a comprehensive industrial strategy can provide. The need for coordination and steering goes beyond individual sectors and crosscuts several specific areas of concern. A prominent example is the opportunity to harness the initiative and potential of regional industrial strategies (developed in the absence of national strategy) into a coherent industrial response to the energy transition.

- **Build on the central insight of 'place-based' approaches to accelerate decarbonisation and drive industrial transformation.** A plurality of technological pathways is needed to achieve the next phase of decarbonisation with solutions tailored to the demands of different geographies. Industrial strategy needs to recognise different geographies can require different decarbonisation solutions, and that these differences also present longer-term opportunities for technological innovation and novel infrastructural development in ways that support manufacturing transformation.

- **Use 'world leading' policy rhetoric sparingly.** The carryover of such claims to industrial policy from the climate policy domain (which centre on the Climate Change Act and phase out of coal) obscures the nature of the challenge in relation to UK manufacturing and supply chains. Hyperbolic rhetoric gets in the way of establishing effective and meaningful forms of intervention at a time when industrial policy and strategy needs to be smart and tailored to the specific circumstances (and capabilities) of the UK. The US IRA and EU Green Deal have 'made the weather' in relation to industrial strategy for decarbonisation, and a UK response should focus on identifying niches and synergies rather than out-classing them in the level of support.

- **Ensure industrial strategies for the energy transition see nature beyond carbon and climate, and support biodiversity and environmental protection.** While it is imperative that transition happens at pace, it must not be 'at any cost'. Industrial strategy can, with very little added burden, encompass environmental and biodiversity targets at its core. While this had been the norm in industrial policy documents, it has slipped from recent iterations of industrial policy and should be restored and strengthened. To overlook these broader environmental and social benefits of energy transition is to fail to recognise its transformative potential.

5.2 Recommendations for research

- **Improve understanding of the dynamics of low carbon supply chains and how they condition national manufacturing capacities.** This requires moving beyond narrow assessments of the risk of disruption to material flows or nationally based assessments of supply security. It should include consideration of long-term technological risks (drawing, for example, on UKERC's long-standing work on Technology and Policy Assessment), alongside political economic analyses of corporate/national ownership and control in supply chains.

- **Improve understanding of the connections between manufacturing and the circular economy in relation to low carbon production.** This should include material stocktaking studies to highlight the scale, trajectories, location and value of material stocks and flows related to the manufacturing aspects of energy transition and circular economy; a range of methods for assessing material and product flows, including those used in research by UKERC and CREDS, can complement existing assessments of critical minerals and material foresight analyses by other organisations (e.g. CMIC).

- **Develop place-based studies of the regional dynamics of global supply chains within the UK.** Where manufacturing activities take place, how new green energy investment relates to existing structures of inequality, and who can secure livelihoods and opportunities from green manufacturing are important questions that speak to consequences of a low carbon economy for prosperity, social inclusion and just transition. Understanding how regional legacies of earlier periods of industrialisation shape inclusion and opportunity in the new economies of decarbonisation is an important task that requires further research.

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