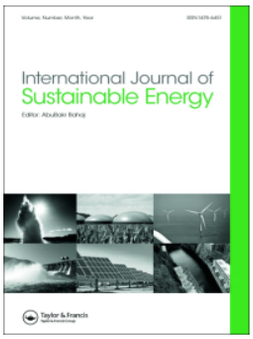

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RESEARCH ARTICLE

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Normative expectations of government as a policy actor: the case of UK steel industry decarbonisation

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ABSTRACT

The literature on technological expectations finds these to be performative: mobilising, coordinating and directing investment and decision-making. Expectations can involve conditionality and be normative, empirical or realist; that is, they may concern what should happen or what is considered likely. Expectations may also be of a form involving conditionality. Here we examine the interrelated role of normative, empirical and conditional expectations, their function in managing expectations relating to techno-science policy, and their implications for how stakeholders state that they perceive their agency and locus of control. Looking at UK steel industry decarbonisation, we show how stakeholders direct both their normative expectations and direct their locus of control towards the Government, as a form of strategic positioning. Commercial actors state the policy responses that they expect of the UK government mostly relate to reducing costs. We comment on actors' arguably strategic appeals to normative expectations that displace responsibility from themselves, and the Government's potential role in terms of intervention.

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Conditionality; industrial decarbonisation; sociotechnical expectations; steel industry; rhetoric

1. Introduction

The UK Government is committed to moving to a low-carbon economy and reducing greenhouse gas emissions by 2050 (BEIS 2017a, 2021a; Priestley 2019; The Climate Change Act 2008 (2050 Target Amendment) 2019). The Net-Zero target affects the most energy-intensive (EI) sectors: chemicals, glass, paper and pulp, oil refining, ceramics, food and drink, cement and iron and steel (BEIS 2017d). While these contribute to economic growth, they consume significant energy to generate heat and provide raw material inputs, among other uses. For this, the fuels used are mostly fossil fuels (1 900 Mtoe) and electricity (250 Mtoe) (IEA 2020a).

Among the EI sectors, the iron and steel sector is one of the more challenging to decarbonise, not least because of a combination of energy intensity and a current – as well as historic – reliance on coal for primary ironmaking. At the same time, steel is an essential material for building, infrastructure, transport, energy generation, including low-carbon technologies, such as wind power components and everyday products. According to the IEA (IEA 2020c), the iron and steel sector

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represents 20% of industrial energy use and accounts for 8% of global final energy use and 7% of global direct energy-related CO_2 emissions. Moreover, these sectors have doubled their total energy consumption globally in the last thirty years. In the UK, the situation is similar (Griffin and Hammond 2019; Pimm, Cockerill, and Gale 2021), representing 26% of greenhouse gas emissions for the iron and steel sector. In terms of energy consumption, iron and steel are the third-largest industrial emitting industries in the country.

More generally, the UK Government has developed a set of policies (BEIS 2017a, 2017d; IEA 2020a) to improve energy efficiency, in part by targeting low-carbon technologies. Notably, the pursuit of Cleaner Growth is tackled by Industrial Strategy (BEIS 2017a, 2017d), which sets it out as one of the Grand Challenges. One of the missions of this challenge is to *establish the world's first net-zero carbon industrial cluster by 2040 and 4 low-carbon clusters by 2030(*BEIS 2019b*).*

Decarbonisation will result in an enormous and complex transformation that, with time, will give rise to what sociotechnical sustainability transitions theorists refer to as a new *regime* (Geels 2002), in the sense of a stable network of mutually reinforcing elements, including policies, markets, technologies and social norms. However, the development of new sociotechnical configurations requires various conditions to be met. One of these is that key actors, particularly those with access to relevant resources, have some degree of alignment among their expectations of the future regime. In this respect, sociotechnical expectations are often described as performative: they mobilise investment and agency in particular directions (Berkhout 2006). In short, expectations are important for transitions.

When the future is particularly uncertain, it is difficult for expectations to coalesce around a future vision that investors are willing to commit to. To some extent, this is an inherent problem with decarbonisation processes, which can involve a high level of uncertainty (Bakker and Budde 2012; Borup et al. 2006; Konrad 2006). These uncertainties arise in part because actors often have opposing interests. Moreover, these interests do involve not only technological actors but also wider societal actors. In general, though, for future visions, scenarios and options to garner support, they need to make sense and be perceived as plausible by actors who have some influence over their realisation.

Plausibility is, in turn, related to the extent to which these futures meet actors' expectations regarding factors such as market, technological and policy developments. Sensemaking and the achievement of plausibility for a future option is enhanced to the extent that actors with different interests and needs find a common interest in supporting that option and when they expect it to be plausible and to succeed. While this can be enhanced through proactive dialogue between the stakeholders, including Government, producers, trade organisations and civil society, it is not surprising that the shift towards a low-carbon future is difficult to navigate.

In the EI sectors, there is a lack of consensus on what technologies will prove most suitable for decarbonisation; it is clear that there are costs (ranging from capital investment to training and the difficulty of maintaining production during the transition to low carbon technologies) to replacing and installing new infrastructure through the systems involved. In some, if not many cases, nationally-specific political, institutional, and market factors and how these integrate with the global market for materials and products will prove key in the steelmaking sector, shaping the landscape in which the sector operates and influencing the extent to which niche innovations are reinforcing or disruptive (Geels 2002; Geels and Schot 2007). This is particularly so in the case of the UK, our focus here, where steelmaking has a long but increasingly precarious history.

Our aims in terms of theoretical development are to add firstly to the understanding of the role of conditionality in sociotechnical expectations (Alkemade and Suurs 2012; Borup et al. 2006; Upham et al. 2018; Van Lente 2012; Van Lente and Bakker 2010). Secondly, to add to the understanding of how conditions and expectations interact to shape an evolving decarbonisation agenda and choices among alternative decarbonisation pathways (Geels 2002; Geels et al. 2017; Geels and Schot 2007). Thirdly, to highlight the relevance of the distinction between normative and empirical expectations for strategic corporate positioning with respect to decarbonisation policy. Fourthly, we

illustrate how these different factors help actors to displace their own agency strategically, shifting the onus on to Government as a prime actor and government action as a prime condition.

In terms of sampling stakeholder views of technological and policy options, our empirical base is intentionally illustrative, not comprehensive. There is already a large and up to date literature on the empirical options. In a review of international work on this topic (Kim et al. 2022) identify 271 closely relevant studies on the range of options and 'barriers' to their deployment. Consideration of these can also be structured in terms of their value at different points in processes of technological development and diffusion (see e.g. Chiappinelli et al. 2021). For our purposes, however, we select a small number of stakeholders embedded at different points in the iron and steel sociotechnical system. We also do not attempt to address the wide range of options and issues via review and discussion (again, for this see e.g. Kim et al. 2022). Our research questions rather, firstly (and empirically) concern the *conditions* that regime actors state are necessary for achieving their expectations in terms of decarbonisation pathways for UK iron and steel, including changes to the prevailing environment in which they operate. Inductively, we then discuss these conditions as both having a material basis and constituting a means of expectations management, i.e. a rhetorical value.

In terms of the structure of the paper, we begin with an introduction to the UK steel sector, treated as a sociotechnical regime, and associated decarbonisation efforts and policy to date. We then introduce expectations as a source of sensemaking and as informing strategic decision-making (Tsvetanova et al. 2022). We pay particular attention to the conditionality of expectations (Upham et al. 2020) and to the role of normative expectations (Berkhout 2006) not only as distinct from empirical expectations (what is considered likely or plausible), but also in terms of their discursive value in directing expectations of agency towards one or more third party (here, the UK government). We then describe our case study methods and present our analysis of UK steel actors' expectations vis a vis decarbonisation.

2. Decarbonising the steel industry in the UK

Steel plays a pivotal and transversal role in many industries (Alkemade and Suurs 2012; Geels and Schot 2007; Greenwood 2017) and global demand for steel is projected to increase by more than a third through to 2050 (Geels 2002). However, in the UK, the economic contribution of the steel sector as a whole is nationally small, although locally significant, and the industry has long been in a fluctuating state of decline. The economic value of the sector is just 0.1% of the total national GDP and 1.2% of manufacturing output. There are 1100 businesses involved in the industry, supporting 33,400 jobs in the UK, 0.1% of total employment (Hutton 2021). At the time of writing, there are six steel producers in the UK; two use the blast-furnace route (Tata Port Talbot, British Steel Scunthorpe), and four use the electric-arc- furnace (Celsa, Liberty Rotherham, Outokumpu, Sheffield Forgemasters)(UK Steel 2021a).

The UK steel sector has been impacted by several crises throughout the last century and the past twenty years. The global and regional dynamics of steel production; international trade negotiations; the role of China and India as exporters of steel and the rise in competition with Russia, the Middle East and the EU (UK Steel 2021c); and global over-capacity in steel production (OECD 2021) has put the sector in the UK under severe pressure (Greenwood 2017; Griffin and Hammond 2019; Hutton 2021) with consequences like the decision to close large industrial plants and reduce the capacity of Teeside or Scunthorpe, among others.

Still, the potential of the steel industry in the UK should not be dismissed. Several reports have identified areas where the UK could have opportunities (BEIS 2017b, 2017c, 2019a, 2020a). Proximity to the North Sea could facilitate access to renewable energy to produce hydrogen and carbon capture, utilisation and storage (CCUS) (21, 28), support wired rod, coated and rail products like the HS2 high-speed rail project (HS2 2022), meet smaller order volumes (and the demand for specialist steels) and target national markets over exports (BEIS 2017b).

Globally more than 80% of steel is produced through primary routes using iron ore and some scrap (IEA 2020b). The main source of energy in the sector is coal, accounting for around 75% of the sector's energy use (IEA 2020a). Nationally, the situation is very similar. In the UK, primary steel production takes place in two integrated sites: Port Talbot and Scunthorpe, using blast and oxygen furnaces (together, they account for around 90% of UK steelmaking emissions (Lytton and MacDonald 2021). Also, four sites are using electric arc furnaces (EAF) for primary and secondary production. Both methods currently use large quantities of coal, electricity, and natural gas. For example, in terms of coal, the iron and steel industry is one of the major users in the country. In 2021 it used 2.6 Mtoe of coal, comprising 36% of UK total coal consumption (BEIS 2022b)

The sector will need to address significant barriers to succeed in decarbonisation. The high cost of decarbonising the iron and steel industry is, by far, one of the most significant challenges globally and nationally. Technology readiness, the inability to pass the cost to the end-user, difficulty in demonstrating that technology can reduce GHG emissions cost-effectively, high electricity prices (UK Steel 2021c), old infrastructure (combined with long financial payback periods on new capital investments), and the availability of fuels and networks to transport and store CO_2 are all hampering the process in the UK (BEIS 2020a).

Decarbonisation options include creating a market for near-zero emission steel, developing and increasing the maturity of earlier stage technologies, fostering scrap use for steel production(when and where possible), and accelerating material efficiency strategies. The latter could help reduce energy demand enormously (IEA 2020a; Milford et al. 2013; Norman, Garvey, and Barrett 2019). From a technological perspective, innovation is critical to deep emissions reductions. Technology performance improvements could deliver substantial emissions reductions by 2030 (IEA 2020c). So far, however, there is no agreement on which technology would be the most appropriate to decarbonise the industry (BEIS 2020a). Options that have drawn much attention include could CCUS and hydrogen-based production (Griffin and Hammond 2019; Mandova et al. 2019; Vogl, Åhman, and Nilsson 2018). For instance, primary steelmaking based on direct hydrogen reduction and electric arc furnaces can be competitive with blast furnaces – basic oxygen steelmaking (Pimm, Cockerill, and Gale 2021). However, of the available options, only CCUS, bioenergy, hydrogen or electrification would be able to achieve a low level of net GHG emissions (Pimm, Cockerill, and Gale 2021).[1]

From a policy point of view, some steps have been taken to incentivise the adoption of Net-Zero goals. Going forward, in terms of the policy context, the most relevant for the steel industry is the Clean Steel Fund (BEIS 2019a). Presented as a subsidy and with a sectoral approach, this fund is worth £250 million and is focused on implementing new technologies and processes in parallel with improving skills and growth opportunities in the sector. Currently, though, this funding has yet to be distributed. Other recommendations include the development and introduction of cross-border carbon regulation for iron and steel products (Pimm, Cockerill, and Gale 2021) to increase and guarantee the competitiveness of the UK industry if this were to decarbonise in advance of competitors and prevent carbon leakage. With a more industrial approach, pricing mechanisms such as a carbon tax are considered efficient for cost-effective mitigation (Garvey and Taylor 2020).

Industrial infrastructure policy is also crucial for transitioning to a decarbonised steel industry. One of the most relevant initiatives in the UK is backed up by the Industrial Challenge Fund (BEIS 2017d, 2019b), which supports the development of low-carbon technologies and infrastructure and which is intended to reduce carbon emissions from energy-intensive industries, such as iron and steel, cement, oil refining and chemicals. Under this fund, the Industrial Clusters Mission aims to establish the world's first net zero industrial clusters by 2040 in areas with more significant abatement potential. In 2020 (UK Government 2020), the UK Government announced an investment to enhance green recovery, after COVID hit the national economy. From a total of £350 million worth of investment, £139 million is intended to cut GHG emissions from heavy industry by supporting

the transition from natural gas to clean hydrogen, and scaling up carbon capture and storage technology. Also, £149 million is intended to drive the use of innovative materials in heavy industry, including projects to reuse waste ash in the glass and ceramics industry, and for the development of recyclable steel, from hitherto unrecyclable grades of scrap.

Having introduced the context to steel decarbonisation in the UK, in the next section, we outline the literature on sociotechnical expectations, their conditionality and normativity. This sets the stage for subsequent empirical examination of which conditions are viewed as requisite by stakeholders and how their assumptions about plausibility and associated strategic sensemaking stand to shape the steel decarbonisation agenda and policy.

3. Expectations, conditions, norms and sensemaking

In the most general sense, expectations can be considered beliefs about the future (Upham, Bögel, and Johansen 2019) that are crucial in sociotechnical changes and innovation processes (Alkemade and Suurs 2012). Expectations are influential, helping to guide under conditions of uncertainty (Sutcliffe 2016) and when the status quo is expected to change (Weick, Sutcliffe, and Obstfeld 2005). Expectations can shape innovation agendas. Expectations help to transform technological 'promises' (unless unachievably hyperbolic) into standards that become requirements. Their objects may relate to organisations' strategies as well as technologies. Most importantly, expectations help to interlock and coordinate activities, behaviours and policy shifts (Van Lente and Bakker 2010), such that a given direction is deemed to make sense to pursue – at least at a given moment, albeit with an awareness that technologies or practices currently regarded as too implausible may become more plausible, and hence expected, a little further into the future.

Drawing on social psychological literature, we can also distinguish between empirical and normative expectations, where the first refers to what is thought to be likely or plausible, and the second refers to what ought to happen (Bicchieri 2005). This normativity introduces an implicit conditionality – it is implied that what *should* happen is what *needs* to happen for expectations to be realised or plausible. They are also held to contain an implicit 'script' that indicates a promising research and technology development line that can coordinate actions, guide strategy building (Borup et al. 2006; Konrad 2006; Van Lente and Bakker 2010), and that position actors (including 'others') within a particular *story*. Meeting expectations depends on the coordination of action between those involved; moreover, when these expectations occur at different 'levels' of an organisation *(micro, meso, and macro*) and policy level (Borup et al. 2006). Regulations and policies constrain the outcomes of those expectations. Crucially the performativity of expectations (the extent to which they result in action) depends on the extent to which they are also accepted by other actors influential in a regime, as that regime comes under different types of pressure (Borup et al. 2006).

Here sensemaking is relevant, mainly if the different expectations, aims and needs of different stakeholders are to become congruent – a prerequisite for the development of a stable, reconfigured regime. Although there are multiple understandings of sensemaking (Maitlis and Christianson 2014), here we treat this as a social process (Weick 1995; Weick, Sutcliffe, and Obstfeld 2005) in which people develop an understanding of specific issues, and interpret and act in their environment through exchange with others (Jalonen, Schildt, and Vaara 2018; Weick 1995; Weick, Sutcliffe, and Obstfeld 2005).

Sensemaking is initiated and required when there is an inconsistency between what one expects to happen and what *actually* happens; when the status quo is disrupted (DeKrey and Portugal 2014; Maitlis and Christianson 2014). In the context of decarbonisation processes, where there is a disconnect between the need for rapid decarbonisation globally and the actuality of global GHG emission trends, *strategic* sensemaking is even more relevant. Actors create new meanings with strategic concepts to collectively make sense of their environment, in terms also shaped by their professional background and interests. This is a specific activity that takes place more or less consciously and deliberately within an organisational environment. Organisations deal with strategic issues in

part by constructing, and also with the objective of constructing, shared (sometimes locally shared) understandings of particular issues and the actions required as a response (Jalonen, Schildt, and Vaara 2018; Thomas, Clark, and Gioia 1993). However, we would suggest that organisations also use statements of expectation (normative or empirical) discursively as a form of strategic positioning.

Sensemaking is influenced by meaning-making and legitimation (Jalonen, Schildt, and Vaara 2018) and is connected to performance and action (Thomas, Clark, and Gioia 1993; Weick, Sutcliffe, and Obstfeld 2005). Meanings do not need to be perfectly shared to mobilise actors toward a goal. However, there is at least a need for common ground (a *boundary object* – something that connects actors but allows for multiple interpretations) that allows co-orientation by facilitating discussion of ideas, issues and initiatives, even when there is no agreement on exact meanings (Jalonen, Schildt, and Vaara 2018). While, of course, accuracy matters in many contexts, imprecision is possible in social contexts because individuals rely on plausibility to make judgements about future and expected actions rather than accuracy alone. Individuals have the capability of influencing each other expectations and how these may be met, by interpreting not only object-specific information (e.g. solely technological prospects), but also contextual factors – such as market, technological and policy developments. Actors integrate this information cognitively, and while their judgments may also be informed by statistical modelling of likelihood, they know that as a time horizon moves forwards, predictive models risk compounding error due to base assumptions becoming incorrect. Hence sensemaking and expectations are connected (Weick 1995). For expectations to be accepted – to make sense-they do not necessarily demand accurate predictions but rather need to be perceived as *possible* and preferably *plausible*.

4. Methodology

Our empirical work is the result of combining both primary and secondary qualitative data. We conducted in-depth expert interviews in 2019; we sought a variety of sectoral views but not a comprehensive set, such that we do not claim representativeness. The sample comprised an environmental NGO, two policy advisors in the Central Government department, a representative of a relevant international trade organisation, a representative of a national trade body, two structural steelwork companies and a representative of a manufacturers' organisation (i.e. eight individuals). The approach to sampling is informed by theory relating to expectations, sensemaking and sociotechnical transitions theory, in that we include actors with differing interests at different points in the steel production and forming regime. The purpose is to identify their expectations, associated conditions and sensemaking; and to consider the degree of congruence among these, such congruence being a prerequisite for the development of a new configuration of sociotechnical elements – in this case, a decarbonised steel regime. As the number of interviews is modest, the wider aim is to illustrate an approach to the study of new regime development and to inform directions for further empirical work, rather than firmly evidencing the direction of that development.

In the interviews, expectations and sensemaking theories and their role in the transition are used for developing the interview protocol Figure 1. Based on document review to understand the background to the situation and informed by modelling of options being conducted in parallel, we included in the interview protocol topics and themes that interviewees were judged likely to consider essential, important and/or relevant for decarbonisation of the UK steel regime. In addition, we also asked interviewees directly during the interviews what those issues were for them and followed up with further questions that probed their responses. The interviews thus focused on three areas that the stakeholders questioned considered critical for decarbonising the steel industry: the current, broad context of the industry; the main technological issues; and the main policy issues affecting the sector (Figure 2). The questions were phrased so as to ask about expectations in both a realist and a normative way. The first relates to what is considered likely and plausible, as described above; normative expectations relate to what is considered desirable. In addition, we

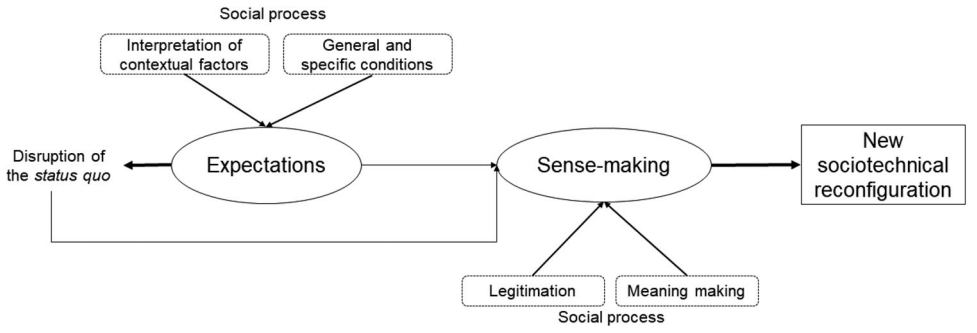

Figure 1. Theoretical representation: expectations influencing a new sociotechnical configuration.

also probed conditions that stakeholders considered necessary for the fulfilment of their expectations (realist and normative). The full version of the interview protocol is appended (Supplemental material 1), and the Ethics Committee of the research grant-holding university approved the research..

The second part of the study used secondary data to examine *how* and *to what extent* stakeholder expectations are already being translated into strategic actions towards decarbonisation by actors within the evolving steel regime. These actions are viewed as outcomes, in part, of previous expectations and sensemaking, by these actors and/or others. The secondary data were selected from various sources describing and relevant to the evolving steel regime, including media releases, organisation reports and roadmaps on decarbonisation actions, government documents and public hearings.

5. Results and discussion

To reiterate, here we aim to identify, characterise and theorise the realist and normative expectations held by an illustrative selection of UK steel regime stakeholders regarding decarbonisation conditions. We pay particular attention to how expectations about other actors and their behaviour

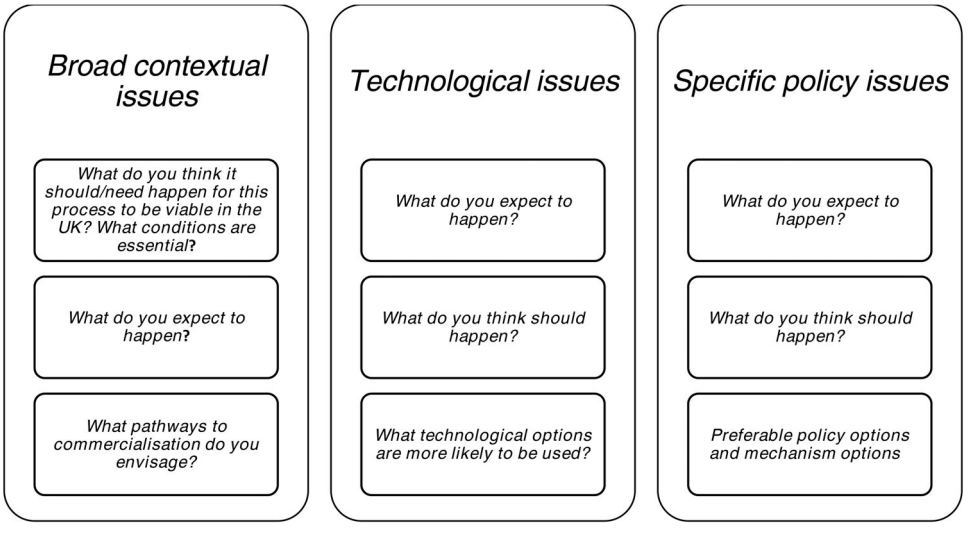

Figure 2. Interview protocol.

are connected and can influence strategic action in response to decarbonisation, including what may be interpreted as discursive impression management (Ozsozgun Caliskan, Esen, and Barkemeyer 2021).[2] We also discuss how those expectations and conditions may influence the emergence of a new sociotechnical configuration.

Accordingly, this section is organised into three parts. First, describe some of the conditions that stakeholders state are required for decarbonisation. Implicitly, this also provides a picture of where the industry stands now in that regard, which is essentially a position of waiting for government action. Then we describe stakeholder expectations relating to three elements of the steel regime: policies, technologies and markets (Geels 2004). We show that organisations are already using their expectations relating decarbonisation in their public messaging. Finally, we comment on the possible forms of new regime configurations as perceived by the stakeholders interviewed. Where possible, we show how stakeholders' interview responses (in italics) are evident in the secondary sources (in text boxes) that describe actions in which the same expectations are implicit.

5.1. Conditions for decarbonisation

While we turn to specific expectations in the next section, here we document more general conditions that the stakeholders say are prerequisites for steel decarbonisation. First and foremost, they express a belief in the need for government action as a precondition for change, though they see dialogue within the regime as valuable. Thus although the UK Government has nominally set decarbonisation as a nominal priority (BEIS 2021c, 2021a; Priestley 2019), stakeholders express the view that both it and the sector as a whole are still (at best) finding their way:

> So if you were to be really fair and give Government all the benefit of the doubt on this, it is in the process of being developed and they're trying to find routes to where they can find common ground and what policies they need to consider to adopt and implement, as such. Manufacturers' organisation representative.

Secondly, stakeholders express a need for a collaborative process and fora in which the various actors with different priorities, goals and needs may become better aligned:

> Think that's [climate group SteelZero] a starting point where we've seen stakeholders come together and talk about the challenges and talk about maybe the expertise that they have or the experience that they've had with clients and then sharing solutions to those challenges, so I think that's a step forward. Similar initiatives like that would be also beneficial. Private company representative

Thirdly, there is a perception that decarbonisation policy options are still in the process of development internationally and that more specificity in this regard will be required:

> Each Government will have to look at what they think works for them given their particular circumstances, and I think that makes sense. Trade body representative

At the same time, fourthly, such policy will need to mitigate carbon leakage, however difficult that is to attribute to decarbonisation policy specifically (Sato and Burke 2021). While the steel regimes of some countries are increasing production and their international competitiveness (China, India), others are experimenting actively with low-carbon fuels (e.g. hydrogen, Sweden)(IEA 2020b). Relocation of production away from the UK to locations with higher fossil energy intensity is viewed doubly problematic, as a private company interviewee reflects:

> So that's something the Government needs to look at along with other partners and trading partners to protect a producer who's doing everything they can in the UK to manufacture things correctly and reduce their carbon footprint but yet I can ring up and buy it from China or from South Korea or from wherever and at a much cheaper price because they don't have the same environmental policies or concerns in their country. So there has to be an offset of that so that you pay duty on that that it sets it out.

In terms of a corresponding policy response, UK steel actors view the situation as within the purview of the Government. Here is Gareth Stace, Director General, UK Steel, and Co-Chair of the Steel Procurement Taskforce in a public response to questioning by Members of Parliament:

> *I have already touched on it. It is just giving us a competitive business landscape in the UK Government policy—not just this Government but many governments historically, of different colours—has always seemed to want to tie our hands behind our backs. It really is a competitive business landscape of electricity prices, business rates and public procurement of steel, as well as Government just wanting to support their steel sector*. (Anonymous 2021)

The environmental NGO interviewee also refers to carbon leakage, regardless of carbon border adjustments, although no condition for remedying this is offered:

> We've met our UK target because we're not making any steel in this country anymore, so our emissions have decreased by X amount" but as a result, you'll just be buying steel from elsewhere and increasing [GHG emissions.]

Stakeholders did not volunteer an unambiguous answer as to whether sectorally distinct decarbonisation targets are a desirable condition or whether these should be set for the heavy industries as a whole. Rather, as said, Government was seen as key for its ability to influence the pricing of inputs, and uncertainty over most parameters was perceived and expected:

> Uncertainty yes, and the next five years are going to be difficult, they can't really take long term decisions in that way, so kind of there's a lot of uncertainty there to add on. Policy advisor in Central Government Department

While the above conditions are generalised, in the next section we turn to specific expectations and conditions, many of which are normative.

5.2. Normative expectations and conditions

Stakeholders held a range of specific normative expectations that, in their view, would help to unlock the current regime from its carbon-intensive configuration. These largely relate to government action in terms of technology, policy, and market conditions. Government is seen as responsible for coordinating activities, fostering a more active market and demand, and building consensus on achieving decarbonisation. Yet, the conversation about how to do it remains open.

> They need to get the logistics in place first and make sure all the bits are there to make it work. The Government will have to come up with ways. It's okay saying, "We want you to do this. Here's the target. Okay, but how are you going to help us get there?" It's not as simple. Private company representative

In their expectation that Government needs to be the prime actor and that this action is a precondition for decarbonisation progress, the interviewees are reflecting on their concurrent public statements. Hence in July 2022, the chairman of Tata group warned that without Government help, the transition to greener steel would not happen, and this could lead to the closure of their steel plants (Raval et al. 2022):

> *A transition to a greener steel plant is the intention that we have . . . But this is only possible with financial help from the Government* (Raval et al. 2022)

As said, the forms of this help can be categorised in the terms below.

5.2.1. Policies and funding

The stakeholders interviewed state that policy shifts are necessary, or at least the creation of a regulatory framework that can provide guidance and support for decarbonisation. That is, there is a normative expectation of the Government as an actor, and this policy shift or regulation is seen as a

precondition for decarbonisation. More specifically, this framework needs to be sufficiently flexible and realistic – e.g. find the right balance between capital investment and technology development – to be beneficial and, as already mentioned, include the different voices of the sector:

> Policy options; achievable policies: there needs to be some kind of tax but, also, I think there need to be collaboration with the industry in order to come up with solutions which are strict enough but which are possible because otherwise it just wouldn't work. So I think that there needs to be collaboration with companies within the supply chain and in the steel industry to make sure that any policies or legislation that come about are strict enough and are challenging enough but also possible at the same time. Representative of private company

The stakeholders did not state more particular expectations or conditions regarding how policies should or will be articulated. In fact, the lack of specificity and the scarcity of realistic expectations was quite striking and did not give the impression of a regime that believes that it is about to reconfigure. Nonetheless, on the matter of whether government policy should address energy-intensive industries as a whole or be focused on steel for the purpose of steel decarbonisation, the manufacturers' organisation interviewee supported the latter:

> Carbon border adjustments might work for the steel industry, it might not work for the paper industry or the cement industry and because of the trade intensity of the different sectors that might also matter, I think if you think that kind of one size fits all policy approach, you're not going to get there, you will have to take into consideration, each separate sector and that makes it much more complex and much harder for the Government to do

The Policy advisor in Central Government Department expected (empirical) advantages *and* disadvantages of focusing on one sector at a time:

> You will basically end up having a lot of unintended consequences if you don't take a sector by sector approach, but the problem is as well that if you choose to, for example, decarbonise the steel sector with its own separate policies first and kind of accelerate those first, then you will end up making steel more expensive because you pass on the cost to the consumer

A broader policy package could take a more general industrial approach, with clear boundaries to demarcate the steel industry. This disadvantage would be that targeting multiple industries (for example, a fund looking into specific low-carbon technology development) would risk slowing the decarbonisation of specific regimes and potentially overlooking regime-specific problems. Hence the expectation of the Environmental NGO interviewee:

> Some of the challenges and vulnerabilities of the steel industry would not be tackled effectively. I think if you're targeting multiple industries at once, I think that some of the challenges are I think that eventually there will become a realisation that although change is happening, it's just not really happening fast enough or to the extent which is needed.

The above uncertainties arguably reflect the limited specificity of planned decarbonisation measures relevant to the steel regime. The Clean Steel Fund (BEIS 2019a, 2020a) will be allocated in 2023, a few months from the time of writing, but does not state which technologies and projects will be eligible. This ambiguity regarding even general decarbonisation policy is relevant here (BEIS 2019a) and has been a cause of concern for the Environmental Audit Committee of the House of Commons, evident in a recent consultation:

> *Please set out in response (i) the Government's rationale for the decision to withhold the Clean Steel Fund until 2023, when industry players are prepared to set out their decarbonisation plans now, and (ii) what plans the Government has to review the ambition of the Clean Steel Fund*. (Environmental Audit Committee 2022)

The UK's Net Zero Innovation Portfolio (BEIS 2021b) includes a 1 billion GBP competition fund to develop low-carbon technologies and systems of potential value to the steel regime for hydrogen or industrial switching projects. Yet, the UK Government is perceived as not having committed to a

specific direction or plan in relation to this funding (Green Alliance 2021b), for example, industrial CCUS, hydrogen and associated business models. At the time of writing, the total spend and detailed rules are still to be agreed upon; moreover, support for hydrogen-related activity may, in principle, support hydrogen production rather than, or in addition to, hydrogen use.

Some steel regime actors are concerned that the current UK policy environment is placing the UK in a worse position relative to other European economies (Smeeton 2021). As corroboration for this (empirical) expectation, there are warnings signs coming from different studies (ECIU 2021) and a UK parliament Hearing (Environmental Audit Committee 2022):

> *When compared with progress overseas, it is clear that the current level of ambitions for clean steel in the UK are not sufficient to ensure that the industry catches up in the race to clean up steel production (…) with the gap only set to grow if current timescales for government support are maintained.* (Environmental Audit Committee 2022)

One condition perceived as requiring addressing is a reduction in electricity prices and costs. These are expected to compromise the steel sector's viability during any decarbonisation process, unless addressed:

> Don't know whether I'd use the word "abandon" but at least at the moment, the Government hasn't provided the right framework for us to take the necessary steps to decarbonise. They haven't really, even though we've now highlighted electricity prices for a number of years, it's yet to be addressed for us. Manufacturers' organisation representative

Commenting on this issue (MAKEUk 2021a), the Director General of UK steel states Gareth Stace, Director General of UK Steel, said:

> *The UK steel sector is a big user of power, consuming as much electricity as 800,000 homes annually. We are also highly trade intensive, importing 70% of our steel needs and exporting 45% of everything we make. The UK's disproportionately high electricity prices have a hugely negative impact on the sector's ability to compete, trade, attract inward investment and ultimately be sustainable in the long-term.*

Conditional expectations are similarly articulated around policy choices to guarantee and provide a competitive landscape to the national trade and electro-intensive industries. It is anticipated that the Government would exempt the industry from additional charges that their European competitors do not face. High electricity prices are seen as one of the main barriers to competitive disadvantage, and addressing these urgently is cited as a precondition for a competitive industry in the UK (MAKEUk 2021b). MAKEUK urges the implementation of German/French style network cost reduction and providing 100% compensation for indirect costs of carbon in electricity, among other mechanisms, to provide competitive electricity prices (MAKEUk 2021b).

This is not to say that the UK Government has *not* created a portfolio of policies targeted at energy-intensive industries. It has a stated aim of increasing the share of electricity generated from renewable sources, including the renewables obligation and feed-in tariffs. 'Contracts for Difference' to those businesses will need to show that their electricity costs amount to 20% or more of their Gross Value Added (GVA) over a reference period (BEIS 2022d). Also, under the Climate Change Agreements scheme, the second phase began in 2013 and has been extended until 2025, firms joining the scheme must commit to sector-based umbrella agreements, which outline targets for energy and carbon emissions reductions. In return, firms receive a discount on their Climate Change Levy (UK Government 2022). However, these are perceived as insufficient conditions compared to other European countries, particularly Germany and France:

> On network costs, we pay I think six to eight times as much in network costs as they do in Germany per megawatt hour and that's because the German network regulator and energy regulators have decided: "We believe that energy intensive industries, because of the service they provide to the grid in terms of balancing and stability overall and the trade intensity, we're going to provide exemptions", so they get a 90% exemption from

their network cost. But we face the full cost of our network costs here in the UK. And we have an additional carbon price here in the UK on our electricity as well. Manufacturers' organisation representative

5.2.2. Technology and infrastructure

Alongside high electricity prices, the UK steel sector is characterised by ageing power-grid infrastructure, the renewal of which is perceived as another condition for decarbonisation. This is not expected to change in the near future. Rather, new and old infrastructures are expected to coexist and compete due to the cost and level of investment required. This could even result in the demise of some businesses, given competition during the period of co-existence and the lack of enough economic resources to survive that stage of competition. The British Construction steelwork Association BCSA expects (BCSA 2021) that the technology-neutral approach of the UK government will mean that the use of old technology – notably coking coal – will coexist with CCUS technology such that it meets net-zero targets:

> *In the roadmap, a 50:50 split has been assumed between the carbon emissions abated via CCUS and hydrogen DRI-EAF. This is consistent with UK industrial decarbonisation strategy which takes a technology-neutral approach and so does not rule out the use of coking coal in an integrated steelmaking process together with CCUS as a net-zero compliant option going forward.* (BCSA 2021)

It may be noted in regard to the above that the BCSA roadmap is not written at a level of detail that specifies the carbon capture technology, the hydrogen production technology, nor the transport of either. The requirement of capital expenditure for infrastructure and breakthrough technologies is such that it would be naive to think that the sector would (or even could) navigate decarbonisation alone. Options include passing operational costs to consumers – without disadvantaging UK-produced steel, relative to imports so as to produce a level playing field-, the use of carbon taxation, or provision of CAPEX support:

(…) taxation is an incentive, no doubt about it. If you have to pay a carbon tax then there would be an iincentive.to do it but they would need assistance as well on the technology side.

The Government would need to help investment to come up with new ways of producing low cost energy so they could operate the steel plants. Representative of private company

In general, then Government involvement is seen as a necessary condition in relation to investment in technological innovation and to prevent small companies from being left behind. The Government itself expects the same:

They would expect, I'm sure they would expect Government to be paying for infrastructure costs and making sure that that infrastructure is in place in a timely fashion. And hydrogen, well there's costs to setting up a network of hydrogen and that's where they'd expect it. I think that's where you could probably break it down that if it's a direct cost for the firm, they would look for support, especially if it's ground-breaking research. Policy advisor in Central Government Department

As part of their long-term strategy suggested as Written Evidence to the UK Parliament in 2021 (Green Alliance 2021a), the NGO partnership Green Alliance envisions a clean steel hub to secure some clean primary steel production. Their proposal is envisaged as being delivered through a competitive tender administered by the Government and with private funding backing initial funds from the Government. However, the role of the latter is again deemed irreplaceable:

> (…)The initial pilot trialling clean steel could be funded in partnership with any number of interested businesses, possibly including the Jingye Group, the owners of the Scunthorpe steelworks plant, or Tata Steel, the owners of Port Talbot. Crucially, existing Government commitments could provide much of the funding. The Government has already set aside £250 million in the Clean Steel Fund and may also be able to make use of funds committed to industrial clusters and hydrogen. (Green Alliance 2021a)

Relatedly, the UK is seen as having supportive geographic conditions for some of the technological options. The UK has access to offshore CO_2 storage sites and hence potential for CCUS, given that many of the UK's plants are integrated[3] and located near coastal areas (BEIS 2020b). Elsewhere in Europe, renewables and related innovative technologies are expected to be more cost-effective (Elia et al. 2021; Neuhoff et al. 2014).

A technology-neutral approach was welcomed by the stakeholders whom we questioned, i.e. a portfolio of technologies based on the local context/country characteristics. This flexibility and openness are positive considering the context-dependency nature of the industry:

> And I don't believe, the other thing I would say actually isn't that, I don't think there's a silver bullet for the steel sector. There's not a technology that will fix the problem for us. There will be a portfolio of technologies and they will be adopted in different countries depending on local conditions and local policies and resources, and that's fine. Trade body representative

5.2.3. Market development and public procurement

Another key condition perceived as necessary for more rapid decarbonisation is a market for decarbonised steel, with Government again viewed as the prime actor. The BCSA highlights the lack of incentives in its Decarbonisation Roadmap (BCSA 2021), describing its normative expectations of policy and technology development, plus market conditions: parity of electricity prices with European levels, and access to abundant and affordable clean energy, among others:

> *Support is therefore needed from Government and industry to enable the roll-out of low-emissions steelmaking*. (BCSA 2021)

The challenge is viewed as ensuring sufficient demand such that the supply chain can incentivise stakeholders to engage in decarbonisation via steel pricing and cost recovery:

> You have to create a market for low carbon, let's call it low carbon steel and low carbon materials, so the companies who make low carbon steel, want to invest breakthrough technologies, are able to be sure that they're going to get the return that justifies the great costs that they will face as a result of that. Trade body representative

The role of the Government is vital to get the mechanism in place to incentivise a market. Here procurement decisions can make a significant difference in maximising opportunities for UK steel manufacturers and suppliers and bringing environmental benefits. Public procurement is expected to force and incentivise interest toward decarbonised steel; in words of the Policy advisor interviewee:

> Whether it's through green procurement rules, either public or private, that's one option to help create a market for a lower carbon steel or whether it's through more complicated policies such as carbon border adjustment mechanisms would be another way for us to try and create this demand for lower carbon steel.

The Government states that it is willing to use it to drive change and create demand for greener industrial products (BEIS 2021c). More specifically, the Government states in its National Public Procurement Policy Statement published in 2021 (Cabinet Office 2021) that public procurement will support *tackling climate change and reducing waste by contributing to the UK Government's legally-binding target to reduce greenhouse gas emissions to net zero by 2050*. Yet, while this synergy is reflected in the policy development for reaching Net-Zero, this is a general strategy and stakeholders see sector-specific measures as necessary. With an eye on the steel industry, the Government recently updated the Steel Procurement Pipeline (BEIS 2022c). In addition, some organisations like MAKEUK have suggested measures to increase engagement and facilitate public procurement regarding steel (UK Steel 2021b):

> *Requiring those tendering for contracts to present supply chain plans. If done just in relation to steel this could be as simple as setting out how steel will be tendered for, or if already known, how and from which supplier steel will be sourced. Alternatively, many organisations may wish to consider requesting more comprehensive plans, looking at issues such as local content, innovations, skills, and job opportunities right across project supply chains*. (UK Steel 2021b)

In addition to the forms of policy support referred to above, Government is also expected to use public procurement. The 2022 UK Steel Procurement Taskforce gave clear recommendations on how the sector could complete major procurement projects, including *procurers engaging with the steel supply chain early in the buying process (*BEIS and UK Steel 2022*).* Public procurement is thus viewed as one of the main potential drivers for decarbonising the steel industry, acknowledged by the Chancellor of the Exchequer and former MP Kwasi Kwarteng in 2021 (Anonymous 2021), in a statement that, in this case, once again displaces the locus of control away from the actor in question (from the UK to the EU):

> We have mentioned a couple of things in this short session that can deal with the problem that you have described, Mr Howell. The first issue is in terms of public procurement. When we were in the EU, we were subject to all sorts of government-procurement rules in terms of how the Government could spend money, and what industries they could or could not support in spending money on procurement. Now that we are out of the EU, we can make those rules ourselves. As I have said, we have a procurement taskforce, led by Lord Grimstone, looking at this exact issue. In 2018–2019, we spent a lot of money on our steel purchases here in the UK, so you are absolutely right. (Anonymous 2021)

5.2.4. Conditional expectations as policy rhetoric

While we do not contest the material bases of the stakeholders' stated views, at the same time, we also view the way in which they displace responsibility to government and to the future as materially convenient. Together, they constitute an espoused, over-arching narrative in which an array of conditions (normatively and empirically) need to be in place before industry action is possible, with little attention to how non-governmental regime actors might support the achievement of those conditions, or make other material changes. We do not see promissory forms of expectation (Van Lente 1993), by which is meant expectations of technological advance that become self-fulfilling because they help to attract the investment necessary for their realisation – rather, quite the opposite. Speculatively, perhaps the lack of promissory expectations is a feature of industries in decline – of those experiencing phase-out or exnovation (Rosenbloom and Rinscheid 2020) If so, this does not bode well for the iron and steel sector in the UK. Alternatively, it might be interpreted as a cognitive form of regime resistance (Geels 2014) (or even cognitive dissonance), in the face of a challenge (decarbonisation) that requires substantial sociotechnical change. These are all issues that we think merit further examination.

6. Conclusion

This study has investigated stakeholder expectations relating to decarbonising the UK steel industry, as evident in interviews and publicly available documents, has identified conditions that stakeholders consider important for those expectations to be realised, and has distinguished between normative and empirical forms of expectation. We have shown how actors use conditional, normative expectations to discursively shift the locus of agency (the capacity to act) in their field. By this, we mean that actors argue that they cannot act unless another actor, typically the Government, provides supportive conditions. In other words, the normative expectation is that this nominated prime actor *should* provide those conditions, and until they do, the original actor should not be expected to act. We see this as a form of strategic sensemaking and action with rhetorical policy value, in the sense that it seeks to be persuasive while minimising regime actor commitment.

The conditions and expectations referred to all have plausible, material bases concerning regulation, investment, technology development, the creation of markets and public procurement. Yet regime actors remain crucial to action on all of these. At issue is how to incentivise economically and commercially viable steel decarbonisation. This is likely to involve approaches to value creation that reduce operational and infrastructure costs for commercial actors, indeed supported by governmental action. At the same time, discursively shifting responsibility for the sector's decarbonisation to the UK government is not in itself helpful and is a situation in need of change.

Notes

1. Various qualifications can be made to technical decarbonization claims in this context. These include the consideration that it is often not possible to completely replace coke with biomass in current blast furnace designs, given the lower compressive strength of biomass. Blast furnaces designed for use with biomass have to be far shorter than those designed for coke. Hence, with legacy blast furnaces, only partial substitution of biomass is possible. Moreover, use of (in the UK, imported) biomass is controversial, with its sustainability being contested. Further discussion of partial substitution of coke with biomass is available in H. Mandova et al., 'Possibilities for Co2 Emission Reduction Using Biomass in European Integrated Steel Plants', *Biomass and Bioenergy,* 115 (2018/08/01/2018), 231–43.
2. Arguably with some justification, given the precarity of the sector – we discuss this later.
3. Integrated plants are those that convert ore to iron, then to steel, and further on to other semi-finished or finished products.

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References

Alkemade, Floortje, and Roald A. A. Suurs. 2012. "Patterns of Expectations for Emerging Sustainable Technologies." *Technological Forecasting and Social Change* 79 (3): 448–456. doi:10.1016/j.techfore.2011.08.014.

Anonymous. 2021. *Oral Evidence: Liberty Steel and the Future of the UK Steel Industry, HC 118', Business, Energy and Industrial Strategy Committee*. London: House of Commons.

Bakker, Sjoerd, and Björn Budde. 2012. "Technological Hype and Disappointment: Lessons from the Hydrogen and Fuel Cell Case." *Technology Analysis & Strategic Management* 24 (6): 549–563. doi:10.1080/09537325.2012.693662.

BCSA. 2021. "BCSA 2050 Decarbonisation Roadmap." British Constructional Steelwork Association, 24.

BEIS. 2017a. *The Clean Growth Strategy: Leading the way to a low Carbon Future*. London: Department for Business, Energy and Industrial Strategy.

BEIS. 2017b. "Future Capacities and Capabilities of the UK Steel Industry." In *Energy and Industrial Strategy*. Department for Business, 26, 19.

BEIS. 2017c. *Upgrading our Energy System: Smart Systems and Flexibility Plan*. London: Department for Business, Energy and Industrial Strategy.

BEIS. 2017d. "Industrial Strategy: The Grand Challenges, updated 26 January 2021." Accessed May 11, 2022. https://www.gov.uk/government/publications/industrial-strategy-the-grand-challenges/industrial-strategy-the-grand-challenges.
BEIS. 2019a. *Creating a Clean Steel Fund: Call for Evidence*. London: Department for Business, Energy and Industrial Strategy.
BEIS. 2019b. "The Grand Challenge Missions." In *Energy and Industrial Strategy*. Department for Business, London.
BEIS. 2020a. "Summary of Responses to the Clean Steel Fund Call for Evidence. Putting the Steel Sector on a Path Consistent with Net-Zero." In *Energy and Industrial Strategy*. Department for Business, London, 38.
BEIS. 2020b. *CCS Deployment at Dispersed Industrial Sites*, 89. London: Department for Business, Energy and Industrial Strategy.
BEIS. 2021a. "Net Zero Strategy: Build Back Greener." In *Energy and Industrial Strategy*. Department for Business, London, 368.
BEIS. 2021b. "Net Zero Innovation Portfolio." In *Energy and Industrial Strategy*. Department for Business, London.
BEIS. 2021c. "Industrial Decarbonisation Strategy." In *Energy and Industrial Strategy*. Department for Business, London, 170.
BEIS. 2022b. "Digest of UK Energy Statistics, Annual Data for 2021." In *Energy and Industrial Strategy*. Department for Business, London.
BEIS. 2022c. "Steel Procurement Pipeline 2022." In *Energy and Industrial Strategy*. Department for Business, London.
BEIS. 2022d. "Energy Intensive Industries (EIIS). Guidance for Applicants Seeking a certificate for an Exemption from the Indirect Costs of Funding Contracts for Difference (CFD), the Renewables Obligation (RO) and the Small-Scale Feed in Tariff (FIT)." In *Energy and Industrial Strategy*. Department for Business (ed.), (London).
BEIS and UK Steel. 2022. "Steel Procurement Taskforce. Final Report." In *Energy and Industrial Strategy*. Department for Business and MAKEUK, London.
Berkhout, Frans. 2006. "Normative Expectations in Systems Innovation." *Technology Analysis & Strategic Management* 18 (3-4): 299–311. doi:10.1080/09537320600777010.
Bicchieri, Cristina. 2005. *The Grammar of Society: The Nature and Dynamics of Social Norms*. Cambridge: Cambridge University Press.
Borup, Mads, N. Brown, K. Konrad, and H. Van Lente. 2006. "The Sociology of Expectations in Science and Technology." *Technology Analysis & Strategic Management* 18 (3-4): 285–298. doi:10.1080/09537320600777002.
Cabinet Office. 2021. National Procurement Policy Statement'.
Chiappinelli, O., T. Gerres, K. Neuhoff, F. Lettow, H. de Coninck, B. Felsmann, F. Joltreau, G. Khandekar, P. Linares, J. Richstein, A. Śniegocki, J. Stede, T. Wyns, C. Zandt, and L. Zetterberg. 2021. "A Green COVID-19 Recovery of the EU Basic Materials Sector: Identifying Potentials, Barriers and Policy Solutions." *Climate Policy* 21 (10): 1328–1346. doi:10.1080/14693062.2021.1922340.
The Climate Change Act 2008 (2050 Target Amendment). 2019. "The Climate Change Act 2008 (2050 Target Amendment) Order 2019." In *Energy and Industrial Strategy*. Department for Business, London.
DeKrey, Steven J., and Edwin J. Portugal. 2014. "Strategic Sensemaking: Challenges Faced by a New Leader of an SME." *Procedia - Social and Behavioral Sciences* 150: 56–65. doi:10.1016/j.sbspro.2014.09.007.
ECIU. 2021. *Stuck on the Starting Line. How the UK is Falling Behind Europe in the Race to Clean Steel*. Energy and Climate Intelligence Unit.
Elia, A., M. Kamidelivand, F. Rogan, and B. Ó Gallachóir. 2021. "Impacts of Innovation on Renewable Energy Technology Cost Reductions." *Renewable and Sustainable Energy Reviews* 138: 110488. doi:10.1016/j.rser.2020.110488.
Environmental Audit Committee. 2022. "Technological Innovations and Climate Change Inquiry: Green Steel." In *House of Commons, London*, 7.
Garvey, Alice, and Peter G Taylor. 2020. "Industrial Decarbonisation Policies for a UK Net Zero Target. A review of mechanisms for ambitious greenhouse gas mitigation." Centre for Research and Energy Demands Solutions (CREDS).
Geels, Frank W. 2002. "Technological Transitions as Evolutionary Reconfiguration Processes: A Multi-Level Perspective and a Case-Study." *Research Policy* 31 (8): 1257–1274. doi:10.1016/S0048-7333(02)00062-8.
Geels, Frank W. 2004. "From Sectoral Systems of Innovation to Socio-Technical Systems: Insights About Dynamics and Change from Sociology and Institutional Theory." *Research Policy* 33 (6): 897–920. doi:10.1016/j.respol.2004.01.015.
Geels, F. W. 2014. "Regime Resistance Against Low-Carbon Transitions: Introducing Politics and Power Into the Multi-Level Perspective." *Theory, Culture & Society* 31 (5): 21–40.
Geels, Frank W., and Johan Schot. 2007. "Typology of Sociotechnical Transition Pathways." *Research Policy* 36 (3): 399–417. doi:10.1016/j.respol.2007.01.003.
Geels, Frank W., G. K. Sovacool, T. Schwanen, and S. Sorrell. 2017. "Sociotechnical Transitions for Deep Decarbonisation." *Science* 357 (6357): 1242. doi:10.1126/science.aao3760.
Green Alliance. 2021a. *Clean Steel in the UK. Making the UK a world leader in the production of clean steel', HNZ0095 - The role of hydrogen in achieving Net Zero*. UK Parliament.

Green Alliance. 2021b. "Making the UK a World Leader in the Production of Clean Steel", 9.
Greenwood, Ian. 2017. *The All Party Parliamentary Group on Steel and Metal Related Industries. Forging a Future for the British Steel Industry*. London: The All Party Parliamentary Group on Steel and Metal Related Industries.
Griffin, Paul W., and Geoffrey P. Hammond. 2019. "Industrial Energy use and Carbon Emissions Reduction in the Iron and Steel Sector: A UK Perspective." *Applied Energy* 249: 109–125. doi:10.1016/j.apenergy.2019.04.148.
HS2. 2022. "High Speed Two Ltd." Accessed October 3, 2022. https://www.hs2.org.uk/.
Hutton, Georgina. 2021. "UK Steel Industry: Statistics and Policy." In *House of Commons Library*.
IEA. 2020a. *Energy Technology Perspectives 2020*. Paris: International Energy Agency.
IEA. 2020b. *Iron and Steel Technology Roadmap. Towards More Sustainable Steelmaking, Energy Technology Perspectives*. Paris: International Energy Agency.
IEA. 2020c. "The Challenge of Reaching Zero Emissions in Heavy Industry." https://www.iea.org/articles/the-challenge-of-reaching-zero-emissions-in-heavy-industry.
Jalonen, Kari, Henri Schildt, and Eero Vaara. 2018. "Strategic Concepts as Micro-Level Tools in Strategic Sensemaking." *Strategic Management Journal* 39 (10): 2794–2826. doi:10.1002/smj.2924.
Kim, Jinsoo, B. K. Sovacool, M. Bazilian, S. Griffiths, J. Lee, M. Yang, and J. Lee. 2022. "Decarbonising the Iron and Steel Industry: A Systematic Review of Sociotechnical Systems, Technological Innovations, and Policy Options." *Energy Research & Social Science* 89: 102565. doi:10.1016/j.erss.2022.102565.
Konrad, Kornelia. 2006. "The Social Dynamics of Expectations: The Interaction of Collective and Actor-Specific Expectations on Electronic Commerce and Interactive Television." *Technology Analysis & Strategic Management* 18 (3-4): 429–444. doi:10.1080/09537320600777192.
Lytton, Wilf, and Phil MacDonald. 2021. *Mapping Coal Use in the UK Steel Sector*. UK steel Database, October 11, 2022.
Maitlis, Sally, and Marlys Christianson. 2014. "Sensemaking in Organisations: Taking Stock and Moving Forward." *The Academy of Management Annals* 8 (1): 57–125. doi:10.1080/19416520.2014.873177.
MAKEUk. 2021a. "The UK's Uncompetitive Electricity Costs Are a Barrier to Decarbonisation Says New UK Steel Report." Accessed August 11, 2022. https://www.makeuk.org/insights/reports/a-barrier-to-decarbonisation-industrial-electricity-prices-faced-by-uk-steelmakers.
MAKEUk. 2021b. *A Barrier to Decarbonisation: Industrial Electricity Prices Faced by UK Steelmakers*. MAKEUK.
Mandova, Hana, Piera Patrizio, Sylvain Leduc, Jan Kjärstad, Chuan Wang, Elisabeth Wetterlund, Florian Kraxner, and William Gale. 2019. "Achieving Carbon-Neutral Iron and Steelmaking in Europe Through the Deployment of Bioenergy with Carbon Capture and Storage." *Journal of Cleaner Production* 218: 118–129. doi:10.1016/j.jclepro.2019.01.247.
Milford, Rachel L., Stefan Pauliuk, Julian M. Allwood, and Daniel B. Müller. 2013. "The Roles of Energy and Material Efficiency in Meeting Steel Industry CO2 Targets." *Environmental Science & Technology* 47 (7): 3455–3462. doi:10.1021/es3031424.
Neuhoff, Karsten, B. Vanderborght, A. Ancygier, A. T. Atasoy, M. Haussner, R. Ismer, B. Mack, et al. 2014. *Carbon Control and Competitiveness Post 2020: The Steel Report*. Climate Strategies.
Norman, Jonathan, Alice Garvey, and John Barrett. 2019. *Clean Steel Fund: Call for Evidence*. Oxford: Centre for Research into Energy Demand Solutions (CREDS).
OECD. 2021. "Last Developments in Steel Making Capacity, September 2021." Organisation for Economic Co-operation and Development (OECD).
Ozsozgun Caliskan, Arzu, Emel Esen, and Ralf Barkemeyer. 2021. "Impression Management Tactics in the CEO Statements of Turkish Sustainability Reports." *Business Ethics, the Environment and Responsibility* 30 (4): 485–506. doi:10.1111/beer.12374.
Pimm, Andrew J., Tim T. Cockerill, and William F. Gale. 2021. "Energy System Requirements of Fossil-Free Steelmaking Using Hydrogen Direct Reduction." *Journal of Cleaner Production* 312: 127665. doi:10.1016/j.jclepro.2021.127665.
Priestley, Sarah. 2019. "Net Zero in the UK." In *House of Commons Library*.
Raval, Anjli, et al. 2022. "Tata Threatens to Close Port Talbot Steelworks Without £1.5bn of Aid." *Financial Times*.
Rosenbloom, Daniel, and Adrian Rinscheid. 2020. "Deliberate Decline: An Emerging Frontier for the Study and Practice of Decarbonization." *WIREs Climate Change* 11: e669. doi:10.1002/wcc.669.
Sato, Misato, and Josh Burke. 2021. What is Carbon Leakage? Clarifying Misconceptions for a Better Mitigation Effort'.
Smeeton, George. 2021. *Report: UK is Falling Behind Europe in Clean Steel Race [Press Release]*. Energy and Climate Intelligence Unit. https://eciu.net/media/press-releases/2023/further-delays-to-energy-efficiency-in-private-rented-sector.
Sutcliffe, Kathleen M. 2016. "Sensemaking." In *The Palgrave Encyclopedia of Strategic Management*, edited by Mie Augier, and David J. Teece, 1–4. London: Palgrave Macmillan UK.
Thomas, James B., Shawn M. Clark, and Dennis A. Gioia. 1993. Strategic Sensemaking and Organizational Performance: Linkages among Scanning, Interpretation, Action, and Outcomes." *The Academy of Management Journal* 36 (2): 239–270.

Tsvetanova, Lora, Laura Carraresi, Michael Wustmans, and Stefanie Bröring. 2022. "Actors' Strategic Goals in Emerging Technological Innovation Systems: Evidence from the Biorefinery Sector in Germany." *Technology Analysis & Strategic Management* 34 (7): 760–773. doi:10.1080/09537325.2021.1919300.
UK Government. 2020. "PM Commits £350 Million to Fuel Green Recovery." London.
UK Government. 2022. "Environmental Taxes, Reliefs and Schemes for Businesses." https://www.gov.uk/green-taxes-and-reliefs/climate-change-levy.
UK Steel. 2021a. "Key Statistics Guide for 2021." MAKEUk, 10.
UK Steel. 2021b. "Maximising Value: Positive Procurement of Steel, MAKE UK." *The Manufacturer's Organisation*, 16.
UK Steel. 2021c. *Closing the Gap: How Competitive Electricity Prices can Build a Sustainable Low Carbon Steel Sector*, Make UK.
Upham, Paul, Paula Bögel, Elisabeth Dütschke, Uta Burghard, Christian Oltra, Roser Sala, Monica Lores, and Julia Brinkmann. 2020. "The Revolution is Conditional? The Conditionality of Hydrogen Fuel Cell Expectations in Five European Countries." *Energy Research & Social Science* 70: 101722. doi:10.1016/j.erss.2020.101722.
Upham, Paul, Paula Bögel, and Katinka Johansen. 2019. *Energy Transitions and Social Psychology: A Sociotechnical Perspective*. 1st ed. Routledge.
Upham, Paul, Elisabeth Dütschke, Uta Schneider, Christian Oltra, Roser Sala, Monica Lores, Rita Klapper, and Paula Bögel. 2018. "Agency and Structure in a Sociotechnical Transition: Hydrogen Fuel Cells, Conjunctural Knowledge and Structuration in Europe." *Energy Research & Social Science* 37: 163–174. doi:10.1016/j.erss.2017.09.040.
Van Lente, Harro. 1993. *Promising Technology. The Dynamics of Expectations in Technological Developments*, Eburon.
Van Lente, Harro. 2012. "Navigating Foresight in a sea of Expectations: Lessons from the Sociology of Expectations." *Technology Analysis & Strategic Management* 24 (8): 769–782. doi:10.1080/09537325.2012.715478.
Van Lente, Harro, and Sjoerd Bakker. 2010. "Competing Expectations: The Case of Hydrogen Storage Technologies." *Technology Analysis & Strategic Management* 22 (6): 693–709. doi:10.1080/09537325.2010.496283.
Vogl, Valentin, Max Åhman, and Lars J. Nilsson. 2018. "Assessment of Hydrogen Direct Reduction for Fossil-Free Steelmaking." *Journal of Cleaner Production* 203: 736–745. doi:10.1016/j.jclepro.2018.08.279.
Weick, Karl E. 1995. *Sensemaking in Organisations (Foundations for Organizational Science)*. Thousand Oaks: Sage.
Weick, Karl E., Kathleen M. Sutcliffe, and David Obstfeld. 2005. "Organising and the Process of Sensemaking." *Organization Science* 16 (4): 409–421. doi:10.1287/orsc.1050.0133.