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Incentives and actions of a transitioning industry

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Abstract

This thesis seeks to investigate the role of the Sustainable Development Goals (SDGs), the Paris Agreement, and the Swedish Climate Act in the transition to net-zero in energy intensive industries, with a focus on the steel sector. Several empirical studies have previously been done on both national and international policies and how they influence low-carbon transitions and technological innovation within industry. What is somewhat lacking in the literature on the decarbonization of energy intensive industries is the analysis of how they themselves conceptualize and mention specific policies and climate-related issues. This research fills an important gap on the ways in which companies externally conceptualize, react to, and talk about external pushes towards decarbonization. Based on green state theory and transition theory, this research uses quantitative and qualitative methods to examine five Swedish companies' annual reports in the steel sector. The findings show that there have been increased efforts to steer toward climate-mitigating strategies by the companies in this sector. The discussion applies transition theory and finds that the Swedish steel sector is in transition to become greener, but more can be done. The specific extent the role the SDGs, the Paris Agreement and The Swedish Climate Act has played in this transition is not determined.

Keywords: climate change, the Paris Agreement, Swedish climate act, Sustainable Development Goals, steel sector, transition theory, green state theory, Multi-Level Perspective

Words: 9200

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1. Introduction

After the release of the Sixth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC) in April 2022, Jim Skea, Co-Chair of the IPCC Working Group III said, “It’s now or never, if we want to limit global warming to 1.5ºC; without immediate and deep emissions reductions across all sectors, it will be impossible” (United Nations, 2022a). The Sixth Assessment Report assesses the options available to mitigate climate change; the state of technical, scientific, and socio-economic knowledge on climate change, and future impacts and risks (IPCC, 2022a). The report finds that net anthropogenic Greenhouse Gas (GHG) emissions have increased across all sectors since 2010, and that limiting global warming to 1.5ºC will require GHG emissions to peak prior to 2025 (IPCC, 2022b). The report also highlights mitigation strategies which have been proven to be effective. After the Fifth Assessment Report, the expansion of policies and laws pertaining to climate mitigation has led to the prevention of “emissions that would otherwise have occurred” while also increasing investments in “low-GHG technologies” (ibid.). Moreover, the Sixth Assessment Report notes that reaching net-zero CO_2 emissions within the industrial sector is challenging, but not impossible. Reducing industrial emissions requires the promotion of all mitigation options, “including […] materials efficiency, circular material flows, as well as abatement technologies and transformational changes in production processes” (ibid.). The widespread news coverage this report received across the globe follows several years of initiatives, treaties, and legislation on climate-change.

These initiatives include the Sustainable Development Goals (SDGs) and the 2030 agenda, which are an assortment of goals for sustainable development, including climate focused goals. The 2030 Agenda for Sustainable Development was adopted by all United Nations member states in 2015 and provides a framework and is an “urgent call for action” to tackle climate change, amongst other things (UN, 2022b). The Paris Agreement “is a legally binding international treaty on climate change” with the goals to limit global warming to 2°C and preferably to 1.5°C (UNFCCC, 2022a). The Paris Agreement was ratified in 2016 and requires “all Parties to put forward their best efforts through ‘nationally determined contributions’ […] and to strengthen these efforts in the years ahead” (UNFCCC, 2022b).

In June 2017 a climate policy framework was introduced by the Swedish Parliament which set out the implementation of the Paris Agreement (Ministry of the Environment, 2018). In 2018, industrial GHGs accounted for 32 percent of Sweden's total emissions, where the highest amounts came from the iron and steel industry at 34 percent (Ministry of the Environment, 2020). Through the Paris Agreement the Swedish government commits to help limit global warming by keeping the global temperature under 2ºC above pre-industrial levels, while also pursuing efforts to contain the increase to only 1.5ºC (Ministry of the Environment, 2020). This framework includes several climate goals: net-zero emissions of GHGs into the atmosphere, followed by achieving negative emissions; a reduction of emissions from domestic transport, excluding aviation, by 70 per cent by 2030 from 2010 levels; a reduction of emissions from sectors that are covered by the EU Effort Sharing Regulation by 63 percent by 2030 from 1990 levels, followed by a reduction of 75 percent by 2040 from 1990 levels (ibid.). To achieve these goals the reform also included the establishment of the Climate Act to ensure that Swedish governments base their climate policy on the climate goals. Furthermore, the act requires that the Government presents an annual climate report in its Budget Bill, that the Government draws up a "climate policy action plan" every four years, and that "climate goals and budget policy goals" work together (ibid.). The third pillar of this new framework is the establishment of a climate policy council, tasked with supporting the Government by providing independent assessments of how the "the overall policy presented by the Government is compatible with the climate goals" (ibid.). The legislation passed in Sweden "legally binds the country to net-zero emissions by the year 2045" and provides the "long-term conditions for business and society to implement the transition needed to solve the challenge of climate change" (UNFCCC, 2022c).

Meadowcroft (2005, p. 3) considers the transformation of the welfare state leading to the genesis of an "ecological state" which is a state that places ecological considerations "at the core of its activity". The ecological state (which is used interchangeably with the green state and ecostate within the literature) describes "arrangements" that are taking place in developed countries, where climate politics is acknowledged to be "an essential responsibility of the public power" (ibid, p. 3). Meadowcroft (ibid.) further categorizes the ecological state as one that is "committed to sustainable development" and one that secures social development trajectories so that it "remains within the frontiers of environmental sustainability". Meadowcroft (ibid.) categorizes other essential components of the ecological state to help us conceptualize it; the ecological state goes "*above and beyond*" the minimum needed to avoid socioecological catastrophe by securing “environment-related benefits” such as “enhancing human welfare or the welfare of other species and ecosystems”. To assume this role, the ecological state would have to keep track of environmental changes, map patterns of interactions between humans and nature and anticipate future developments, have effective strategies and policy instruments, and act as well as engage with both national and international spheres. Hildingsson, Kronsell and Khan (2019) highlight the tension which exists between ecological concerns and the “economic imperative of the state” – that is the need of the state to endlessly promote economic and industrial development which leads to resource extraction, material consumption and environmental degradation. While green state theory has yet to resolve the tension between economic and ecological concerns, the theory “assumes that a green state will develop a more ecologically sustainable approach to economic objectives” (Ibid.). Tobin (2015, p. 151) examined to what extent Sweden displays the characteristics of the green state “with regard to the most significant environmental threat, climate change” by analyzing policy actions “in each of the four main emissions reductions areas prioritized” by the state between the years 2006-2010. Tobin (2015, p. 152) finds that Sweden’s policies did not facilitate a significant reduction in overall emissions. Furthermore, Sweden’s policies proved sufficient “to protect Sweden’s status as a climate pioneer” but not “enough to facilitate a transition from environmental welfare state to green state” (Ibid.).

Several empirical studies have previously been done on both national and international policies and how they influence low-carbon transitions and technological innovation (see Nilsson et al, 2021; Andersson, 2019; Åhman, Nilsson, Johansson, 2017; Khan, Johansson, Hildingsson, 2021). Hildingsson and Khan (2015, p. 162) present an overview of climate policy instruments introduced in Swedish policy in the last twenty years. Hildingsson and Khan (ibid, p. 163) find that the policy framework ”is clearly insufficient to facilitate technological innovation” and that technology-specific policies “fostering innovation” are lacking, especially within the iron and steel, mineral, and chemical industries which are still largely dependent on fossil fuels. Furthermore, decarbonization is not institutionalized as a core objective for Swedish climate governance, nor is it operationalized in terms of ”targets, policy strategies and governance initiatives in other sectors (e.g industry and transport)” (ibid, p. 169). This is explained by contestations ”in policy making circles” over the means of governing the transition to low-carbon – the question then is whether climate governance only entails the regulation of carbon emissions by carbon pricing, or whether it ”should also foster decarbonization by transforming societal structures and systems” (ibid). The climate mitigation strategies of the past 20 years have successfully transformed sectors where mature technological alternatives have been presented, but has been less successful in sectors where the need for technological innovation and changed patterns of behavior are necessary (ibid, p. 170). Previous studies on the impacts of policies have also been done in other energy intensive sectors, such as wind and energy. Lindman and Söderholm (2015) investigate the impacts "of FIT schemes and public R&D support […] on innovation in the empirical context of wind power technology" by using patent application counts as a proxy for innovation.

What is somewhat lacking in the literature on the decarbonization of energy intensive industries is the analysis of how they themselves conceptualize and mention specific policies and climate-related issues. As insights "on how industry and industrial innovation are related to environmental governance and the green state" (Hildingsson, Kronsell and Khan, 2019), are lacking, this research fills an important gap on the ways in which companies publicly communicate, react to, and talk about, external pushes towards decarbonization. The role of technological innovation as a driver for the decarbonization of energy intensive industries is strongly emphasized in the literature on the green state (Lindman and Söderholm, 2016; Vogl, Åhman and Nilsson, 2021). Energy intensive industries consist of industries such as the steel, mining, and plastics industries. While technological advancement is crucial in the transition to low-carbon or to reach deep decarbonization, the role of policy support is said to be critical to foster technological innovation (Peters *et al.*, 2012). The green state is a generic concept with different meanings consisting of a "normative or an analytical construct, a counterfactual ideal of ecological responsiveness to strive for" or "an evolving institutionalization of ecological responsibilities that can be empirically assessed" (Hildingsson, Kronsell, and Khan, 2019). Within green state literature one tradition which has emerged is "empirical-oriented and found [...] in the field of comparative environmental politics" (Bäckstrand and Kronsell, 2015). However, both theoretical insights as well as empirical research is somewhat lacking "on how industry and industrial innovation are related to environmental governance and the green state" (Hildingsson, Kronsell, and Khan, 2019).

2. Research questions and aims

This thesis seeks to investigate the role of the SDGs, the Paris Agreement, and the Swedish Climate Act in the transition to net-zero in energy intensive industries, with a focus on the steel sector. It aims to do so by examining to what extent and how companies in the Swedish steel sector discuss and mention climate-related activities.

These aims have led to the research questions:

- How do LKAB, SSAB, SKF AB, Boliden AB, and Sandvik mention the SDGs, the Paris Agreement, and the Swedish Climate Act?
- Is the introduction of the SDGs, the Paris Agreement, or the Swedish Climate Act reflected in increased efforts to transition to net-zero and mitigate climate change?

3. Theoretical Framework

The thesis is informed by, and wishes to contribute to, previous literature on the green state and transition theory. Pioneered by Eckersley (2004), green state theory accepts the premise that any foreseeable green transformations are out of necessity state dependent. Those who are concerned about the destruction of our climate must contend to "rebuild the ship while still at sea" (Eckersley, 2004, p. 5). Duit, Peter and Meadowcroft (2016) affirm several reasons for the significance of the state in both the analysis and practice of environmental politics and policy. The fact that states "maintain legal frameworks (including systems of property rights) backed by coercive power, and deploy significant economic and administrative resources through taxation", while also structuring political, economic and social interactions means that the state "obviously" still matters as a unit of analysis (ibid, p. 3; Meadowcroft, 2005, p. 5). Hysing (2015, p. 28), building upon Eckersley (2004) and Meadowcroft (2005), also argue that the state can be seen as the only political entity that harbors "key political authority and steering capacity to take action against environmental problems" because of the "unique features of states, such as their monopoly on the legitimate use of force and the legal right of sovereignty". And while the monopoly of states and their monopoly of the means of coercion "is a most serious matter" as Eckersley (2004, p. 7) puts it, it does not "necessarily imply that they must have frequent recourse to that power" and that whether the "state's coercive powers [are] to be deplored or welcomed" depends to the purposes for which that power is exercised. Furthermore, it is states that engage in international environmental treaties, and therefore can choose to either cooperate with or defect from them (Weiss and Jacobson, cited in Duit, 2014 p. 3). Also, while the influence of the EU in environmental affairs has been significant, especially in the past ten years, it is the member states that retain "a significant direct influence in decision making and policy implementation" and "to the extent that the EU determines the development of environmental governance within its sphere (and acts as a unified external political actor), it comes to display 'state-like' characteristics" (Duit, Pether and Meadowcroft, 2016). However, as the process of environmental degradation is a globalized problem, individual states are often thought to "lack both the ability and the incentive to address" the problem (Duit, 2014, p. 2). A second common argument is that representative democracies "will tend to promote economic growth, tax revenues, or employment opportunities over environmental protection due to electoral pressures" (ibid). Therefore, the state can only be expected to supply "a basic level of environmental regulation" that is compatible with sustained economic growth (Buttel, cited in Duit, 2014, p. 2). Further critiques have been levied against the liberal democratic state, "for not allowing civic society and social movement representatives access to environmental decision- and policy-making processes" (Duit, 2014, p 2). As early green state theory did not conceptualize the process of transition from a capitalist state to a green state beyond addressing the need for value changes emanating from civil society and the need for democratic institutions, it did not sufficiently theorize other processes of change (ibid.). It has therefore been necessary to incorporate transition theory to further advance green state theory (ibid; Bäckstrand and Kronsell, 2015, p. 5).

Transition theory, which is a multidisciplinary scholarly field, studies conditions for innovation "in socio-technical systems" and looks at the conditions of change over time and concerns the governance for transformation "toward sustainability and climate objectives" (Bäckstrand and Kronsell, 2015, p. 11). Transitions are therefore understood as "structural change in major societal" systems and indicate a shift from one dominant and incumbent equilibrium to another (Meadowcroft, 2009). The Multi-Level Perspective (MLP) is an approach that focuses on transition in systems, specifically those that provide societal or end-use services (Geels, 2019). MLP puts an emphasis on radical innovation (electrical-vehicles, renewable electricity, heat pumps), while also considering transition as a process that is facilitated by social groups, such as companies or policymakers, who engage in activities "in the context of rules and institutions, including belief systems and norms" (ibid.). As a process theory, MLP has "global" and "local" components. The global component consists of analytical levels and temporal phases that "describe the overall course of socio-technical systems, and the local component "addresses specific activities and causal mechanisms in multi-level interactions" (ibid.). These components are outlined below. MLP suggests that transitions happen in the interaction between processes at niche, regime and landscape levels (ibid.).

There are three concepts which are the pillars of transition theory. Firstly, the global component, *landscapes*, which are what provides context for transformation as "transitions always occur in an environment of a broader context of norms, which are institutionalized over time" (ibid.). Landscapes consists of the dominating discourse that orders society and culture, and moreover "give significance and legitimation to, as well as frame issues and discourses of, regime actors (ibid.). Secondly, *regimes* (local component), which are "the (network of) actors that exercise constitutive power" (Avelino and Rotmans, 2009, p. 560, cited in Kronsell and Bäckstrand 2015, p 11). Regimes are therefore actors which have the powers to establish "or enact" social order "tied to […] certain distribution of resources". The power that the regime exercises is "through practices that distribute privilege and recourses" (ibid.). The third and last concept is *niches* (local component). Change and transformation happens when the current "regime is weakened by the influence of niches" (ibid, p. 12). Niches can be seen as outside and independent of regimes, and within niches "new ideas that encourage transition can flourish" (ibid.). These niches can come about because of "participatory arenas" where a set of "relevant actors can meet, deliberate and generate innovation – new niches – leading to transitions" (ibid.). Incumbent and niche systems are different in their structure and bendability, as in the latter, dominant technologies, behaviors, rules or actors have not yet been determined; they are therefore generally smaller and less stable than incumbent systems (Rijnsoever and Leendertse, 2020).

These three concepts are the pillars of transition theory and are what comprises the "transitions storyline" (Smith and Kern, 2009). The transitions storyline "broadens policy focus beyond firm-level processes of cleaner technology and improved environmental management" as it implies a structural change to socio-technical systems to decouple the economy from environmental degradation (ibid.). Transition theory is interested in how regimes, such as regimes which are incumbent on "old" technologies that represent an obstacle for transformation, can be "circumvented and changed" (Kronsell and Bäckstrand, 2015 pp. 11-12). The political science scholarship on sustainability and environmental governance has highlighted the importance of an inclusive policy process which engages and includes a broad range of societal actors as essential "to the success of a transition strategy" and a way "to safeguard legitimacy for the kind of transitions required to reach climate objectives" (ibid.).

4. Methodology

The research questions of this study concern the potential impact of the SDG's, the Paris Agreement, and the 2045 goal of the Climate Act on the operations of Swedish steel companies. The annual reports of companies are a primary source for information about company operations and were therefore chosen as source material to investigate and try to answer these questions. The annual reports of companies contain not only income statements of raw numbers on investments, income, taxes paid etc. Annual reports also describe a company's moral values, goals, visions, and strategies, and outlines what the company believes can be expected to happen in the industry in the near- to long-term future, as well as external factors (such as other companies, regulations, laws, environmental issues) that may or may not impact the industry at large, or the company and its "well-being". In fact, these descriptors of external risks, as well as company successes, are always reserved a spot on the frontpage of annual reports as well as being highlighted in the President's and/or the CEO's letter and are a rich source of information on both the company's past, present, and planned actions and investments, as well as what incentivizes these. Furthermore, annual reports contain segments about everything related to the running of the company, such as research and development (R&D), company priorities and strategy, and more recently, dedicated segments on sustainability.

Relevant data about company operations related to net-zero and climate change were collected from company annual reports, with a timespan framing the introduction of the SDGs, the Paris Agreement, and the Swedish Climate Act in 2015-2017 to be able to compare data from reports written before and after their introduction. Both quantitative data and qualitative data were extracted from the annual reports (for details, see below). Results from both the quantitative and qualitative approach were analyzed with green state theory and transition theory to frame the discussion.

4.1. Research Design

In approaching the design of the research, attention was paid to practical circumstances, the context of the research, the research questions, as well as the material used. Considering all factors, a decision to use a mixed-method design was taken due to the nature of the data and the limitations potentially imposed on conclusions if using only one approach. This research combines both qualitative and quantitative approaches to capitalize "on the strengths of the two approaches, and to compensate for the weaknesses of each approach" (Punch, 2005, p. 240). However, as per Punch (ibid., p. 241) there "is the question of what 'combine' here might mean". Moreover, it is important to distinguish between "combining methods, combining data, and combining findings" (ibid.). This design's approach to the combination of qualitative and quantitative data is called *logic of triangulation* and can be summarized as "[t]he findings from one type of study" being checked "against the findings deriving from the other type" (ibid.). While the source material that the data is collected from is the same, the type of data is not and there are therefore two types (qualitative and quantitative) of data that are brought together and compared in the findings.

4.2. Data collection

Companies were selected for this research based on a list of leading steel and mining manufacturers in Sweden from Jernkontoret (2021b). From this list, the five companies which had annual reports spanning the years 2005-2021 were chosen as this provides a sufficient timespan both before and after 2015-2017 for the quantitative analysis. The annual reports were downloaded from the respective companies' websites. Both the qualitative and quantitative data were obtained from the annual reports. Quantitative data on R&D spending and total yearly expenditures were gathered from the consolidated income statements of the annual reports of the companies. Quantitative data aiming at getting a first rough estimate of the companies' engagement with climate-related goals, and potential incentivization by organizational bodies, treaties, or acts were obtained by counting the number of hits for proxy variables consisting of key words or phrases commonly used in climate-related literature on energy intensive industries and decarbonization.

4.3. Quantitative analysis

To obtain an initial overall estimate of the awareness and importance that the companies within the steel sector in this study are placing on the climate, their emissions, as well as their carbon-curbing actions, annual reports were searched using a set of climate and action-related keywords and phrases, and the number of hits enumerated. The keywords/phrases used were *emissions* | *climate* | *greenhouse* | *greenhouse gas* | *GHG* | *fossil*-free | *fossil free* | *renewable* | *renewables* | *research and development* | *research & development* | *r&d,* where the symbol '|' represents a logical "or" and separates synonyms for which hit counts were aggregated. The searches were applied with a temporal limit of 2012-2021, partially due to time constraints, but also as the timespan sufficiently shows significant changes in the number of returned hits from the queries. References to organizational bodies, treaties, or acts, reflecting awareness of and, possibly, incentivization by these, were enumerated by searching the annual reports for occurrences of the keywords/phrases *sustainable development goals* | *sdg* | *paris* | *paris agreement* | *2045* | *net zero* | *net-zero* | *carbon neutrality*. By the nature of their recent establishments these searches were carried out with temporal limits from their respective beginnings to 2021.

To investigate if the introduction of the Climate Act, the Paris Agreement, or the SDGs had an effect on overall R&D investments, a regression analysis was carried out, with the variables *Rdmsek* (percentage of annual expenses spent on R&D) as the dependent variable, and *Climateact*, *Parisagreement*, and *SDGs* as the independent dummy variables that were either included (1) or excluded (0) in the model, and *Year* as an independent variable ranging between the years 2005-2021.

4.4. Qualitative analysis

The process of content analysis combines both quantitative and qualitative approach and is loosely based on the steps outlined in Halperin and Heath (2012, pp. 320-322). For the qualitative approach, an initial quick reading of the annual reports for 2005, 2013, and 2021 was performed. This indicated common themes; a circular economy, decarbonization, fossil-free fuel consumption, and development and innovation toward sustainable operations that were used as the basis for organizing the results. From this first reading it became apparent that the later annual reports, and in particular the ones from 2021, are a very rich source of information since they have a clear focus on climate throughout, contain both retrospective and forward-looking views, and contain a (now mandatory) sustainability section. By careful reading of the reports from 2015 and onwards, statements related to *actions* aimed at limiting climate change and *incentives* for change were identified and collected. The statements were sorted into a first set of categories; decarbonization, fossil-free fuel consumption, GHG emissions, sustainability, net-zero, R&D investments, circular economy, cooperation, SDGs, the Paris Agreement and Swedish climate goals. Analysis of the grouped statements showed noteworthy overlap and co-dependence on many of the initial categories, leading to a final categorization of *actions* (circular economy, R&D) and *incentives* (SDGs, Paris Agreement, Swedish Climate Act).

5. Results

5.1. Actions

A plot of the percentage of total expenses allocated to R&D yearly (Figure 1) shows that investments in R&D have increased linearly since 2005. To investigate if the introduction of SDGs in 2015, the Paris Agreement in 2016, and/or the 2045 goal of the Swedish Climate Act in 2017 was followed by an increase in overall R&D spending, regression analysis with the years of the respective initiative or legislation as a dummy variable was performed. The result shows that none of the initiatives/legislations have had a significant impact on overall R&D spending as: SDGs, $P > 0.05$; Paris Agreement, $P = 0.0.5$; 2045 goal, $P = 0.0.5$ (see Figures 1-3 in Appendix).

5.1.1. Move to a circular economy

Hits for the query *fossil-free | fossil free | renewable*, as seen in Table 1, indicates an increased interest in fossil-free and renewable sources for various processes.

Fossil-Free/ Renewable	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total	33	33	31	26	37	77	88	161	340	301
LKAB	9	4	3	1	4	8	13	23	41	54
SSAB	0	1	0	9	12	44	41	101	235	182
SKF AB	22	23	24	12	9	15	23	19	36	45
BOLIDEN AB	2	3	1	1	8	4	4	8	8	3
SANDVIK	0	2	3	3	4	6	7	10	20	17

Table 1. Number of hits on *query: fossil-free | fossil free | renewable by company and year. Source: Annual Reports (LKAB, 2012-2021; SSAB, 2012-2021; SKF AB, 2012-2021; Boliden AB, 2012-2021; Sandvik, 2012-2021).*

The mentions of the query *fossil-free | fossil free | renewable* by SKF in 2021 addresses it's "development of fossil-free bearing steel" (SKF, 2021, p. 29). In 2021 SKF also launched "a new target to have a net zero supply chain by 2050" as they "have a proven track record in this field and are confident that, by 2030, our own facilities will have net zero greenhouse gas emissions" (ibid., p. 13). Boliden AB (2018, p. 35) declares the plans for a fossil free mine through improved process efficiency and increased electrification to combat air pollution emissions and highlights the "transition to fossil-free fuels and reducing agents" as some measures to decrease carbon dioxide emissions (Boliden AB, 2020, p. 5). Sandvik (2021, p. 17) discusses their contribution to the HYBRIT initiative consisting of them "delivering an electric heating solution for the project that heats hydrogen gas". Furthermore, Sandvik (ibid., 7) emphasizes the shift to fossil-free energy sourcing as a major contributor to their CO_2 emissions.

The hits for the queries *recycle* | *recyclable* | *recycling* | *reuse* | *circular* | *circularity* saw a total increase from 112 in 2012 to 255 in 2019 at its peak, followed by a decline in the subsequent two years (see Table 2). The term circular economy or variations of a circular value chain become more and more popular, and circularity is increasingly becoming part of major goals, such as Sandvik (2019, p. 14) hoping to become 90 per cent circular as part of their 2030 sustainability goals. SSAB (2021, 44) call circularity a "key factor" in mitigating environmental impact. In 2019, circularity is given a lot of hits and the circular use of resources is indicated to be a main way to become more sustainable and mitigate environmental impacts (SKF AB, 2019, p. 8), and the belief that "business models which incentivize circular economies are the future" (ibid. p. 11) is espoused in the CEO letter. Furthermore, SKF state that they help "customers move towards a circular economy by providing products and solutions" as well as "remanufacturing services" (SKF, 2021, p. 22).

Boliden AB (2020, p. 10) calls their business model an essential part of the circular economy, with “[c]utting-edge expertise” in the extraction and refinement of base and precious metals,

Recycle / Reuse	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total	112	102	106	117	190	177	202	255	224	176
LKAB	4	15	16	5	2	6	12	16	19	22
SSAB	8	10	6	6	46	41	44	67	56	27
SKF AB	22	19	20	31	32	29	36	64	64	37
BOLIDEN AB	72	47	51	57	55	51	48	54	40	46
SANDVIK	6	11	13	18	55	50	62	54	45	44

Table 2. Number of hits on recycle | recyclable | recycling | reuse | circular | circularity by company and year. Source: Annual Reports (LKAB, 2012-2021; SSAB, 2012-2021; SKF AB, 2012-2021; Boliden AB, 2012-2021; Sandvik, 2012-2021).

and the recycling of metals after use, as a way to ensure that they have the “least possible environmental impact”. LKAB is also increasingly focusing on the reuse and recycling of products from waste and residual products (LKAB, 2021, p. 38).

5.1.2. Research and Development

The number of hits for the queries *research and development | research & development | r&d* does not provide any insight as to whether the importance placed upon R&D has increased. The number of returned hits from the queries show that the number of times R&D was mentioned peaked in 2013, and slowly declined until 2016. Between the years 2016-2021 the hits from the queries appear to stagnate.

R&D is mainly mentioned in two different ways. Firstly, that R&D is carried out with a view to reduce emissions as “this is […] important for preparing for potential stricter requirements [environmental permits] in the future” (LKAB, 2020, p. 51; Boliden, 2019, p. 28), to increase energy efficiency (Sandvik, 2017, p. 28), and to develop “environmentally solid technologies (SSAB, 2019, p. 51). Secondly, the sections on R&D within the annual reports are at times used as the place to highlight newly developed or developing technologies and processes. As a part of cutting emissions stemming from the iron and steel industry, a joint industrial development project, Hydrogen Breakthrough Ironmaking Technology (HYBRIT) was initiated between the State-owned companies LKAB and Vattenfall, and the public company SSAB which is “Sweden’s single largest carbon dioxide emitter” (Jernkontoret, 2021).

Research and Development / R&D	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total	119	170	162	153	100	104	92	103	100
LKAB	13	20	25	22	16	16	16	16	11
SSAB	17	21	15	31	30	28	29	29	31
SKF AB	31	35	37	38	16	19	18	22	17
Boliden AB	6	6	6	8	7	7	9	9	11
Sandvik	52	88	79	54	31	34	20	27	30

Table 3. Number of hits on research and development | research & development | r&d by company and year. Source: Annual Reports (LKAB, 2012-2021; SSAB, 2012-2021; SKF AB, 2012-2021; Boliden AB, 2012-2021; Sandvik, 2012-2021).

HYBRIT, if successful, “has the potential to reduce Sweden’s total carbon dioxide emissions by 10 percent” (LKAB, 2021) and is partially funded by the individual companies themselves and by support of the Swedish Energy Agency (Jernkontoret, 2021). SKF (2021, p. 13) highlight their ability to “enable significant energy and carbon savings […] by making […] products lighter, more efficient, longer lasting and repairable. SKF AB (2021, p. 17) states that they over time intend to increase their R&D expenditure by 50% to improve and develop technologies which help “operations and reduce emissions”.

5.2. Incentives

Searches of the annual reports with the keywords *climate* | *emission* | *greenhouse* | *greenhouse gas* | *GHG* between the years 2012-2021 show that the importance the companies of this study place on the environment and climate change in their annual reports have increased. All three search terms doubled in hits from 2012 to 2021 (see Table 1-3 in Appendix). To examine to what degree this awareness is motivated by the goals laid out in the SDGs and Paris Agreement, and the legislation in the Climate Act, searches using keywords related to these were carried out.

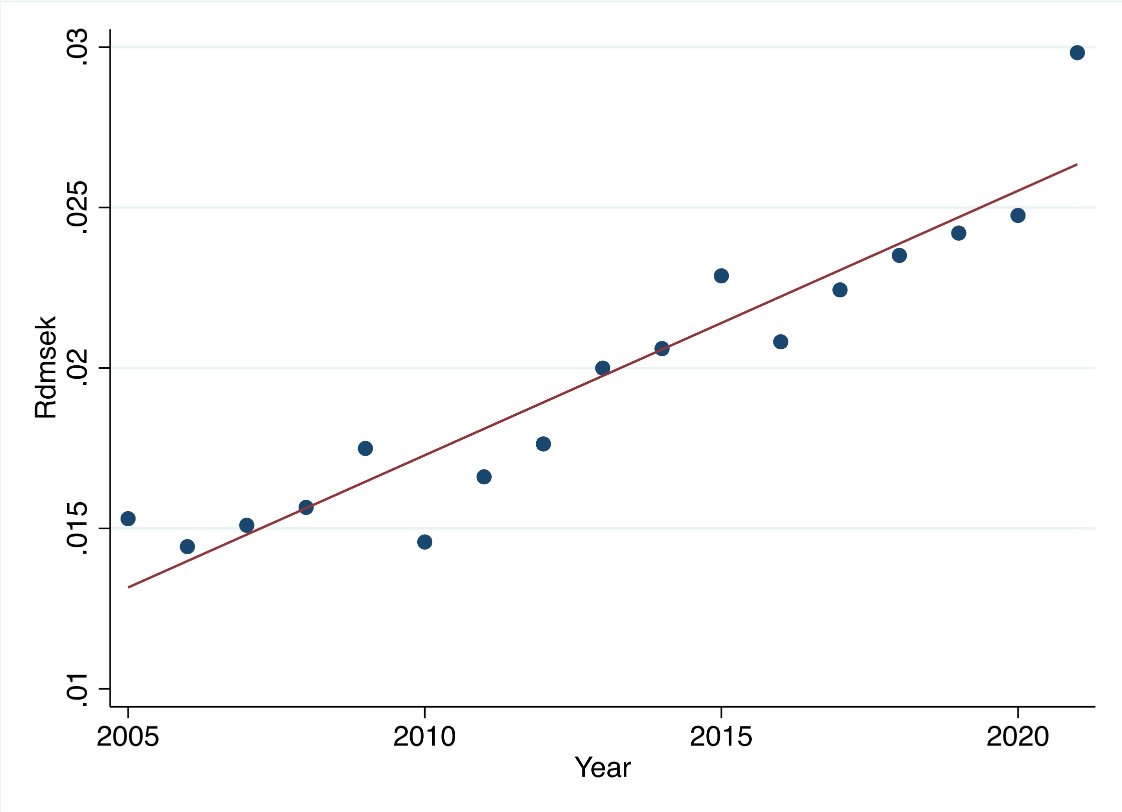

Figure 1. Total investments into total R&D as a percentage of total expenditures by year. *Source: Annual Reports (LKAB, 2005-2021; SSAB, 2005-2021; SKF AB, 2005-2021; Boliden AB, 2005-2021; Sandvik, 2005-2021).*

5.2.1. SDGs

The inclusion of the SDGs as a dummy variable in the linear regression of R&D spending against year shows that there was no significant increase in R&D investments after the year 2015 compared to earlier years ($P > 0.05$) (see Figure 1 in Appendix). Furthermore, as shown in Figure 1, investments in R&D have increased linearly since 2005 without any effect of the parameters represented by the dummy variables.

Since 2015, there has been an increase in the mentions of the Sustainable Development Goals (SDGs). Furthermore, as Table 4 shows, the increase in mentions has increased almost by a factor of ten since the inception of the SDGs. The SDGs are mentioned in various ways, and it can differ from company to company, but usually mentions of the SDGs are part of an outline of how the company has mapped their own operations to contribute to the global agenda. Certainly, the scope has changed in the case of some companies. LKAB (2015, p. 69), regarding their emissions to the environment stated in 2015 that they seek to minimize their "negative impact on our environment and surroundings due to emissions to air", while in the 2020 annual report they dedicated five pages to their efforts to become carbon-free by 2045 (LKAB, 2020, pp. 12-17). Sandvik (2016, p. 130) first mentions the SDGs in 2016; and only in the capacity that other organizations they are part of are basing their sustainability initiatives on the SDGs. In 2021, Sandvik (2021, p. 17) dedicates a page to the SDGs and the goals which they contribute to, such as a commitment to halve their CO_2 impact by 2030 and the development

Sustainable Development Goals & SDG	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Total	2	11	21	29	48	37	49
LKAB	2	1	2	4	14	13	9
SSAB	0	5	8	7	11	12	7
SKF AB	0	2	4	6	6	5	18
BOLIDEN AB	0	2	1	3	3	1	2
SANDVIK	0	1	6	9	14	14	13

Table 4. Number of hits on Sustainable Development Goals or SDG by company and year. Source: Annual Reports (LKAB, 2015-2021; SSAB, 2015-2021; SKF AB, 2015-2021; Boliden AB, 2015-2021; Sandvik, 2015-2021).

of "[a] new electric underground crushing and conveying system" that "will reduce CO_2 emissions by 250 tons annually". SKF AB (2021, pp. 119-123) has four pages in 2021 on the climate goals and ways in which they are curbing their emissions or otherwise making their company more sustainable where in 2015 they only had one sentence mentioning the SDGs and stating that they are "subscribed to a number of internationally recognized principles, charters and guidelines which promote sustainable and ethic business practices" (SKF AB, 2015, p. 37).

5.2.2. Paris Agreement

The inclusion of the Paris Agreement as a dummy variable also shows that there was no significant increase in R&D investments after the year 2016 ($P > 0.05$) (see Figure 2 in Appendix). Since the Paris Agreement entered into force in 2016, the number of hits for the search *Paris | Paris Agreement* increased, as seen in Table 5.

The Paris Agreement is discussed as an incentive and a goal, or target, to strive for (LKAB, 2021, p. 20; Boliden AB, 2019, p. 36). Sandvik (2021, p. 8) defines key external factors which impact the company, and states that "[t]he Paris Climate Agreement's goal to limit global warming to 1.5°C places demands on companies […] for change in new thinking", and that an outcome of the 1.5°C goal is "the rapid electrification of society and the need for fossil-free energy recourses". Sandvik (ibid.) emphasizes the need for more efficient and optimized manufacturing processes to reduce carbon emissions. The large-scale development of the HYBRIT initiative is highlighted as a contributor to reaching the global climate goals "under the Paris Agreement and the national climate goals in Sweden" (SSAB 2020, p. 63).

Paris Agreement	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Total	4	1	1	3	9	15
LKAB	0	0	0	0	0	1
SSAB	4	0	1	2	7	9
SKF AB	0	0	0	0	0	2
BOLIDEN AB	0	0	0	1	2	2
SANDVIK	0	0	0	0	0	1

Table. 5. Number of hits on query Paris Agreement or Paris by company and year. Source: Annual Reports (LKAB, 2016-2021; SSAB, 2016-2021; SKF AB, 2016-2021; Boliden AB, 2016-2021; Sandvik, 2016-2021).

5.2.3. 2045

The inclusion of the Climate Act as a dummy variable also shows that there was no significant increase in R&D after the year 2017 ($P > 0.05$) (see Figure 3 in Appendix). Hits for the search *2045* only gave results for LKAB and SSAB, while SKF AB, Boliden AB, and Sandvik does not mention the query term once over the period 2017-2021. As shown in Table 6, the hits for *2045* peaked in 2020, with a sharp drop in mentions in 2021.

Climate Act / 2045	2017	2018	2019	2020	2021
Total	12	16	18	41	14
LKAB	1	2	3	18	10
SSAB	11	14	15	23	4
SKF AB	0	0	0	0	0
BOLIDEN AB	0	0	0	0	0
SANDVIK	0	0	0	0	0

Table 6. Number of hits on query Climate Act | 2045 by company and year. Source: Annual Reports (LKAB, 2017-2021; SSAB, 2017-2021; SKF AB, 2017-2021; Boliden AB, 2017-2021; Sandvik, 2017-2021).

LKAB (2020, p. 14) outlines its strategy that "sets out the path the company will take to achieve zero carbon emissions from its own processes and products by 2045". LKAB emphasizes the need to develop "mining through digitalization, automation, and new design" as well as "investments in the expansion of renewable electricity and hydrogen" to enable the transformation to net-zero carbon emissions (ibid.). SSAB (2020, p. 63) highlights the HYBRIT initiative as a "new revolutionary steelmaking technology" which aims "to replace coking coal […] with fossil-free electricity and hydrogen", a process which would leave "virtually no carbon footprint". SSAB (ibid.) says that the HYBRIT initiative "will contribute to reaching the global climate goals under the Paris Agreement and the national climate goals in Sweden and Finland". SSAB (ibid, p. 78) also emphasizes the need to electrify "processes" as a part of their long-term goal to become fossil-free in their operations by 2045.

While SKF, Boliden AB, and Sandvik do not mention the Swedish Climate Act or the year 2045 they do also highlight their plans and timelines to reach net-zero. Boliden AB (2021, p. 36) state that they aim to "achieve net zero carbon dioxide by 2050" based on the EU's ambitions. Sandvik (2021, p. 14) likewise mention plans to reach "net-zero emissions by 2050 at the latest". SKF AB (2021, p. 12) has plans to reach net-zero emissions from their own operations by 2030, while "achieving a net zero supply chain by 2050".

6. Discussion

6.1. Reflections about the methodology

Since the underlying reality of socio-technical systems is complex, the scope of this research is rather large, and deals with several intertwined factors, mechanics, and actors. As such, the discussion of findings veers to the abstract and less certain. Nevertheless, several themes and trends could be identified.

It is worth quickly discussing the validity and trustworthiness of annual reports as sources of information, and whether they disclose real plans and motives. Annual reports are in a sense an important part of the public face of the company, and by extension PR products. However, annual reports are governed by laws and regulations that companies must abide by so there is limited freedom for companies to make things up with impunity.

6.2. Discussion of findings

The results show that the SDGs, Paris Agreement, and the implementation of the Climate Act had no significant effect on R&D investments in the Swedish companies within the steel sector. This is also reflected in the qualitative findings which find that the mentions of R&D have been stagnant since 2013. I suggest two possible reasons for this. One, it is possible that R&D investments into climate-related R&D has increased, and investments in non-climate-related areas of R&D has simultaneously decreased. This could then result in the linear trend that was found in this research. The increased focus on innovation and development, as well as emerging norms, treaties, acts and laws regarding the climate discussed in the annual reports could indicate that this is the case. Two, the SDGs, the Paris Agreement, and Climate Act has not been sufficient to spur increased R&D investments within the Swedish steel sector. Two, the measurement of R&D investments as an indicator for the steel sector's responsiveness to policy-induced technological development related to climate-change is flawed at evaluating what it is set out to measure, or at least has to be understood and analyzed in conjunction with all other actions companies take. Given the results of this study, it is clear that R&D investments is flawed as a measure of the desired industry outcome of climate policies, namely research, innovation and development.

There have been increased mentions of climate-related keywords in the annual reports. That the mentioning of GHGs, the climate, and emissions all doubled in the studied timeframe suggests an increased presence of climate-related thinking within the steel sector. Likewise, there has been a very sharp increase after 2016 in mentions regarding the goal of becoming fossil-free and the use of renewables to curb carbon emissions, as seen in Figure 2.

To what extent this is due to the SDGs, the Paris Agreement, or the Climate Act is hard to establish. It is however possible to imagine the formation of these goals, treaties and acts as

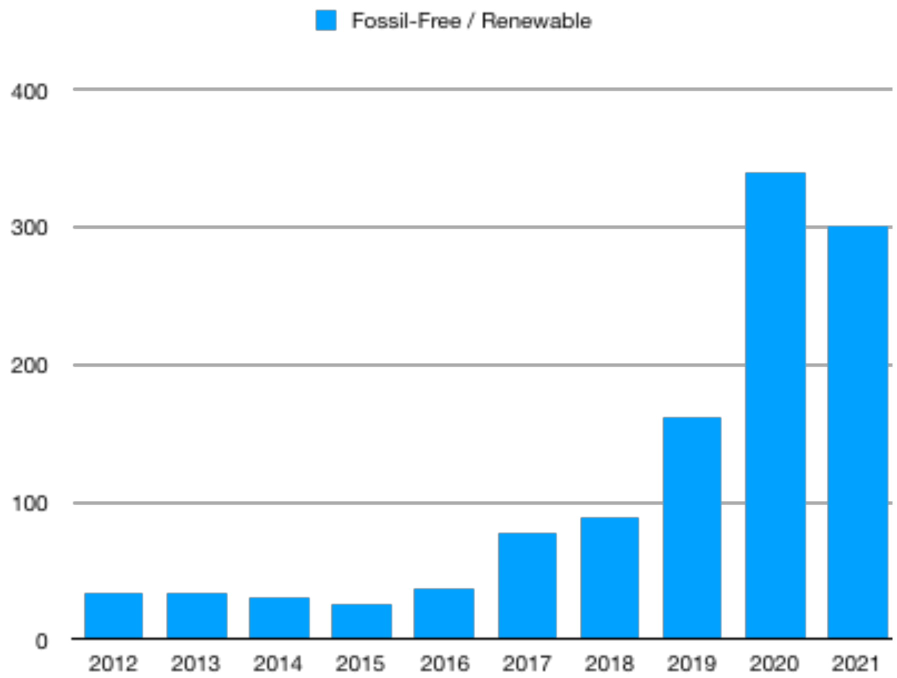

Figure 2. Total number of hits on query Fossil-free | fossil free | renewable by year. Source: Annual Reports (LKAB, 2012-2021; SSAB, 2012-2021; SKF AB, 2012-2021; Boliden AB, 2012-2021; Sandvik, 2012-2021).

resulting from the landscape concept of transition theory. Because the landscape is influenced by for instance exogenous shocks (Rijnsoever and Leenderste, 2020) such as climate-change, the landscape naturally sets the stage for the configuration of norms. The broader contexts of these norms consist of the configurations of “institutions, markets, culture, knowledge base, material interests, and user relations that co-evolve with technological development" (Smith and Kern, 2009).

Postulating that the SDGs, and the Paris Agreement are important facilitators of global norms, and part of the landscape in which these configurations operate becomes apparent as they are continuously mentioned as informing the steel sector's policies and actions regarding environmental matters. As a result, the SDGs, and the Paris Agreement are also the institutions which facilitate the discourse of storylines, which Hajer (cited in Smith and Kern, 2009) defines as the "specific ensemble of ideas, and categorizations that are produced, reproduced and transformed […] and through which meaning is given to social and physical realities". While discourse is not the cause of transitions, it is an influential factor, as discourses "benefiting from greater institutional embodiment, and supported by established interests, structure the array of reasonable policy storylines available" (Smith and Kern, 2009). Smith and Kern (ibid.) conceptualize storylines as "devices for simplifying discourses" – such as the need to limit global warming – that can "build powerful coalitions for change, and have a galvanizing influence upon policy". These coalitions are the SDGs and the Paris Agreement. However, "policy storylines need institutionalization to make a policy impact: flexible meanings have to be arbitrated into binding norms" (ibid.). This process was made concrete in Sweden when the Climate Act was enacted and adapted to reach the goals set out in the Paris Agreement.

6.2.1. The Industry Regime

The actors in this study which make up the regime are the UN, the Swedish government, and companies in Sweden's steel sector, as they form the formal institutions (laws, standards, and directives) and establish and enact rules that guide the actors' behaviors (Rijnsoever and Leendertse, 2020). Furthermore, they are the actors who establish the social order tied to the distribution of resources in the steel industry (Kronsell & Bäckstrand, 2015, p. 11). This arrangement of actors is what Geels (2013) conceptualizes as an industry regime. Geels (ibid.) proposes the concept of "industry regime" to mean "industry specific institutions that mediate perceptions and actions of [companies'] towards external environments". These industry regimes consist of four types of elements which have been found in this research. The first element is technical knowledge, and this both constrains and enables the functional capacity of companies to answer towards external environments. In the Swedish steel sector, the advancement of technical knowledge is crucial not only to continue economic growth but also to answer toward external environments. As external environments are constantly evolving, and changes in external pressures also evolve, technical knowledge also must increase to respond to these external pressures. The Swedish steel sectors efforts to develop new technological solutions to emit less carbon dioxide emissions, and the linear trend that was observed in total R&D investments, is a product of the first element Geels (ibid.) proposes industry regimes consists of; technical knowledge and capabilities.

The second element consists of "mindsets and cognitive frames, which constitute how actors perceive the nature of social reality" – and can also be called "industry mindset" which is how actors, in this case the steel sector, interpret external environments which influence their strategic decisions (Phillips, cited in Geels, 2013). That Swedish companies within the steel sector interpret climate change as an external environment which influences their decisions is reflected in the increased mentions of several keywords, such as *climate* or *emissions*, as well as in how they use them. The third element, which consists of the "values, identity, mission", and specifies what actors see as appropriate actions to take, works in conjunction with the second element. These elements are present in what is commonly referred to in the annual reports as either 'stakeholder engagement' or 'strategic risks' sections, and is where mitigation of industry specific institutions is discussed. The broadened discussion and implementation regarding circular value chains and the circular economy, and the need for R&D as mitigating strategy for carbon emissions could indicate that companies within the steel sector have decided that these are the appropriate measures and behaviors in response to external environments. The nature of social reality is the building-block of the industry specific institutions that are meant to impose and elicit certain behavior from industries through pressures and opportunities. These industry specific institutions are the fourth and last element of the industry regime and consist of "taxes, subsidies, intellectual property laws, tariffs, R&D programs", and mold companies by influencing production decisions and innovation processes (ibid.). While the presence of all these specific institutions is not explicitly discussed in this research, they are by-products of the SDGs and the Paris Agreement, as all subsequent externally imposed policy implementations after the 2017 Climate Act stem from the goals within it.

6.2.2. The industry regime in transition

Internally oriented strategy approaches encapsulate how companies adapt to environmental pressures by transforming their "routines, capabilities, belief system[s]" and goals (ibid.) to adapt to changing landscapes. It is also important to note that these stages, at least in the case of companies within the Swedish steel sector, are not set in stone, and overlaps occur. This can be due to the steel sector still being in the process of transition, and the years where one stage can be said to "begin", and the other "end" may perhaps only be truly comprehended when sufficient time has passed since a completed transition. Geels (ibid.) outlines this transformation in four steps. However, the first step, when "firms often deny or downplay problems arising from external pressures" had already come to pass at the start of the timeframe of this study. In the second stage, "when the problem can no longer be denied", companies, if the problem is tied to their operational business, employ strategies of "retrenchment strategies", calling for "efficiency improvements" and "tighter controls", develop "incremental technical innovations" and write symbolic changes in mission statements; basically, expressing concern without any real change. This research did not contain any keywords relating to retrenchment strategies; however, it is unlikely that this stage happened during the studied timeframe as the companies within the Swedish steel sector in this study were already showing signs of being well into the third stage of transition at the start of the studied timeframe as discussed below.

The third stage of transition consists of companies performing larger strategic changes, which include changes in disposition of resources, and in the products produced. Examples of this include LKAB (2012, p. 22) who highlight the on-going work to reduce the use of fossil fuel and the switch to renewable energy sources, investments in new technologies to make sure carbon dioxide emissions do not increase (Boliden AB, 2014, p. 47), and increases in expenditures going into R&D (SKF AB, 2021, p. 17). While the total R&D investments remained linear, the increased hits for the queries *fossil-free | fossil free | renewable* (see Table 1) and what is said in connection with them indicates a shift in the range of products produced and constitute a shift from "exploitation of existing technologies" to the "exploration of new knowledge bases and more radical alternatives" (ibid.). Furthermore, it is in the third stage that "core firms may enter into collaborations with peripheral firms […] if these have developed relevant technical knowledge" (ibid.). And while neither LKAB nor SSAB are peripheral companies in any sense of the word they did both possess the relevant technical knowledge to attract collaboration. This is reflected in the HYBRIT initiative which both SSAB and LKAB are a part of. The re-allocation of resources, small and large-scale development of new technologies, and increased fossil free and renewable fuels are factors that could indicate that the steel sector have implemented, or are in the processes of implementing, large strategic changes. It is possible to postulate that stage three began around 2016, which was the year the

HYBRIT collaboration begun, and the year the total hits on the keyword's *fossil-free | fossil free | renewable* increased from 37 in 2016 to 77 in 2017 (see Table 1).

We may be in the beginnings of transition from the third stage to the fourth and final stage. Geels (2013) conceptualizes the fourth stage to consist of the "continuation of problems" which then motivates companies to examine "deep-structural beliefs" such as core-beliefs, mission, and identity. While it is possible to discuss this, it is not possible to draw any concrete conclusions as another kind of content analysis with a different focus would be required for this. However, from the terminology used in the annual reports, and the fact that environmental aspects permeate through almost every aspect of the companies' business, operations, and decisions, as well as strategies indicate a step towards greener thinking.

As socio-technical transitions are still "uncertain processes" (Rijnsoever & Leendertse, 2020) discussion surrounding them sometimes lead to more questions than answers. As mentioned by Kronsell and Bäckstrand (2015, p. 13), transformations happen in the dynamic relation between niches, regimes, and landscapes, and transformations emerge from niches. If the HYBRIT initiative proves to be successful and fossil free steel becomes a reality it would suggest that transition took place within the incumbent regime without the emergence of a completely new one from the emergence of a niche. This contradicts the idea that niches necessarily are at the periphery of existing systems as defined by Geels (2019). However, as stated by Avelino and Rotmans (2009) *niches* "are also part of the societal system, but able to deviate from the dominant structures, practices and actors within that system". As the first phase is where "changes occur in the 'background' at landscape and niche level" and the second, where "structural change picks up momentum, in the sense that these changes pressure the regime in such a way that it starts breaking down", it is possible that what we are witnessing with HYBRIT is not because of a new *niche-regime*, but rather a regime transition (ibid.).

However, this raises the question whether a complete transition can take place without the influence of niches, and that perhaps what is being observed is instead a form of system *management* rather than system *transition.* Are alternative paths and transitions being "locked out"? Is the incumbent industry regime "locked-in" and path-dependent? To address this, transition theory suggests two objectives to policy makers: "system improvement", which are incremental changes to the incumbent system to address a perceived problem, and "system innovation", which are experiments which if successful would lead to fundamental adjustments to the incumbent regime (Meadowcroft, 2009).

The Swedish Climate Act and the specific effects of it on the transition of the industry regime are unclear. A transition is certainly happening in Sweden, and the new framework in the Climate Act is an important step to reach net-zero, but one cannot simply take it out of context and ignore the broader, global norms which have been influential in national change. Would the Climate Act have been enacted without treaties such as the Paris Agreement, or goals such as the SDGs? It is difficult to say either way for sure. The role of the state in environmental governance is important as it is the political entity which has maintenance over legal frameworks, and the only entity which harbors "key political authority" (Hysing, 2015, p. 28) and therefore the capacity to act upon and legislate societal pressures and demands. As mentioned by Peters (et al., 2012), the role of policy support is said to be critical to foster technological innovation. This is reflected in the annual reports. Even if not specifically stated outright, the annual reports clearly reflect awareness and concern for the climate that strongly affects how each company operates, and this includes direct innovation, development of new materials sourcing, product distribution pipelines, sources of energy, and energy consumption, all examples of an industry in transition.

7. Conclusion

This research has looked at how the Swedish steel sector conceptualises and acts upon external influence on its operations by analysing annual reports. It finds that many elements and behaviours within the studied companies have changed since 2015, as climate change has increasingly gotten more focus. To what extent this is due to specific incentives is not easily determined, and this research does not come to any definitive conclusions. The discussion argues that while the Swedish Climate Act and the Swedish government is the only actor with legitimacy for legislative actions that can coerce companies to display specific behaviours, the surrounding contexts and norms which have influenced it are global. Further studies can be made on individual companies, and more specific policy elements could be analysed in conjunction, to inform a clearer picture on how specific, targeted policies affect companies. Applying the Multi-Level Perspective to the steel sector from an earlier date to fully go through all its phases in analysis would provide insight as to the role of niches. A more detailed dataset would allow for a more in-depth quantitative analysis. Specifically, it would be interesting to see what percentage of total R&D investments is afforded to climate-specific technologies, and how that has changed over time regarding targeted policies.

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Appendix

Source	SS	df	MS			
				Number of obs	=	85
				F(2, 82)	=	5.83
Model	.001386215	2	.000693107	Prob > F	=	0.0043
Residual	.009756482	82	.000118981	R-squared	=	0.1244
				Adj R-squared	=	0.1030
Total	.011142696	84	.000132651	Root MSE	=	.01091

Rdmsek	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
Sdg	-.00015	.0044288	-0.03	0.973	-.0089602	.0086602
year	.0008364	.000432	1.94	0.056	-.000023	.0016958
_cons	-1.663911	.8683529	-1.92	0.059	-3.391342	.0635191

Fig 1. Regression output with SDG (2015) as dummy variable for LKAB, SSAB, SANDVIK, Boliden AB, SKF AB. Source: Annual Reports (LKAB 2005-2021; SSAB 2005-2021; SANDVIK 2005-2021; Boliden AB 2005-2021; SKF AB 2005-2021)

Source	SS	df	MS			
				Number of obs	=	85
				F(2, 82)	=	5.83
Model	.001386215	2	.000693107	Prob > F	=	0.0043
Residual	.009756482	82	.000118981	R-squared	=	0.1244
				Adj R-squared	=	0.1030
Total	.011142696	84	.000132651	Root MSE	=	.01091

Rdmsek	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
Parisagreement	-.00015	.0044288	-0.03	0.973	-.0089602	.0086602
year	.0008364	.000432	1.94	0.056	-.000023	.0016958
_cons	-1.663911	.8683529	-1.92	0.059	-3.391342	.0635191

Fig 2. Regression output with Parisagreement (2016) as dummy variable for LKAB, SSAB, SANDVIK, Boliden AB, SKF AB. Source: Annual Reports (LKAB 2005-2021; SSAB 2005-2021; SANDVIK 2005-2021; Boliden AB 2005-2021; SKF AB 2005-2021)

```
      Source |       SS           df       MS      Number of obs   =        85
-------------+----------------------------------   F(2, 82)        =      5.85
       Model |  .00139179          2  .000695895   Prob > F        =    0.0042
    Residual | .009750906         82  .000118913   R-squared       =    0.1249
-------------+----------------------------------   Adj R-squared   =    0.1036
       Total | .011142696         84  .000132651   Root MSE        =     .0109

------------------------------------------------------------------------------
      Rdmsek | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
  climateact |    .000929    .004239     0.22   0.827    -.0075037    .0093618
        year |    .000756   .0003943     1.92   0.059    -.0000283    .0015403
       _cons |  -1.502298   .7926649    -1.90   0.062    -3.079161    .0745645
------------------------------------------------------------------------------
```

Fig 3. Regression output with climateact (2017) as dummy variable for LKAB, SSAB, SANDVIK, Boliden AB, SKF AB. Source: Annual Reports (LKAB 2005-2021; SSAB 2005-2021; SANDVIK 2005-2021; Boliden AB 2005-2021; SKF AB 2005-2021)

Greenhouse gases / GHG	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total	45	51	40	54	51	62	66	77	104	93
LKAB	1	3	4	1	1	8	5	10	8	10
SSAB	2	2	1	24	25	25	25	22	45	22
BOLIDEN AB	4	4	3	4	4	5	7	11	11	10
SANDVIK	2	2	0	0	6	3	8	10	15	4
SKF AB	36	40	32	25	15	21	21	24	25	47

Table 1. Number of hits on queries *Greenhouse gas* | *greenhouse* | *GHG* by company and year. Source: *(LKAB, 2012-2021; SSAB, 2012-2021; SKF AB, 2012-2021; Boliden AB, 2012-2021; Sandvik, 2012-2021).*

Climate	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total	96	105	105	102	98	96	116	198	238	304
LKAB	20	39	25	6	11	20	28	49	60	82
SSAB	3	4	2	16	14	9	17	27	63	90
SKF AB	54	47	56	54	41	37	42	44	48	44
BOLIDEN AB	10	8	12	14	9	16	16	57	52	73
SANDVIK	9	7	10	12	23	14	13	21	15	15

Table 2. Number of hits on queries *Climate* by company and year. Source: *(LKAB, 2012-2021; SSAB, 2012-2021; SKF AB, 2012-2021; Boliden AB, 2012-2021; Sandvik, 2012-2021).*

Emissions	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total	303	379	348	513	534	566	551	585	669	569
LKAB	86	117	109	114	105	113	108	126	154	151
SSAB	41	45	31	217	214	241	213	221	255	176
SKF AB	95	95	103	83	75	91	97	110	108	128
BOLIDEN AB	69	105	91	81	62	61	72	67	71	80
SANDVIK	15	17	14	18	78	60	81	61	81	34

Table 3. Number of hits on queries *Emission* by company and year. Source: *(LKAB, 2012-2021; SSAB, 2012-2021; SKF AB, 2012-2021; Boliden AB, 2012-2021; Sandvik, 2012-2021).*