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Beyond leaders and laggards: How incumbents navigate transformative policy missions

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ABSTRACT

Governments increasingly deploy transformative policy missions to accelerate industrial decarbonisation, combining ambitious climate targets with large-scale funding and coordination. Yet the roles of incumbent firms responsible for most current emissions remain underexplored in both research and policy design. This paper investigates how Sweden's 20 largest industrial emitters respond to the country's legally binding net-zero by 2045 target, focusing on their participation in the Industry Leap and Climate Leap programmes. Using a mixed-methods approach that integrates emissions statistics, project-level funding data, and social network analysis, we analyse firms' emissions profiles, decarbonisation ambitions, mitigation pathways, scope of action, collaborations, and engagement with mission-oriented policy instruments. We find that declared ambition levels are a poor indicator of active engagement, as several firms with very ambitious targets show limited participation, while medium-ambition actors emerge as central project participants. Our analysis identifies four strategic roles, transformative frontrunners, system enablers, adaptive followers, and peripheral bystanders, that capture the diversity of incumbents' responses. These findings move beyond binary leader–laggard framings and highlight the need for policy instruments that reward concrete engagement, foster collaborative infrastructures, and tailor support to heterogeneous roles in order to align incumbent behaviour with long-term mission objectives.

1. Introduction

The climate crisis calls for a rapid and far-reaching transition to production and consumption systems with net zero emissions (IPCC, 2023; Köhler et al., 2019). This requires developing and implementing new technologies at a large scale, while dismantling fossil fuel-dependent systems (Kivimaa and Kern, 2016; Turnheim and Geels, 2013). To stimulate and shape this decarbonisation process, governments at different levels are increasingly setting bold climate goals and introducing extensive support schemes. For example, the legislative package 'Fit for 55' commits EU member states to substantial emission reductions, aiming for climate neutrality by 2050 (European Council, 2023).

These policy developments have co-evolved with academic literature that frames innovation as a part of transitions that address social and environmental problems, rather than as a means to (merely) strengthen national competitiveness and economic growth (Diercks et al., 2019; Schot and Steinmueller, 2018). Literature on transformative innovation policy (Haddad et al., 2022) proposes an active role for government and argues that a desirable direction of change should guide policymaking (Weber and Rohracher, 2012). While this direction may emerge bottom-up from the market interactions of actors (Schot and Steinmueller, 2018), the climate crisis has led governments to increasingly impose goals in top-down political processes (Parks, 2022). This aligns with the notion of mission-oriented innovation policy, introduced and popularised by Mazzucato (2018). Indeed, recent government initiatives to address the climate crisis are well-described as *transformative policy missions*, which, unlike open-ended transitions, focus on the transformation of existing sectors and the adoption of specific targets such as net zero emissions (OECD, 2022; Wittmann et al., 2021). In contrast to open-ended sustainability transitions, which emphasise emergent change across multiple arenas, we here see transformative policy missions as characterised by explicit policy directionality, time-bound goals, and coordinated instruments that actively structure actor engagement toward predefined outcomes.

Despite the availability of rich conceptual frameworks for

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transformative innovation policy, empirical research on how transformative policy missions unfold in practice remains scarce (Haddad et al., 2022; Janssen et al., 2022). In particular, there is a lack of systematic empirical understanding of how incumbent industrial actors engage with such missions and what roles they come to perform within them. This gap is significant because incumbents typically occupy central positions in existing socio-technical systems and therefore exert disproportionate influence over the pace, direction, and form of transformation (Kungl, 2025). Their responses can shape whether mission objectives are translated into concrete transition pathways, how quickly implementation proceeds, and which technological and organisational solutions gain prominence (Bergek et al., 2023). Greater empirical insight into incumbent roles is therefore essential for understanding the effectiveness of transformative policy missions and designing policy instruments capable of mobilising and coordinating heterogeneous actors toward collective decarbonisation goals.

While empirical research on incumbents in transformative policy missions remains limited, there is an extensive literature examining incumbent behaviour in more open-ended sustainability transitions (van Mossel et al., 2018; Kungl, 2025). This literature documents a wide range of incumbent strategies and forms of influence, from resistance and delay through lobbying and institutional work (Kungl, 2015; Lauber and Jacobsson, 2016; Lamb et al., 2020) to proactive engagement in innovation, coalition-building, and policy design (Firdaus and Mori, 2023; Gomel and Rogge, 2020). Recent contributions emphasise that incumbents' roles are neither uniform nor fixed, but situational and temporally contingent, shaped by firms' positions within socio-technical systems and by the governance contexts in which transitions unfold (Kungl, 2025). However, it remains unclear how these heterogeneous roles translate into mission-oriented settings characterised by explicit directionality, time-bound goals, and coordinated policy instruments. This highlights the need for empirical studies that examine how incumbent roles are enacted in transformative policy missions across sectors and national contexts.

Against this background, the aim of this paper is to analyse how incumbent firms with large greenhouse gas emissions interpret, engage with, and adopt different roles within transformative policy missions for industrial decarbonisation. Focusing on Sweden, we, analyse and identify patterns across firms' emission profiles, decarbonisation ambitions, mitigation pathways, scope of action, collaborations, and engagement with mission-oriented policy instruments. This allows us to clarify how heterogeneous incumbent roles shape the implementation of transformative policy missions and their capacity to deliver deep industrial decarbonisation.

Sweden provides a relevant empirical context due to an ambitious climate policy framework, which legally commits the government to achieving net-zero domestic emissions by 2045, followed by net-negative emissions thereafter (Swedish Government, 2017). These targets establish a clear, long-term policy direction that guides and coordinates a range of policy instruments to transform emission-intensive industrial sectors. While national greenhouse gas emissions have declined by 33% since 1990 alongside strong economic growth (SCB, 2023; SEPA, 2023), the current pace of decarbonisation remains insufficient to meet the stated climate goals (Swedish Climate Policy Council, 2024). A central challenge lies in mitigating large point-source emissions from industrial production plants (ETC, 2018), which are concentrated among a small number of incumbent firms in iron and steel, metals, petrochemicals, cement and minerals, and heat and power industries. These sectors are characterised by continuous, large-scale production processes, long-lived capital investments, and exposure to global competition (Löfgren and Rootzén, 2021; Wesseling et al., 2017), conditions that both motivate and constrain incumbents' engagement in transformative policy missions.

In the empirical analysis, we operationalise incumbents as the firms with the largest current emissions and focus on the top 20 emitters in Sweden. Adopting a mixed-methods approach, the analysis draws on official emissions statistics and secondary data regarding the climate goals and mitigation activities of these firms. Moreover, we compile and analyse a dataset with information about all projects granted funding from the 'Industry Leap' and 'Climate Leap' programmes, which are the two primary funding schemes launched by the Swedish Government to support industrial decarbonisation (Swedish Government, 2017). Our findings show that incumbents adopt different roles in the decarbonisation of Swedish industry, ranging from transformative frontrunners and system enablers to adaptive followers and passive bystanders. This offers new insights into the role of incumbents in transformative policy missions, suggests important implications for policy design, and demonstrates an analytical approach for future research.

2. Incumbents in transformative policy missions

Following the literature on mission-oriented innovation policy, this paper views transformative policy missions as characterised by clearly articulated societal goals, explicit time horizons, and coordinated policy instruments aimed at steering multiple actors towards a common direction of change (Mazzucato, 2018; Larrue, 2021; OECD, 2022). Rather than constituting a separate type of transition, they can be seen as a governance configuration within broader sustainability transitions, distinguished from more open-ended transition processes by explicit directionality and deliberate policy coordination (Wittmann et al., 2021; Turnheim and Sovacool, 2020).

The transformative policy mission in focus of this paper involves a radical transformation of industries characterised by significant point-source emissions from a few production plants. Firms that own and operate these plants have invested in infrastructure with long payback times, aligning their competencies, capacities and relationships with existing industry structures and institutional frameworks (Geels, 2014). This shapes whether and how these firms participate in mission-oriented innovation activities and places them in a position where their actions are likely to influence the achievement of mission objectives, especially since the barriers to entry are high for new actors that develop alternative solutions (Löfgren and Rootzén, 2021).

Firms with significant market influence are commonly termed "incumbents" (Christensen, 1997). More recent contributions have refined this concept by emphasising incumbents' functional role in sustaining and reproducing socio-technical systems over time. In particular, Kungl (2025) conceptualises incumbents as firms that occupy central positions in the reproduction of existing systems at a given point in time, rather than defining them solely in terms of size, age, or regime membership. He defines incumbent firms as "firms that, at a certain point in a sustainability transition process, hold a central position for the reproduction of an existing socio-technical system" (Kungl, 2025, p. 10). This perspective highlights that incumbency is both relational and temporal, and that incumbents may perform heterogeneous and even ambivalent roles in transition processes. Such a view is particularly relevant in mission-oriented contexts, where incumbent firms are often explicitly targeted by policy instruments due to their central role in delivering essential societal functions and material significance for achieving collective climate goals.

Incumbents have co-evolved with production technologies, supply chains, market demand, laws and regulations, societal norms and beliefs. In sustainability transitions, these actors are part of the regime governing production and consumption, deriving profitability and competitiveness from it (Rip and Kemp, 1998; Geels, 2014). They may also be contrasted with new entrants that lack vested interests in established structures (Christensen, 1997). New entrants are often associated with niches that challenge the dominating regime by promoting alternative modes of production and consumption (Kemp et al., 1998). While this regime–niche distinction has been influential, it has also been criticised for oversimplifying the diversity of incumbent strategies and roles in transition processes.

The literature on transformative innovation policy increasingly emphasises the role of directionality (Weber and Rohracher, 2012). Scholars highlight that transitions can unfold along trajectories that result in different organisational, technological, and institutional configurations in future regimes, shaping the outcomes for stakeholders (Hojckova et al., 2018; Andersson et al., 2021). This underscores the need to develop transformative policy missions with attention to incumbents, not only as potential blockers of transitions, but also as central actors whose responses shape how policy directionality is translated into concrete transition pathways.

While the analysis and categorisation of incumbents and new entrants vary significantly (Kungl, 2025), the reasoning by Hockerts and Wüstenhagen (2010) is representative of a large part of the literature. The authors see incumbents as actors with many employees, large revenues, and a long presence on the market. They also suggest that in the early stages of sustainability transitions, new entrants (referred to as 'Emerging Davids') are more inclined to pursue sustainability-related opportunities than incumbents (referred to as 'Greening Goliaths'). In response to the activities of new entrants, however, incumbents engage in corporate sustainable entrepreneurship activities. It is also noted that while incumbents may be less ambitious in their environmental and social goals, their reach can be broader due to their established market presence.

This reasoning is supported by Karttunen et al. (2021) in a study of environmental innovation in the cement industry. They argue that incumbents prefer environmental process innovations and prepare for radically reduced climate impact with novel products but postpone implementation. Dahlström (2015) also illustrates how collusion and the formation of market cartels have been dominant industrial strategies in the cement industry in Sweden and Europe during the 1900s. These cartels have hindered competition and innovation within the industry, making it nearly impossible for new entrants with alternative solutions to enter the market. Similarly, a study on the chemicals industry shows that few new actors offering more sustainable solutions have managed to enter the market (Epicoco, 2016). However, new entrants were nevertheless active in developing technologies with a high potential and more radical nature than those pursued by incumbents. Compared with the cement industry, new entrants in the chemicals industry thus appear to at least have a presence in forming new markets.

Additional support to this view is offered by Johnstone et al. (2017), who study a wider range of firms in the energy transition. They argue that in the face of climate change, incumbents will likely pursue different technology strategies than new entrants. More specifically, incumbents favour large-scale solutions that allow them to utilise their existing infrastructure and maintain market positions, which, according to the authors, will not result in the necessary system-level change.

The literature also shows how incumbents form political coalitions (Hess, 2014) and formal networks (Musiolik et al., 2012) to influence policy in various ways. It has been noted that they often take a defensive position against new policy goals and instruments, for example, by lobbying against the German *Energiewende* which was designed to promote renewable electricity production (Kungl, 2015; Lauber and Jacobsson, 2016; Wassermann et al., 2015). This resistance to change has also been described in terms of deploying various institutional counterstrategies against new solutions offered by new entrants (Johnstone et al., 2017), such as strategically setting technical standards (Smink et al., 2015), managing the expectations for novel technologies (Bakker, 2014; Konrad et al., 2012) and resisting political work by institutional entrepreneurs (Jolly et al., 2016).

At the same time, however, research shows that incumbents, under certain conditions, can be at the forefront of innovation, developing new products and driving regulatory change. For example, Bergek et al. (2013) and Berggren et al. (2015) show that incumbents can act as both regime and niche actors, balancing exploitation and exploration. Firdaus and Mori (2023) explain this by referring to a fear of ending up with large, stranded assets, such as production plants and infrastructure with little value in a net zero emission future, which incentivises incumbents to promote change and lobby for even more stringent policies to increase their competitive advantage (Porter and van der Linde, 1995).

The response of incumbents to transformative policy missions thus seems difficult to generalise. The literature also shows that their attitudes and strategies depend on many different factors (Karltorp and Sandén, 2012), including the timing and nature of the pursued transition (Geels and Schot, 2007), expectations about the future regime (Budde et al., 2012), possible dissatisfaction with the established system (Kishna et al., 2017), as well as internal capabilities and resources (van Mossel et al., 2018). Not surprisingly, what emerges as essential is the fit between the strategic orientation of incumbents (i.e., their motivation), the institutional framework and existing technologies and infrastructure (Hellsmark and Hansen, 2020). This will likely result in incumbents adopting different roles in different transformative policy missions. We, therefore, agree with Turnheim and Sovacool (2020) that a fruitful approach is to pluralise the view on incumbents approaching their role as situational rather than general.

More recent contributions to the literature on incumbents in sustainability transitions conceptualise incumbents' roles as patterns of influence exerted through firms' activities, often synthesised into ideal-typical configurations that capture recurring combinations of influence across cases (e.g., Kungl, 2025). While such typologies are analytically useful, they are typically developed at a high level of abstraction and span multiple arenas of action, including technological, organisational, political, and discursive domains. In this study, we build on this conceptual understanding of roles but focus more narrowly on how incumbents enact their influence within the specific governance context of transformative policy missions. We, thus, conceptualise the role of incumbents as the influence firms exert on transformation processes through observable forms of engagement, expressed in how they interpret policy directionality, orient their technological and organisational strategies, and position themselves—relative to their emissions—within mission-oriented policy instruments and collaborative arrangements.

Rather than adopting predefined ideal types, we capture incumbent roles by analysing emissions profiles, decarbonisation ambitions, mitigation pathways, scope of action, collaborations, and engagement with mission-oriented policy instruments. These analytical dimensions are informed by the incumbency literature and tailored to mission-oriented contexts, and they function as complementary analytical lenses that enable systematic comparison and synthesis of incumbent roles across firms within transformative policy missions, rather than as independent causal variables.

3. Methodology

This section describes the empirical approach used to examine how incumbents interpret, engage with, and adopt different roles within transformative policy missions for industrial decarbonisation. The analysis focuses on the 20 firms in Sweden with the largest emissions under the EU Emissions Trading System (EU ETS). This delimitation is analytically justified, as these firms account for approximately 80 percent of emissions among Swedish EU ETS installations, corresponding to about 28 percent of the country's total greenhouse gas emissions. In the following, we elaborate on the data sources, analytical dimensions, indicators and operationalizations, as well as the three types of cluster analysis, which in the end allow us to derive a role typology. Our methodological schema is illustrated in Fig. 1.

3.1. Data sources

The study combines official emissions statistics from the Swedish Environmental Protection Agency (SEPA, 2023) with publicly available secondary data on firms' stated climate targets and mitigation strategies. In addition, we compile and analyse project-level data from two national funding programme—Industry Leap and Climate Leap—which have been central to the government's efforts to support industrial

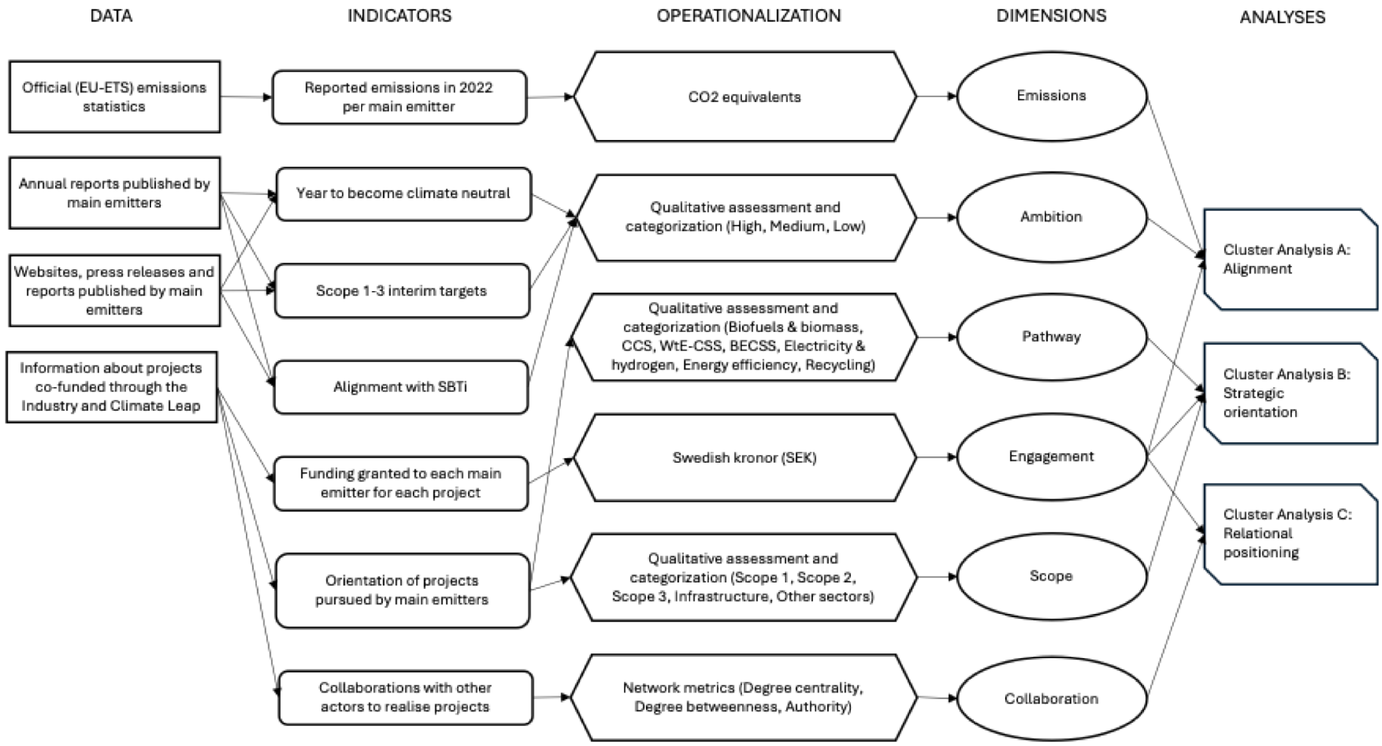

Fig. 1. Methodological scheme for analysing the role of incumbents in transformative policy missions. The figure shows how six analytical dimensions—emissions, ambition, pathway, engagement, scope and collaboration—are operationalized based on indicators and data sources. These dimensions are analysed through three complementary clustering analyses, addressing alignment (A), strategic orientation (B), and relational positioning (C).

decarbonisation. Over the studied period (2017–2024), the two programmes collectively funded 97 projects to reduce emissions from the top 20 emitters, representing a total public investment of approximately 5.9 billion SEK directed to these firms and their project partners.

The Industry Leap and the Climate Leap operate within a broader transformative policy mission context that includes Sweden's legally binding net-zero-by-2045 target, complementary policy initiatives, and coordination platforms such as Fossil Free Sweden and sectoral transition roadmaps. Rather than treating the two programmes as stand-alone representations of the mission, we analyse them as key mechanisms through which the Swedish state seeks to translate mission objectives into concrete, publicly supported decarbonisation activities targeting high-emitting industries. Participation in these programmes requires firms to articulate projects aligned with policy priorities, accept programme conditions, and commit substantial co-funding. While we do not attempt to capture the full spectrum of firms' internal climate investments or regulatory responses, we treat programme participation as a theoretically grounded proxy for analysing incumbents' strategic engagement with the mission through project-based commitments and collaborative arrangements (Andersson and Hellsmark, 2024). This approach thus enables systematic comparison across firms based on comparable and verifiable project-level data, while maintaining analytical focus on how incumbents navigate the policy instruments most directly linked to the national decarbonisation mission.

3.2. Analytical dimensions, indicators, and operationalization

To assess how incumbents engage with the transformative policy mission, we analyse and identify patterns across six analytical dimensions—emissions, ambition, pathway, scope, collaboration, and engagement (Fig. 1). These dimensions capture how firms interpret policy directionality, orient their strategies, and position themselves within the transformative policy mission. Together, they provide a structured and comparable basis for identifying recurring patterns in how incumbents enact roles within the mission context.

To begin with, *emissions* capture incumbents' annual and total greenhouse gas emissions, operationalized as CO_2 equivalents. Notably, we approach this dimension as an indicator of firms' material centrality to the existing socio-technical system rather than as a measure of mitigation performance. *Ambition* refers to how incumbents interpret and respond to the directionality of climate policy, as reflected in the level of commitment demonstrated in their stated climate strategies. Drawing on Fankhauser et al. (2022) and Christiansen et al. (2023), we assess this dimension through two key aspects: the comprehensiveness of emissions covered in corporate targets (Scope 1–3), and the urgency or immediacy of planned emission reductions. This includes the target year for achieving net-zero emissions, the presence of interim targets, and alignment with external validation frameworks such as the Science Based Targets initiative (SBTi). Based on these criteria, we classify firms into three categories: high ambition (targets include Scope 1–3, interim milestones, and SBTi validation), medium ambition (Scope 1–2 included but with less clarity on interim targets or SBTi alignment), and low ambition (targets are vague, partial, or lack independent validation).

Pathway captures the technological orientation of incumbents' decarbonisation strategies, reflecting how firms seek to reconcile existing assets and capabilities with competing transition pathways discussed in the literature. Each funded project is categorised by its primary technological focus, allowing us to analyse the types of solutions firms prioritise. The categorisation was developed inductively, informed by prior work (Wesseling et al., 2017; Andersson and Hellsmark, 2024), and includes: 'Biofuels & biomass' aimed at substituting fossil inputs with renewable feedstocks; 'CCS' (i.e., carbon capture and storage) targeting point-source fossil emissions, including related transport and storage; 'WtE-CCS' (i.e., waste-to-energy CCS) targeting point-source emissions from waste incineration; 'BECCS' (i.e., bio-energy with CCS) targeting point-source emissions from bio-energy installations and thus enabling negative emissions; 'Electricity & hydrogen' covering electrification and replacing fossil fuels with green hydrogen; 'Energy efficiency' including process optimisation and heat recovery; and, 'Recycling' targeting circularity and reduced primary material demand.

Scope reflects the strategic intent regarding whose emissions are reduced, and thus whether incumbents focus on transforming their own core activities or enabling broader system-level change. Building on the distinction between 'Scope 1', 'Scope 2', 'Scope 3' emissions (WRI and WBCSD, 2015), we identify reductions in different parts of the value chain. We also include distinct categories for reductions in 'Other sectors' and related to 'Infrastructure'. For example, a CCS facility installed at a cement plant to capture its own process emissions would fall under Scope 1, whereas electrification of a supplier's operations would be Scope 3. A project supplying district heating from industrial waste heat to households would be categorised as Other sectors. Likewise, investment in shared hydrogen pipelines or CO_2 transport networks would be categorised as Infrastructure, because the primary effect is to enable other actors' decarbonisation rather than directly lowering the investor's own emissions.

Collaboration assesses the extent to which incumbents are integrated into networks formed through co-participation in publicly funded decarbonisation projects. Using established metrics from social network analysis (Borgatti et al., 2009), we examine firm-level positions in the combined Industry Leap and Climate Leap project network. Degree centrality is used to indicate direct connectedness, while betweenness centrality highlights brokerage roles based on shortest path dependencies. In addition, authority scores are applied to identify structurally influential actors whose roles may not be reflected in simple connectivity measures. These network metrics help distinguish between firms that are centrally embedded in collaborative efforts and those occupying more peripheral or strategic positions. In line with the literature on incumbents, these network positions indicate different forms of system-building, coordination, or brokerage within mission-oriented policy processes.

Lastly, *engagement* captures the extent of incumbents' active participation in mission-oriented decarbonisation efforts. We operationalise this dimension through the amount of funding firms have been granted from the Industry and Climate Leap programmes, reflecting the degree to which incumbents mobilise resources and commit to publicly coordinated transition activities.

3.3. Cluster analyses and role typology

Departing from the framework described in the previous section, we use unsupervised clustering (Kassambara, 2017) as an exploratory method to analyse incumbents' roles in the transformative policy mission across multiple dimensions. The identified clusters are not roles themselves but intermediate groupings that capture patterns across dimensions, helping compare multidimensional variation across firms rather than relying on standalone typologies (Fig. 1). We applied three complementary clustering approaches—referred to as A, B, and C—each capturing a different dimension of incumbents' strategic behaviour. The results from each approach are grouped into numbered clusters (A1–A3, B1–B7, and C1–C7) and serve as the basis for our cross-case analysis and role typology.

The first analysis (A) combines the dimensions emissions, ambition, and engagement to assess whether incumbents' declared climate goals are matched by proportional responsibility for current emissions and observable commitment to mission-oriented decarbonisation. This captures the level of *alignment* between emissions profiles, decarbonisation ambition, and concrete engagement, indicating the extent to which formal commitments translate into participation in publicly coordinated mission activities. Given the weak correspondence between ambition and engagement, we applied k-means clustering (Hartigan and Wong, 1979) to systematically group firms based on total emissions and cumulative public funding received through the Industry and Climate Leap programmes (i.e., indicating the dimensions emissions and engagement). The optimal number of clusters was chosen by examining both the within-cluster sum of squares ("elbow") method and silhouette scores (Kassambara, 2017), which consistently indicated three clusters. This clustering revealed distinct profiles among incumbents, allowing us to move beyond predefined ambition levels and identify patterns such as low-emission actors with high engagement and high-emission actors with limited engagement.

The second analysis (B) examines the relationship between the dimensions pathway and scope to assess how incumbents translate mission goals into concrete decarbonisation strategies through funded projects. Together, these dimensions capture incumbents' *strategic orientation* within the mission, revealing whether they prioritise transforming their own core production processes or contributing to broader system-level decarbonisation through value chain-, cross-sectoral-, or infrastructure-oriented interventions. For the analysis, we used manually coded project-level data to identify each firm's prioritised mitigation pathway and scope of action (Table A.3 in the Appendix). This information was transformed into a weighted, undirected network in which nodes represent firms and pathway–scope categories, and edges represent participation links weighted by the firm's total public funding (SEK) for that category. The fast-greedy community detection algorithm (Clauset et al., 2004) was then applied to this network. The algorithm iteratively merges nodes into communities to maximise the network's modularity score—a measure of how much more densely connected nodes are within communities than between them. The point at which modularity reaches its maximum defines both the membership and number of communities. In our case, this process produced seven clusters, each corresponding to a coherent decarbonisation logic and grouping together firms with structurally similar mitigation pathways and scope of action.

The third analysis (C) examines the relationship between the dimensions engagement and collaboration to assess incumbents' *relational positioning* within the mission, distinguishing between firms that contribute primarily through financial commitment, network centrality, brokerage, or more peripheral forms of participation in collaborative project structures. For the analysis, we constructed a one-mode actor network derived from a two-mode actor–project matrix, including all actors involved in projects where one or more incumbents received funding. Centrality measures (degree and betweenness) were used to assess the relative embeddedness of incumbents in the network, while authority scores provided additional insight into the influence of certain nodes (Borgatti et al., 2018). To identify recurring patterns, we then applied k-means clustering to group firms based on their total public funding and degree centrality (i.e., indicating the dimensions engagement and collaboration). The number of clusters was determined using the elbow and silhouette methods, both indicating seven clusters. The resulting clusters reveal different collaborative profiles, distinguishing highly connected integrators from more isolated or peripheral actors.

The three clustering analyses address analytically distinct aspects of incumbent role performance that cannot be meaningfully reduced to a single clustering exercise—A captures alignment between emissions, ambition, and engagement, B captures strategic orientation through pathways and scope; and C captures relational positioning through engagement and collaboration. Separating these analyses allows each aspect of role performance to be examined using methods appropriate to the structure of the underlying data. Different clustering techniques are therefore employed across analyses because the data structures differ fundamentally: continuous firm-level input variables in A and C are suited to k-means clustering, whereas the relational, categorical, and weighted network data in B require community-detection methods. Methodological variation thus reflects data properties rather than analytical inconsistency.

The quantitative outputs from A, B and C were synthesised through a comparative, configuration-based assessment of each firm's position across the three analytical domains. Rather than assigning formal weights to individual analyses or collapsing them into a single composite measure, A, B, and C were treated as complementary lenses with equal analytical status, each illuminating a distinct aspect of incumbent role performance. For each firm, cluster memberships from analyses A–C were combined into an A–B–C configuration, documented in Appendix Table A.2, which serves as the empirical input to the role construction process.

Strategic roles were then constructed by grouping firms with similar configuration patterns through an iterative synthesis that combined the A–B–C configurations with qualitative interpretation of project descriptions, technological solutions, and sectoral contexts. This step did not involve an additional clustering algorithm. Instead, roles represent analytically meaningful aggregates of heterogeneous configurations rather than one-to-one mappings from specific cluster combinations. The appendix complements this synthesis by providing brief firm-level motivations that explain how each role assignment follows from the observed A–B–C configuration. This bottom-up process resulted in four strategic roles—*transformative frontrunners, system enablers, adaptive followers,* and *peripheral bystanders*—summarised in Table 1. Explanatory power thus derives from the consistency or tension between firms' positions across the three analyses, rather than from any single cluster assignment.

4. The roles of incumbents in the decarbonisation of Swedish industry

In this section, we describe the results of the three cluster analyses, focusing on alignment (A), strategic orientation (B), and relational positioning (C).

4.1. Cluster analysis A: alignment

The climate ambitions among the 20 largest industrial emitters in Sweden vary significantly in terms of scope, interim targets, and alignment with STBi, although all of them have set the target of becoming climate-neutral by 2050. Most firms (11 out of 20) exhibit a high level of ambition, characterised by clearly defined interim targets for emission reductions across Scope 1–3, and alignment with Science Based Targets initiative (SBTi) guidelines (Fig. 2). Notably, incumbents such as Preem, Höganäs, Nordkalk exemplify this group by setting ambitious goals and interim targets well before 2050. In contrast, Renova, St1, Sysav, and Vargön Alloys demonstrate low ambition, either lacking clearly defined targets or comprehensive emissions scopes. Five other incumbents—including LKAB and SMA Mineral—exhibit a moderate level of ambition, typically committing to reductions in Scope 1 and 2 emissions but lacking either alignment with the Science Based Targets initiative (SBTi) or clearly defined interim targets.

When comparing incumbents' engagement with their ambitions, we find no clear association between high ambitions and high engagement (Fig. 2).[1] On the contrary, firms with medium ambitions appear more engaged than those with high ambitions. Here, we find LKAB and Tekniska Verken standing out, being highly engaged but with medium ambitions of becoming carbon neutral by 2050, compared with, for example, Preem, Höganäs, and E.ON, with high ambitions but showing considerably less engagement in this context.

Since the level of ambition is a poor indicator of the level of engagement, we instead chose to cluster the incumbents based on their engagement versus their emissions with the k-means algorithm (Fig. 3). In total, we find three main clusters (A1-A3).

A1: Lower Emissions and Lower Engagement. This cluster includes eight incumbents from the steel, cement, municipal energy, and utility sectors, all characterised by relatively low emissions among the top 20. Their emissions range from approximately 0.4% (Outokumpu) to 1.0%

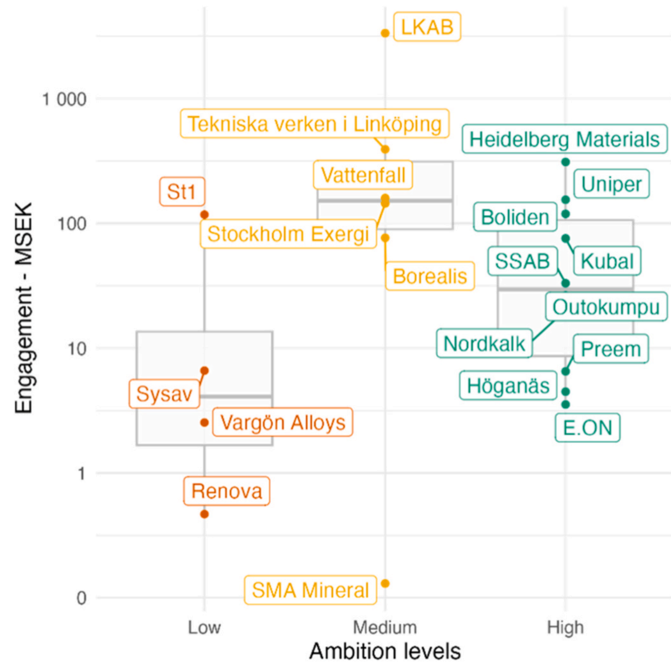

Fig. 2. Engagement in public decarbonisation programmes (measured in MSEK) across firms with low (red), medium (orange), and high (green) climate ambition levels. The figure highlights the absence of a clear relationship between ambition and engagement, with several medium-ambition firms receiving more public funding than those with high ambition (see Table A1 in Appendix). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

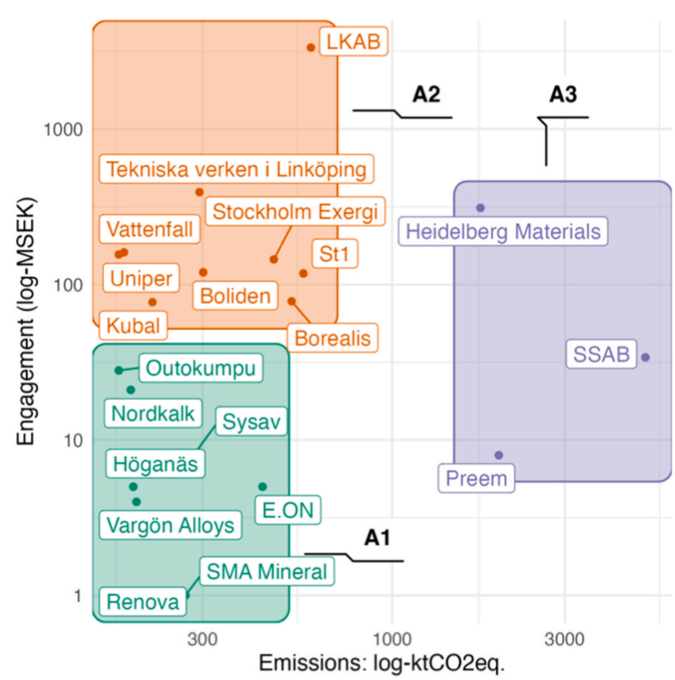

Fig. 3. Clustering of incumbents(A1–A3) based on total emissions (log $ktCO_2e$) and cumulative public funding received (log MSEK). The K-means algorithm (Hartigan and Wong, 1979) was applied to identify distinct engagement-emissions profiles, revealing three clusters: (A1) low emissions and low engagement, (A2) low emissions and high engagement, and (A3) high emissions with varied engagement (Analysis A).

[1] However, one should note that SSAB, LKAB, and Vattenfall are collaborating on the joint venture Hybrit, which also receives funding to develop hydrogen-based steel production planned to be integrated into SSAB and LKAB's operations. Regardless, we find a wide range of engagement levels regardless of ambition level.

(E.ON) of Sweden's total (45 $MtCO_2e$ in 2022), and they also show low engagement, with funding received ranging from 0.1 MSEK (Renova, SMA Mineral) to 30 MSEK (Outokumpu). Outokumpu produces stainless steel, Höganäs manufactures metal powders, and Vargön Alloys produces ferrochrome—each relying on fossil fuel combustion for high-temperature smelting, contributing significantly to emissions. In the cement sector, Nordkalk and SMA Mineral produce burnt lime, where emissions stem from calcination, the release of CO_2 during limestone heating. Sysav and Renova, municipal waste companies, emit primarily from waste incineration; only fossil-based emissions are covered by the EU ETS. E.ON's emissions originate from heat and power generation, using waste, coal, and biomass as fuel sources.

A2: Relatively Low Emissions and High Engagement. This cluster includes incumbents with relatively low emissions among the top 20 emitters—ranging from 0.4% (Uniper) to 1.3% (LKAB) of Sweden's total emissions—but showing high engagement, with funding received from approximately 70 MSEK (Kubal, Borealis) up to 3.3 billion SEK (LKAB). Firms include municipal energy and utility actors such as Uniper, Vattenfall, Stockholm Exergi, and Tekniska verken Linköping, whose emissions mainly stem from waste incineration, particularly the fossil-based plastic content, which accounts for up to 7% of Sweden's total emissions. In the chemical sector, Borealis—a petrochemical company—emits primarily from cracker processes converting hydrocarbons like naphtha and ethane into base chemicals. St1, in the refinery sector, produces both fossil and biofuels, with Scope 1 and 2 emissions arising mainly from fossil refining. In the metals and mining sector, Kubal produces aluminium, generating emissions from electrolysis, fossil fuel combustion, and fluorinated gases. Boliden, active in copper and zinc, emits mainly from smelting. LKAB, the state-owned iron ore miner, emits primarily from fossil fuel-based iron ore pellet production.

A3: High Emissions, Varied Engagement. This cluster includes three incumbents with high emissions, collectively accounting for approximately 4%–11% of Sweden's total emissions, and varying degrees of engagement from moderate to significant in emission reduction initiatives. SSAB is Sweden's largest steel producer, with emissions primarily resulting from using fossil coal as a reducing agent in blast furnaces, essential for steelmaking. The significant heat and energy requirements in refining crude oil into various fuels lead to substantial emissions for Preem, Sweden's largest oil refinery. Heidelberg Materials, the only cement producer in Sweden, has emissions predominantly from the calcination process, involving high-temperature treatment of limestone and substantial fossil fuel combustion for heating the kilns.

Taken together, the identified clusters (A1–A3) reveal substantial variation in the degree of alignment between incumbents' stated decarbonisation ambitions, their emissions profiles, and their observable engagement within the transformative policy mission. The identified clusters show that formal ambition alone provides limited insight into how firms position themselves in mission-oriented decarbonisation, underscoring the need to assess engagement relative to current emissions.

4.2. Cluster analysis B: strategic orientation

To further unpack how the incumbents respond to the Industry Leap and Climate Leap programmes, which form the core of the transformative policy mission, cluster analysis B examines their strategic orientation by combining targeted mitigation pathways and scope of action, using data about funded projects (weighted by engagement) (Fig. 4). In total, we find seven main clusters (B1–B7).

B1: Exploring Biofuels and Biomass for addressing Scope 1&2 emissions. Incumbents in this cluster—Outokumpu, Höganäs, Vargön Alloys, and St1—primarily focus on mitigation pathways related to increasing the use of biomass and biofuels to reduce their Scope 1 and Scope 2 emissions. Outokumpu is involved in increasing its use of biogas and replacing natural gas in its key processes (P41) and energy efficiency measures, addressing its Scope 2 emissions (P42). Vargön Alloys is also actively working on biofuel integration, specifically developing bio-briquettes for ferrochrome production under the Bio4SAF project

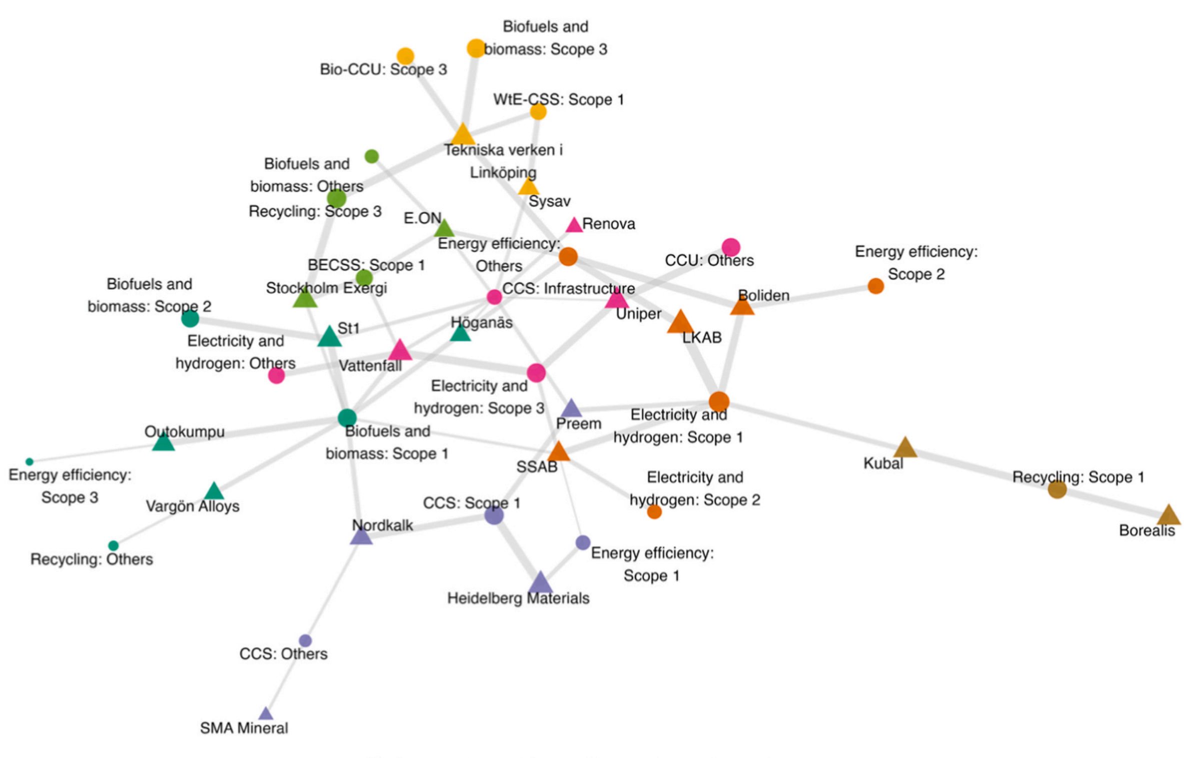

Fig. 4. Incumbents, their solution pathways and the emissions scopes they are addressing with their investments (Analysis B). The combination of emitters' pathways and scope is clustered with the fast-greedy-algorithm as implemented in igraph (Clauset et al., 2004) weighted by incumbents' engagement (log-million SEK).

(P87). However, the company also explores materials circularity through a separate initiative to establish a large-scale polyester recycling demonstrator (P88). This project aligns more with cluster B7 and is largely unrelated to their value chain, focusing on reducing others' emissions. Höganäs focuses on replacing fossil coal with renewable alternatives, demonstrated in pilot projects exploring the use of CO_2-neutral biochar (P24) and efforts to scale up biochar production for the fossil-free value chain (P23). These initiatives directly target Scope 1 emissions. Höganäs also expands its district heating capabilities through energy recovery measures (P26), reducing emissions for external actors (cf. cluster B2). The company also participates in broader CCS infrastructure development through the Carbon Network South Sweden (CNetSS) initiative (P25) (cf. cluster B4). Lastly, St1 supports biofuel development and usage through several infrastructure and production projects, including the Ellinge upgrade facility (P59), the Högbytorp drying facility (P61), and the Borås liquid biogas site (P60). These projects target Scope 1 emissions by expanding biofuel capacity, although they do not directly replace existing fossil-based infrastructure. St1 also engages in CCS infrastructure development through its involvement in shared initiatives such as the CinfraCap project and related carbon transport and storage infrastructure efforts (P62; P63), which are more directly aligned with cluster B4.

B2: Scaling electrification and hydrogen to address Scope 1 and 2 emissions while also reducing emissions from others. Incumbents in this cluster —Boliden, LKAB, and SSAB—concentrate their efforts primarily on electricity and hydrogen projects targeting Scope 1 and Scope 2 emissions, complemented by investments aimed at improving energy efficiency, particularly for Scope 2 emissions, and also contributing to emission reductions beyond their own Scope 1–3 activities. Boliden is implementing electrification and hydrogen solutions to transition its mining processes towards fossil-free operations. Key projects aim at electrifying underground mining equipment and testing hydrogen-based slag reduction processes (P1; P2). Additionally, Boliden invests in energy efficiency by developing projects to utilise excess heat generated during operations, including heat recovery from mine ventilation in a project called "Heat exchanger facility for mine ventilation in Kankberg mine" (P3). Energy efficiency is also enhanced through the Ecolink project, "Utilizing waste heat for Skellefteå's district heating network" (P4), thus supplying excess heat and reducing emissions for external actors. LKAB, on the other hand, actively engages in electrification and hydrogen-based production methods through participation in the Hybrit initiative. This includes several pilot projects and feasibility studies, targeting fossil-free iron, steel, and pellet production (P30-P35). LKAB also undertakes energy efficiency initiatives in collaboration with Tekniska verken in Kiruna, where waste heat from mining processes is utilised for municipal district heating (P36), exemplifying efforts aimed at reducing emissions for external actors (Others). Similarly, SSAB is involved in electricity and hydrogen projects under the Hybrit joint venture with LKAB and Vattenfall, encompassing pilot demonstrations, feasibility studies, and research activities for fossil-free steelmaking and hydrogen storage technologies (P53-P57). In parallel, SSAB explores energy efficiency solutions to reduce its Scope 1 emissions by reducing process-related emissions, while creating new and valuable products by converting waste gases into chemicals through gas fermentation technology (P58).

B3: Towards implementing CCS for reducing Scope 1 emissions. Incumbents in this cluster—Heidelberg Materials, Nordkalk, SMA Mineral, and Preem—primarily invest in CCS to address their direct emissions (Scope 1). The most active firm is Heidelberg Materials, which has made progress with its CCS initiative at the Slite cement plant on Gotland, aiming to establish the world's first climate-neutral cement factory by 2030. Heidelberg's CCS-related projects include feasibility studies (P17; P18), Front-End Engineering Design (FEED) preparations (P19), and pilot implementations such as plasma-assisted rotary kilns to optimise thermal transfer and reduce emissions during cement clinker production (P14; P15; P16). Additional efforts include energy efficiency projects like installing silo capacity for low-carbon concrete production (P21; P22) and radio-based calcination monitoring (P20). Nordkalk actively participates in Heidelberg Materials' CemZero project to understand the properties of plasma technologies in combination with calcium-based bed materials (P39). In parallel, Nordkalk also leads its own CCS initiative through a pre-study for carbon capture at its lime production facility in Köping (P40). These efforts align with Nordkalk's broader objective of reducing direct emissions from limestone calcination. Furthermore, Nordkalk is transitioning to renewable fuels through projects aimed at adapting equipment for biofuels and integrating renewable energy carriers into lime production (P37; P38). SMA Mineral also engages in the CemZero initiative (P49), focusing on exploring the technical potential of plasma-assisted calcination processes using calcium-based bed materials, although with a more limited scope compared to Heidelberg and Nordkalk. Lastly, Preem, operating in the refining sector, is advancing its CCS capabilities through dedicated capture and storage projects aimed at reducing Scope 1 emissions (P45). It also contributes to building shared infrastructure for carbon transport and storage via the CinfraCap project and other joint efforts (P43; P44). In parallel, Preem is exploring renewable hydrogen production as a complementary decarbonisation pathway (P46).

B4: Creating infrastructure to address others' emissions. Incumbents in this cluster —Uniper, Vattenfall, and Renova—strategically focus on enabling emission reductions beyond their direct operations, emphasising electricity, hydrogen, and CCS infrastructure development. Vattenfall is most clearly engaged in the Hybrit initiative, including pilot projects for fossil-free iron, steel, and hydrogen production (P93; P94; P95), underground hydrogen storage (P96), and renewable hydrogen production feasibility studies aimed at supporting fossil-free steel production at an industrial scale (P92). These activities reflect a strategic focus on system-level decarbonisation, rather than direct reductions in Vattenfall's own Scope 1–3 emissions. Uniper contributes through "Project AIR" (P85), a project owned by the chemical company Perstorp. The purpose of the project is to implement carbon capture combined with hydrogen electrolysis to produce sustainable methanol at an industrial scale (CCU). Uniper is also involved in the Carbon Network South Sweden initiative (CNetSS), which aims to coordinate regional CCS infrastructure development (P84). From both Vattenfall's and Uniper's perspective, these projects primarily reduce emissions on a system level. Renova, alongside these actors, plays an active role in developing shared CCS infrastructure through participation in initiatives such as CinfraCap and other infrastructure-focused projects for CO_2 transport and intermediate storage (P47; P48). Vattenfall also contributes to infrastructure development through a system study on CO_2 transport by rail (P91). Additional actors from other clusters, including Preem (B3), E.ON (B5), and Sysav (B6), also contribute to building this shared CCS infrastructure framework.

B5: Bioenergy, BECCS, and Recycling for Emission Reductions. Incumbents in this cluster—Stockholm Exergi and E.ON—strategically focus their activities on BECCS and recycling to address both Scope 1 and Scope 3 emissions, as well as energy efficiency and biofuels and biomass to address emissions beyond their direct operations. Stockholm Exergi actively advances BECCS to directly reduce emissions from its combined heat and power (CHP) plants. Significant projects include carbon capture with Svante technology (P65), and a series of high-performance carbon capture (HPC) tests for BECCS refinement and implementation (P66; P67; P68). The company also explores chemical looping combustion of biomass and waste through pilot operations aimed at optimising bioenergy production (P64; P69). Complementing these efforts, Stockholm Exergi invests in recycling infrastructure through its sorting facility for residual waste (P70), contributing to Scope 3 emission reductions by improving waste sorting and recycling. E.ON pursues similar bioenergy strategies, including feasibility studies for implementing bio-CCS at its Åby and Händelö CHP plants (P11), and a planned BECCS project at a new CHP facility in Malmö's energy port (P12). E.ON also engages in bioenergy solutions beyond its own operations, such as supplying biogas to industrial customers in southern Skåne (P9), and participating in large-scale biochar production projects for the fossil-free iron and steel value chain (P10). Additionally, E.ON supports energy efficiency efforts (P13) and contributes to regional CCS infrastructure initiatives like the Carbon Network South Sweden (P7; P8). Firms in B5 thus prioritise bioenergy, BECCS, and recycling projects, strategically aiming to reduce direct and indirect emissions within their operations while simultaneously contributing to broader decarbonisation efforts. Notably, similar investments in BECCS are also pursued by Vattenfall in B4.

B6: Strategic Engagement in Waste-to-Energy CCS and Bio-based Solutions. Incumbents in this cluster—Tekniska verken i Linköping and Sysav—strategically invest in WtE-CCS to manage Scope 1 emissions, complemented by bio-based and recycling initiatives that reduce Scope 3 emissions. Tekniska verken i Linköping is the most active firm within the cluster, pursuing a broad range of decarbonisation strategies. A key focus is the increased production and use of liquefied biogas (P80, P81). The company also invests in bio-based carbon capture and utilisation (Bio-CCU), illustrated by the project “Liquefaction of carbon dioxide from biogas production” (P77). To address direct emissions, Tekniska verken is exploring WtE-CCS through a feasibility study for implementation at the Gärstadverket plant (P75). These efforts are complemented by additional biogas-related projects aimed at increasing production and lowering emissions (P78; P79), as well as investments in recycling infrastructure that target Scope 3 reductions. These include the “reuse” initiative at Linköping's recycling centres (P82) and the Gärstad sorting facility (P83), which together contribute to more efficient material recovery and reduced waste-related emissions. Sysav shows a more limited but focused engagement in WtE-CCS. It is conducting both an overarching feasibility study for waste-to-energy carbon capture (P73) and a plant-specific feasibility study for its own operations (P74). Sysav also contributes to regional CCS infrastructure through its involvement in the Carbon Network South Sweden initiative (P71; P72), supporting the development of systems for CO_2 transport and intermediate storage.

B7: Strategic Recycling to Address Direct Emissions. Incumbents in this cluster —Borealis and Kubal—strategically focus on recycling to reduce Scope 1 emissions. Kubal targets resource efficiency and emission reductions by co-locating primary production with remelting of aluminium (P28), integrating recycling into its core operations. The company also pursues electrification through the conversion of its anode preheating process to electricity and hydrogen (P27), complementing its recycling strategy and contributing further to Scope 1 decarbonisation. Borealis strengthens its position through investments in plastics recycling, particularly via its refinery project in Stenungsund (P5; P6). The project transforms waste plastics into refined feedstocks, directly reducing fossil resource dependency and associated process emissions.

Taken together, the identified clusters B1–B7 reveal distinct patterns of strategic orientation among incumbents within the transformative policy mission, reflected in how mitigation pathways are combined with different scopes of action. The results show that firms pursue qualitatively different decarbonisation logics, ranging from direct transformation of core production processes to infrastructure-oriented and system-enabling strategies extending beyond their own emissions.

4.3. Cluster analysis C: relational positioning

To understand the relational positioning of incumbents, cluster analysis B examines the relationship between the engagement and collaboration. The analysis departs from the broad collaboration network emerging from projects involving incumbents. This network comprises 86 actors and 355 ties, resulting in a network density of 0.097, indicating that nearly 10% of all possible ties are realised (Fig. 5). To contextualise, we compared this empirical network with a random network of equal size and density. The empirical network displays a substantially higher global clustering coefficient (0.51 compared to 0.097), suggesting a stronger tendency for actors within the transformative policy mission to form tightly knit, collaborative subgroups rather than random connections. Additionally, the observed average path length of 3.1 slightly exceeds that of the random network (2.32),

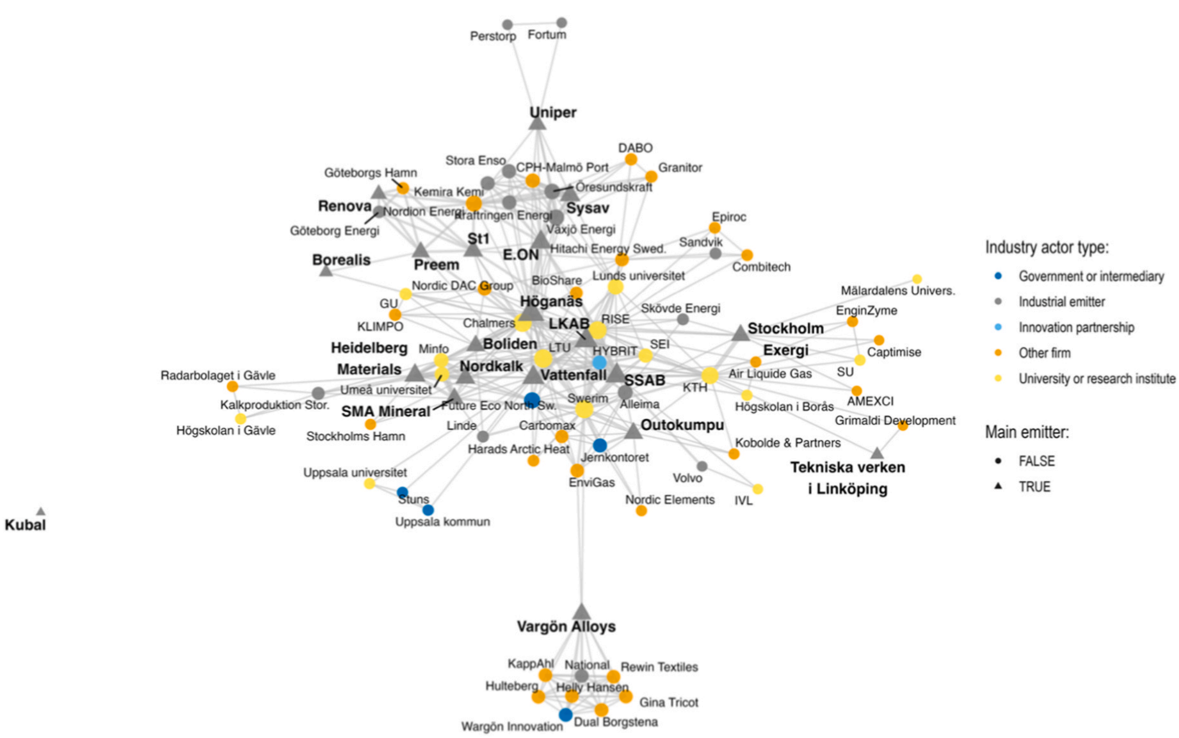

Fig. 5. Actor network of funded emission reduction projects involving at least one incumbent as a recipient. The network includes all actors co-participating in these projects and receiving public funding. Incumbents are highlighted in bold and with larger font text. Node placement is based on the Fruchterman–Reingold layout algorithm (Fruchterman and Reingold, 1991), which positions more central actors closer to the centre of the plot (Analysis C).

further supporting the presence of structured sub-communities. This structural cohesion likely facilitates trust, repeated collaboration, and efficient knowledge exchange within established actor constellations (Uzzi, 1997). However, the high clustering—well above what would be expected in a random network—also suggests a relatively closed network. This may pose barriers to entry for new or peripheral actors and could limit the diffusion of knowledge and practices across different parts of the network, particularly if bridging connections between tightly knit clusters are sparse (Boschma, 2005; Granovetter, 1973).

At the centre of the network are a mix of incumbents and research institutions. Höganäs stands out with the highest number of direct ties and notable authority, suggesting a key role as an active participant in many projects, though mostly at a low level of engagement. Research institutions such as LTU, Chalmers, RISE, and Swerim also rank among the most connected actors and function as hubs linking industrial partners. Swerim, in particular, holds a high betweenness centrality, highlighting its role as a bridge between otherwise disconnected actors, focusing on actors within the iron and steel industry. This hybrid core structure—where industrial emitters and knowledge institutions co-anchor the network—demonstrates a collaborative mode of knowledge production and governance (Etzkowitz and Leydesdorff, 2000; Kuhlmann and Rip, 2018).

To further analyse how incumbents position themselves, we clustered the top 20 emitters using k-means based on their degree centrality and engagement (log million SEK) (Fig. 6). In total, we find seven main clusters (C1–C7) that capture distinct combinations of collaborative embeddedness (collaboration intensity) and programme engagement.

At one end of the spectrum, the cluster *Highly Central and Highly Engaged Anchors (C3)* include Heidelberg Materials, Vattenfall, LKAB, and Uniper, all deeply embedded in collaborative project structures and showing substantial engagement, with LKAB standing out in terms of engagement. Similarly, actors in *Moderately Central and Highly Engaged Actors (C1)*, such as Boliden, Stockholm Exergi, and St1, combine strong engagement with active participation in the collaboration network.

Fig. 6. Clustering of incumbents (C1–C7) based on their level of engagement (total public funding in MSEK) and collaborative embeddedness (degree centrality) in the actor network. The K-means algorithm was used to identify seven strategic profiles, capturing different combinations of financial commitment and network positioning in the Industry Leap and Climate Leap programmes (Analysis C).

In contrast, the cluster *Highly Central but Low-Engagement Actors (C2)*, including Preem, Vargön Alloys, Sysav, and E.ON, is well integrated into the network while exhibiting comparatively limited engagement. This pattern suggests participation through smaller-scale, early-stage, or selectively funded projects, or engagement that is oriented towards co-ordination and learning rather than large programme commitments. A smaller cluster is *Low-Centrality and Selectively Engaged Actors (C5)*, including Kubal, Tekniska verken, and Borealis, where relatively high engagement is combined with low network centrality, indicating a focus on stand-alone or narrowly coordinated projects rather than broad collaboration.

Incumbents such as Outokumpu, Nordkalk, and SSAB are a part of the cluster *Moderately Central and Moderately Engaged Actors (C7)*, reflecting intermediate profiles that combine sustained but not dominant collaboration with moderate engagement levels. At the network's periphery, *Peripheral and Minimally Engaged Actors (C6)* include Renova and SMA Mineral, both characterised by low collaboration and minimal engagement. Finally, Höganäs occupies a distinct position within *Extremely Central and Low-Engagement Actors (C4)*, combining extensive collaboration with relatively modest engagement, consistent with a strategy centred on participation, knowledge exchange, and co-development rather than capital-intensive leadership.

Taken together, the identified clusters (C1–C7) reveal distinct patterns of relational positioning among incumbents within the collaborative structures of the transformative policy mission. Differences in how firms combine network embeddedness and programme engagement indicate that incumbents participate in the mission through qualitatively different collaborative roles, ranging from central coordinating positions to more peripheral and selective forms of involvement.

5. Discussion

Drawing on official emissions statistics, secondary data about incumbents climate goals and mitigation strategies, as well as information about all projects granted funding from the Industry Leap and Climate Leap programmes, this paper analysed the emission profiles, decarbonisation ambitions, mitigation pathways, scope of action, collaborations, and engagement of Sweden's 20 largest emitters to identify recurring patterns. Methodologically, our contribution lies in combining emissions statistics, project-level funding data, and social network analysis to investigate, in a structured and comparative way, how incumbents interpret, engage with, and adopt different roles within transformative policy missions. By clustering firms across distinct dimensions in three separate analyses, we move beyond ambition statements to identify empirically grounded roles. This multi-dimensional, configuration-based approach provides a framework for future studies seeking to analyse how incumbents respond to mission-oriented policymaking across sectors and national contexts.

A key empirical finding concerns the weak alignment between stated decarbonisation ambitions and observable engagement in public funding programmes. Ambition, even when robustly formulated, proves to be a poor indicator of proactive engagement under mission-oriented policy instruments. Several firms with very high ambitions, such as Preem, E.ON, and Höganäs, display relatively limited engagement in funded projects, while LKAB stands out as a medium-ambition actor that nonetheless exhibits the highest level of engagement among all emitters. This divergence underscores that formal commitments—whether framed by target years or SBTi alignment—are insufficient proxies for action and may obscure how firms actually mobilise resources in response to policy incentives. In line with Fankhauser et al. (2022), what ultimately matters is not whether net-zero targets exist, but how incumbents act on them. Our results, therefore, highlight the importance of assessing ambition in relation to concrete participation in publicly funded decarbonisation programmes and of examining how firm-level strategies and engagement patterns align with broader policy objectives.

Grounded in recurring patterns across cluster analysis A, B and C, our cross-cluster analysis identifies four strategic roles that incumbents occupy within transformative policy missions (Table 1). These roles are derived from firm-level A–B–C configurations that combine engagement relative to emissions profiles, mitigation pathways, scope of action, and collaboration, as documented in Appendix Table A.2. By synthesising recurring configuration patterns rather than relying on any single analytical dimension, the typology captures how incumbents enact distinct, empirically grounded roles within the mission context.

The first role, *transformative frontrunners*, comprises SSAB, LKAB, Boliden, Heidelberg Materials, and Stockholm Exergi. These firms exhibit strong engagement relative to their emissions profiles or combine very high emissions with substantial engagement (cluster analysis A), prioritise pathways that directly address core process emissions (cluster analysis B), and occupy collaborative positions that enable coordination and scaling, even if not uniformly central across all cases (cluster analysis C). Together, this configuration indicates both capacity and willingness to drive system-level change rather than engage primarily in isolated or incremental initiatives.

Within this role, two empirical sub-patterns can be distinguished that reflect different mitigation pathways within a shared configuration logic. SSAB, LKAB, and Boliden prioritise electrification, hydrogen, and energy efficiency, targeting core industrial processes while also generating system-level spillovers, for example through waste heat recovery or the valorisation of industrial by-products. This reflects a strategy aimed at reconfiguring production systems beyond niche experimentation, consistent with incumbents acting simultaneously at niche and regime levels (Berggren et al., 2015).

By contrast, Heidelberg Materials and Stockholm Exergi advance large-scale CCS and BECCS initiatives that rely heavily on cross-sectoral coordination and shared infrastructure. These strategies exemplify what Bergek et al. (2013) describe as creative accumulation: leveraging existing assets while integrating new technologies to extend their relevance under changing regime conditions. Taken together, these sub-patterns illustrate how transformative frontrunners can drive system transformation through both direct reconfiguration of core processes and the anchoring of collaborative infrastructures that enable sector-wide change.

The second role, *system enablers*, is exemplified by Vattenfall and Uniper. These firms combine substantial engagement relative to their emissions profiles (cluster analysis A) with collaborative positions that enable coordination across multiple actors (cluster analysis C), while their strategic orientation centres on the provision of enabling infrastructures rather than the direct transformation of their own core production processes (cluster analysis B). Their projects are therefore primarily oriented toward building and operating system-level infrastructures upon which other firms' decarbonisation strategies depend.

Vattenfall plays a pivotal role in the HYBRIT initiative by advancing renewable hydrogen production and underground storage, while also contributing to the development of CCS transport solutions. Uniper, through Project AIR, develops carbon capture and utilisation integrated with hydrogen electrolysis for large-scale methanol production and participates actively in regional CCS networks. Together, these activities support coordination, scaling, and interdependence across industrial actors, providing critical infrastructures that underpin broader system transformation. This role corresponds closely to what Hellsmark and Jacobsson (2009) and Musiolik et al. (2012) describe as system builders—actors that facilitate socio-technical change primarily through structural coordination rather than direct emissions reduction within their own operations.

At the same time, the configuration that defines system enablers also reveals a potential tension. Despite their substantial engagement and central coordinating roles, these firms devote comparatively limited effort to reducing their own Scope 1 emissions. This highlights both their systemic importance within the mission and the risk of partial alignment, whereby enabling others' decarbonisation advances the mission while leaving their own transformation challenges only indirectly addressed.

The third role, *adaptive followers*, is the most diverse and internally differentiated in the typology, comprising Preem, Höganäs, Outokumpu, Nordkalk, E.ON, St1, Sysav, Vargön Alloys, Borealis, Kubal, and Tekniska verken. These firms display heterogeneous A–B–C

Table 1

Strategic roles of incumbents in transformative policy missions, derived from cross-analysis of cluster analysis A, B, and C. The table summarises a typology of four roles—transformative frontrunners, system enablers, adaptive followers, and peripheral bystanders. Source: Own compilation. See also Table A2 in the appendix.

Strategic role	Definition	Typical A-pattern	Typical B-pattern	Typical C-pattern	Incumbents
Transformative frontrunners	Actors that directly target core process emissions and play anchoring roles in coordination-intensive projects that reconfigure industrial systems.	Strong engagement relative to emissions responsibility, or high emissions combined with engagement that is substantial though not uniformly proportional (A2–A3).	Core Scope 1 transformation through hydrogen, electrification, CCS or BECCS (B2, B3, B5).	Highly engaged and moderately to highly central positions enabling coordination and scaling (C1, C3, C7).	SSAB (A3–B2–C7), LKAB (A2–B2–C3), Boliden (A2–B2–C1), Heidelberg Materials (A3–B3–C3), Stockholm Exergi (A2–B5–C1).
System enablers	Actors whose primary contribution lies in providing shared infrastructure that enables decarbonisation by other actors rather than transforming their own core processes.	High engagement relative to emissions responsibility (A2).	Infrastructure-oriented pathways addressing others' emissions (e.g. hydrogen systems, CCS networks) (B4).	Highly engaged and central coordinating positions (C1, C3).	Vattenfall (A2–B4–C3), Uniper (A2–B4–C1).
Adaptive followers	Actors that engage with the mission through selective, incremental, or preparatory activities without committing to comprehensive transformation of core production processes.	Low proportionality or mixed alignment between emissions responsibility and engagement (A1–A2, and in some cases A3 with limited coordination).	Incremental, niche, or preparatory pathways such as biofuels, recycling, waste-to-energy CCS, or early-stage CCS (B1, B3, B5, B6, B7).	Peripheral to semi-central positions with selective or uneven engagement (C2, C4, C5, C7).	Preem (A3–B3–C2), Höganäs (A1–B1–C4), Outokumpu (A1–B1–C7), Nordkalk (A1–B3–C7), E.ON (A1–B5–C2), St1 (A2–B1–C1), Sysav (A1–B6–C2), Vargön Alloys (A1–B1–C2), Borealis (A2–B7–C5), Kubal (A2–B7–C5), Tekniska verken i Linköping (A2–B6–C5).
Peripheral bystanders	Actors that remain marginal across engagement, strategy, and collaboration, with limited integration into mission-oriented activities.	Low engagement relative to emissions responsibility (A1).	Limited or preparatory activities without sustained mission engagement (B3, B4).	Peripheral positions with minimal engagement (C6).	SMA Mineral (A1–B3–C6), Renova (A1–B4–C6).

configurations, combining weak or uneven proportionality between emissions profiles and engagement (cluster analysis A) with peripheral to semi-central positions in the collaboration network (cluster analysis C). Their strategic orientations (cluster analysis B) are characterised by selective, incremental, or preparatory mitigation pathways rather than sustained commitments to transforming core production processes.

Within this role, several empirical sub-patterns can be identified that reflect different adaptive responses to the mission. Höganäs, Outokumpu, and St1 prioritise bio-based and efficiency-oriented pilot projects that substitute fossil inputs but remain limited in scale and scope. Preem and Nordkalk have initiated CCS-oriented activities at a preparatory or pre-study stage, indicating responsiveness to mission signals without corresponding large-scale investment. Sysav and Tekniska verken form a distinct WtE-CCS configuration, focusing on emissions from incineration alongside experimentation with recycling and bio-based solutions. Borealis and Kubal stand out as selective innovators, combining relatively high engagement with low collaborative embeddedness, particularly through recycling-oriented pathways. E.ON has pursued BECCS and recycling trials, but with engagement levels and collaborative positioning that remain limited relative to its system relevance.

Taken together, these patterns illustrate the heterogeneous ways incumbents adapt within transformative policy missions. Rather than being inactive, adaptive followers engage in experimentation, learning, and selective innovation, but do so in ways that remain partial or fragmented. As such, they are positioned between experimentation and strategic commitment—their activities may contribute to learning and incremental alignment with mission goals, while also allowing core decarbonisation challenges to remain unresolved or deferred (van Mossel et al., 2018). In this sense, some adaptive follower configurations resonate with mechanisms discussed in the literature on discourses of climate delay, where incremental or preparatory action may stabilise existing systems while deferring more fundamental change (Lamb et al., 2020).

Fourth and finally, *peripheral bystanders*, including SMA Mineral and Renova, remain marginal across all three analytical dimensions. Their configurations are characterised by low proportionality between emissions profiles and engagement (cluster analysis A), pathway orientations that remain limited or preparatory in nature (cluster analysis B), and peripheral positions with minimal engagement in collaborative project structures (cluster analysis C). While these firms are not entirely absent from mission-oriented activities, their participation is fragmented and weakly integrated into the coordination and scaling dynamics that characterise more active roles.

As such, peripheral bystanders illustrate the lower boundary of incumbent engagement within the mission context. Whether due to structural constraints, limited strategic capacity, or low external pressure, their configurations suggest that current policy instruments have had limited influence on their strategic orientation. This role therefore highlights not only variation in incumbent responses, but also potential limits of mission-oriented policy in mobilising firms that remain weakly connected to both transformative pathways and collaborative infrastructures.

Taken together, these findings support Turnheim and Sovacool's (2020) call to move beyond binary classifications of incumbents as "regime actors" and instead recognise the plurality of roles they play in sustainability transitions. Importantly, the incumbents analysed span multiple sectors, ownership forms, and societal functions—from energy and materials production to waste management and infrastructure provision—highlighting that transformative policy missions necessarily engage heterogeneous actors with different mandates, constraints, and strategic capacities. Our results show that incumbents may act as system-oriented frontrunners proactively shaping emerging socio-technical systems, as system enablers that facilitate decarbonisation by other actors, as adaptive followers that engage selectively and incrementally, or as peripheral bystanders with limited participation. These roles are not determined by emissions intensity alone, nor by sector or ownership per se, but reflect how incumbents position themselves across responsibility, strategy, and collaboration within a given policy mission—shaped by sectoral dynamics, organisational capacities, ownership structures, and alignment with policy logics.

6. Conclusions and policy implications

This paper has examined how incumbent industrial firms in Sweden interpret, engage with, and adopt different roles within a transformative policy missions aimed at achieving net-zero emissions by 2045. Our results show diverse and uneven behaviour among the studied firms. Formal decarbonisation ambitions are weak predictors of concrete action, while actual engagement in public programmes reveals incumbents acting as frontrunners, system enablers, adaptive followers, or peripheral bystanders. These roles highlight the heterogeneity of firm behaviour and the importance of moving beyond binary classifications of leaders and laggards. Taken together, the findings demonstrate that the success of transformative policy missions depends not only on the presence of ambitious targets, but also on how incumbents align their strategies, resources, and collaborations with broader mission objectives.

From a policy perspective, several implications emerge. First, funding instruments must be designed to both support individual projects and promote strategic alignment with long-term goals. Participation in programmes like the Climate Leap and Industry Leap should be assessed not only on technical merit or cost efficiency, but also on contributions to broader mission objectives—including cross-sectoral learning and collaborative infrastructure development. Notably, some firms pursue highly complex and uncertain mitigation pathways, such as WtE-CCS, bio-based carbon capture and utilisation (bio-CCU), or advanced plastic recycling, while remaining relatively disconnected from collaborative networks. This applies not only to peripheral actors like Renova but also to more engaged firms such as Borealis and Kubal, which pursue technologically advanced solutions with potentially broad system impact, yet show limited embeddedness in cross-firm collaborations. While such projects may reflect high ambition or innovation potential, the lack of integration raises questions about long-term scalability, infrastructure synchronisation, and knowledge diffusion. Second, tailored policy support is needed to support incumbents that adopt different strategic roles; frontrunners may require regulatory relief and mechanisms for scaling, while adaptive followers rather need support for risk-sharing, piloting, or capacity-building. Third, peripheral actors should not be ignored. In sectors where technological alternatives are scarce or organisational inertia is high, stronger regulatory signals may be necessary to ensure that all relevant actors are drawn into the transformative effort. This is particularly important for municipal monopoly actors like Renova, which face limited market pressure and may require explicit alignment incentives to overcome structural disincentives for collaboration and investment.

On a final note, this paper underscores the importance of integrating an analysis of incumbents. While transformative policy missions aim to align diverse actors toward a common goal, the evidence here suggests that alignment is uneven and contingent. To improve effectiveness, mission-oriented instruments should be assessed not only by their formal criteria, but also by their ability to shift incumbent behaviour in ways that are robust, inclusive, and genuinely transformative.

CRediT authorship contribution statement

Hans Hellsmark: Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Johnn Andersson:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Data curation, Conceptualization. **Barbara Hedeler:** Writing – review & editing, Validation, Data curation.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix

Table A.1
Overview of climate ambitions among the 20 main industrial emitters (incumbents) in Sweden. Firms are assessed based on target year, inclusion of Scope 1–3 emissions, interim targets, and alignment with the Science Based Targets initiative (SBTi). Ambition levels (low, medium, high) reflect the combination of these factors. Abbreviations: NA = Not available, UD = Under development.

Incumbents	Year	Scope	Interim targets	SBTi	Ambition	Motivation
Boliden	2050	1–3	Reduce Scope 1&2 emissions by 42% until 2030	Yes	High	Scope 1–3, clear interim targets, STBI
Borealis	2050	1 & 2	Reduce Scope 1&2 emissions from 5.1 million tons to less than 2 million tons by 2030 from base year 2019	No	Medium	Scope 1–2, interim targets, no SBTI
E.ON	2050	1–3	Reduce Scope 1 & 2 emissions by 50% by 2030 and 90% by 2040 from 2019 levels; reduce Scope 3 emissions by 50% by 2030 and at least 90% by 2050.	Yes	High	Scope 1–3, clear interim targets, STBI
Heidelberg	2050	1–3	Reduce scope 1–2 emissions per tonne cementitious material by 26.7% by 2030, in relation to base year 2020, scope 3 by 25% by 2030	Yes	High	Scope 1–3, clear interim targets, STBI
Höganäs	2037	1–3	Reduce Scope 1 and 2 GHG emissions 51% by 2030 from 2018 base year, reduce absolute Scope 3 GHG emissions by 30% within same timeframe	Yes	High	Scope 1–3, clear interim targets, STBI
Kubal	2050	1–3	By 2030, reduce Scope 1–3 GHG emissions by min. 35% against 2018 baseline	Yes	High	Scope 1–3, clear interim targets, STBI
LKAB	2045	1&2	Achieve 10% energy reduction per tonne by 2030; cut CO2 emissions from operations by 25% (not further specified in scopes).	No	Medium	Scope 1 & 2, clear interim targets, no SBTI
Nordkalk	2040	1–3	By 2032, fossil-free fuels in all limestone sites, by 2038, fossil-free quicklime production and carbon neutrality	Yes	High	Scope 1–3, clear interim targets, STBI
Outokumpu	2050	1–3	Reduce emissions by 42% per tonne of stainless steel by 2030 from 2016 base year	Yes	High	Scope 1–3, clear interim targets, STBI
Preem	2035	1–3	Scope 1 & 2 reduced by at least 50% by 2030, all GHG emissions by at least 30% by 2030 (Scope 1–3)	UD	High	Scope 1–3, clear interim targets; STBI u.d.
Renova	2045	NA	None	No	Low	Undefined scope, interim targets and no STBI
SMA	2050	1&2	Unclear scope to reduce CO2 emissions by 50% by 2027.	No	Medium	Scope 1–2, unclear interim target, no STBI
SSAB	2045	1–3	By 2032, 35% reduction of GHG emissions (CO2e) in Scope 1,2 from 2018 base year	Yes	High	Scope 1–3, clear interim targets, STBI
St1	2050	NA	Under development	No	Low	Undefined scope, interim targets and no STBI
Stockholm Exergi	2032	1–3	Scope 1 target: Construct large-scale bio-CCS by 2027.	No	Medium	Scope 1–3, Scope 1 target, no SBTI
Sysav	2030	1–3	None	No	Low	Scope 1–3, no clear interim targets, no SBTI
Tekniska V.	2045	1–3	None	No	Medium	Scope (1–3), no interim targets, no STBI
Uniper	2040	1–3	Reduce Scope 1 and 2 emissions by 55% and achieve carbon neutrality for both by 2035; reduce Scope 3 emissions by 35% by 2035.	UD	High	Scope 1–3, clear interim targets; STBI u.d.
Vargön Alloys	2050	UD	Under development	No	Low	Undefined scope, no interim targets, no STBI
Vattenfall	2040	1–3	Reduce scope 1 and 2 emissions by 77% per kWh by 2030 from 2017, reduce scope 1 and 3 emissions from sold electricity by 78% per kWh. Cut absolute scope 3 GHG emissions from sold fossil fuels by 54.6%.	Yes	High	Scope 1–3, clear interim targets, SBTI

Source: Own compilation from various source.

Table A.2
Cross-analysis cluster configurations of incumbents (Analyses A–C), assigned roles and their motivation

Roles	Incumbents	Clusters	Motivation
Front-runner	SSAB	A3-B2-C7	SSAB combines very high emissions responsibility with engagement levels that are substantial but not uniformly proportional (A3) and prioritises core Scope 1 transformation through hydrogen-based and electrified steelmaking (B2). Its semi-central but sustained collaborative position (C7) reflects an anchoring role in coordination-intensive projects shaping pathway directionality in steel production.
Adaptive	Preem	A3-B3-C2	Preem combines very high emissions responsibility with engagement that remains limited relative to its system relevance (A3) and a strategic focus on CCS-oriented pathways at a preparatory stage (B3). Its peripheral collaborative position (C2) indicates selective participation rather than anchoring in coordination-intensive mission activities.

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Table A.2 (*continued*)

Roles	Incumbents	Clusters	Motivation
Front-runner	Heidelberg Materials	A3-B3-C3	Heidelberg Materials combines very high emissions responsibility with engagement that is substantial relative to peers but not uniformly proportional (A3) and a clear strategic orientation towards CCS as a core process pathway in cement production (B3). Its central collaborative position (C3) reflects the infrastructure- and coordination-intensive nature of this strategy.
Front-runner	LKAB	A2-B2-C3	LKAB shows strong engagement relative to its emissions responsibility (A2) and focuses on electrification and hydrogen-based pathways targeting core mining and iron production processes (B2). Its highly central collaborative position (C3) indicates an anchoring role in large-scale, mission-oriented projects.
Adaptive	St1	A2-B1-C1	St1 combines relatively high engagement compared to emissions responsibility (A2) with a strategic focus on biofuels and biomass-based pathways addressing Scope 1 and 2 emissions (B1). Despite its central and highly engaged collaborative position (C1), its pathway orientation remains focused on incremental substitution rather than transformation of core production processes.
Adaptive	Borealis	A2-B7-C5	Borealis combines relatively high engagement with moderate emissions responsibility (A2) and a strategic orientation towards recycling pathways addressing direct emissions (B7). Its low collaborative embeddedness (C5) reflects selective engagement with limited integration into broader mission-oriented coordination.
Front-runner	Stockholm Exergi	A2-B5-C1	Stockholm Exergi combines high engagement relative to emissions responsibility (A2) with a strategic focus on BECCS and bioenergy pathways addressing core emissions and delivering system-level effects (B5). Its central and highly engaged collaborative position (C1) supports large-scale, coordination-intensive mission activities.
Adaptive	E.ON	A1-B5-C2	E.ON exhibits low proportionality between emissions responsibility and engagement (A1) and focuses on bioenergy, BECCS, and recycling pathways (B5). Its peripheral collaborative position (C2) indicates participation that remains limited in scope and coordination.
Fron-trunner	Boliden	A2-B2-C1	Boliden combines significant process-related emissions responsibility with high engagement (A2) and a strategic focus on electrification and efficiency measures addressing core metallurgical processes (B2). Its moderately central and highly engaged collaborative position (C1) supports both firm-level decarbonisation and system-level integration.
Adaptive	Tekniska verken i Linköping	A2-B6-C5	Tekniska verken combines relatively high engagement with lower emissions responsibility (A2) and a strategic focus on waste-to-energy CCS and bio-based solutions (B6). Its low network centrality (C5) reflects participation oriented toward operational decarbonisation rather than system-coordinating transformation.
Adaptive	Sysav	A1-B6-C2	Sysav shows low engagement relative to emissions responsibility (A1) and prioritises waste-to-energy CCS and bio-based pathways (B6). Its peripheral collaborative position (C2) indicates selective and project-specific participation.
Bystander	SMA Mineral	A1-B3-C6	SMA Mineral combines low engagement relative to emissions responsibility (A1) with a CCS-oriented pathway at an early or exploratory stage (B3). Its peripheral collaborative position and minimal engagement (C6) indicate marginal participation in mission-oriented project structures.
Bystander	Renova	A1-B4-C6	Renova shows low engagement relative to emissions responsibility (A1) and a strategic orientation towards infrastructure-related activities with limited direct mission engagement (B4). Its peripheral collaborative position and minimal engagement (C6) reflect weak integration into mission-oriented coordination and project networks.
Adaptive	Kubal	A2-B7-C5	Kubal combines relatively high engagement with moderate emissions responsibility (A2) and a strategic focus on recycling and electrification pathways addressing direct emissions (B7). Its low collaborative embeddedness (C5) suggests selective engagement with limited coordination across the mission network.
Adaptive	Vargön Alloys	A1-B1-C2	Vargön Alloys exhibits low engagement relative to emissions responsibility (A1) and prioritises bio-based and efficiency-oriented pathways addressing Scope 1 and 2 emissions (B1). Its peripheral collaborative position (C2) reflects limited integration into mission-oriented coordination structures.
Adaptive	Höganäs	A1-B1-C4	Höganäs combines low engagement relative to emissions responsibility (A1) with a strategic focus on bio-based pilot pathways (B1). Its high collaborative centrality combined with low engagement (C4) indicates a participation-oriented posture focused on learning rather than capital-intensive transformation.
Adaptive	Nordkalk	A1-B3-C7	Nordkalk shows low engagement relative to emissions responsibility (A1) and a strategic focus on CCS-oriented pathways at an early or preparatory stage (B3). Its semi-central collaborative position (C7) indicates participation that has not yet translated into sustained mission-oriented engagement.
Enabler	Vattenfall	A2-B4-C3	Vattenfall combines high engagement relative to its emissions responsibility (A2) with a strategic focus on infrastructure-oriented pathways that address others' emissions, notably hydrogen systems and CCS networks (B4). Its highly central and engaged collaborative position (C3) reflects an anchoring role in coordination-intensive projects enabling system-wide decarbonisation.
Adaptive	Outokumpu	A1-B1-C7	Outokumpu combines low engagement relative to emissions responsibility (A1) with a strategic focus on bio-based and efficiency pathways addressing Scope 1 and 2 emissions (B1). Its semi-central collaborative position (C7) reflects selective engagement without a clear orientation toward transforming core production processes.
Enabler	Uniper	A2-B4-C1	Uniper shows substantial engagement relative to emissions responsibility (A2) and prioritises infrastructure-oriented strategies focused on enabling others' emission reductions, including CCS and hydrogen-related systems (B4). Its moderately central and highly engaged collaborative position (C1) indicates an active coordinating role consistent with an enabling strategic orientation.

Table A.3
All projects that include incumbents.

P	Organisation	Title[2]	Pathway	Scope
1	Boliden	Slag reduction with hydrogen	Electricity and hydrogen	Scope 1
2	Boliden	Fossil-free underground mine	Electricity and hydrogen	Scope 1
3	Boliden	Heat exchanger system mine ventilation Kankberg mine	Energy efficiency	Scope 2
4	Boliden	Ecolink - Utilise waste heat for Skellefteå's district heating network	Energy efficiency	Others
5	Borealis	Plastic recycling refinery in Stenungsund	Recycling	Scope 1
6	Borealis	Plastic recycling refinery in Stenungsund	Recycling	Scope 1
7	E.ON	Carbon Network South Sweden (CNetSS)	CCS	Infrastructure
8	E.ON	Carbon Network South Sweden (CNetSS) – phase 3	CCS	Infrastructure
9	E.ON	Delivery of biogas to industrial customer in southern Skåne	Biofuels and biomass	Others

(*continued on next page*)

Table A.3 (*continued*)

P	Organisation	Title[2]	Pathway	Scope
10	E.ON	Large-scale production of biochar as a renewable raw material in the fossil-free value chain within the iron and steel industry	Biofuels and biomass	Others
11	E.ON	Feasibility study for bio-CCS at Åby and Händelö combined heat and power plant	BECSS	Scope 1
12	E.ON	bioCCS at the new combined heat and power plant in Malmö Energy Port	BECSS	Scope 1
13	E.ON	Energy efficiency	Energy efficiency	Others
14	Heidelberg Materials	CemZero - Heat transfer with plasma in rotary kilns	CCS	Scope 1
15	Heidelberg Materials	CemZero – Carbon dioxide-free products with electrified manufacturing – reactivity of cement clinker with secondary additives	CCS	Scope 1
16	Heidelberg Materials	CemZero-Fundamental properties of standalone plasma and plasma in combination with calcium-based bed materials in rotary kiln.	CCS	Scope 1
17	Heidelberg Materials	Feasibility study CCS Slite – the foundation for the world's first climate-positive cement factory	CCS	Scope 1
18	Heidelberg Materials	Feasibility study Slite CCS - on the way to the world's first climate-neutral cement factory	CCS	Scope 1
19	Heidelberg Materials	Design preparations FEED Slite CCS – towards zero net emissions 2030	CCS	Scope 1
20	Heidelberg Materials	Radiobased calcination determination in the production of cement and burnt lime	Energy efficiency	Scope 1
21	Heidelberg Materials	Installation of silo capacity for the production of concrete with lower climate impact.	Energy efficiency	Scope 1
22	Heidelberg Materials	Installation of silo capacity for the production of concrete with lower climate impact.	Energy efficiency	Scope 1
23	Höganäs	Large-scale production of biochar as a renewable raw material in the fossil-free value chain within the iron and steel industry	Biofuels and biomass	Scope 1
24	Höganäs	Pilot study with carbon dioxide neutral biochar in the Höganäs process	Biofuels and biomass	Scope 1
25	Höganäs	Carbon Network South Sweden (CNetSS)	CCS	Infrastructure
26	Höganäs	Increased energy recovery for district heating	Energy efficiency	Others
27	Kubal	Conversion of preheating of anodes before casting	Electricity and hydrogen	Scope 1
28	Kubal	Co-location of primary production and remelting of aluminum products	Recycling	Scope 1
29	LKAB	HYBRIT pilot project - Hydrogen storage in underground caverns with LRC technology	Electricity and hydrogen	Scope 1
30	LKAB	HYBRIT (Hydrogen Breakthrough Ironmaking Technology) - research project	Electricity and hydrogen	Scope 1
31	LKAB	HYBRIT pilot plant - feasibility study	Electricity and hydrogen	Scope 1
32	LKAB	HYBRIT pilot fossil-free pellets	Electricity and hydrogen	Scope 1
33	LKAB	HYBRIT pilot fossil-free iron, steel, and hydrogen production	Electricity and hydrogen	Scope 1
34	LKAB	Testbed for integrated, efficient, and carbon-free mining system	Electricity and hydrogen	Scope 1
35	LKAB	HYBRIT industrial demonstration project for hydrogen-based direct reduction	Electricity and hydrogen	Scope 1
36	LKAB	Waste heat LKAB/TVAB	Energy efficiency	Others
37	Nordkalk	Renovation and adaptation of equipment from fossil fuel to biofuel	Biofuels and biomass	Scope 1
38	Nordkalk	Renewable energy carriers in the production of burnt lime	Biofuels and biomass	Scope 1
39	Nordkalk	CemZero-Fundamental properties of standalone plasma and plasma in combination with calcium-based bed materials in rotary kiln.	CCS	Others
40	Nordkalk	eliminate carbon capture pilot Köping	CCS	Scope 1
41	Outokumpu	Energy conversion to biogas	Biofuels and biomass	Scope 1
42	Outokumpu	NEMO, climate-neutral molybdenum additive for steel	Energy efficiency	Scope 3
43	Preem	CinfraCap – phase II - Infrastructure for transport and interim storage of captured carbon dioxide	CCS	Infrastructure
44	Preem	Infrastructure for transport and intermediate storage of captured carbon dioxide – an efficient distribution chain	CCS	Infrastructure
45	Preem	Preem CCS – Capture and storage of carbon dioxide	CCS	Scope 1
46	Preem	Renewable hydrogen production – feasibility study towards a fossil-free refinery	Electricity and hydrogen	Scope 1
47	Renova	Infrastructure for transport and intermediate storage of captured carbon dioxide – an efficient distribution chain	CCS	Infrastructure
48	Renova	CinfraCap – phase II - Infrastructure for transport and interim storage of captured carbon dioxide	CCS	Infrastructure
49	SMA Mineral	CemZero-Fundamental properties of standalone plasma and plasma in combination with calcium-based bed materials in rotary kiln.	CCS	Others
50	SSAB	Large-scale production of biochar as a renewable raw material in the fossil-free value chain within the iron and steel industry	Biofuels and biomass	Scope 1
51	SSAB	Pre-study – from fossil-free iron sponge to finished product	Electricity and hydrogen	Scope 1
52	SSAB	From fossil-free iron sponge to finished product	Electricity and hydrogen	Scope 3
53	SSAB	HYBRIT pilot project - hydrogen storage in underground caverns with LRC technology	Electricity and hydrogen	Scope 1
54	SSAB	HYBRIT pilot plant - feasibility study	Electricity and hydrogen	Scope 1
55	SSAB	Electrification demo of continuous annealing line	Electricity and hydrogen	Scope 2
56	SSAB	HYBRIT (Hydrogen Breakthrough Ironmaking Technology) - research project	Electricity and hydrogen	Scope 1
57	SSAB	HYBRIT pilot fossil-free iron, steel, and hydrogen production	Electricity and hydrogen	Scope 1
58	SSAB	Reduction of process-related gas emissions from the steel industry and production of valuable chemicals through gas fermentation	Energy efficiency	Scope 1
59	St1	Ellinge upgrade facility	Biofuels and biomass	Scope 1

(*continued on next page*)

Table A.3 (*continued*)

P	Organisation	Title[2]	Pathway	Scope
60	St1	Borås UBG/LBG	Biofuels and biomass	Scope 2
61	St1	Högbytorp Drying Facility	Biofuels and biomass	Scope 1
62	St1	Infrastructure for transport and interim storage of captured carbon dioxide – an efficient distribution chain	CCS	Infrastructure
63	St1	CinfraCap – phase II - Infrastructure for transport and interim storage of captured carbon dioxide	CCS	Infrastructure
64	Stockholm Exergi	Development of chemical cyclical combustion for domestic fuels	BECSS	Scope 1
65	Stockholm Exergi	Carbon dioxide capture with Svante technology	BECSS	Scope 1
66	Stockholm Exergi	Further development of HPC at combined heat and power plants for the purpose of implementing BECCS	BECSS	Scope 1
67	Stockholm Exergi	Extended testing of BECCS through HPC at combined heat and power plants	BECSS	Scope 1
68	Stockholm Exergi	Testing of BECCS through HPC at combined heat and power plants	BECSS	Scope 1
69	Stockholm Exergi	Chemical cyclical combustion of biomass and waste – pilot operation and feasibility study	Biofuels and biomass	Scope 1
70	Stockholm Exergi	Sorting facility for residual waste	Recycling	Scope 3
71	Sysav	Carbon Network South Sweden (CNetSS)	CCS	Infrastructure
72	Sysav	Carbon Network South Sweden (CNetSS) – phase 3	CCS	Infrastructure
73	Sysav	Sysav - overall feasibility study waste CCS	WtE-CSS	Scope 1
74	Sysav	Feasibility study for waste-CCS at Sysav	WtE-CSS	Scope 1
75	Tekniska verken i Linköping	Feasibility study for CCS at Gärstadverket	WtE-CSS	Scope 1
76	Tekniska verken i Linköping	Energy storage for reduced fossil fuel demand	Energy efficiency	Others
77	Tekniska verken i Linköping	Liquefaction of carbon dioxide from biogas production	Bio-CCU	Scope 3
78	Tekniska verken i Linköping	Increased gas production and reduced emissions	Biofuels and biomass	Scope 3
79	Tekniska verken i Linköping	Gas tank manure pit Åby	Biofuels and biomass	Scope 3
80	Tekniska verken i Linköping	Production facility for LBG in Linköping	Biofuels and biomass	Scope 3
81	Tekniska verken i Linköping	Expanded production of LBG at Linköping's biogas plant	Biofuels and biomass	Scope 3
82	Tekniska verken i Linköping	Develop the reuse at Linköping's recycling centres	Recycling	Scope 3
83	Tekniska verken i Linköping	Gärstad sorting facility	Recycling	Scope 3
84	Uniper	Carbon Network South Sweden (CNetSS) – phase 3	CCS	Infrastructure
85	Uniper	Project AIR – CCU with hydrogen electrolysis for the production of sustainable methanol	CCU	Others
86	Uniper	SkyFuelH2: FEED study	Electricity and hydrogen	Scope 3
87	Vargön Alloys	Development of bio-briquettes for ferrochrome production in submerged arc furnace (Bio4SAF)	Biofuels and biomass	Scope 1
88	Vargön Alloys	Production demonstrator for large-scale polyester recycling facility	Recycling	Others
89	Vattenfall	The role of BioCCS for negative carbon dioxide emissions in Uppsala municipality	BECSS	Scope 1
90	Vattenfall	Conversion of heating system from oil	Biofuels and biomass	Scope 1
91	Vattenfall	Carbon dioxide on trains – a technical system study for efficient, sustainable, and safe loading and unloading	CCS	Infrastructure
92	Vattenfall	Renewable hydrogen production – feasibility study towards a fossil-free refinery	Electricity and hydrogen	Others
93	Vattenfall	HYBRIT (Hydrogen Breakthrough Ironmaking Technology) - research project	Electricity and hydrogen	Others
94	Vattenfall	HYBRIT pilot plant - feasibility study	Electricity and hydrogen	Others
95	Vattenfall	HYBRIT pilot fossil-free iron, steel, and hydrogen production	Electricity and hydrogen	Others
96	Vattenfall	HYBRIT pilot project - Hydrogen storage in underground caverns with LRC technology	Electricity and hydrogen	Others
97	Vattenfall	Production of synthetic sustainable aviation fuel on a commercial scale	Electricity and hydrogen	Scope 3

[2] Auto-translated from Swedish using OpenAI.

Data availability

The project-level dataset on Industry Leap and Climate Leap funding used in this study was compiled from publicly available records provided by the Swedish Energy Agency and the Swedish Environmental Protection Agency. The datasets and code supporting this study are openly available via GitHub at https://github.com/Hellsmark/main_emitters and archived on Zenodo at DOI https://zenodo.org/records/18186739.

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