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RESEARCH ARTICLE

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Directionality challenges for transformative innovation policy: lessons from implementing climate goals in the process industry

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ABSTRACT

In the new paradigm of 'transformative' or 'mission-oriented' innovation policy, which addresses broad societal challenges, policy makers are given a large responsibility for setting or shaping the direction of socio-technical transitions. However, the literature has so far not provided much concrete advice on how to achieve directionality in practice. The main argument of this conceptual article is that a more detailed approach is needed to better understand the challenges policy makers might face when they attempt to translate societal goals into more concrete and actionable policy agendas. It identifies and discusses eight analytically derived directionality challenges: handling goal conflicts, defining system boundaries, identifying realistic pathways, formulating strategies, realising destabilisation, mobilising relevant policy domains, identifying target groups, and accessing intervention points. To illustrate these challenges, the article uses examples from the implementation of the Swedish climate goal in the process industry.

KEYWORDS

Transformative change; sustainability transitions; green transition; process industry; Sweden

1. Introduction

In recent years, innovation policy principles and practices have strived to foster innovation that addresses societal challenges, especially in the form of 'green' sustainability transitions. For example, reaching societal targets is at the centre of the European Green deal and the 'Fit for 55' legislative package that aim at realising the EU's ambitions of reaching climate neutrality.

This can be described as a new paradigm of 'transformative' (Diercks, Larsen, and Steward 2019; Schot and Steinmueller 2018b; Weber and Rohracher 2012) or 'mission-oriented' (Foray 2018a; Hekkert et al. 2020; Mazzucato 2016) innovation policy, in which policy makers are given a large responsibility for shaping or setting the direction of socio-technical transitions. The development of this new paradigm is influenced by, on the one hand, literature on socio-technical transitions (e.g. Berkhout, Smith, and Stirling 2003; Geels 2002, 2004; Kemp, Schot, and Hoogma 1998) and, on the other hand, economics-

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oriented literature (Foray 2018a; Mazzucato 2016, 2018; Mowery, Nelson, and Martin 2010; Robinson and Mazzucato 2019).

A salient feature in this transformative innovation policy paradigm is the focus first and foremost on sustainability and societal development, as articulated in the Sustainable Development Goals, rather than on innovation and economic growth for their own sake. Transformative and mission-oriented innovation policies are still expected to generate economic growth but, as Schot and Steinmueller (2018a, 1583) explain, growth should rather be seen as 'a by-product of a broader type of development.' This implies that this new policy paradigm places political processes over the economic discourse. Consequently, it becomes increasingly necessary – as well as legitimate – for policy makers to intervene and thereby take a much more active role in setting or shaping the future direction of technology and markets (Köhler et al. 2019), especially compared with a traditional market failure approach (Weber and Rohracher 2012). Indeed, for a transformation of large socio-technical systems such as energy, mobility, healthcare, and food to take place, the role of policy also includes the establishment of a portfolio of 'acceptable development paths' (Weber and Rohracher 2012) that are clearly connected to the identified societal challenges (Schot and Steinmueller 2018b).

Such 'directionality' comes with new challenges for policy makers. Most notably, it has been argued that grand challenges and other overarching policy objectives need to be translated into more concrete targets to be actionable (Robinson and Mazzucato 2019). The literature on challenge-driven innovation policy has, for example, discussed how to formulate missions (Mazzucato 2016, 2018) and argued that direction needs to be defined in close collaboration with a broad set of relevant stakeholders (Schot and Steinmueller 2018b).

However, the transformative innovation policy literature has so far neither discussed how directionality could be addressed when formulating transformative innovation policy (Magro and Wilson 2019), nor described how directionality is set in real policy processes (Salas Gironés, van Est, and Verbong 2020). Indeed, in a detailed and critical review of approximately 50 papers associated with the literature, Haddad et al. (2022) found that most of the directionality challenges described in the literature were conceptually derived and not clearly connected to either practical policymaking or real cases of attempts to design and implement transformative innovation policy

Against this background, our main argument is that a more detailed approach is needed to better understand what transformative innovation policy implies for policy making and what directionality challenges national policy makers face when trying to formulate transformative innovation policy measures in real cases. The purpose of this paper is, thus, to initiate a discussion on various considerations involved in translating overarching societal challenges into more concrete and actionable policy agendas supporting green transitions. Our contribution to such a discussion is the identification of eight directionality challenges associated with the translation of a transformative innovation policy goal into policy practice and their wider implications for policy. The primary intention with identifying these challenges is to stimulate academic discussion and further research on how transformative innovation policy theory can be translated into policy practice. However, we also believe that policymakers can benefit from an increased understanding of the challenges they might face when attempting to influence the direction of innovation and transition processes.

The paper departs from recent writings on transformative innovation policy and builds on Diercks, Larsen, and Steward (2019) conceptualisation of policy agendas to develop an analytical framework (Section 2). As described in Section 3, we draw on data from an earlier study on the transformation of the Swedish process industry (see Karltorp et al. 2019), which we have re-analysed for the purpose of this paper. By confronting the analytical framework with the empirical reality that policy makers at a national level face when trying to deliver on ambitious climate targets, we derive specific directionality challenges (Section 4). In the final section (Section 5), we discuss how the identified challenges relate to previous literature and discuss implications for research and policy.

2. Theoretical point of departure

Transformative innovation policy differs in several ways from previous innovation policy generations. For example, it involves a shift in focus from economics and business to grand societal challenges, a predilection for broad stakeholder involvement, and a larger emphasis on directionality (for a complete review, see Haddad et al. (2022)). This paper is mainly concerned with the directionality aspect of this new policy approach.

2.1. Directionality as a distinguishing feature of transformative innovation policy

In complex societal transformation processes, there are numerous directions to move in with regard to both problems and solutions (Wanzenböck et al. 2020). In the context of transformative innovation policy, the directionality concept highlights that all types of innovation are not equally valuable when it comes to solving societal problems and that some innovations even contribute to creating or worsening such problems (Schot and Steinmueller 2018b). This implies that the societal consequences of different pathways have to be considered when designing innovation policy. For policy makers, directionality therefore refers to making 'social choices over alternative pathways of development' (Schot and Steinmueller 2018b, 1562) and 'prioritising specific innovation activities' (Weber and Rohracher 2012, 1042) in relation to grand challenges. In other words, directionality requires policy makers to not only strive to improve the overall rate of innovation but also stimulate innovation in certain (societally beneficial) domains or directions rather than others (Salas Gironés, van Est, and Verbong 2020; Foray 2018b; Könnölä et al. 2021; Mazzucato 2016), while also phasing out non-sustainable options (Schlaile et al. 2017). Thus, a large responsibility falls on policy to shape the direction of sustainability transitions (Hausknost and Haas 2019; Köhler et al. 2019).

Some authors take this to mean that policy makers should define a desired direction of change, for example in the form of 'missions', to provide more concrete guidance to other actors (Mazzucato 2016, 2018). They would then work as innovation system 'orchestrators' and coordinate the actions of relevant actors towards a joint vision or goal (Könnölä et al. 2021; Wittmann et al. 2020). Other authors instead argue that directionality should be allowed to emerge from the bottom-up, through experimentation, negotiation and deliberation involving a broad set of stakeholders with the aim to establish collective priorities that go beyond the boundaries of established actors and systems (Schot and Steinmueller 2018b; Weber and Rohracher 2012).

Regardless of which of these perspectives one takes, the importance of considering many (conflicting) opinions and developing a portfolio of different pathways is emphasised in most of the abovementioned literature. Indeed, in complex and uncertain transition processes, both problem and solution divergence tend to be high (Wanzenböck et al. 2020). However, directionality also requires policy makers to focus on developing certain options to allow for up-scaling and acceleration (Schot and Steinmueller 2018b). This can create tensions between potential winners and losers in the context of specific transitions and highlights the inherently political nature of directionality (Salas Gironés, van Est, and Verbong 2020; Wittmann et al. 2020).

While this discussion is interesting from an academic perspective, it is somewhat problematic that the received literature, as discussed in the introduction, so far has not been able to provide much guidance on how to implement directionality ideas in actual policy practices. Indeed, there is a surprising lack of recommendations on how policy makers could move from providing overall directions in the form of grand challenges or overarching missions to setting concrete policy agendas and, subsequently, designing and implementing policy mixes to realise these agendas (Haddad et al. 2022). In the following, we suggest that this move can be understood as a multi-dimensional translation process, which implies several challenges for policy makers.

2.2. A framework for understanding directionality as a translation process

To illustrate the main challenges associated with translating broad societal goals into actionable policy, we build on Diercks, Larsen, and Steward's (2019) conceptualisation of policy agendas, which includes three dimensions: (1) *policy objective* (the direct aims of policy), (2) *policy logic* (how innovation policy is rationalised) and (3) *policy domain* (the domains for which innovation policy is relevant). To these we add (4) *policy leverage* (the jurisdiction and reach of policy makers), following suggestions by Chaminade and Edquist (2010) that policy makers should not intervene in innovation processes unless there is a reasonable expectation that an intervention will contribute to addressing the identified problem(s). We view directionality as an emerging property, which is specified in a gradual and iterative translation process involving these four dimensions. For each dimension, we highlight the main associated challenges for policy makers as described in the literature.

2.2.1. Policy objective

The first dimension is the policy objective, i.e. the direct aim(s) of the policy in question (Diercks, Larsen, and Steward 2019). In terms of directionality, this implies identifying the issues of concern and developing an effective vision about the future and the intended policy effects (Kugelberg et al. 2021). Innovation policy is seldom aimed at achieving innovation as such (Borrás and Edquist 2013), but rather at achieving economic growth or – as emphasised in the transformative innovation policy discourse – addressing broader societal challenges such as environmental problems, inequality, or demographic change (Diercks, Larsen, and Steward 2019). In order to formulate an overall objective, such underlying motives first need to be explicated (Van den Hove et al. 2012). A potential policy challenge in this regard is that there can be several co-existing – and potentially conflicting – motives and sustainability concerns that need to be considered jointly and possibly traded off against each other (Crespi 2016; Flanagan, Uyarra, and Laranja 2011; Kugelberg et al. 2021; Wanzenböck et al. 2020).

Another issue in the policy objective dimension is that broad societal challenges and overarching visions need to be translated into more concrete, long-term goals with quantifiable ambition levels (Rogge and Reichardt 2016). This can be difficult, due to the complex nature of open-ended societal challenges (Wanzenböck et al. 2020). To provide direction, it has therefore been argued that such goals should be formulated at an appropriate level of aggregation or translated further into more concrete problems that can be acted upon (Robinson and Mazzucato 2019). According to Mazzucato (2016, 2018), these intermediary missions should be realistic, targeted, measurable, and time bound. Careful consideration also has to be given to what this implies – not only for specific domains, but for the wider socio-technical and institutional constellations (Pel, Raven, and van Est 2020). A potential policy challenge related to this is to develop clear visions and objectives that are accepted by and perceived as legitimate by relevant stakeholders, since stakeholders might have diverging views of problems and their causes and implications (Wanzenböck et al. 2020). While exploring and negotiating such divergence can be an important part of the policy process, there is also a risk that the result will be an 'all inclusive' vision or mission that fails to handle trade-offs and conflicts of interest and, consequently, does not give clear enough direction (Kugelberg et al. 2021). This also raises questions of who should be allowed to participate in the formulation of challenges or missions (Janssen et al. 2021; Salas Gironés, van Est, and Verbong 2020; Schlaile et al. 2017).

It should be noted here that policy agendas are formed at various levels of governance: local, regional, national, and supra-national (Flanagan, Uyarra, and Laranja 2011; Magro and Wilson 2013). Since societal challenges tend to be context specific, in that different places will be influenced in different ways, it is likely that different policy levels will make different priorities and define problems in different ways (Jakobsen et al. 2022). The process of translating broad societal challenges into policy objectives therefore needs to take potential interactions – synergies as well as conflicts – between these levels into consideration. This implies that achieving multi-scalar coordination and alignment across governance levels can be a potential challenge for policy makers (Marks and Hooghe 2004; Janssen et al. 2021; Weber and Rohracher 2012), as it might 'expose key political tensions and trade-offs' (Jakobsen et al. 2022, 6).

2.2.2. Policy logic

The second dimension, policy logic, refers to how innovation policy is rationalised. In previous literature, it has been argued that state intervention in innovation processes can be justified when a certain technology is not developed or disseminated to the extent or pace that is desirable or when established industries or regions are locked-in to a certain set of technologies, actors and institutions and need to be renewed in order to adapt to new conditions and exploit new opportunities (cf. e.g. Bergek et al. 2010; Edquist et al. 2004; Tödtling and Trippl 2005).

More specifically, innovation policy should address problems that are not solved 'automatically' by private actors (Chaminade and Edquist 2010). According to earlier innovation policy paradigms, such problems are either due to different types of market failures or to structural and functional innovation system weaknesses (Bergek et al. 2010;

Jacobsson, Bergek, and Sandén 2017; Wieczorek and Hekkert 2012).[1] While the transformative innovation paradigm acknowledges the relevance of systemic weaknesses, it argues that sustainability transitions can be subjected to additional problems, such as directionality, coordination, and reflexivity failures (Weber and Rohracher 2012) and lock-in to established socio-technical configurations (Kivimaa and Kern 2016), which could provide further justification for policy intervention.[2]

This implies that in order to translate broad challenges into more detailed policy agendas, policy makers should, ideally, identify transformational failures and destabilisation needs (i.e. different types of lock-in) associated with the sociotechnical sector they are trying to transform.[3] They also need to decide which of many possible transition options and pathways to include in their 'directionality portfolios' (Schot and Steinmueller 2018a; cf. also Mazzucato 2016) as well as which to exclude. This would require them to envision a wide variety of options and pathways, assess both their potential and their feasibility in the given timeframe, for example in terms of maturity, system integration and infrastructure requirements, societal acceptability, and political feasibility (Turnheim and Nykvist 2019), and identify the relevant (and often technology-specific) systemic weaknesses associated with each of these.

One associated policy challenge is to manage diverging views among stakeholders on the feasibility and long-term sustainability of different solutions (van Est 2017; Wanzenböck et al. 2020), in order to make sure that the selected pathways are the 'right' (i.e. societally desirable) ones and have the support of a critical mass of stakeholders that are committed to their development and implementation (Salas Gironés, van Est, and Verbong 2020; Schlaile et al. 2017). Another challenge is that necessary actions against unsustainable development paths (Hausknost and Haas 2019) might not be socially acceptable in some contexts, since they tend to create 'losers' as well as 'winners' (Janssen et al. 2021; Könnölä et al. 2021).

2.2.3. Policy domain

The third dimension refers to the domains for which innovation policy is relevant. Traditionally, innovation policy has primarily been connected to science, technology, and industry policy. However, innovation-related objectives are also pursued in other policy domains (Magro and Wilson 2013), where innovation is seen as a way to achieve domain-specific goals (Karo and Lember 2016). In this regard, the literature on sustainability transitions especially emphasises the importance of sectoral policy domains, such as energy, transport, agriculture, food, or healthcare (Diercks, Larsen, and Steward 2019;

[1]Structural innovation system weaknesses include, for example, infrastructure failures, institutional failures, and interaction failures (Klein Woolthuis, Lankhuizen, and Gilsing 2005). Functional innovation system weaknesses refer to mechanisms blocking any of the key innovation system functions (knowledge development and diffusion, entrepreneurial experimentation, market formation, influence on the direction of search, resource mobilisation, legitimation, and development of positive externalities) (Bergek et al. 2008).

[2]That several systemic and transformative failures can co-exist is one reason why it is often argued in the literature that policy mixes (rather than single instruments) can be justified or even necessary (cf., e.g. Bhardwaj et al. 2020; Lehmann and Gawel, 2013).

[3]It should be noted that, in practice, innovation policy is not necessarily based on theoretical rationales such as these. For example, policy makers can take some rationales for granted (Edler et al. 2016) or copy ideas from other countries without much consideration of the underlying rationale (Karo and Lember 2016). It can therefore be difficult to identify the specific rationale behind a particular policy (Magro and Wilson 2013), and several – potentially contradictory – rationales can also co-exist in the same context (Karo and Lember 2016).

Schot and Steinmueller 2018a), as well as the environmental policy domain. However, considering the broad scope of challenge-driven innovation policy, many other policy domains could, in theory, also become relevant (Coenen, Hansen, and Rekers 2015; Crespi 2016; Scordato et al. 2018). Regardless, it is important that challenge- and mission-driven policies do not become isolated but are embedded in and aligned with relevant domain-specific policies (Wanzenböck et al. 2020).

To address societal challenges there is, thus, a need to take a systemic perspective in order to identify relevant domains for specific societal challenges. This implies, on the one hand, that it might be necessary to formulate and implement domain-specific policy agendas and instrument mixes (Diercks 2019). On the other hand, it implies a need for coordination between different policy domains (Weber and Rohracher 2012) to avoid internal and external incoherency (Rogge and Reichardt 2016) as well as temporal inconsistency (Huttunen, Kivimaa, and Virkamäki 2014) at the level of policy goals, strategic priorities, instrument choices, and implementation processes. This requires an integrated 'whole-of-government' approach (Hoppe et al. 2016; Kugelberg et al. 2021), which might be a challenge to achieve.

2.2.4. Policy leverage

The fourth dimension, which we added to Diercks, Larsen, and Steward (2019) original framework, is policy leverage. In uncertain and complex innovation and transition processes, it is often difficult to foresee what impact (if any) a particular policy will have (Chaminade and Edquist 2010), and it is also unlikely that individual policies will be able to solve societal challenges on their own. Nevertheless, for policy intervention to be justified, there has to be a reasonable expectation that it will be able to contribute to addressing targeted systemic problems (Chaminade and Edquist 2010). In line with this, we define policy leverage as the (potential) ability of policy to influence the system structures and processes that need to change to remedy a targeted societal problem.

This has two main implications for directionality. First, the objectives and targeted system weaknesses, transformational failures or destabilisation needs (as discussed under 'policy logic') have to be within the policy makers' formal jurisdiction. Within a country, the jurisdiction over different types of problems and sectors are often divided between ministries and government agencies, both at the national level and between the national and regional government levels (Cooke, Uranga, and Etxebarria 1997). This implies that specific policy makers might lack the formal authority to intervene in some sectors or types of problems and, consequently, that the overall direction they can give might be restricted to some options and pathways. Moreover, they might not have access to the instruments that they would need to make certain types of interventions (Jakobsen et al. 2022).

Second, problems and potential intervention points might be out of policy makers' reach. Targeted innovation systems and sectoral socio-technical configurations can span across local, regional, national, and international scales, which means that problem causes are not always accessible for policy makers at one particular scale. For example, national developments can be hindered by inertia and path dependency originating in global sociotechnical regimes (Fuenfschilling and Binz 2018) or lack of local developments (Dewald and Truffer 2012). Moreover, when either technology development or market formation (or both) takes place at an international scale (Binz and Truffer 2017),

Table 1. Analytical framework.

	Policy objective	Policy logic	Policy domain	Policy leverage
Description	Direct (innovation) policy aims	Rationales for policy intervention	Policy domains that are relevant for societal transformation	Jurisdiction and reach of policy
Characteristics of transformative innovation policy	Addresses broad societal challenges	Innovation system weaknesses are combined with transformational failures and destabilisation needs	Sectoral focus and multi-domain involvement	Problems span jurisdictions and geographical scales
Potential policy challenges	Goal conflicts and trade-offs Diverging visions and interests Misalignment between governance levels	Diverging views on the feasibility and sustainability of different options and pathways Lack of social acceptance for actions against unsustainable development paths	Inter-domain coordination and integration needs	Misalignment between objectives/available intervention points and jurisdiction/reach. Coordination needs between jurisdictions and geographical scales

policy makers might not have access to relevant intervention points, in the form of industrial value chains or markets.

Taken together, these issues imply that a challenge for policy makers is to identify problems and intervention points that are within their jurisdiction and reach at the same time as they need to consider potential interactions and need for coordination between different jurisdictions and geographical scales (Weber and Rohracher 2012).[4]

2.3. Summary of an analytical framework for analysing directionality

To sum up, our analytical framework sees directionality as a gradual translation involving four dimensions: policy objective, policy logic, policy domain and policy leverage. The main characteristics, translation tasks and potential policy challenges that are associated with each dimension, which were identified in the previous section, are summarised in Table 1. It should be noted that the identified challenges for the most part are conceptual in nature and have not been empirically verified. In the following section, we will therefore use this framework to identify more specific – and empirically grounded – directionality challenges resulting from the translation of an overall challenge to more concrete actionable policy agendas and measures, using the implementation of the Swedish climate goal in the process industry as an illustrative case.

[4]This is related to the discussion about governance levels in the 'policy objective' section. However, the policy objective governance scale does not necessarily coincide with jurisdiction and reach. For example, even if it is appropriate for regional policy makers to formulate objectives related to improved local air quality that does not mean that they have either the jurisdiction to implement local environmental regulations or the reach to influence, for example, the actors engaged in the development of suitable emission reduction technologies.

3. Method

The paper builds on a data set from an earlier study of the transformation of the Swedish process industry. The aim of that study was to identify challenges for industry climate transition and how the Swedish government could support that.

The data set includes four parallel case studies of the following industries: iron and steel, cement, chemical, and refinery. Each case study consisted of 10–16 interviews with key actors in the four industries and secondary data about the industries from a variety of academic and non-academic sources. Preliminary results were discussed and validated at a workshop with the interviewees and other relevant actors. For more details, see the full report: Karltorp et al. (2019).

While working on the industry analysis, we noticed a number of directionality-related phenomena that stood out in relation to recent literature on transformative innovation policy. We therefore decided to delve deeper into this issue in order to contribute to the conceptualisation of directionality and its translation into policy practice. The directionality challenges discussed in this paper were, thus, not included in the original report but derived through further analysis of the data for the specific purpose of this paper.

By analysing the data set case by case, we first identified industry-specific directionality challenges. We then compared and discussed these challenges across all four cases to identify challenges that applied to two or more industries. On some occasions, two 'minor' challenges were grouped into broader challenges, which represented a common theme. As a final step, we discussed how the identified challenges related to the four dimensions of the analytical framework and the challenges previously identified in the literature.

4. Directionality challenges of translating the Swedish climate goal to the process industries

This section first introduces the Swedish climate goal and the main empirical focus of this article: the Swedish process industry. It thereafter identifies and discusses a set of challenges that policy makers can face when trying to translate a goal such as this to concrete policy agendas and instruments to stimulate developments in a direction that might eventually contribute to reaching the goal. The ambition is not to develop a typology or taxonomy covering all potential challenges, but rather to provide a range of illustrative examples. This means that there might be some overlap between challenges.

4.1. The Swedish climate goal and the Swedish process industry

In recent years, the national and international ambition and pace in the work to combat climate change has increased. Among other things, this has resulted in the Paris agreement of 2015. The aim of this agreement is to keep the global temperature increase well below 2°C as compared with pre-industrial levels and to strive to limit the temperature increase even further to 1.5°C (UNFCCC 2019). The perspective of the Swedish government, as announced before the Paris meeting, is that Sweden should take the lead in this transition, both in terms of reducing greenhouse gas emissions, and stimulating economic growth through innovation (Swedish Government 2015). This was, for example, highlighted in the Swedish Prime Minister's speech before the UN General Assembly: 'My goal is for Sweden to be among the first fossil free welfare nations, and I want Swedish companies to develop the climate-smart innovations that the world is asking for' (Löfven 2015).

Following up on this ambition, the Swedish parliament decided on a comprehensive climate policy framework in June 2017. The overarching objective of this framework is for Sweden to have zero net emissions of greenhouse gases into the atmosphere by 2045 and thereafter have negative emissions (Swedish Government 2017a). In this article, we refer to this goal as 'the climate goal'. There are also other goals connected to the climate goal, for example goals for the energy sector (50% higher energy efficiency in 2030 than in 2005 and 100% renewable electricity generation by 2040) and the transport sector (70% reduction of greenhouse gas emissions by 2030 compared with 2010). However, while all these goals give a clear direction towards a more sustainable future, it is far from clear how they should be translated into concrete policy agendas and measures to support the required transition processes.

This especially concerns the industry sector, for which no explicit goal has been set beyond those that have been decided within the EU Emissions Trading System (EU-ETS). The focus in this article is on the process industry, which converts natural resources (such as iron ore, limestone, petroleum, and biomass) into basic materials. In Sweden, four process industries – Iron and steel, Cement and minerals, Refinery, and Chemicals – are responsible for 26 percent of the total Swedish greenhouse gas emissions (see Figure 1). These are the industries in focus in this paper.

4.2. *Policy objective*

The first dimension of our framework is the policy objective, which involves translating broad visions or ambitions into more direct and concrete aims. As described above, the Swedish government's ambition to become the world's first fossil free welfare nation has been concretised in the form of the Swedish climate goal, which is targeted, measurable, time-bound and perceived as realistic by key stakeholders.[5] It, thus, meets many of the requirements of a suitable mission (cf. Mazzucato 2016, 2018).

According to the literature reviewed in Section 2, it can be difficult to break down a goal to an appropriate level of aggregation. At a first glance, the empirical case of Swedish climate goal seems rather easy to handle in this respect. The goal is to achieve net zero greenhouse gas emissions. Since four sectors – industry, domestic transport, agriculture, and electricity and district heating – are responsible for more than 85% of Sweden's fossil greenhouse gas emissions, it seems reasonable to give most policy attention to these sectors (especially transport and industry, which together are responsible for almost two thirds of the total emissions). Hence, directionality in the form of a clear sectoral focus is given by the very nature of the problem at hand, rather than by decisions made by policy makers or other actors. Moreover, the fact that the Swedish climate goal is defined as zero net emissions implies that all sectors in principle need to

[5]That the climate law has been passed in parliament implies that it has broad political support. Moreover, most industries have handed in road maps where they detail how they will deliver towards the target (Fossil Free Sweden 2020; Karltorp et al. 2019).

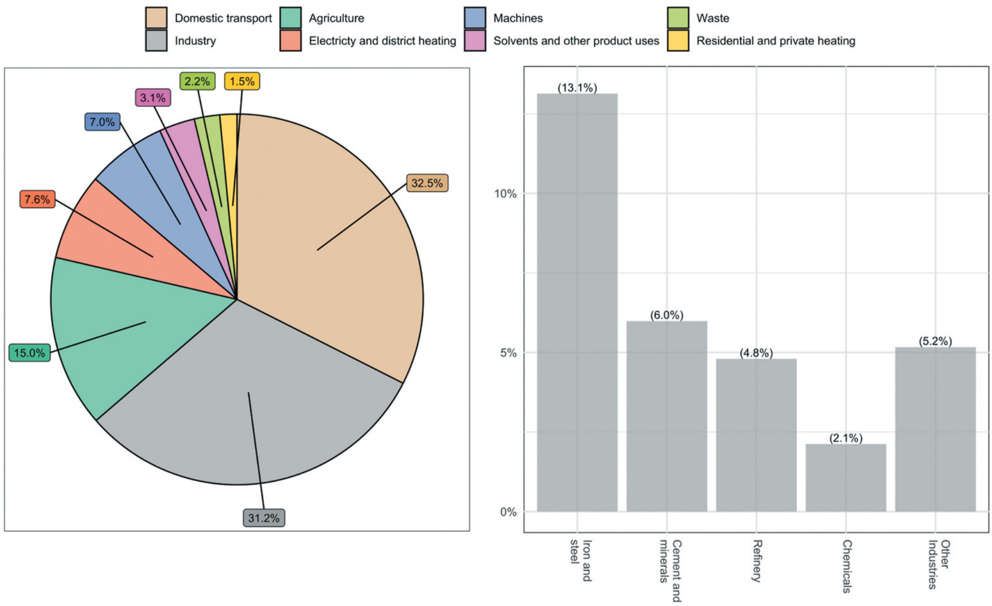

Figure 1. Share of total Swedish greenhouse gas emissions per sector (left) and per industry included in the industry sector (right). (Source: Elaboration on Swedish Environmental Protection Agency (2022a, 2022b)).

achieve zero net emissions by 2045. For this specific case, one could therefore argue that a translation to sector-specific goals is provided automatically by the overall goal. However, despite this the further translation of the climate goal comes with a number of directionality challenges for policy makers. We will here focus on two of these that we derive from our empirical case: handling goal conflicts and defining system boundaries.

4.2.1. Challenge #1: handling goal conflicts

This challenge concerns the difficulties involved in making priorities between different and sometimes conflicting goals.

The main underlying motive of the Swedish climate goal is, obviously, to address the societal challenge of extensive emissions of greenhouse gases that cause climate change. However, while the goal as such makes no reference to economic growth (or other co-existing motives), the Swedish government has explicitly expressed that it expects the climate goal to result in increased national competitive advantage.[6] To what extent and how such synergies will be possible to realise is, however, rather unclear. It is much easier to envision a situation where relatively strict emission targets in Sweden become a liability for companies located in Sweden. Finding ways to transform this potential goal conflict into an opportunity is, thus, a major challenge for policy makers at all governance levels, but it is perhaps especially relevant for local and regional policy makers, since the socio-economic effects of companies relocating or shutting down non-competitive plants and factories can have significant effects on the local level.

[6]See, for example, the roadmaps for fossil free competitiveness developed by various industries (Fossil Free Sweden 2020).

In addition, there are plenty of other sustainability-oriented goals in each of the affected sectors that potentially can come into conflict with the climate goal. For example, as mentioned above Sweden has two energy-related goals: that the Swedish electricity production should be 100% renewable by 2040 and that the national energy efficiency should increase by 50% by 2030 as compared with 2005 (Swedish Government 2017b). While both these goals are in line with reducing greenhouse gas emissions in the energy sector, they will be quite difficult to reconcile with the overall climate goal, considering that increased electrification is seen as one of the main potential solutions for reducing greenhouse gas emissions in the transport and industry sectors. Thus, to stimulate transformation in a given direction will require prioritisation between different goals and, consequently, the development of alternative roadmaps.

4.2.2. *Challenge #2: defining system boundaries*

This challenge concerns defining the problem and the focal system in such a way that a wide enough set of alternative solutions is included, while also considering sectoral specificities. In each affected sector, system boundaries can be drawn in different ways, depending on how policy makers choose to interpret the overarching goal. Such choices determine the overall direction of policy by guiding attention away from some problems and solutions and towards others.

In the implementation of the climate goal in the Swedish process industry, the translation of the goal to have zero net Swedish emissions of greenhouse gases has resulted in system boundary 1 in Figure 2. This is the result of two especially noteworthy system boundary choices. First, the climate goal's focus on *Swedish* emissions has been translated into 'emissions generated from production in Sweden' (system boundary 3 in Figure 2) rather than, for example, 'emissions generated by Swedish consumption'[7] (system boundary 2 in Figure 2). The focus on production implies measures to increase

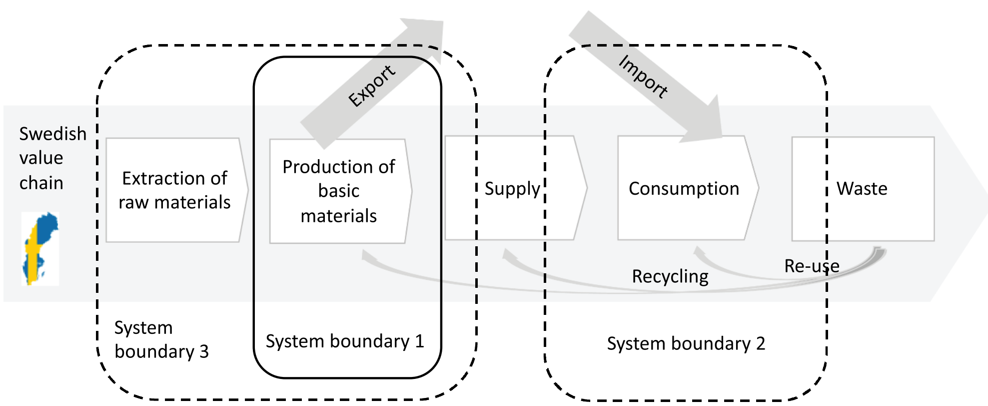

Figure 2. Generalized picture of the process industry value chain with different system boundaries (the current system boundary is drawn with a solid line and the two alternative system boundaries discussed in the text are drawn with dashed lines).

[7]This could include emissions generated by the production of products and services that are consumed in Sweden (and perhaps also products and services consumed by Swedes outside of Sweden, for example through international flights), regardless of where the production takes place.

efficiency in use of materials and energy, reduce emissions, and possibly also reduce production. A focus on consumption could include measures to reduce the need of basic material such as more efficient designs, increased re-use and recycling. Second, the climate goal has been interpreted as referring only to *direct* process emissions, such as the emissions from blast furnaces in steel production or the calcification process in cement production (system boundary 1 in Figure 2), rather than the entire Swedish value chain including raw material extraction and supply of products based on the basic materials (system boundary 3 in Figure 2).

Taken together, these boundary choices result in a highly delineated target system. Consequently, the climate goal has mainly resulted in efforts to find (technical) solutions for current plants, while alternative pathways that could result in more fundamental forms of decarbonisation, such as changes in consumption patterns or alternative value chains, are largely overlooked. For example, the (implicit) goal to reach zero process emissions from cement production has led to a focus on carbon capture and storage (CCS). By widening the system boundaries to larger parts of the value chain, additional options would become interesting, such as input material substitution for cement in road and building construction or development of alternative forms of transport and housing that would require less construction materials.

The case of the Swedish climate goal also shows that the relevance of specific system boundaries might differ between industries. Consider, for example, the relevance of recycling, reuse, reducing use and substituting raw material for achieving emissions reductions in different process industries. The steel industry already has an effective recycling system in place (which could potentially be further exploited). Plastics recycling is a growing concern in the chemicals industry, but only implemented on a very limited scale (which might indicate an untapped potential). In contrast, there is little or no incentive to recycle cheap bulk materials such as cement, and in the refinery industry both reuse and recycling are impossible since the produced fuels are consumed in the use phase. In the chemical industry, and even more so in the refinery industry, where most of the emissions are associated with consumption rather than production, there is a potential in working with renewable raw materials and reducing the consumption. Thus, as these examples show, system boundaries might have to be industry-specific to be relevant.

To sum up, the translation of overall goals into actionable aims and targets require policy makers to define system boundaries that allow for a wide enough set of alternative solutions to be identified, while taking the realities of different parts of the affected sector into consideration. It should be noted, however, that in the case of the Swedish climate goal, the system boundaries have to a large extent been 'handed down' to the Swedish government through international agreements such as the Kyoto protocol and its production-based accounting standard (Kander et al. 2015). This illustrates that policy makers are not always free to define appropriate system boundaries as they see fit (cf. policy leverage).

4.3. Policy logic

The second part of the framework refers to how innovation policy is rationalised, which according to the literature on transformative innovation policy includes a combination of system weaknesses associated with different (technological) options, transformational failures, and destabilisation needs. We will here focus on three empirically derived directionality challenges: identifying realistic pathways, formulating strategies, and realising destabilisation.

4.3.1. Challenge #3: identifying realistic pathways

Contingent on how the system boundaries are set, the next challenge involves identifying realistic pathways, thereby making sure that a wide range of feasible transition options and pathways are fostered and can be realised within the given timeframe. The transitions literature emphasises the benefits of nurturing a broad range of transition options and pathways simultaneously, considering multiple time horizons as well as the opinions and perspectives of a wide set of stakeholders (cf. Turnheim and Nykvist 2019). This seems to be a rather daunting task.

However, in practice there will most likely always be a limited number of available options to consider within the given time frame and system boundaries (as defined by the policy objective). In the case of the Swedish process industry, for example, we were able to identify a total of 26 potential options that involved stakeholders thought could contribute substantially to reducing process-related greenhouse gas emissions.[8] Furthermore, these options could be grouped into a rather manageable set of four overarching transition pathways that are relevant for all industries (see Table 2): (1) hydrogen (using hydrogen in a new way in the process and/or producing hydrogen in a new way), (2) electrification (electrifying processes, taking advantage of the almost fossil-free Swedish electricity system), (3) CCS/CCU (implementing technologies for carbon capture and storage/use), and (4) biomass (replacing fossil fuels and input materials with biomass-based resources). One additional industry-specific option was identified for the cement industry: the introduction of alternative binders.

It should, however, be acknowledged that there is a risk involved in focusing on the options that are available at a specific point in time, within specific system boundaries and as perceived by a specific set of stakeholders. More specifically, it is easy to overlook more radical innovations and solutions that might result in more fundamental sector reconfigurations (e.g. reducing the need to travel as an alternative to introducing new vehicle technologies for personal transport). In the case of the Swedish process industry, some radical innovations, such as hydrogen technology for steelmaking, were identified (see Table 2), but only one option (alternative binders in the cement industry) truly challenges the established production-consumption system. Policy makers therefore need to make an effort to look outside current system boundaries for transition options and consult non-obvious stakeholders in order to identify alternative narratives and perspectives.

In order to determine how realistic it is that the identified options will be realised within the given timeframe, we assessed their potential to reduce greenhouse gas emissions as well as the transition conditions associated with them in terms of their maturity and system integration requirements (following Turnheim and Nykvist (2019), as described in Section 2). The analysis is summarised in Table 2, where we can see that the different pathways and options differ in terms of potential, level of maturity and how

[8]While other options might become available in the future, it is highly unlikely that they will be realisable in time to meet the climate goal by 2045 considering the innovation and investment process lead times.

Table 2. Examples of pathways and options with large potential to reduce process industries' emissions.

			Transition conditions		
				System integration and infrastructure	
Path-way	Option	Potential to reduce emissions	*Maturity of options*	*Required change in technical system*	*Required change in actor network*
Hydrogen	1a) Using hydrogen in production of iron and steel	ca 80% of steel industry's emissions	Concept & pilot	Radical	Modular
	1b) Substituting fossil hydrogen for renewable in the refinery industry	ca 30% of refinery industry's emissions	Niche market	Modular	Incremental
Electrification	2a) Electrification of key processes in the cement	ca 40% of cement industry's emissions	Concept & pilot	Modular	Modular
	2b) Electrification of key processes in the chemical industry	ca 70% of chemical industry's emissions	Concept & pilot	Modular	Modular
CCS/CCU	3a) CCS in the industry cement	80–90% of cement industry's emissions	Demonstration	Modular	Modular
	3b) CCS in the refinery industry	ca 90% of refinery industry's emissions	Demonstration	Modular	Modular
	3c) CCU in the chemical industry	ca 100%	Concept & pilot	Modular	Modular
Biomass	4a) Resources substitution to forest-based biomass in the chemical industry	50–70% of chemical industry's emissions	Niche market	Modular	Modular
	4b) Resources substitution to forest-based biomass in the refinery industry	ca 70% of refinery industry's emissions	Concept & pilot	Modular	Modular
	4c) Resources substitution to forest-based biomass in the cement industry	35–40% of cement industry's emissions	Mature	Incremental	Incremental
Other	5a) Alternative binder in the cement industry	10–90% of cement industry's emissions	Concept & pilot	Radical	Radical

Note: For assessing technology maturity, we departed from the framework on technology development phases as outlined in Hellsmark and Söderholm (2017). We interpreted system integration requirements to include the degree of alignment between the options and exiting technology infrastructures as well as existing actor networks. To assess these, we drew inspiration from Hendersson and Clark's (1990) framework for categorising innovations into incremental, modular, and architectural/radical changes.
Source: Elaboration on Karltorp et al. (2019).

easily they can be integrated into existing technical systems and actor networks. With regard to maturity, some options only exist as concepts or perhaps pilot plants, whereas other options have been demonstrated at larger scale or even exist as mature options in the market. Regarding system integration requirements, most options can be implemented as modular additions to existing technical systems and only require the addition of one or a few actors somewhere in the value chain. For example, CCS/CCU requires a new equipment supplier to provide the technology, which could be added to an existing production process. However, a couple options require more fundamental changes in system architecture, actor-network configuration, or both. For example, developing alternative binders would imply replacing the existing cement-producing technology altogether, which would remove current entry barriers and open up the industry for new competitors.

Some options and pathways are also more politically feasible than others. In principle, the Swedish climate goal could be reached by stopping production of basic materials in Sweden. This pathway would, however, compromise the ambition to increase Sweden's competitive advantage (cf. policy objective) and is, therefore, not considered a feasible option by policy makers. In addition, some options come with strategic opportunities to exploit domestic resources or develop domestic industries that other options lack. For example, resource substitution from fossil fuels and materials to bio-based resources in the refinery and chemical industries provides a commercial opportunity for the Swedish forest industry as well as an opportunity for Swedish pulp and paper companies to develop and commercialise advanced biorefinery solutions (Hellsmark and Hansen 2020). Similarly, since Sweden has a domestic iron ore and mining industry as well as a domestic steel industry, developing new steel production technologies could provide a first mover advantage in the market of fossil free steel. Such options are, rather obviously, much more attractive for national and regional policy makers than options that provide no new opportunities or even imply competitive challenges for existing industries. It would also be easier to implement the required institutional changes if there were some promises of new jobs or economic growth.

In total, this shows a complex picture with a set of different options with different potentials and transition conditions, which in many cases imply conflicting messages (maturity versus system integration requirements versus social acceptance versus political feasibility). Choosing which of these options to prioritise and support is, thus, not an easy task for policy makers as it is difficult to assess which ones are most realistic and promising as a solution to the identified problem.

4.3.2. Challenge #4: formulating strategies

Another challenge for policy makers that wish to stimulate the development of the above-described pathways and industry-specific options is to identify system weaknesses that hinder their development and system strengths that could be exploited further, as well as to formulate strategies to address these weaknesses and strengths.

The literature provides well-developed methods for conducting these types of analyses, such as the technological innovation systems perspective (Bergek et al. 2008), and more recently some progress has been made towards analysing multi-technology pathways (Andersson 2020). Table 3 provides some empirical examples of system weaknesses associated with one of the pathways described above (biomass), together with some potential measures for handling them. For example, it has been argued that the Swedish policy mix is inherently fragmented, making it difficult to scale up innovative concept in the case of increasing the use of forest-based biomass (Hedeler et al. 2020) and

Table 3. Examples of system weaknesses for the biomass pathway and strategies to handle them.

Pathway	Examples of system weakness	Examples of strategies
Biomass	• Fragmented policy mix results in limited scale-up of innovative technology concepts • Weak coordination between ministries, agencies, and regional actors • Low motivation and abilities of actors with access to large biomass resources and complementary infrastructure. • Unclear roles, collaborations, ownership and long-term financing of key research infrastructure • No overall strategy, making prioritization difficult	• Stimulate demand in similar areas in which experimentation takes place. • Develop a cross-sectoral and national sustainable biomass strategy • Strengthen the organizational structure around key research infrastructures

Source: Elaboration on Karltorp et al. (2019), Hedeler et al. (2020), Hellsmark and Hansen (2020), Hellsmark et al. (2016)..

that Sweden, so far, has lacked an overall biomass strategy which makes prioritisation between different areas difficult (Hedeler et al. 2020; Ulmanen, Bergek, and Hellsmark 2022). This fragmentation has, in turn, resulted in low motivation of actors with access to large biomass resources and complementary infrastructure to engage in the development, but also a lack of long-term financing of key research infrastructure (Mossberg et al. 2020).

To our knowledge such analyses are used to a limited extent in existing government agencies and innovation programs, perhaps because it is rather time and resource consuming to analyse even an individual option or pathway. The task becomes even more challenging when several options need to be implemented in parallel, which is the case with the Swedish climate goal since none of the pathways is enough in itself to meet the goal. Consequently, policy makers need to stimulate the implementation of several options and pathways in parallel. As the pathways unfold, policy makers would need to follow and adjust their measures accordingly. These tasks are demanding and requires substantial analytical capabilities and capacity at the government and its agencies.

4.3.3. Challenge #5: realizing destabilisation

The challenge of realising destabilisation involves implementing policies that motivate change rather than dismantle the transformative capacity of industry. It has been argued in the transition literature that policy makers have an important role to phase out existing structures, for example fossil-based socio-technical systems, that are not in line with desired societal transformation. Such 'destabilisation policies' can, for example, involve measures to put pressure on existing regimes, dis-embed regimes from their socio-spatial contexts, coordinate interactions between multiple regimes, or tilt the entire landscape (Kanger, Sovacool, and Noorkõiv 2020; Kivimaa and Kern 2016).

However, while such policies may sound attractive from a theoretical perspective, they pose significant implementation challenges for policy makers. We will here highlight some examples of such challenges. First, in cases such as the Swedish process industry, where the available options and pathways depend on established resources and network, policy makers have to find a balance between destabilisation policies and incentives to mobilise incumbent actors. Indeed, destabilisation policies might become counterproductive unless they allow existing companies to stay competitive and encourage them to contribute to transforming or reconfiguring targeted sociotechnical systems rather than abandon ship and move production to other countries.

Second, in such industries, policy design and implementation are rarely achieved without coordination and collaboration with existing companies. In fact, in the past, strict regulations were most often not introduced until transition options had been identified and deemed feasible by incumbent actors. For example, policies implemented under the Montreal protocol in order to achieve a controlled phase-out of ozone layer-depleting substances went hand in hand with developments in the chemicals and electronics industries (Rothenberg and Maxwell 1997). Similarly, Söderholm, Bergquist, and Söderholm (2019) describe how the introduction of strict regulation on the use of chlorine in the Swedish pulp and paper industry was only possible when new bleaching technologies had already been developed. This implies that policy makers have to balance the benefit from a close relationship with industrial actors and the risk for regulatory capture.

Third, policy makers might face restrictions regarding which destabilisation policies they are allowed to implement. In the case of the Swedish climate law, the process industry falls under the EU-ETS. The purpose of this framework is to set a price on carbon dioxide emissions, which could eventually lead to a phase-out by increasing the competitiveness of fossil-free alternatives. However, so far, the framework has not had much effect on the process industry, since prices have been too low to induce any major investments, and member states are not permitted to complement the EU-ETS with other measures to increase prices further.

Realising destabilisation might, therefore, neither be productive nor feasible, depending on whether identified pathways can be developed and implemented without involving incumbent actors and whether there are external restrictions on which policies can be implemented.

4.4. Policy domain

The broad scope of the climate goal implies that several different policy domains need to be involved to reach the goal. In this section, we will highlight one directionality challenge: mobilising relevant policy domains.

4.4.1. Challenge #6: mobilizing relevant policy domains

This challenge concerns identifying, enrolling, and coordinating relevant policy domain actors at different levels and with different jurisdictions for addressing identified system weaknesses and realising a wide range of pathways. Considering the complexity of most transition processes, it is far from evident which of all possible domains would be most important to involve and which of them (if any) should be put in charge of ensuring that a particular policy objective is met. Identifying the most relevant policy domain(s) could become a rather complicated exercise, as problems and intervention points would first have to be identified to understand which domain is best positioned to address system weaknesses, transformational failures and destabilisation needs within each sector or industry (cf. policy logic) and as domains differ regarding their areas of expertise and jurisdiction (cf. policy leverage).

In the case of the Swedish climate goal and the process industry, several different sectoral policy domains could be relevant to enrol to achieve a transition in a certain direction. For example, strategies needed to address system weaknesses for hydrogen in the steel industry (cf. Karltorp et al. 2019; Kushnir et al. 2020) include science, technology, and innovation policy to stimulate knowledge development and diffusion as well as funding of demonstration and full-scale plants. Realising this option also requires large amounts of electricity and is therefore heavily influenced by the energy policy domain. Other important policy domains (as well as levels of governance) are the municipal and regional domains since hydrogen implies large-scale changes at local industry sites, which require various types of permits, and can influence local economies. Moreover, the environmental policy domain needs to be involved to adapt national environmental permitting processes and to stimulate demand by implementing environmental labels and standards. Finally, it is necessary to enrol the fiscal policy domain if tax rebates or other economic incentives are to be used to stimulate demand.

Second, as the relevant policy domains are identified and enrolled, the next step of this challenge is to coordinate these so that each domain will know what needs to be done in that domain to achieve the policy objectives. Actions and measures taken by different policy domains also needs to be coordinated in time. The overall policy objective, in our case the climate goal, has to be broken down into domain-specific goals and action plans. Again, this hinges on a thorough understanding of the available pathways and options and their respectively system weaknesses (cf. policy logic).

A challenge in this coordination is that it involves handling values or targets in conflict with each other. In the case of the climate goal and the process industry, an example is the permitting process. On the one hand, this process represents democracy and protection of the environment. On the other hand, it is lengthy; for example, while the construction of new transmission grids takes about two years, the permitting process can take ten years (Swedish Government 2019). It lso involves several levels of governance and several policy domains. To align the permitting process with the time plan needed for a transformation of the process industry to reach the climate goal, policy makers are faced with the challenge of coordinating these conflicting values, represented by different domains and level of governance, and prioritising between them.

4.5. Policy leverage

Policy leverage is related to the argument that for a policy intervention to be justified, there should be a reasonable expectation that it will be able to make a difference and have the intended effect. Related to this, we highlight two directionality challenges: Identifying target groups and accessing intervention points.

4.5.1. Challenge #7: identifying target groups

A typical challenge for policy makers that wish to stimulate a certain development is to identify relevant target groups that can implement new technologies or act upon identified technology pathways. However, in the case of the climate goal and the process industry, the emissions from industry are associated with a limited number of plants and companies and it is, therefore, relatively easy to identify the target groups.[9] For example, in the iron and steel industry two blast furnaces and one energy facility accountfor 83% of

[9]A contrasting example is emission from consumption, where there is a large number of individuals and their everyday practices that generate both significant and diffuse emission patterns (Roos 2019; Fauré et al. 2019).

Table 4. Companies, plants, and their share of each industry's process-related greenhouse gas emissions.

Industry	Plants and their share of emissions
Iron and steel	• 2 ore-based blast furnaces (SSAB): 45% • 1 energy plant (SSAB+Luleå Energi): 38% • 1 ore-based direct reduced iron mill (Höganäs): 4% • 10 scrap-based mills: 8% • 7 processing plants: 6%
Cement	• 3 production sites (Heidelberg-Cement): 100%
Refinery	• Preem (2 refineries): 75% • ST1 Refinery (1 refinery): 19% • Nynas (2 refineries): 6%
Chemicals	• Stenungsund cracker (Borealis): 52% • 4 other plants/companies in theStenungsund cluster: 24% • 12 other plants (11 companies): 24%

Sources: Jernkontoret (2018), Karltorp et al. (2019) and Swedish Environmental Protection Agency (2019)..

the emissions within the industry (see Table 4). These facilities are owned by the firm SSAB and the local energy utility Luleå Energi. Cement production is concentrated to three facilities owned to 100% by one firm (HeidelbergCement), 75% of the emissions from the refinery industry are shared between two sites owned by one firm (Preem), and the cracker operated by the company Borealis accounts for over 50% of the emissions from the chemical industry.

Given the focus on reducing emissions from production (cf. policy objective), the high concentration of actors and sites may present itself as an opportunity, as it is relatively easy to identify who is causing the emissions. However, given the dominant position of these actors, it also limits the possibility for policy makers to stimulate experimentation and learning beyond those options that are being prioritised by established actors. It also limits the possibility for policy makers to work with general policy measures, since changing the production methods will vary quite significantly from industry to industry and site to site. This means that the challenge for policy makers extends beyond identification of the target group to also involve adjusting the measures to this target group. These adjustments may become very specific, in this case targeting only a few actors and their activities at a handful of industrial sites.

4.5.2. Challenge #8: accessing intervention points

This challenge refers to the hurdles policy makers face when trying to identify points of entry for various interventions targeting system weaknesses and strengths. In this regard, sectors and industries differ in terms of where technology development and production occur and where markets are located, limiting the reach of supply- and demand-side policies respectively.

In the case of the Swedish process industry, such differences are summarised in Table 5. First, access to intervention points for supply-side policies depends on the structure of ownership and the location of value chains and associated innovation systems. Several firms in all four industries are owned by multinational corporations. This implies that Swedish policies will only affect one or a few local sites of many within complex and geographically dispersed value chains. Moreover, Swedish companies need to follow directives and investment decisions from their headquarters abroad. In some

Table 5. Examples of characteristics of the Swedish process industry that affect policy leverage.

	Steel	Cement	Refinery	Chemicals
Value chains	Global	Local	Global	Global
Ownership structure and local autonomy	Mainly Swedish/Nordic ownership High degree of local autonomy	International ownership High degree of local autonomy	International ownership High degree of local autonomy	International ownership Low degree of local autonomy
Connection to relevant national innovation system	Strong connection to the national innovation system on key technologies, especially electrification and hydrogen	Weak connection to national innovation system on most key technologies	Strong connection to national innovation system on key technologies such as biofuels	Weak connection to national innovation system on key technologies
International vs national markets	75% of products are exported	15% of products are exported	75% of products are exported	90% of products are exported
Applications	Diverse set of application, dominated by business to business	Diverse set of applications; municipals, regions, and the state are the biggest single customers	Limited set of applications, dominated by consumers	Diverse set of applications, dominated by business to business

Source: Karltorp et al. (2019).

cases, this implies that the company's response to particular policies might not be in the hands of the Swedish management team. For example, Bauer and Fuenfschilling (2019) illustrate how sustainability initiatives in the Swedish chemistry industry have been suppressed by global actor structures and rationales from international institutions. In contrast, most of the research, production and associated value chains in the refinery industry are centred on Sweden and the local plants also have a relatively high degree of autonomy from their multi-national owners (Karltorp et al. 2019). As a result, the refineries in Sweden are easier for Swedish policy makers to influence and have also become central actors in the innovation system for the conversion of biomass resources into 2nd generation biofuels (Hellsmark and Hansen 2020).

Second, access to intervention points for demand-side policies depends on what type of markets the industries operate in, where their main customers are located, what types of market transactions dominate etc. In industries that export most of their products, national demand-side policies will have little effect on domestic emissions. This is the case with the chemical, steel and refinery industries, which export 75–90% of the products they produce in Sweden. In contrast, national market incentives and regulations will be much more effective in industries such as the cement industry, in which a very large share (85%) of the production is used in Sweden (Karltorp et al. 2019). In addition, implementing demand-side policies is complicated in multi-application industries, such as steel and chemicals, where policies have to target a wide range of products in which the basic materials are used. In contrast, there are much fewer applications in the refinery industry and a national tax on fuel consumption therefore has a rather high potential to influence domestic production. In the case of cement, the state has a direct leverage over the market through public procurement, building standards, etc.

Taken together, this means that the available intervention points for policy are unevenly distributed across different industries. Policy strategies and measures therefore have to be adjusted to the specific conditions of each industry to be effective.

5. Conclusion and discussion of findings

The purpose of this paper was to initiate a discussion on various considerations involved in translating overarching societal challenges into more concrete and actionable policy agendas supporting green transitions.

By departing from the implementation of the climate goal in the Swedish process industry, we contribute to this discussion by identifying eight directionality challenges associated with such a translation process in four dimensions: policy objective, policy logic, policy domain and policy leverage (see Table 6).

These challenges should be read as illustrative examples of challenges that can occur in the different steps of translating transformative policies into tangible actions, rather than as a complete list that would be valid for all areas. Nevertheless, our findings provide both a more detailed and nuanced perspective compared with the challenges identified in previous literature (see Section 2). In the remainder of this section, we will highlight the five main contributions our study makes to the extant literature on transformative and mission-oriented policy. These contributions have implications for both research and policymakers that are engaged in designing and implementing transformative innovation policy.

First, the case of the Swedish climate goal confirms the importance of *handling different types of goal conflicts (DC1)*. However, in contrast to previous literature, which emphasises diverging interests and perspectives between stakeholders when

Table 6. Summary of directionality challenges.

Directionality Challenge (DC)	Definition	Translation step
1. Handling goal conflicts	Prioritize between different and sometimes conflicting aspects of an overarching goal as well as between this goal and already existing ones.	Policy objective
2. Defining system boundaries	Define the problem and the focal system so that a wide enough set of alternative solutions is included while considering sectoral specificities.	Policy objective
3. Identifying realistic pathways	Identify and prioritize a wide enough range of feasible transition options and pathways that can be realized within the given timeframe.	Policy logic
4. Formulating strategies	Analyse system strengths and weaknesses for multiple pathways, formulating appropriate measures and strategies.	Policy logic
5. Realising destabilisation	Implement policies that motivate change rather than dismantle the transformative capacity.	Policy logic
6. Mobilising relevant policy domains	Identify, enrol, and coordinate relevant policy domain actors at different governance levels and with different jurisdictions.	Policy domain
7. Identifying target groups	Find relevant actors, which by different means can act upon the identified pathways and adjust strategies to these target groups.	Policy leverage
8. Accessing intervention points	Identify (industry-specific) supply- and demand-side points of entry within reach for various interventions.	Policy leverage

formulating a vision or mission (cf. Crespi 2016; Flanagan, Uyarra, and Laranja 2011; Kugelberg et al. 2021; Wanzenböck et al. 2020), we did not see much conflict over the climate goal as such (perhaps because it had already been decided and was about to be implemented). Instead, we identified inconsistent goals by the same set of stakeholders (the Swedish government and parliament), in the form of potential conflicts with already existing sectoral goals. The latter resembles the 'all inclusive' visions described by Kugelberg et al. (2021), which fail to handle trade-offs between different goals. Moreover, we provide new support for the argument made in previous literature that coordination is a major challenge for policymakers (cf. Flanagan and Uyarra 2016; Huttunen, Kivimaa, and Virkamäki 2014; Rogge and Reichardt 2016; Weber and Rohracher 2012) by showing that goal conflicts can hinder the *mobilisation of relevant policy domains (DC6)*, which, in turn, could make it difficult to achieve the 'whole-of-government' approach suggested by Kugelberg et al. (2021) (cf. also Hoppe et al. 2016).

In our case, there was also a rather unreflective expectation from the government that the climate goal would support various economic goals at the national and regional level. In contrast, our analysis showed that in *identifying realistic pathways (DC3)* some technically realistic transition options and pathways might not be politically feasible, especially at the regional level, as they would have large negative effects on local industries. This touches on the misalignment and potential trade-offs between different governance levels (cf. Jakobsen et al. 2022), as a transition can have large distributional effects if some regions win and others lose when old plants are closed, and new ones are built elsewhere (or 'dirty' production is shifted to other countries). While previous literature mainly discussed cross-level misalignment as a coordination issue (cf. Janssen et al. 2021; Weber and Rohracher 2012), our case, thus, connects it more with the challenge of realising destabilisation (DC5). Here our findings provide more detailed insights into the challenges involved in implementing 'destabilisation policies' (cf. Kivimaa and Kern 2016), handling incumbent firms and industry structures (without dismantling their transformative capacity) as well as dealing with the winners and losers of transitions (Janssen et al. 2021; Könnölä et al. 2021).

Second, we highlight the importance of *defining system boundaries (DC2)* already when setting missions and formulating goals, since they influence directionality by determining which problems and solutions are even considered. While these points were not mentioned as challenges in previous literature – the literature on missions-oriented policy has a strong emphasis on the importance of setting ambitious goals that cut across sectors and domains (Mazzucato 2016, 2018), but pays less attention to the consequences of how this is done – our case demonstrates them well. We argued that the Swedish climate goal, and the system boundaries intrinsically associated with it, have been defined in such a way that they direct the attention to substantially reducing direct emissions from the process industry through four main technological pathways and away from emissions reductions achieved through behavioural change or new consumption patterns. It was here interesting to note that the goal was restricted by decisions at the international policy level, which Swedish policy makers had limited possibility to influence.

Third, this paper illustrates some of the previously identified challenges related to *identifying target groups (DC7)* (Salas Gironés, van Est, and Verbong 2020; Schlaile et al. 2017). In particular, the case of the Swedish climate goal highlights the tension between the need to get commitment from existing industrial actors (even though some of them might not benefit from the targeted transition) and achieving destabilisation by taking action against unsustainable development paths (Hausknost and Haas 2019). On the one hand, policy makers might not have much choice with regard to target groups, as the problem might be restricted to a few actors who are also the only ones with the resources to commit to developing and implementing new options. In our case, the climate goal clearly focuses on a core set of actors who own and operate existing production facilities, since it is only by transforming or closing these facilities that the goal can be fulfilled. This implies that finding options with commitment and support from a critical mass of stakeholders is not necessarily as difficult as described in previous literature (cf. Salas Gironés, van Est, and Verbong 2020; Schlaile et al. 2017).

On the other hand, such a focused approach might result in limitations with regard to experimentation. The literature on sustainability transitions emphasises the importance of experimentation outside existing regime pressures and the inclusion of new actor groups (Schot and Steinmueller 2018a, 2018b). Our case shows that this is unlikely to take place when policy objectives target transformation of existing socio-technical systems. Although we agree with previous literature that it is a challenging task to *identify realistic pathways (DC3)* and prioritise between them (cf. Mazzucato 2016; Schot and Steinmueller 2018a), we would therefore argue that increasing divergence by actively soliciting alternative views regarding the feasibility and sustainability of different options and pathways from a broader set of stakeholders can be as important as handling already expressed, diverging views of different stakeholders (van Est 2017; Wanzenböck et al. 2020).

Fourth, policymakers also face the challenge of *accessing relevant intervention points (DC8)* within a certain area of jurisdiction (in our case primarily national borders) (cf. Binz and Truffer 2017; Cooke, Uranga, and Etxebarria 1997; Fuenfschilling and Binz 2018; Jakobsen et al. 2022). In particular, our analysis highlights the limited leverage that national policy makers often have in that some part of the system that needs to change in order to stimulate a transition (i.e. international markets) can be out of their reach. This is a different image than that given by literature on how to stimulate transition via a policy mix approach (e.g. Kivimaa and Kern 2016) or by strengthening selected technological innovation systems (e.g. Bergek et al. 2008). In addition, access to intervention points differs between industries and sectors, which implies a risk that the policy makers' attention might be directed to those target groups and systems that they can reach rather than those that are more important for the transition.

Fifth, as the three previous points show, defining missions and setting goals is not enough for policy makers to enable and facilitate a societal transition in a certain direction. Conditions for transitions are given by structures and processes in established sectors and possible technological pathways. Along the same line as the reasoning of Kattle and Mazzucato (2018) and Kuhlmann and Rip (2018), we find that government and agencies would have to strengthen their dynamic capabilities and navigational capacities in order to understand how policy objectives affect these structures and processes as well as the direction of the possible societal transformations that they stimulate. Kuhlmann and Rip (2018) propose a 'meta-governance' approach in which the role of the government is reduced to structuring the conditions for self-organisation and a model which would fit all types of settings. In contrast to this, our discussion demonstrates the need for context specific *strategies (DC4)*, which requires policy makers to understand how policy objectives, strategies and measures affect sectoral and techological structures and processes that differ from context to context. To overcome the identified directionality challenges, government and agencies would therefore have to strengthen their capabilities and capacities to understand the prerequisites for transition and transformation of the involved regimes, sectors, and possible additional innovation systems related to technologies that are not currently part of the focal sector(s).

To conclude, we see that our paper primarily contributes with a discussion on policy-relevant directionality challenges that the existing literature has overlooked. In contrast to previous, mainly conceptual contributions on transformative innovation policy, this paper provides examples of the difficulties involved in translating theoretically founded advice into policy practice. While we do not provide a solution for how to handle the identified challenges, we hope that the paper will inspire future research on the implementation of transformative innovation policy and the development of sound policy strategies to address the identified directionality challenges. Future research could, for example, complement our case study with valuable insights from studies of similar translation processes in other sectors and countries.

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