Circular Industrial Transition

Can the green industrial policy revival support circular industrial transition in Sweden?

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Abstract

The major driver of the climate and biodiversity crisis is our unsustainable production and consumption patterns, but the need to transition to a circular and resource-efficient economy has not been sufficiently addressed by policymakers. Policies supporting circular industrial transition are still rare, not the least in contrast with the recent momentum gained by green industrial policy in EU and in USA. The lack of industrial policy in this field is therefore relevant to address. While there is also a lack of research on industrial policy for Circular Economy, this thesis is an exploratory contribution to the Swedish policy landscape, seeking to gain an understanding of the need for an industrial policy for Circular Economy, combining interviews with 18 senior experts with literature findings from related research fields. The study finds that a Swedish industrial policy for CE is needed, as well as larger public investments into CE. The few existing policy instruments functioning as industrial policy for CE are identified, but many additional instruments could serve this objective. The interviews provide insights into the specific policy needs, the factors determining policy-design, and the choice of sectors and value chains for policies to target. A relevant policy mix includes policy instruments such as green tax shifting, differentiated VAT, Circular Public Procurement, funding schemes, but also an improved institutional framework. Policy criteria should be based on environmental impact, but also competitive advantages, and alignment with EU. The study concludes that a policy mix combining new and expanded industrial policy instruments, focusing on correcting market failures, market creation, and capacity-building, can support circular industrial transition, and that the current upsurge in interest for CE and for green industrial policy can be leveraged to realise such a policy. But complexities regarding the varying CE definitions, implementation, measurement, ideological divergencies, and the fact that circularity does not equate resource-efficiency, policy needs firm anchoring in analysis of environmental impact, clear governmental vision and well-defined targets.

Populärvetenskaplig sammanfattning

Dagens produktion och konsumtion är inte hållbar. Nuvarande resursanvändning bidrar till 90% av förlusten av biologisk mångfald och 50% av klimatpåverkan. En mer cirkulär ekonomi kan bidra till att minska negativ påverkan från resursanvändning genom att hushålla med resurser, och genom återbruk, reparation och återvinning. Omställning till en cirkulär och resurseffektiv industriell produktion är nödvändig för att uppnå Sveriges miljö- och klimatmål.

Politiska styrmedel har en viktig roll att stötta företag som vill ställa om till cirkulär produktion och cirkulära affärsmodeller. Sådana stöd är etablerade inom klimatpolitiken, som en del av det omfattande klimatpolitiska ramverket. Sverige har nyligen gjort ett antal industripolitiska satsningar inom utveckling av klimatvänlig teknik, t ex Northvolt och Hybrit. Dessa har finansierats med medel från Sverige, men även från EU:s Innovationsfond. EU har också annonserat en satsning på grön industripolitik med inriktning mot klimatvänlig teknik. Men medan Sverige har etablerade industrisatsningar inom klimatomställning, finns ännu inte motsvarande för den cirkulära omställningen. Syftet med uppsatsen är att se på om, och i så fall hur, man bör beakta frågor som berör cirkulär ekonomi inom industripolitiken.

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1.Introduction

1.1. Problem definition

Our time can be described as a perfect storm of multiple crisis all connected to our unsustainable way of life: climate change, biodiversity crisis, global pandemics, and resource waste (IPCC, 2023; IPBES, 2019; IRP, 2019). Globally, policy responses are emerging: in particular, as climate change has risen on the global agenda, policy focus has been directed towards GHG mitigation and decarbonisation, with EU (EC, 2019; EC, 2021a), and countries such as Sweden (Government, 2017) leading the way. But the main cause of these multiple crisis, our unsustainable production and consumption patterns, is not receiving sufficient policy attention. While global gross domestic product has doubled since 1970, enabling substantial welfare and economic development gains (MEA, 2005a; IRP, 2019), our consume and throwaway models of consumption have had devastating impacts on our planet (EEA, 2020; IRP, 2019; Altenburg & Assmann, 2017). It is well known that growth in production and consumption is the major driver of growth in GHG emissions (Dhakal, et al, 2022), but this is not sufficiently addressed by policy.

Current patterns of economic activity depend on a permanent throughput of materials that are extracted, traded, and processed into goods, and finally disposed of as waste or emissions (IRP, 2019). In this linear industrial production model, inputs are extracted, combined, and processed, consumed, and discarded (Hartley, et al, 2019), described as "take-make-dispose" system. Over the last 50 years, global material extraction has tripled, with the extraction rate accelerating since 2000 (IRP, 2019).

To meet this growing resource demand, humans have changed ecosystems more rapidly and extensively than in any comparable period in human history, resulting in substantial and largely irreversible loss in the diversity of life on Earth. Currently, biodiversity loss and ecosystem collapse are the fastest deteriorating global risks (WEF, 2023), and the costs are also growing in the form of degradation of ecosystem services, increased risks of nonlinear ecosystem changes, and exacerbation of poverty (MEA, 2005a). Measured by the planetary boundaries concept, anthropogenic perturbation levels of five earth system processes, including novel entities such as plastics, already exceed planetary boundaries (Steffen et al, 2015a; Persson et al, 2022). Just the extraction and processing of natural resources are currently causing more than 90% of the global loss of biological diversity and water scarcity, and around 50% of global climate impact (IRP, 2019). Natural resource use is also increasingly resulting in negative impacts on human health (id).

High-income countries maintain levels of material footprint consumption 13 times higher than those of low-income countries (id). EU consumption already generates environmental impact considered to be outside the safe operating space for humanity for several impact categories[i] (Sala et al, 2019a). As an affluent industrialised country, Sweden's environmental impact from resource use is among the highest in the EU (id). While the Earth Overshoot Day 2023 is 27 July, Sweden's Overshoot Day is 3 April. If global consumption equalled that of Sweden, it would take almost four Earths to support humanity (Global Footprint Network, 2023)

Under a business-as-usual scenario, global materials use is expected to double until 2060 (OECD, 2018b), and global waste is expected to grow 73% by 2050 (Kaza, 2020). Therefore, global transition to sustainability does not only require reduced GHG emissions, but also a transition of current non-sustainable production and consumption (Steffen et al, 2015). Our unsustainable resource use needs to be put at the centre of climate and biodiversity policies (IRP, 2019).

Consequently, to stay within planetary boundaries, economic growth must be decoupled from resource use and environmental degradation (IRP, 2011; Rockström et al. 2009), and solutions in the form of Circular Economy and resource efficiency must be realised (EMF, 2013; Hartley, et al, 2020). Resource efficiency is a step toward decoupling through achieving improved outputs with fewer inputs and adverse impacts (IRP, 2019), but structural economic changes will also be necessary, i.e., shifting focus from high-pressure-intensive industries to low-pressure–intensive industries and services (EEA, 2020; EEA, 2013). Transitioning from a linear model of economic consumption and production to a circular economy, means resources are used efficiently, and materials and products can be reused or recycled at their highest possible value, reducing waste, and keeping the extraction of new resources to a minimum (Wilts, 2016).

The benefits of such a radical shift, though, are plenty. Besides reducing pressures on environment, climate, biodiversity, and human health, it would also bring economic benefits: improved resource use is estimated to add $2 trillion annually to the global economy (UNEP, 2017). Circularity and resource efficiency also play increasingly important roles for both supply chain security, and for conventional national security through decreasing risks incurred by international dependencies (Månberger, 2023). Such insights have manifested themselves in increased attention to circular industrial transition in Sweden (Swedish Confederation of Enterprise, 2022; Flack et al, 2023).

Governmental policies play an important role in supporting companies in the circular transition (Lindahl & Dalhammar, 2022), but the Circular Economy (CE) policy landscape in Sweden and in the EU is still in its infancy compared to other environmental policy fields. Importantly, while circular industrial transition needs policy support, such policies are still rare, and industrial policies addressing CE are almost non-existent. The same policy pattern exists in Sweden and on EU level. In comparison, the urgency of climate change (IPCC, 2023) has generated an unparalleled policy endeavour (Bulkeley & Newell, 2015; EC, 2021a). In response to the climate policy agenda, and guided by the necessity of green industrial transition, there has been a revival for *green industrial policy* as an essential element of the decarbonisation policy mix (Johnstone et al, 2021; Fischer, 2017; Mazzucato, 2019; Meckling, 2021, etc). Green industrial policy is now an established part of climate policy mixes (Tillväxtanalys, 2022). Industrial policy has a long-standing tradition in Sweden, and recent green IP developments have resulted in high-profile projects such as the Hybrit fossil-free steel project and the Northvolt battery plant (EPA & Energy Agency, 2022). Current debate includes numerous calls for strengthening green IP (Åhman et al, 2023). Green industrial policy is also high on the international agenda, through the EU Green Deal Industrial Plan (EC, 2023a) and the US Inflation Reduction Act (White House, 2023), and is increasingly causing high-level international political repercussions (Stolton, 2023a).

Transitioning from a linear Production and Consumption System to a Circular Economy is a vast challenge. Therefore, the lack of industrial policy for circular transition is a highly relevant issue to address. What are the needs for industrial policies targeting CE? How should such policies be designed, and what activities should they target? How could policymakers promote circular industrial transition through formulating and implementing such policies?

1.2. Existing research and knowledge gaps

Literature on policies for Circular Economy and resource efficiency (RE) has grown over the past years, and there is a range of research on Circular Business Models (CBM), as well as on barriers and drivers for CE and RE. The literature on green industrial policy and other business-targeting policies for green or climate transition is substantial. Not the least, the current climate policy agenda has increased scientific interest in industrial policy (f ex Johnstone, et al, 2021; Coffey et al, 2015; Busch et al, 2018, Hildingsson et al, 2019; Nilsson et al, 2021), and in how green industrial policy has impacted climate politics (f ex Allan et al, 2021; Meckling, 2021). Casting the net wider, the general industrial policy research covers broad ranges of aspects from theoretical to empirical approaches.

However, there is limited research on industrial policy targeted towards CE, both from a theoretical perspective and an empirical, since this policy type is rarely on policy-makers agenda and even more rare in existing policy. There is little understanding of how policy can promote the circular industrial transition through supporting circular business models. Nevertheless, the topic emerges amongst other topics, mainly in literature on CE policy and green industrial policy. An overview of relevant research can be found in ch.3.4.

This thesis, which is being conducted as part of the research programme Mistra REES (Resource Efficient and Effective Solutions), can contribute to filling a knowledge gap in the research, but also contribute to the development of policy proposals relevant for policymakers, public authorities, and CE stakeholders.

1.3. Aim and research questions

The aim of the thesis is to identify the need for and support the design of a possible Swedish industrial policy targeted at circular economy. This will be done through a study of several relevant scientific literature streams, analysing existing practices and initiatives, and perform interviews with selected experts. The findings will have to work in synergy and complementarity with existing strategies and plans. It will also have to be based on technological, economical, and organizational potentials for the implementation of CBM, as well as an approach combining environmental benefits with commercial feasibility.

The overall research question for the thesis is:

- *How can a Swedish industrial policy for circular economy be formulated?*

To answer this overall question, more specific research questions are formulated as follows:

- *RQ1: What policy instruments are currently functioning as, or could function as, industrial policy for circular economy?*
- *RQ2: What industrial policy mix and policy instruments should be used, and what industry sectors are appropriate to target, in the development of a Swedish circular economy industrial policy?*
- *RQ3: How should such policy instruments be prioritized and on what criteria?*
- *RQ4: What would be the key elements of such a policy?*

1.4. Scope and delimitations

In policy contexts CE is often overlapping with climate policy, and within academia, CE is overlapping with resource efficiency (RE) and Sustainable Production and Consumption (SCP). The concept of green industrial policy is also interpreted in several ways. Defining these two concepts are therefore essential. Delimitations are done vis-à-vis other environmental, climate and industrial policies. The geographical delimitation is self-evident, but some comparisons with relevant EU policies are made when this provides additional context and analytical relevance.

In the literature review, the level of abstraction is kept at a relatively high level, to not lose sight of the most relevant findings. Industrial policy tends to have cross-border economic and trade-related effects, but there is no ambition to go in depth into issues relating to compatibility with EU competition law in this thesis, state aid rules, and WTO rules.

The thesis focuses on Swedish manufacturing industry, in line with Mistra REES focus on material resource efficiency. Policy-wise, even though production and consumption are interlinked, the thesis excludes CE consumption policy. This also makes sense considering that Swedish industry is mainly B2B, and less consumer oriented. Resource use of Swedish industry sectors will be important to consider, but there is no ambition to go in depth into the analysis.

1.5. Environmental relevance

The thesis is written as exam project within the Lund University master's programme in applied climate strategy. The main reasons behind current growth in GHG emissions and environmental damage are modern production and consumption patterns (Dhakal, et al, 2022). Halting environmental pressures through steering towards sustainable production and consumption systems is therefore a fundamental environmental policy concern, and Circular Economy is a widely recognized model to achieve this. While circular industrial transition is crucial to achieve a Circular Economy, there is a lack of knowledge on how industrial policy can support this transition, and it is therefore a relevant topic to study.

1.6. Ethical considerations

The interview methodology often generates ethical consequences necessary to consider before launching the research project. Interview planning needs to consider whether the interviewees participate anonymously or not. Special consideration is required in the case of difficult, confidential or controversial interview questions, where the non-disclosure of identity is necessary, and the risk of disclosure needs to be mitigated. Trust between the interviewing researcher and the interviewee is essential to attain as relevant interview responses as possible, and the interviewer therefore must create and maintain trust.

In this thesis, the interviewees are experts, interviewed in their capacity as senior practitioners within policy development, strategy or research, of which all have a professional role within public policymaking. Therefore, it is likely that many interviewees neither wish for nor need for anonymity, but rather see public statements as a function of their professional role. However, the question of possible need for anonymity is important to consider in relation to each interviewee. In connection to this, there is also a risk that interviewees respond with the self-interest or interest of their respective organisation in mind. Since several interviewees represent industrial activities, and the thesis topic is industrial policy, i.e industrial state-aid, source criticism is needed.

Another ethical aspect, intrinsic to the study of policy measures, relates to the political dimension of the research topic, where diverse political views prevail on all the research topics, green industrial policy, circular economy and policy design. This has to be taken into account in the analysis.

2. Method

2.1. Research design

The thesis is conducted as an explorative interview study, based on a context-sensitive policy research approach. Since there is practically no research on industrial policy targeted towards CE, because this policy type is still very rare, an exploratory qualitative research approach is suitable (Stebbins, 2001). Because policy research is problem-oriented and is taking place in a specific context, it needs to be contextually sensitive (Clarke, 2007).

Exploration as a method is valuable when the scientist has little or no scientific knowledge about the group, process, activity, or situation she wants to examine but nevertheless has reason to believe it contains elements worth discovering (Stebbins, 2001).

Exploration is different from confirmation as a research method, and it uses inductive rather than deductive logic. Exploration is preferred as methodological approach when a phenomenon has received little or no systematic empirical scrutiny (Stebbins, 2001). As scientists come to understand more clearly the examined topic, they move further away from exploration and closer to prediction and confirmation, using deductive reasoning (Stebbins, 2001; Shaffir & Stebbins, 1991). This process is illustrated in figure 1.

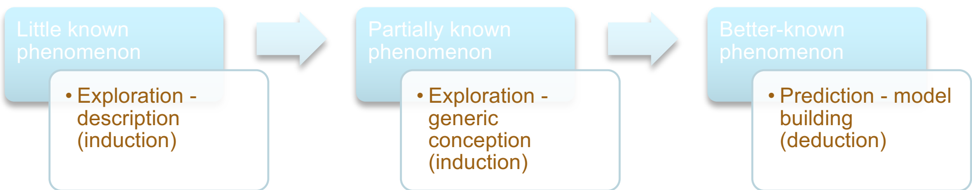

Figure 1. Qualitative methodology.
Qualitative methodology: relationship between knowledge of the research topic and the choice of research design. Adapted after Shaffir & Stebbins (1991).

The topic of industrial policy for circular economy is a *little-known phenomenon*, where a reasonable methodology is *exploration via description and induction*.

But the two approaches studied to close in on the topic – green industrial policy and CE policy – are *better-known* and *partially known phenomena* respectively, which means that the "map" to be approached in this thesis is not entirely blank (on data collection methodology, see below). Then it is more reasonable to conclude that the research topic could be seen as *partially known* – and that an appropriate method is *exploration via generic conception and induction.*

Exploration starts in acquiring an understanding of the phenomenon. In searching for this understanding, two approaches are essential: *flexibility* in looking for data and *open-mindedness* about where to find them (Stebbins, 2001). Another key aspect of policy research design is how to take the specificities of policy into consideration. Since most policy researchers are problem-oriented, the focus tends to be on a set of problems in distinctive settings (Clarke, 2007). Context is therefore a critical explanatory element (Maxwell, 2004), and since variations in context and setting are important aspects of data observations, context-sensitive methods allow more systematic and rigorous research (Clarke, 2007).

But context-sensitive methods can also increase the potential impact of policy research on actual policymaking, since they are accessible and knowable to policymakers and citizens because they, in comparison with generalizing policy research, retain the contextual features that give observations meaning and emphasise the processes that connect events and factors to outcomes (Clarke, 2007). This is important, since the aim of this thesis is to develop policy proposals.

2.2. Data collection

As the thesis is based on problem-oriented contextual policy research, the data collection has been under development during the research process, as the researcher gained better understanding of the problem (Clarke, 2007; Bryman, 2012). During the examination of the initially collected data, the need for other types of data collection became obvious. This is a strength of contextual research, not a flaw in the research design (Clarke, 2007).

2.2.1. Literature review

In exploratory research, because of the lack of pre-existing research on the specific research topic, literature can be used in several ways (Stebbins, 2001). After an initial literature review to demonstrate that little or no work has been done on the research topic, using an open-ended approach to data collection (id), literature closely related to the research topic could be reviewed and incorporated in the analysis (id).

In this thesis, the researcher has chosen this approach, making an exploratory literature review on literature related to the research topic, in three different areas: green industrial policy, circular economy policy, and to some extent environmental impact of Swedish industry. This is done for three reasons. Firstly, the answering of research question 1 requires searching the literature for existing and potential industrial policies targeting CE. Secondly, the analysis needs to be connected to empirics and existing research, to provide some validity. While there is very little industrial policy for Circular Economy, and very little research in this field, the closest related policy areas are green industrial policy and CE policy. The researcher has assumed that these two policy fields have aspects overlapping with the researched topic, give valuable insights for the analysis, and provide needed anchorage in existing research. Some research on the environmental impact of Swedish industry has also been studied. The thesis analysis will be based on "marrying" the different research areas and discourses (Esaiasson et al, 2007). The third reason is that a solid interview work needs to be based on a carefully formulated and structured interview guide, as well as knowledge attained by earlier research. The researcher has chosen to base this interview guide on a conceptual framework, and for this, literature related to the research topic has been studied, focusing on Circular Business Models (CBM), barriers to and drivers for CBM, CE policy design, Swedish CE policy, the logic of green IP, policy design for green IP, and green IP in Sweden. As the study is explorative, the literature review has been performed while avoiding a too detailed level of abstraction, to maintain focus on the main themes.

Besides academic literature, relevant grey literature on existing and planned policy initiatives in Sweden has also been studied. Following Stebbins (2001), literature has been sought and identified in a flexible and open-minded way. The literature review is not done with the ambition to provide a complete picture of these research topics, not the least since it only to a very small extent is able to cover the specific topic of the thesis. The literature review is still intended to provide a solid basis for interviews and development of policy recommendations.

Literature searches have been performed in LUBSearch, Web of Science and Scopus. Grey literature has been identified through Google searches, searches on specific public websites, as well as via the thesis supervisor. In several cases, the snowball method has provided relevant literature. Since the thesis is cross-disciplinary, literature from several academic disciplines have been selected, which from different angles provide insights on either environmental related industry policy or CE policy. The literature has been chosen based on scientific impact, relevance, and generalizability for a Swedish context and for real-world contextual policymaking. Literature on EU policy has been studied if relevant.

2.2.2. Interview methodology

The core data collection of this thesis has been done via interviews. Interviewing is a widely used methodology in qualitative research (Bryman, 2012), and particularly in contextual policy research (Clarke, 2007). While enquiries often answer questions related to frequency, interviews are about making visible the embodiment of a phenomenon (Esaiasson et al, 2009).

The interview persons were selected via a purposive sampling approach, in which relevant interview persons are chosen because of their relevance to the research questions (Bryman, 2012). The 18 selected experts were identified based on their respective knowledge and experience, as well as representativity regarding sectoral and organisational belonging, to ensure insights from academia, politics, industry, industrial and other sector organisations, government administration and NGO's.

Table 1. List of interviewed experts.

Sector and organisation	Name	Title	Additional relevant assignments
Industry organisations			
Confederation of Swedish Enterprise (Svenskt Näringsliv)	Marcus Wangel	Expert circular economy	
The Haga Initiative (Hagainitiativet)	Nina Ekelund	Executive Director	Member Fossil Free Sweden (Fossilfritt Sverige) reference group
Swedish Recycling Industries (Återvinningsindustrierna)	Maria Wallin	Head of Circularity and Recycling	
Association of Swedish Engineering Industries (Teknikföretagen)	Miriam Münnich Vass	Expert business policy, climate and energy	
Association of Swedish Engineering Industries (Teknikföretagen)	Stina Andersson	Expert business policy, environment and chemicals	
Industry			
Large Swedish technological manufacturing company	Anonymous	Head of Sustainability	
Electrolux AB	Viktor Sundberg	VP Environmental and EU Affairs	Electrolux engaged in Circular Initiative
Swedish manufacturing company	Anonymous	Head of Sustainability	
Research			
RISE Research Institutes of Sweden	Marcus Linder	Director Sustainable Business	Board member CradleNet
Re:Source Strategic Innovation Programme	Cecilia Tall	Programme manager Re:Source	
Swedish university	Anonymous	Researcher in environmental systems analysis	
Luleå Technical University	Patrik Söderholm	Professor in Economics	Member Swedish Climate Policy Council (Klimatpolitiska rådet),

			Member Governmental Committee on Economic Policies for Circular Transition
Policymakers & Government administration			
Swedish public agency	Anonymous	Division Head CE	
Swedish Parliament	Stina Larsson	Member of Parliament, environmental spokesperson	
Governmental commissions			
Delegation for Circular Economy (Delegationen för Cirkulär Ekonomi), RISE	Peter Stigson	Director, research and business development, RISE	Fmr Chair, Expert group on systems perspective, Delegation on CE
Delegation for Circular Economy, National Node for Sustainable Production/ SuPr	Mats Lundin	Programme manager, SuPr	Fmr Chair, Expert group circular production, Delegation on CE
Governmental Committee on Economic Policies for Circular Transition (Kommittén om ekonomiska styrmedel för att främja övergången till en cirkulär ekonomi)	Carl Gustav Fernlund	Chairman	
NGOs			
Swedish Society for Nature Conservation (Naturskyddsföreningen)	Marit Widman	Management strategist, SSNC	

2.3. Method of analysis

Exploratory science is not equivalent to structure-less (Stebbins, 2001). Social science exploration is "a broad-ranging, *purposive*, *systematic, prearranged* undertaking designed to maximize the discovery of generalizations leading to description and understanding of an area of social or psychological life" (Vogt, 1999). In this case, the researcher has deliberately chosen a clearly structured way of conducting interviews and analysis: it is necessary to provide structure and consistency to a research project that otherwise could risk being vague, both because of the knowledge gap within research and lack of policy, but also because of the varying definitions of the terms circular economy and green industrial policy.

The literature review provided the most relevant themes and analytical categories for designing and analysing the interviews. This was done through a conceptual framework, which shows the relationships and dynamics between the main analytical factors, categories and parameters needed to design an industrial policy for CE (ch.3.5). The conceptual framework served as basis for the interview guide (in Annex

1), which is thematically structured, addressing the key policy elements and the key features of industrial production usually addressed by CE policy and green IP. The interviews were conducted in a semi-structured way (see Bryman, 2012) to provide significant space to reflect the competence and individual views of the respective expert. Finally, the results of the interviews were discussed in relation to the literature and to current policy developments, and to provide the base for policy recommendations.

2.4. Reliability and validity

Validity and reliability are essential criteria for evaluating research, but for explorative and/or contextual policy research, these criteria need to be adapted (Stebbins, 2001; Clarke, 2007). Making evidence-based claims based on contextually sensitive research can be challenging, since the contextual-policy researcher lacks the tropes or accepted language of reliability and validity available to quantitative researchers (Clarke, 2007). The most important is to gain a full and accurate understanding of the trends and conditions contributing to the problem and understanding the likely impact of alternative policy solutions. Policy researchers must be aware of the interdependence and complexity of the problems they are involved in (id), which complicates the analysis and eventual claims of validity.

In addition, policy is closely connected with discourses, rhetoric, argumentation, and narratives (Clarke, 2007; Gottweis, 2007; van Eeten, 2007). In the study of problem definition processes – and ideologically charged topics as environmental policy – narratives and discourses are important aspects of the policy research analysis (Hajer & Laws, 2008; Clarke, 2007). Since these approaches emphasise the multiple ways in which people come to understand an event or phenomenon, validity is furthermore complicated.

It should also be remembered that the exploration method is a process that unfolds not only within individual studies but also across several studies, wherefore validity must be seen across a series of concatenated exploratory studies (Stebbins, 2001). This thesis should be seen in this light, i.e. as one exploratory study, for which validity has to evolve across further studies on the topic.

3. Literature review

Since there is very little research on industrial policy for circular economy, this thesis approaches the subject from different research angles: green industrial policy research, and research on CE and RE policy. This will give scientific anchorage and theoretical understanding to the interviews. The chapter is concluded with an overview of existing and proposed industrial policies for circular economy, which is answering RQ1, as well as a conceptual framework for the analysis.

3.1. Swedish industry

While manufacturing industry has declined in Sweden since the 1960's in terms of employment opportunities, like in most other OECD countries, it has grown in terms of productivity and product volumes (Alvstam, et al, 2020). The Swedish manufacturing industry answers for 20% of GDP (Ekonomifakta, 2023), though the distinction between manufacturing and service sector is not always clear (Alvstam et al, 2020). Swedish industry is largely B2B and export-oriented (id), and large sectors are process industry such as forestry, chemicals and steel, as well as automotive and vehicle industry (Ekonomifakta, 2022). The main export products are industrial goods such as vehicles, machinery, and forestry products (id.).

To formulate CE policy for industrial transition, knowledge is needed on the environmental pressures caused by resource use in production and consumption, their importance, and their causes. However, measuring environmental impacts through resource use requires specific methodologic considerations, which are outside the analytical scope of this thesis. Nevertheless, for the interested reader, details on the environmental impact and resource use of Swedish industry that is of relevance in a CE perspective, such as resource use, resource efficiency, and environmental and material footprint of Swedish industry, explaining differences, and relevance for circular economy policies, can be found in Annex 6.

3.2. Circular economy

This chapter briefly presents key aspects of circular economy identified in the research, focusing on conditions shaping possibilities for circular industrial transition, such as circular business models, and barriers hindering their realisation. Finally, CE policy is explained, along with relevant choices for CE policy design and policy mix. While the CE concept and the CE logic is generally well understood today, there are some explanatory notes found in Annex 5.

3.2.1. Circular production and circular business models

The radical change inherent in the circular transition requires radical technical and product innovations, and very likely also changes to the traditional business models (Bocken et al, 2016). Circular production and business models are attracting increasing interest (Government, 2020; Confederation of Swedish Enterprise, 2022). Besides societal expectations on environmental impact reductions, more sustainable products can become competitive advantages, both meeting customer preferences and meeting future sustainability requirements (EPA, 2021). Additional drivers for CBM are volatile resource prices, new information technology enabling new BM, as well as shifts in consumer and business preferences from ownership to performance (Planing, 2015).

Circular product design

Circular production starts with circular product design. Since up to 80% of products' environmental impacts are determined at the design phase (EC, 2020), integrating circular economy concerns early in the product design process is necessary. Circular product strategies generally aim for slowing or closing resource loops (Bocken et al, 2016). Strategies for slowing resource loops include: design for long-life products, product life-extension, including repair or upgrading, design for remanufacturing or reuse through modularization or standardization, or product performance optimization through big data, automation, remote sensing. Closing loops generally refer to recycling, but can include upcycling, i.e retaining or improving the products or the material, as well as downcycling, when materials are reprocessed into lower value products, such as chemical recycling. Circular design can include shifting to recycled materials, while new challenges in terms of materials mixing can occur (examples above from Bocken et al, 2016; Lindahl & Dalhammar, 2022; EPA, 2021; Material Economics, 2018; Karltorp, 2019). In line with circular thinking, keeping as high values as possible in both product strategies should be prioritised.

Circular business models

Business models are usually focused on commercial aspects - how a company's competitive strategy is defined through the design of its products or services, how it charges for it, what it costs to produce, how it differentiates itself from other firms by the value proposition, and how the firm integrates its own value chain with those of other firms in a value network (Bocken, et al, 2014) – while circular business models reconcile creation of commercial value with adoption of resource efficiency strategies (Bocken et al, 2016). In contrast to linear business models, in which a product is commonly downgraded after a single use phase and its embedded value is lost, CBMs support the development of product systems that incorporate strategies to preserve the embedded value at the highest possible level of utility (Stahel, 1994). Compared to regular business models, CBMs differ in terms of the *what?*, the value propositions; the *how?,* circular activities, resources and processes; the *why?,* the revenue models; and the *who?,* the customers. But they also differ in terms of the channels, which are often virtual; and the partnerships within the value chains (Frankenberger et al, 2013; Lewandowski 2016). Revenue streams and cost structure are of particular relevance from the pure business perspective, since product-service systems can radically shift the revenue streams (Mont, 2002). CBMs can provide new opportunities for companies to create and capture value (Bocken et al, 2016), but circular strategies can also require overarching and radical changes in companies offers and value chains, both changes upstreams and down-streams (Nussholz, 2020).

Building on the sustainable business models archetypes proposed by Bocken et al (2014), the following CBMs described in the literature (Bocken et al, 2016; EMF, 2015; Lewandowski, 2016; Lindahl & Dalhammar, 2022; Mont, 2002; EPA, 2021) are the most relevant from a manufacturing perspective:

Maximise material and energy efficiency

- Extending product value, where residual values of products are exploited. Ex: remanufacturing parts in automotive industry, sales of refurbished electronics, repair, clothing return initiatives.
- Long-life model, focused on delivering long product-life. Ex: White goods manufactured for long life and repair.
- Encourage sufficiency, i.e non-consumerist solutions seeking reduced end-user consumption. Ex: certain high service, high quality brands.
- Virtualisation, i.e turning physical products into digital.
- Design for a sustainable life cycle: possibilities for value-increasing collaboration across value chains, with customers/suppliers, etc – for longer use, more users, retake for remanufacturing, refurbishment etc (EPA, 2021).

Deliver functionality rather than ownership

- Access and performance models, or Product-as-a-Service, where user's needs are satisfied without ownership of physical products. Ex: integrated product-service offerings, renting, subscriptions, digitalization.

Create value from 'waste'

- Extending resource value, where "wasted" resources are collected and turned into new forms of values. Ex: take-back-system.
- Industrial symbiosis, a particular type of CBM, see below.

Important to note, however, is that environmental gains from CBMs can come with trade-offs or imply rebound effects. Current research insufficiently considers environmental considerations (Nussholz, 2020).

CE ecosystems

Circularity stretches beyond the individual business, however, both upstreams and downstreams. Circularity can be realized between different companies, engaging suppliers into sustainable supply chain management (Lewandowski, 2016; Nussholz, 2020). Importantly, CBMs may involve a variety of actors and development of entirely new value networks (Nussholz, 2020), and development of the surrounding ecosystem is therefore needed for CBM to function.

This circularity on the meso-level include key elements such as infrastructure, logistics and industrial symbiosis. Infrastructure for re-use and for resource-efficient logistics is crucial for efficient resource and materials flows (EPA, 2021). A specific way to organise the flow of materials and energy through local and regional economies is industrial symbiosis (Södergren & Palm, 2021). This engages traditionally separate industries in a collective approach to competitive advantage, involving physical exchange of materials, energy, water, and/or by-products. The keys to industrial symbiosis are collaborative willingness and geographic proximity (Chertow, 2000).

3.2.2. Barriers and drivers for circular production and circular business models

Identifying and addressing barriers to and drivers for the fulfilment of policy objectives is a key step in policymaking. There is a vast range of barriers for a circular transition, affecting the ability and willingness of actors in society and economy to transform current strategies and operations. Sometimes this is analysed in terms of a web of constraints, hindering circular transition (POLFREE, 2016). Understanding these barriers, how they affect companies, and in what ways public policymakers can address them, is a key requirement for designing industrial policy for CE.

Existing CE policy frameworks, both public policies (EU 2020; OECD, 2022), and policy proposals (Mont et al, 2017; Flack, 2023; Milios, 2016) base policy recommendations on analysis of current barriers, and sometimes also factors functioning as drivers or enabling conditions for circular transition.

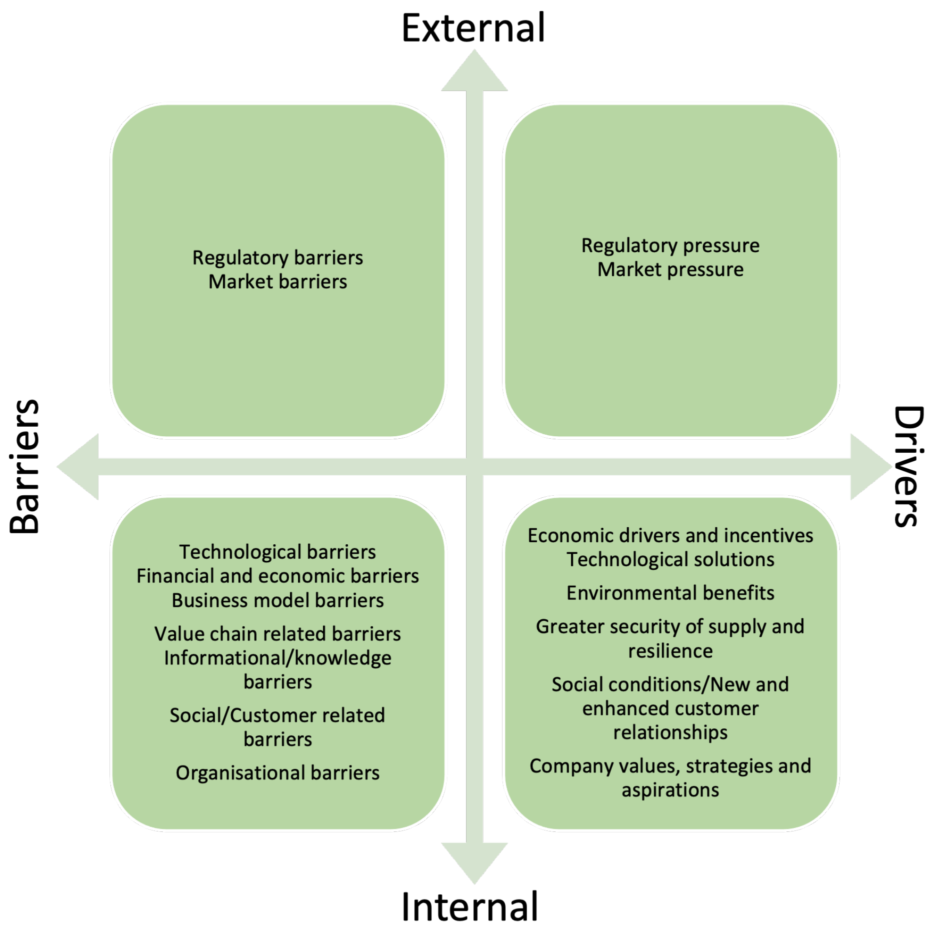

Figure 2. Barriers and drivers for circular industrial transition.
The figure summarises barriers and drivers affecting companies either externally or internally. Framework adapted from Mont et al. (2017), Milios (2016), and Kirchherr (2017b).

Barriers

There are extensive mappings of barriers hindering circular industrial transition. For the purpose of this study, a framework provides a typology of barriers and drivers. This is illustrated in Figure 2. Barriers that have specific relevance for the purpose of studying industrial policy and for understanding the specific conditions relating to Swedish industry have been identified in current CE research (Mont et al., 2017; Milios, 2016; Kirchheer 2017b; POLFREE, 2016; Hansen et al., 2021; Lindahl & Dalhammar, 2022; Domenech, 2019; Flack et al., 2023; OECD, 2022; Svensson-Höglund et al., 2021; DG GROW, 2022; Tillväxtanalys, 2022a; EC, 2020; EPA, 2021; IRP, 2019). Main regulatory barriers are current laws and regulations influenced by linear thinking, lack of incentives for CE and RE, and lack of specific CE policies and regulations. Market barriers include market failures, mispricing of raw materials, consumer behaviour, and lack of recycled raw materials. There are also technological barriers, such as product design, and value chain-related barriers, such as transaction costs and lack of value chain collaboration. An extensive list of relevant barriers identified in literature can be found in Annex 2.

Drivers and enabling conditions

Transitions are catalysed by drivers. They have a steering effect, and increase the potential of policies (Milios, 2016). In the case of CE, it is the drivers that stimulate the uptake of CBM. The identification of drivers is closely connected to the policy design - so key drivers will only be briefly covered here.

Enabling conditions relate to the removal or reduction of barriers. There is substantial literature on enablers for CE, including Mont et al (2017), Kirchheer (2017), and Milios (2016), but knowledge is still lacking on the overall picture regarding the effectiveness of applying enabling conditions, and there is no "Golden Formula" for realising a CE (Milios, 2016). Using the Milios (id) definitions to distinguish real-world drivers from what is often idealised or theoretical enabling conditions, drivers refer to actual conditions that would potentially incentivise greater circularity, while enabling conditions refer to hypothetical sets of drivers, which if put in place could promote the circular transition. For this reason, only drivers will be covered here.

Main CE drivers relate to economic factors (costs, taxes, profitability, material supplies), regulatory pressure, strong market forces (see below). Fiscal and taxation systems are key framework conditions that shape the behaviour of economic actors and what is considered feasible and viable (Domenech, 2019). But this also applies to other areas, such as innovation and R&D systems, public CE strategies (id.).

Important economic or market-related drivers include (Milios, 2016; Mont et al, 2017):

- Profitable new business models based on dematerialisation, asset sharing and extended product use
- Taxes on natural resources promote resource efficiency
- Rising or volatile costs of virgin raw materials
- Supply risks

- Cost savings through reusing and recycling
- Market triggers material innovation
- Strengthening of competitiveness

Other drivers playing a particular role in catalysing circular transition include (Mont et al, 2017; Domenech, 2019; Milios, 2016; Govindan & Hasanagic, 2018):

- Perceived environmental and social benefits
- Increased governmental intervention
- Circular public procurement
- Compliance with legislation
- Extended producer responsibility participation
- Best Available Techniques (BAT) in industrial processes
- Legal compliance requirements
- Legal pressure to decrease certain material resources
- Public CE strategies and targets

3.2.3. Circular economy policy

The overarching goal of CE and RE policies is resource decoupling (IRP, 2019), through overcoming barriers to CE and RE, and counter externalities and market failures (OECD 2018; Ministry of Finance, 2022). Circular transition also requires new CBMs, and these usually need policy support for their implementation (Dalhammar & Milios, 2016; Whalen, 2020). Public policies can create conditions under which CBMs can scale up from their current niches, supporting the broader uptake of CBMs and helping realise their environmental benefits (OECD, 2022). However, policy frameworks for RE/CE are complex and challenging, as competing goals and visions reduce effectiveness of measures (Domenech, et al, 2019; Ekvall et al, 2016). Importantly, the variety of CE definitions can pose problems for developing political frameworks and policies (Lindahl & Dalhammar, 2022).

Typology of CE policies

In line with the multitude of conceptual understandings of CE, policies for CE and RE are categorised in several ways. For the purpose of this thesis, CE policy instruments identified in the literature will be combined with industrial policy instruments to form a conceptual framework and an interview guide. Therefore, the CE policy analysis cannot contain too many parameters. The researcher has chosen to base it on top-level policy categories, a horizontal/vertical policy dimension, as well as a sectoral dimension. Policy examples (Table 2) are selected based on potential relevance from an industrial policy perspective and formulated on a general level.

Table 2. Policies for Circular Economy and Resource Efficiency
Policy categorisation adapted based on Mont & Dalhammar (2005), Wasserbaur et al (2022), Milios (2020).
Policy examples are from Milios (2020), Milios (2016), Milios (2020b), Domenech (2019), OECD (2022), POLFREE (2016), Lieder & Rashid (2016), Wilts & O'Brian (2019), Wilts et al (2015), Ekvall et al (2016), Hennlock et al. (2021).

CE/RE POLICIES	Horizontal – policy examples	Vertical – sector policy examples
Administrative & regulatory	Targets – national or EU Circular public procurement Producer responsibility Product standards for CE Waste legislation	Manufacturing: Recycled content mandates; Construction: Industry standards/ material passports
Economic & financial	Tax shifting Taxes on virgin raw material Preferential taxes/subsidies on recycled materials Differentiated VAT reduction on reuse, repair Incineration taxes Product taxes on hard-to-recycle products Funding for investments or R&D Investments and support in innovation, technology etc	Mining: Raw material policies Primary material tax
Informative	Info on product content Certification schemes for secondary raw materials Promotion of education & skills	
Support mechanisms and capacity building	Take-back infrastructure for reuse, remanufacturing Value chain interventions Industrial symbiosis Collaboration platforms Funding and policies for R&D and innovation Investments in collection and recycling Incentives for secondary markets	Electronics: Take-back systems for reuse

Circular policies differ in how they address market failures in relation to either individual companies or industrial systems (Hennlock et al, 2021). On the one hand, circular lifecycles can be created within each company or in collaboration with actors along its value chain, i.e., with product/service-systems (Mont, 2008). On the other hand, in larger systems, circular flows can be incentivised through combinations of environmental policies, which steer and connect different markets (f ex Fullerton & Wu, 1998).

CE policy design

In ideal conditions, CE policy design should be conducted in a systematic fashion, such as is suggested by Ekvall et al (2016) and Wilts & O'Brian (2019), but this is never possible in real-life policymaking. For the purpose of this thesis – to identify possible CE policies in an exploratory way, it is most relevant to study generic, top-level factors guiding the choice of possible or emerging policies.

Knowledge is the first requirement for policy design. Knowledge on material flows, content of possible dangerous substances, effects on other policies, is needed to support strategic policy choices. Gaps in knowledge will affect the possibilities to design efficient policies (EPA, 2021).

This is particularly relevant for the emerging landscape of CE policies, since established environmental and climate policies are based on long-established indicators on GHG emissions, pollution, etc, but as discussed earlier, CE data and indicators are less well-developed (ch.3.1). In fact, CE policy design is hampered by the lack of measurement methods and is therefore usually challenging (De Pascale et al, 2021; POLFREE, 2016).

In the choice between different policy options, criteria for policy choices need to be decided. The size of the environmental impact is a widely agreed criteria: maximisation of environmental gains (EEA, 2013), or generation of as large circular transitional leap as possible (Ministry of Finance, 2022). Combining the requirements on knowledge and impact, EEA (2013) narrows CE policy design to two fundamental questions: which elements of European consumption and production patterns are the key causes of environmental pressures?, and where can the greatest environmental gains be attained?

This should be done while maintaining a systems perspective, ideally ensuring that policies reinforce positive feedback loops (Milios, 2018). But there is generally a clear trade-off between those instruments that offer the highest potential for increasing resource efficiency, and those that are most easily introduced (POLFREE, 2016).

3.2.4. Circular economic policy in Sweden and the European Union

Currently, CE strategies and policies are developing fast both on EU level and in many Member States. EU regulatory framework for CE and sustainable production and consumption is still in its infancy, but several large EU initiatives are impacting national policies (Hallquist & Vanacore, 2023). The overarching EU policy is the Circular Economy Action Plan (EC, 2020), describing the various EU tools and policies for fostering CE in different sectors and value chains, mainly plastics, textiles, construction, electronics. Several policies are far-reaching, filling substantial gaps in the current regulations.

The national CE Strategy (2020) lacks specific, measurable and quantifiable goals, but is targeting Sweden's environmental and climate goals, as well as the generational goal, and Agenda 2030. Material resource efficiency is included in the generational goal, and recycling etc in the environmental goals (EPA, 2021).

The CE policy field in Sweden is in fast development, however. Currently, a governmental commission is investigating and proposing economic policy measures for CE, including analysing relevant material flows, product groups or services, for which economic policy measures would be appropriate (Ministry of Finance, 2022). The government has also appointed a Commission to investigate Bioeconomy (Government, 2022).

Table 3. Key elements of the Swedish Circular Economy policy landscape

Key elements of the Swedish Circular Economy policy landscape
• *CE Strategy (2020)* Vision: a society where resources are used efficiently in circular flows, replacing virgin raw materials. Four focus areas: (i) sustainable production; (ii) sustainable consumption; (iii) circular material cycles; and (iv) circular economy as a driving force for business • *CE Action Plan (2021)* Presents policy instruments and measures that the Swedish government will use to achieve the environmental goals in the 2030 agenda; it covers the development of specific national strategies for electrification, water and the bioeconomy • *Action Plan for Plastics (EPA, 2022a)* Includes specific funding for industry transition • *Delegation for CE (2020, 2021, 2023)* Yearly policy proposals

3.3. Green industrial policy

This chapter will provide an outline of industrial policy logic, including the motivations for industrial policy, and the risks arising from the policy. Thereafter, different policy types will be described, as well common policy design challenges.

3.3.1. Green industrial policy logic

As decarbonization necessitates industrial transition, the global climate agenda has reinvigorated green industrial policy as a necessity to support and foster the industrial pathway to net-zero. Green industrial policy has drawn considerable interest in recent literature (see ex Rodrik, 2014; Coffey et al, 2015; Meckling, 2017; Weiss et al, 2021; Allan et al, 2021; Warwick, 2013; Hallegatte et al, 2013; Andersson et al, 2021; Terzi et al, 2022; Nilsson et al, 2017).

Industrial policy (IP) is – just as the concept circular economy – defined in several ways (Warwick, 2013). Historically seen as industrialisation policy, today IP mostly means a targeted sectoral policy, close to competitiveness or productivity policy, or a horizontal policy, aiming at securing framework conditions favourable to industrial competitiveness (id.). IP encompasses sets of governmental measures used to influence a country's economic structure, primarily to enhance productivity and competitiveness, allowing for economic growth and higher incomes (Altenburg & Assmann, 2017). Both in literature and in real policy, there is also a strong connection between green industrial policy and innovation policy (Nilsson et al, 2017; Söderholm & Frishammar, 2018). While non-intervention for long was a generally agreed international principle, limiting the acceptance for state-aid, to ensure free-trade (ex Andersson et al, 2021), climate change and other large challenges have led to a revival for industrial policy (ex Mazzucato, 2014).

In contrast, green IP is a policy supporting certain sectors or technologies aiming to reach both environmental goals and increased competition[ii] (Söderholm & Frishammar, 2018). In much literature, there is also a strong connection between green industrial policy and innovation policy (T, 2018).

Using a World-Bank-backed definition, green industrial policies combine *objectives* (green and industrial restructuring or job creation) and *tools* (non-neutral policies) (Hallegatte et al, 2013). Usually, green IP will require a combination of industrial and environmental policy tools[iii] (Meckling, 2021).

The role and specificities of IP vary over time and level of development (Weiss, 2021). Overall, IP has a "very chequered history" (Rodrik, 2014). While having fostered strong industrial development in many countries, there are also many more or less expensive failures, caused by prestige projects, rent-seeking or bad policy-decisions (id). Among notable successes are major inventions or clusters directly or indirectly attributed to the US Defense Advanced research Projects Agency (DARPA), such as the internet, GPS, the emergence of Silicon Valley, the key technologies of the iPhone (Terzi et al, 2022). In many OECD countries, the economic and financial crisis 2008-2009 triggered new IP initiatives, promoting future innovation-induced productivity growth, and tapping into new or unmet demands, such as the demand for green growth (Warwick, 2013).

Motivations for green IP

The classic economic motivation for green industrial policy is market failures (Rodrik, 2014; Fischer, 2017; Andersson et al, 2021). Theoretically, in well-functioning markets, natural and environmental resources are priced appropriately[iv], and both technological benefits and costs are fully internalised by those undertaking R&D (Rodrik, 2014). In this case, technological investment decisions could be solely left to entrepreneurs, companies, and financial markets, without government intervention (id). If environmental damage is allowed because of incorrect pricing, this is considered a market failure. The result is externalities, where the actors involved in the economic transaction do not bear the full costs, including costs for environmental damage (Fischer, 2017; Bourg et al, 2003). In current research, the term "system weaknesses" is considered more relevant than "market failures", since it points to the state's role to also correct systemic problems, (such as lack of connections between actors in the system or institutional barriers) (Söderholm & Frishammar, 2018). The market failures and system weaknesses constitute barriers for internalizing environmental costs, and thus prevent more environmentally friendly technology and business models (id).

Climate change has been called the biggest market failure ever (Stern, 2006). From this perspective, it is the mispricing of carbon - and similar factors – that leads to environmental damage. Mispricing results in underpricing of existing technological alternatives, below what is an appropriate level from a long-term societal perspective, and thus resulting in externalities in the form of environmental damage (Bourg et al, 2003; Rodrik, 2014). The underpricing is a form of indirect governmental subvention, resulting from a political incapacity to internalize negative externalities. Importantly, in cases when the best policy option – correct pricing and internalisation of costs – is non-feasible, green industrial policy is an important toolbox for policymakers, since it constitutes the "second best" policy choice (Rodrik, 2014; Söderholm & Frishammar, 2018).

An opposing approach to the market failure discourse is primarily based on Mazzucato's (2013) theories on the role of the state in innovation policy, but also on earlier formulated concepts of systems of innovations (f ex Lundvall, 1992; Freeman & Soete, 1997). Breaking with ideas of private investments as sole drivers for breakthrough innovations, Mazzucato showed that private innovation depends heavily on public frameworks of funding and research.While the market failure perspective sees the necessity of state intervention to secure second best policies (Mazzucato, 2019), the market creation perspective recognises the state as an active player in the innovation system, fundamental for expanding the knowledge base of the private sector, and taking larger or more long-term "entrepreneurial" risks to spur innovation than private venture capital is capable of – hence the concept "the entrepreneurial state" (Mazzucato, 2013). Just as the ICT revolution was largely dependent on public innovation strategies (Terzi et al, 2022), the green transition will be dependent on proactive public industrial and innovation strategies (Mazzucato, 2019). Mazzucato's influence on contemporary policy is extensive, and her ideas (2021) have guided much of EU's green policies.

In economic research, a third motivation for green IP is the collective good character of development of new technological knowledge, which has positive spillover effects in the form of knowledge or other benefits (Malhotra & Schmidt, 2020; Andersson et al, 2019). While knowledge spillover or leakage happens in all technological development, and is positive for society, such spillovers cannot fully be captured by the investors and entrepreneurs, which then constitute a "market failure" (Rodrik, 2014). Instead, these spillovers can become realised as cross-firm externalities, industry-wide learning, skill development or agglomeration effects (Rodrik, 2014). The high risks involved in investments in green alternatives (Söderholm & Frishammar, 2018), and the high costs involved in developing pioneering technologies (EPA & Energy Agency, 2022) are barriers, motivating governmental intervention, but the knowledge generated can itself also be a motivation for IP (id.).

A fourth motivation for countries to pursue green IP is strengthening domestic industry's global competitiveness, i.e., to create first-mover advantages, which can impact technological development in a direction closer to a country's comparative advantages (Rodrik, 2014).

Risks

While green IP provides opportunities, it also comes with a range of risks (Dutz & Pilat, 2014). Several risks relate to government's (informational deficit, relating to f ex characteristics of market/system failures, extent of internalisation/externalisation etc. It is challenging for state actors to select appropriate sectors or industries for investment, i.e., "picking winners" (Rodrik, 2014), and difficult to design policies addressing the most important risks and knowledge leakages (Söderholm & Frishammar, 2018). Policy failures include the creation of new lock-ins or path-dependencies, the supported technology not being internationally competitive, and in a globalised economy with high spillover risks, the realisation of positive impact abroad (id). A second major risk is rent-seeking (Fischer, 2017; Rodrik, 2014), i.e., companies seek income through manipulating institutions and political preconditions setting the games of play, not by developing better products or services, or by better production - this is often result of lobbying by special interests (Rodrik, 2014; Hess, 2014).

3.3.2. Green Industrial Policy Instruments and Taxonomy

Green industrial policies are usually based on a policy mix affecting different stages of technology development and sector growth and targeting both supply and demand (Altenburg et al, 2071; Hallegatte et al, 2013). The main green IP tools are (1) subsidies and state-aids in their many forms — from production subsidies to credit guarantees and subsidised loans with lower interest rates for green projects; (2) direct government participation; (3) green public procurement rules (e.g., "domestic sourcing" requirements); (4) targeted public investments, for example in infrastructure; and (5) cluster policies, testbeds and other forms of innovation policies, including green R&D support (id). State-aid is defined as public financial support to an economic activity, which results in economic advantages compared to other actors, and potentially impacting competition (Government, 2019). Because of the potentially distortive effects on international trade, state-aid is governed by the EU and the WTO (Andersson et al, 2021).

The main industrial policy taxonomy is the distinction between different interventions based on the horizontal/vertical dimension, i.e., general policies or sectoral or technology-specific policies (Weiss, 2013). Tax credits for R&D are applied horizontally and rationalized by technology spillovers, while state venture-capital funds are vertical instruments, applied selectively and rationalized by a risk-taking externality (Weiss, 2021). Horizontal measures are often preferred, due to their technology- and sector-neutral character, while sometimes the specific needs and characteristics of individual sectors or technologies need to be addressed more selectively (Warwick, 2013). The literature formulates other taxonomies, based on degree of selectivity and cost of subsidy (Benhassine & Raballand, 2009), or making distinctions within vertical policy, such as technology supporting or market shaping/making policy instruments (Söderholm & Frishammar, 2018). Industrial policy packages can also be looked upon depending on the type of intervention. In Table 4, three relevant but differing taxonomy frameworks for green IP are outlined: based on the horizontal/vertical distinction, policy objectives, and type of intervention.

Table 4. Taxonomy frameworks for green industrial policy

Taxonomy frameworks for green industrial policy		
• Horizontal • Vertical (Weiss, 2013; Warwick, 2013)	• Directionality • Knowledge creation and innovation • Creating and reshaping markets • Building capacity for governance and change • International coherence • Sensitivity to socio-economic implications of phase-out (Nilsson et al, 2021)	*Supply-side measures:* • Innovation and technology infrastructure • Higher education and training • Production capacity and operations advancement • Long-term financial capital • Resource access • Infrastructure and network *Demand-side measures:* • Internal demand and public procurement • External demand and international market development (Andreoni, 2017)

3.3.3. Green industrial policy design

Green industrial policy is particularly complex to design. The time perspectives are usually long-term and investment risks can be high (EPA & Energy Agency, 2022). A core challenge is navigating the twin dangers of market failure of the supported technologies and sectors, and governance failure, with unintended negative effects, such as rebound effects, misallocation of capital, or rent-seeking (Hallegatte et al, 2013; Dutz & Pilat, 2014). Policy options must also phase out environmentally harmful industries, which is challenging when capital investments are high and there are vested interests defending the status quo (Cosbey et al, 2017; Hess, 2014). The phasing-in of green technologies also cope with a variety of disincentives: the new green business need to grow and become competitive vis-à-vis established industries and technologies, that benefit from lock-ins and economies of scale, from path-dependent consumer behaviour and from vested interest groups (Never & Kemp, 2017).

Sensitivity to socio-economic implications of phase-outs is also fundamental (Nilsson et al, 2021). It is necessary to get public buy-in, allowing gradual timelines for change and support measures for those negatively affected. (Cosbey et al, 2017). Information is therefore an important complement to green economic policies, and a prerequisite for acceptance, since an efficient and legitimate green policy is dependent on popular problem awareness and anchoring (Söderholm, 2012).

In an international context, the largest challenge is posed by international trade and state-aid policies (Nilsson et al, 2021). Green IP might be restricted by international trade law, and regulated through multi- and bilateral agreements, including the EU and the WTO, prohibiting subsidies (Cosbey et al, 2017). Yet, many green IP options are not affected by trade law, such as feed-in-tariffs, performance requirements for training of staff, science and education policies, funded demonstration projects, and others (id).

3.3.4. Green industrial policy in Sweden and the EU

The use of IP as a policy tool has shifted not only in accordance with political priorities, but also over time. During parts of the 20th century, IP was a key policy measure for Sweden's growth as an industrialised country, developing into state-aid for declining sectors during the 1970's, and further into innovation during the past decades (Nilsson et al, 2017). Currently, green IP has become an essential element of Sweden's climate policy (Energy Agency, 2022). There is no overall Swedish industry strategy, but IP initiatives, instruments and measures are integrated within and across several sectoral national and EU strategies, and several are implemented by means of programmes. Among recent large IP initiatives were the Strategy for Green and Digital Transition (SGovernment, 2022b), the national Electrification strategy (Government, 2022d), and strategies for industrial climate transition (EPA & Energy Agency, 2022; Tillväxtanalys, 2022a) in the forthcoming Climate Political Action Plan.

While IP is more a national competence than an EU mandate, EU drives several industrial policy-related initiatives, including the EU Green Deal (EC, 2019) and Fit-for-55-package (EC, 2021a), which are agenda-setting packages of policies, strategies, acts and laws, the Updated Industrial Strategy (2021b) featuring pathways for green and digital transitions of selected industrial ecosystems. Most importantly, though, EU governs the internal market competition policy, thus steering types of accepted Member State industrial policy state-aid. Successively, EU has loosened rules to allow more state-aid to national industries (EC, 2022a; EC, 2023b; EC, 2023c), and state-aid for CE objectives is now allowed. A specific instrument is the IPCEI (Important Project of Common European Interest) mechanism allowing larger state-aid (EC, n.d.b). So far, only two Swedish companies have received state-aid under IPCEI, Hybrit and Northvolt (EC, 2022a; IPCEI-Batteries, n.d). Industrial policy has recently become the subject of heated international debate, when China's long-term support for national industry and USA's recent, extensive Inflation Reduction Act have been met by the EU with the Green Deal Industrial Plan (EC, 2023a, Stolton, 2023a and 2023b; Rankin, 2023; Laurent, 2023).

Much of the existing Swedish green IP state-aid could be labelled innovation policy, and is governed by the national agencies Energy Agency, Swedish innovation agency Vinnova, the Swedish Environmental Protection Agency, Growth Agency[v] (Tillväxtanalys, 2015), but funding is also distributed through EU programmes, such as the European Innovation Fund (EIF), one of world's largest financing programmes for green R&D (Energy Agency, 2022). Importantly, in practice, IP and R&D/innovation policies are tightly intervowen, and most programmes combine both objectives. Funding opportunities and subsidies vary widely. Swedish industry has been successful in attracting EIF grants for large scale projects (EC, n.d.c; EC, 2022b; Energy Agency, 2022) while the national programme funding is smaller. Public financing is also done via governmental venture capital, i.e., Industrifonden (n.d) and Saminvest (n.d.), export credit (EKN, 2023), and green credit guarantees (Riksgälden, 2021). Proving the advantages of complying with the new EU Taxonomy, the new Green Export Credit Guarantee offers up to 100 percent risk cover if projects comply with the Taxonomy (EKN, 2023).

3.4. Industrial policies for Circular Economy

The first research question of this thesis is "What policy instruments are currently functioning as, or could function as, industrial policy for circular economy?" There is both limited academic research on industrial policy targeted towards CE, and limited grey literature, since this policy type is rare in existing policy and on policy-makers agenda. Certain studies in the CE and RE literature cover industrial policy instruments (Domenech, 2019; Milios, 2016; Milios, 2020), while making specific policy proposals (Ekvall et al, 2016; Hartley, 2020), or while analysing the relation between policy and circular business models (Wasserbaur et al, 2022). In some cases, green industrial policy literature includes circularity aspects (i. Nilsson et al, 2021; Balke, et al, 2017; Altenburg & Assman, 2017).

To be able to identify current and potential policy instruments, the researcher has based her analysis on a definition of what constitutes industrial policy instruments for CE, starting in the Hallegatte et al (2013) definition, combining circular industrial *objectives* and policy *tools,* aiming to develop the domestic industry. In this case the main objective is supporting domestic circular industrial transition. Consumer policies are thus excluded, as are regulations and laws setting conditions, but not having a promoting function. The definition has not been used too strictly, though, since the thesis is explorative, and seeks to encourage discussion.

3.4.1. Existing policies

While there is no specific industrial policy with the sole objective of circular economy in Sweden, there are several overlaps between industrial policy and CE policy, manifested as green industrial/innovation policy instruments including CE objectives or targeting CE, and reversely, several CE policies containing industrial or innovation policy elements. It is essential to view this topic against the background of the overall Swedish innovation policy landscape, since many of the policies studied in this section fall within the wider innovation policy landscape.

Existing and implemented policies of this type are mainly addressing public procurement, differentiated VAT, i.e for repair, funding of CE-related projects by Swedish or EU programmes for industry R&D, innovation, pilot projects etc (listed in Table 7). The Swedish Strategy for CE (Government, 2020) features a broad range of IP-type policies, but these are largely unspecific, and have not been transformed into concrete actions in the CE Action Plan (Government, 2021). There has also been a recent growth in financing instruments: green credit guarantees are technology neutral, and target large industry investments contributing to reaching national environmental goals and the Swedish climate political framework (Riksgälden, 2021; Government, 2017), and green export credits (EKN, 2023) are more beneficial for projects supporting green or circular transition. A list of current industrial policy instruments targeting CE is found in Annex 4, Table 7.

While CE is the only objective of a specific high-level programme, the Swedish strategic innovation programme ReSource (2020), tthe range of current and past industrial support schemes, addressing climate, energy or various industrial restructuring objectives, are numerous (see ch. 3.4.4). While having other purposes, several of these programmes can fund CE projects, CBM, or solutions for circular transition. Such is the case with the Swedish Energy Agency programmes, funding R&D and pilot projects, including the *Industry Leap*. Among funded CE-related projects, most are recycling projects[vi]. The climate transition programme Climate Leap partly funds RE and CE projects, and the interest in CE and recycling projects is steadily growing (EPA, 2022b). Among larger recent funded projects, are the Swedish Plastic Recycling technology for plastics sorting (Energy Agency, n.d.b), and the Northvolt electric car battery recycling plant (EPA, 2023). The funding criteria and funding amounts vary, from smallish amounts in the range of 100.000 SEK to large subsidies, such as the 159 MSEK for Northvolt (TT, 2020).

3.4.2. Proposed policies

Industrial policy for CE is an evolving policy field (Government, 2020; EC, 2020, etc). EU's raised ambition for CE policy is expected to contribute to green and circular industrial transition (EPA & Energy Agency, 2022). CE is also important objective in EU's forthcoming Taxonomy, a classification system for environmentally sustainable activities, aiming at facilitating green investments (EC, n.d.a), where the transition to CE is one out of six overarching objectives.

New industrial policy measures with the objective of supporting circular industrial transition are sometimes proposed in strategy or policy reports (Flack et al, 2023; etc ref), and in public strategies or roadmaps, such as Swedish Roadmap on sustainable Plastics (EPA, 2021; Government, 2022a), the industrial climate transition reports constituting the basis for the Swedish climate policy action plan (Tillväxtanalys, 2022; EPA & Energy Agency, 2022), Fossil Free Sweden roadmaps (source), and the EU Green Deal (EC, 2019), which covers both industrial policy and CE. Since financing of investments plays an essential role in IP, reports on financing CE opportunities, circular business models or green industrial transition, often suggest financing of circular solutions through industrial policy type strategies or instruments (see f ex Fossil Free Sweden 2022; EPA 2022a; RISE, 2019b; EMF, 2021).

Such proposed policies mainly include:

- Funding via programmes – new technology, risk-sharing, pilot and demonstration projects, upscaling
- Financial instruments addressing CBM-specific problems, such as PaaS
- Differentiated VAT – addressing the pricing market failure of virgin raw materials being cheaper than recycled materials
- Circular public procurement, aiming for market creation
- Taxation instruments

- New institutions for CE financing – investment banks or investment funds
- New funding policies for market introduction phase
- Classification of resources/waste
- Knowledge and dissemination, including platforms
- Education and skills, including process and method development
- Value chain facilitation, incl industrial symbiosis
- Collection systems and take-back infrastructure
- Testbeds and other innovation support infrastructure

A range of proposed industrial policies for CE, identified from the literature, are described in Annex 5 Table 8, along with policy proposals from the interviews, to facilitate comparisons between research-based proposals and practitioners suggestions.

Among recent proposals, three large initiatives stand out. A recent government initiative is addressing economic and financial policy instruments. The Governmental Committee on economic policy instruments for CE (Ministry of Finance, 2022) investigating how economic policies can promote the transition to a CE, including which sectors to address and in what way policies can be used for this objective (id.). The outcome of this committee will probably pave the way for several IP-type policies for CE. The Swedish Delegation for CE has recognised the difficulty for supporting industry in transitioning to circular business models and particularly in financing it (Delegation CE, 2021a). The "Circular lift" is a proposed programme supporting circular industrial transition (Delegation CE, 2020). The Delegation also proposes the setting-up of a new institution, a credit guarantee board (check term), providing guarantees and beneficial loans for upscaling (Delegation for CE, 2020). Addressing current barriers for accessing capital for upscaling, there is a need for flexible state credit guarantees and better coordination of state risk capital resources. A particular funding gap exists between the R&D/pilot phases, supported by governmental programmes, and the commercial phase, eligible for bank loans. The proposed credit guarantee board would contribute to closing this funding gap (Delegation CE, 2021a).

3.5. Conceptual framework

As discussed earlier, it is necessary to provide a clear structure to the thesis' analysis. Without structure, the analysis would risk being vague, both because of the knowledge gap within research and lack of practical policy, but also because of the varying definitions of the terms circular economy and green industrial policy.

With a conceptual framework guiding the interviews and the interpretation of the results, a basic analytical structure is created. Relevant themes and analytical categories are provided by the literature review. The framework shows the main relationships and dynamics between the main conditions, factors and policy categories characterising and shaping a potential industrial policy for CE. The framework therefore serves as a basis for developing the interview guide.

The conceptual framework starts in the overall landscape of factors having hampering or driving effects on circular industrial transition – the matrix to the left. The assumption is made that such factors are similar to the combined hampering and driving factors identified in the CE literature and the green IP literature. For the purpose, the matrix of internal and external barriers and drivers for CE (ch.3.3) is used, with text coloured in black. But to reflect industrial policy motivations, the matrix has been complemented with the main factors identified in the literature that hinder the internalisation of environmental costs, and those factors driving/incentivising the greening of business, marked in red colour. Factors identified in both literature streams are marked in purple colour.

The identification of barriers and drivers provides a base for policy design with the objective of formulating industrial policies promoting circular transition – the arrow pointing towards the policy matrix. But policy design is also guided by a set of criteria, such as environmental benefits, commercial potential, economic /social cost/benefit analysis, etc. Included here are a few examples from the literature.

A possible industrial policy for CE consists of a policy package, where the individual policy instruments belong to certain policy categories. Due to the lack of research on the topic, the researcher suggests a policy matrix outlined based on the two main IP categories – horizontal and vertical IP instruments. But the policy matrix needs to reflect policy categorisation specific to CE policy. The latter could reflect several CE policy categories or targets, but the researcher has chosen the steps in the circular flow cycles, to identify potential points of intervention for the intended policy package. Addressing the full value chain with the circular flows – including sharing, reuse, repair, remanufacturing and recycling – will allow the intended policies to incentivise the main goal, i.e circular industrial transition.

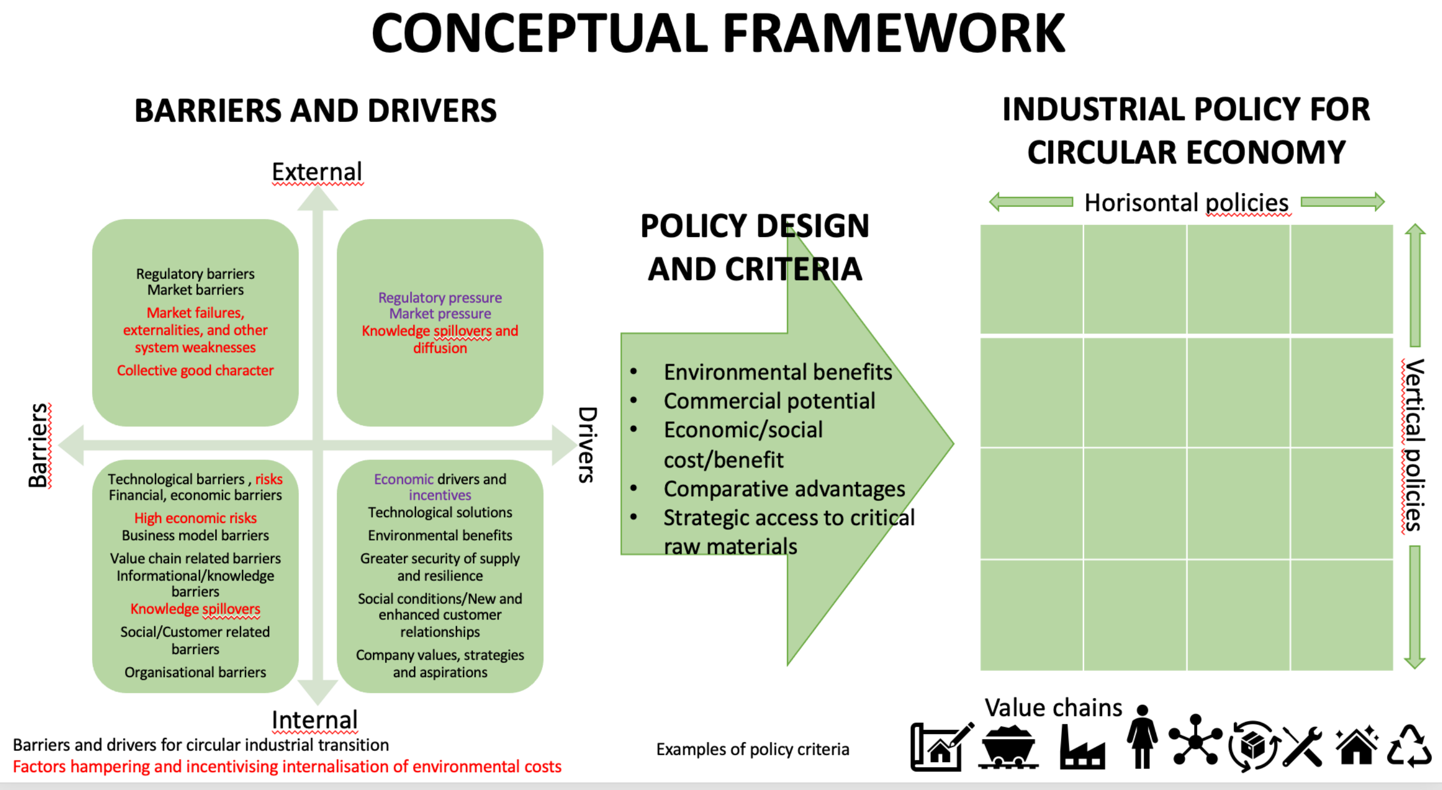

Figure 3. Conceptual framework

4. Results: interviews

The main empirical findings of this thesis were obtained by interviews with 18 selected experts, as described in ch.2.2. This chapter describes the interview findings. The structure of the interview guide (Annex 1) was thematically guided by the conceptual framework (ch.3.5). It addresses the key conditions and factors framing the transition to CE, the key features of industrial production usually addressed by CE policy and green IP, and the main elements of relevant policies. The interview questions were clustered under six themes: 1) Circular industrial transition – Barriers and potential; 2) Industrial policy for CE – general questions; 3) Industrial policy for CE – policy measures, sectors, and steps in value chains; 4) Policy prioritisation and criteria; 5) Strategy and policy mix; 6) Other comments.

4.1. Circular industrial transition – barriers and potential

Barriers for circular transition and upscaling of circular business models in Swedish industry

The first question raised numerous answers: there are many barriers to circular industrial transition, and most stem from market conditions or regulatory frameworks and the ensuing lack of incentives. The primary barrier identified by almost all respondents is the pricing of virgin raw materials compared to recycled ones. Virgin materials are cheaper than recycled, particularly steel and plastics. Other respondents simply saw the lack of targeted economic policy instruments, and the lack of appropriate CE targets and indicators as the main barriers. Other problems broadly recognised are the barriers emerging from existing legislation designed within a linear economic logic: from product guarantee legislation, causing difficulties for remanufactured products, to waste legislation, where classification as waste hinders use of secondary resources. Companies with specific financial flows, such as PaaS companies, are particularly suffering from this. Usually, companies' internal operations are also impregnated by linear thinking through accounting and business systems, ICT systems, legal, insurance, rules, and regulations packages, all complicating the transition to circular operations. Among the systemic problems identified, are the fundamental market conditions inherent in the global trade structure, where labour costs in production countries are usually low, while labour costs in the countries where repair and remanufacturing take place are significantly higher. Another systemic barrier relates to shifting of economic power structures: a CE implies changes to the landscape of economic actors and their relative positions in the marketplace, which can trigger resistance from established actors. Importantly, many respondents also mentioned lack of knowledge or established CE definitions as fundamental barriers: either manifested as unclear benefits for industry or society, as underused CPP, as difficulties to market circular products because of the unclear CE definition, or a "fat and happy" behaviour, with low risk awareness. Many other barriers were identified, and the complete list is found in Annex 2.

Sectors, processes and value chain steps with potential for circular business models

Based on the interviews, there is potential for CBM in most industry sectors, in all value chains and in most industrial processes. The design phase is the step in the value chain having the largest potential, due to its importance for the environmental impact of a product. But several respondents also point out the potential that could be achieved through general public support to facilitate value chain flows, since logistical flows and interaction along the value chain are fundamental for circular production but generate barriers today. Another approach would be to steer efforts towards sectors where B2B collaboration along value chains is easy, such as mining. There is also large untapped potential in the Product-Service Shift, according to most respondents. The potential of digitalisation to improve production process efficiency is also raised. As one interviewee points out, for SMEs unable to make large investments, in combination with PaaS BMs, new digitalisation technology becomes more accessible. In terms of commercialisation stages, there is need for support in the upscaling/"Valley of Death" phase, where there currently is a funding gap.

There is a large difference regarding the CBM potential in different CE cycles. While there is untapped circularity potential for all products in the outer CE cycles, i.e., recycling, the CBM potential in the "inner CE circles" repair, reuse, remanufacturing, is mainly relevant for long-lived or more valuable products, and in product categories where technological change is slower.

Sectors with potential highlighted by the respondents include textiles and textile fibre recycling, ICT and small electronics, critical raw materials, and mining. Most interviewees base their recommendations on their own experiences, but in addition, some refer to the recommendations of the Swedish CE Strategy (Government, 2020) and the Circularity Gap Report (Conde et al, 2022), adding the sectors food, construction and property, renewable and biobased materials, as well as those material flows with the highest emissions: steel, concrete, aluminium, and plastics.

Where is there less CBM potential?

Areas with little circular potential are few. One respondent mentions products with long lifespan or produced with long-lived materials, while others see this as highly circular. Depending on which targets are prioritised, business areas within security or health care can also have less circular potential. While a few respondents see the potential in repairability, one respondent argues that repair policies are less useful: since policy efforts should be directed towards industrial processes with the largest potential environmental gains, other sectors should be targeted, such as steel production.

4.2. Industrial policy for Circular Economy – general questions

Attitude towards green industrial policy in Sweden

The attitudes towards green industrial policy vary, with the main dividing line between industrial representatives and other interviewees. Most respondents are positive towards green IP in general, seeing it as an essential driver for green transition.

Some industry respondents have a more sceptical approach to the type of governmental policy that IP represents, instead emphasizing free-market conditions such as competitiveness, fair competition, and trade rules. A few respondents mention Sweden's historically good experience with and outcomes of IP, and one respondent underlines the importance of IP through pointing out the interconnections between IP, innovation policy and technology development policy. For others, IP has negative connotations, associated with 1970's IP subsidies, associated with high costs, but meagre outcomes, and distorted competition. The complexity of IP policymaking is a general theme: *"Green IP can be positive, but it is not easy"*, a high-ranking official commented.

Need for a Swedish industrial policy for circular economy?

The answers vary along similar lines. Eight respondents provide a clear yes, based on a range of motivations: importance to promote circular transition, limits to resources and emissions, need for policy upstreams in value chains, the benefits Sweden would gain in terms of environmental protection, employment and welfare, and the need to match the growing EU portfolio of CE and RE policy, climate policy, green IP, and green finance. At least three interviewees representing industry are hesitant, and several respondents of varying backgrounds condition their reply to the eventual policy design.

Among the respondents hesitant towards IP in general, several point out the scope and ambition of industry-driven green transformation as sufficient, making public policy unnecessary. Others regard the Swedish CE policy as sufficient as a policy framework, but several call for more clear governmental vision for circular transition. As alternatives to a new specific policy, other interviewees suggest varying policy combinations within existing policy packages, to include CE, RE and biodiversity into existing IP and climate policy frameworks and roadmaps, or to create a holistic green IP, merging climate and CE.

Positive and negative effects of a Swedish industrial policy for CE

Besides the policy benefits above, the interviewees discussed other positive effects of such a policy. The high environmental requirements and general green capabilities provide Swedish industry competitive advantages, thus promoting domestic industry. Or as one interviewee phrased it: *"It pays to be an early mover"*. Of course, early movers also contribute to agenda setting, encouraging other countries to follow. Sweden could also benefit from existing competitive advantages, such as competence in industrial cooperation, which is necessary to develop CE value chains. Other economic-wide benefits could follow, such as employment opportunities, new industries, and tax incomes. As a resource-rich country, the growing need for rare earth metals and biobased products is highly relevant – as pointed out by one respondent, Sweden is producing around 95% of European steel, and has Europe's second most managed forestland. From a less nationalistic perspective, it is also important that the development of CE policy has standardisation effects and agenda-setting effects. The policy also needs an international dimension – it can bring benefits if entailing a European and global outlook, but risks if policies apply unilaterally to Sweden.

Some respondents don't see any negative effects or risks, but a few connect industrial policy with high risks, notably risks for single-sided politics, for competition biaises, for a "race-to-the-bottom" with state-aids, for regulatory capture, for failed technology prioritisations and for lock-in-effects, because of the "states cannot pick winners" problem. However, one of the respondents with most IP experience reminded that a trial-and-error approach is necessary, and since green IP per definition implies investments in specific new technologies, technology-neutrality is neither sought nor possible.

An interviewee within a CE organisation underlines that while there are no risks as such, green and circular transition per definition, in combination with the current fast economic development, leads to some companies being driven out of business. Other risks mentioned relate to the lack of CE knowledge, and the partly unclear objectives of CE, but also the complexity of CE as such. For instance, secondary materials are not per definition sustainable, neither should they be classified as such.

"Circular does not equal resource efficient", comments one respondent, while another notes that "*CE is promoted as a solution to something that is not well defined*".

4.3. Industrial policy for Circular Economy – policy instruments, sectors, and value chains

Relevance of specific policy instruments

The most supported policy instruments, measured by number of mentions, and/or importance attached to a policy instrument, were circular public procurement, green tax shifting, differentiated VAT, funding via programmes such as Circular Leap, and Industry Leap, R&D support, taxation supporting PaaS and product/service shifts, infrastructure, and value chain interventions.

- *Taxation and VAT*

Suggested policy instruments included green tax shifting, lower taxation/VAT on recycled materials and remanufactured products, repair, sharing services, and removed VAT on second-hand. Tax shifting was the most supported economic policy overall. Taxation issues relating to the sharing economy and the product/service shift were raised by several interviewees, since servicitisation and PaaS BMs have large impact on companies' income streams. Since product purchase costs in a PaaS BM initially far exceed income from subscriptions/renting, *"companies are turned into banks"*. The income streams problem can become an insurmountable financial burden for a new company, increasing risks for creating lock-ins in existing linear BMs and production and consumption systems. Designing taxation systems to cater for PaaS BMs is therefore an important policy.

- *Circular public procurement*

Respondents generally found circular or green public procurement a very good instrument for promotion of circular transition. An example that is brought up is the conscious effort of the region of Västra Götaland to implement CPP within textiles and furniture. But since the decentralized mandates of the Swedish regional and municipal sector hamper capacity-building, public procurement support is essential via SKR or the Procurement Agency.

- *Funding/state aid*

State-aid and funding is the topic with most diverging views, but probably depending on which terms are used (see ch.5.1). Several respondents are sceptical to state-aid or condition their response to compliance with EU state-aid regulation. On the other hand, all respondents call for strengthening of existing funding programmes, or creation of additional funding opportunities, for upscaling of new technology, for investment support etc. The Industry Leap programme is appreciated, and a specific Circular Leap programme is also called for.

- *R&D support*

This was a self-evident policy instrument to respondents. A specific recommendation was support for process innovation, since most Swedish industry production features complex processes, but little product differentiation, and also since much current policy tend to focus on product innovation. Testbeds were also called for.

- *Other economic instruments*

Risk loans, credit guarantees, and other risk-sharing instruments were mentioned. Credit guarantees can support first-of-a-kind facilities.

- *Infrastructure and interventions along value chains*

Several interviewees expressed need for infrastructure support such as electricity infrastructure or housing supporting large industry initiatives, but also logistical support for improvement of recycling processes. The interviewed experts within industrial manufacturing and processing raise the complexity of material flow management along the value chains as a problematic issue needing public support. Value networks need to be created, to allow the waste generated in one industry to become raw materials in another industry. The state has an important role to facilitate the interactions, collaboration, and logistics along the value chain, and support the development of material standards. One expert raised the early Swedish steel sector, which benefited from different support measures, where the state facilitated collaboration in the steel value chain. The outcome – the development of material standards – today serves as the basis for steel recycling, and it could not be realised without state support.

- *Legislative and administrative policies*

While not IP per se, several legislative or administrative polices were raised, such as product regulation, standardisation, legislation for critical raw materials, quotas on recycled material content, and repair checks. A few regulations, though, have a hindering effect on growth in CE, and their removal would be beneficial: the municipal waste monopoly, that hinders innovation, and the waste classification, hindering use of secondary materials.

Size of public investments in CE

All the interviewed experts called for more extensive public investments in CE, and generally more public support for circular industrial transition. One respondent commented that larger support is needed for CE market creation, where demand today is higher than supply. Another commented that funding needs to be adapted for SMEs in terms of i.e., smaller co-funding requirements.

Policy design: horizontal or vertical measures

Both horizontal and vertical/sector-specific policy instruments are needed. In general, interviewees want policies to be broad and open to all actors, but horizontal policies are not enough. Vertical/sector-specific policies are needed: *"to be effective, policy has to be adapted to products and value chains"*, says one respondent. Innovation often happens in new sectors, and sector-specific IP is important for technological development and upscaling.

Sectoral focus

Preferences for sectoral focus vary between interviewees. A few would like policy to steer support to those sectors who are the largest GHG emitters: steel, plastics, aluminium, concrete, and food. One respondent points out the large waste characterising the food and construction industries, but also the unsustainable practices in the fashion sector. A few see a large need in recycling facilities, where support is needed to scale up capacity and technology. Particularly textiles and plastics recycling are in need of technological and logistical development as well as upscaling. One respondent sees a large potential in mining waste, considering the demand for rare-earth metals for large-scale electrification. Only one respondent mentions the circular nutrient flows in the biological cycle, with the example fertilizer in the agri-food sector.

Several respondents point out the importance of supporting new actors, such as SME's. There is a specific need for state risk investments in the upscaling "Valley of death" business phase, where there is a current funding gap. One interviewee sees a risk for public policy support for established industry sectors, instead underlining the need to steer towards the "inner CE circles" – using an example from the transportation sector: policy should support "mobility" as such, not "cars" specifically – but lobbying from established industry can counteract such policy goals.

All interviewees want support for new technology. Several discuss the appropriate level of specificity: while technology-neutrality might seem desirable in theory, it is not possible. Green industrial policy cannot be technology-neutral, since the green transition per definition implies a technology shift, and any green IP aims to support the transition to this new technology. But if the technological scope is too narrow, there is a risk.

Value chain focus

Most respondents recommend focusing policy strategies upstreams in the value chains, since design and raw materials processing have the largest impact on a product's environmental footprint. Several discuss the importance of well-functioning recycling systems - both to ensure logistics and materials flows. Industry representatives underline the need to increase quantities of high-quality recycled materials. Logistics chains are also emphasised: public policy must build on and support circular flows and logistics.

Policies promoting the "inner CE circles"

As discussed earlier, taxation and VAT are fundamental policies: in terms of green tax shifting, higher tax on virgin raw materials, and taxation and other economic and administrative policies to promote the product/service shift. This does not mean *"uncritically supporting all PaaS models"*, in the words of one respondent. Electrical scooters, for example, generate *"much waste and little benefits"*. Other suggested taxation policies include reduced VAT on reuse and recycled materials, removal of the chemicals tax for reused electronics, lower VAT on repair, even though the views on the benefits of repair policies are divided.

In the Swedish context, reuse is seen as more profitable than remanufacturing because of the high Swedish labour costs, and because of the large scale of the remanufacturing industrial processes. Nevertheless, remanufacturing can have potential for longlived products, but depending on the values of components, and the market characteristics.

4.4. Industrial policy for Circular Economy – criteria for policy design

Prioritisation of policy measures and selection of policy criteria

The is consensus among the interviewees that environmental impact is the main criteria for prioritizing industrial policy for CE, measured as environmental gains from a policy or negative environmental impact from an activity. The selection of environmental impact category depends on the policy objective, the time perspective, and the amount of potential environmental damage. If data is less specific, criteria can be based on rules of thumb in the form of utilization rate and product lifetime. But where environmental impact is the largest, legislation is a better instrument than IP.

Industry generally requests policy should be European or global, and not national. Several other policy criteria were mentioned, notably:

- Market driving or market creating effect;
- Based on identification of barriers;
- Long-term and predictability is particularly important for industry;
- Balance between environmental and socio-economic impacts;
- Measurability and target-based;
- Benefits to Swedish industry;
- Domestic comparative advantages;
- Knowledge spillover;
- Achievement of synergy effects;
- Upscaling potential;
- Needs of new actors, i.e. SMEs;
- Preferably upstream, early in value chain;
- Preconditions for new industries, i.e., infrastructure;
- Security of supply: reduce risks due to long supply chains;
- Avoidance of dependence, particularly for critical raw materials; and
- High acceptability is preferred, since it improves policy outcomes.

Criteria for termination of support measure

All respondents have similar views: an industrial policy measure should be terminated when either the supported company can hold their own, or when the business idea is shown to not be viable. Support should aim at stimulating transition, and be beneficial for society, and be continually evaluated as regards efficiency and further need. Dependency on support should be avoided.

4.5. Strategy and policy mix

Assessment of Sweden's current CE Strategy and Action Plan

Opinions on the CE Strategy (Government, 2020) range from ”good” to ”tame”. Industry is generally quite supportive of it, while noting that the Action Plan (Government, 2021) is vague. Several CE practitioners find that the CE Strategy needs much development. One compares with the Finnish CE strategy, and finds that it is a much better plan, with concrete steps for implementation.

Need for national CE targets

The question on national CE targets raised many reflections from the interviewees. A CE expert noted that CE targets are probably needed, covering wider CE aspects than current national targets for recycling and waste management. But formulating CE targets is significantly more challenging than climate goals, because of the challenges in measurability and evaluation, and the tradeoffs between factors such as material efficiency, recycling and product life, resulting in target conflicts. The Finnish target for materials use was raised as a pioneering example. However, industry representatives were hesitant to setting national targets, preferring joint EU minimum rules.

The need for CE statistics was also addressed: data on materials, RE and CE-related activities are currently lacking, but indicators are currently being developed by SCB, EU and OECD. Needs include statistics on product lifetime, utilization rate, remanufacturing, etc, but also on CE business models. However, the difficulties in measurability were emphasized, with the Circularity Gap Report (Conde, et al, 2022) as example – some judging it very useful, and some critical towards the methodology used: *"Sweden is 3,4% circular, that does not say anything"*, commented one respondent.

Coordination of CE industrial policy with other green industrial policy

Generally, all respondents emphasize that closer coordination between climate, CE, and other environmental policy, such as biodiversity policy, is needed. Climate and CE are interconnected, and often joint policies are needed. One interview remind that the Swedish Climate Political Council wants CE to have a large role in climate policy. Among the specific proposals is inclusion of CE/RE in the forthcoming national climate action plan, a national arena for gathering of actors, and setting up a public-private collaboration platform for CE, modeled on Fossil Free Sweden, with sector-specific roadmaps.

Trade-offs between opportunities and risks in policymaking

Because of the complexities regarding definitions, scope and measurability of CE policy, compared to i.e., climate mitigation policy, trade-offs are relevant to consider. Notably, there were two different perspectives on potentially toxic materials. On the one hand, conflicts of objectives can occur between chemicals and waste legislation, because of need to recycle and phase out dangerous substances at same time. On the other hand, there is a risk that companies use non-toxicity as a pretext for non-action, therefore resulting CE being prioritised too low. Among other problems identified are:

- Conflicts of objectives: economics, climate, standard of living, effects on consumers and industry – policy options must therefore be analysed carefully;
- Risk that one environmental policy leads to other environmental impact;
- Circularity sometimes increase resource use;

- While there are trade-offs, much can be solved with today's technology;
- Better waste technology can reduce the necessary focus on the important design step. Therefore, policy must build on LCA thinking;
- Risk for back-lashes;
- Multitude of objectives, besides circularity. There is a need to *"simultaneously bear more than one thought in mind"*, as one respondent phrased it.

4.6. Other questions

Among other themes identified, two stood out. The first was the need for alignment with EU strategies and regulations, both to avoid policy conflicts and to create policy synergies. Swedish state-aid must not conflict with EU state-aid regulations. EU is perceived as driving both CE policy and IP development fast forward, resulting in growing policy frameworks covering strategies, legislation, and new targets. Keeping up with, drawing the benefits from, and ensuring coordination with, these developments were seen as crucial. The forthcoming EU taxonomy will be essential for facilitating policy and investments.

The second theme is the vagueness of the CE concept, and the need for knowledge and capacity-building – across society and the economy. From an industry perspective, the identified lack of knowledge, as well as unclear benefits, was perceived as a particular barrier for circular transition. Wider knowledge and clarity around the CE concept was also seen as a prerequisite to allow marketing of circular products and services. Current and future industry needs for skilled workforce also brought up the need to broaden university education on CE. One respondent concluded that there is currently no specific CE education programme in Swedish universities. From the government perspective, also public administrations need more knowledge on CE for developing policy support for circular industry. The lack of broader CE-relevant statistics and indicators is both a reason for and a consequence of this perceived lack of knowledge.

Table 5. Summary of interview findings

Summary of interview findings	
Circular industrial transition - barriers and potential	
Barriers to circular industrial transition	There are many barriers, including: • Incorrect pricing of virgin raw materials vs recycled • Linearity in economy, legislation, and internal business processes, hindering CBM

	• Lack of targeted CE policies • Lack of knowledge on CE and diverging CE definitions
Potential for CBM	• Generally, there is potential for CBM in most industry sectors, in all steps in the value chains and in most industrial processes. • Largest potential in the design phase, and supporting value chain flows; in PaaS business models; in textiles, small electronics and critical raw materials sectors.
Industrial policy for CE – general questions	
Attitudes towards green industrial policy	Mostly positive attitudes towards green IP, although industry representatives are more sceptical. Attitudes are marked by historical experiences of IP.
Need for Swedish Industrial Policy for Circular Economy?	The majority believe that a specific Swedish industrial policy for CE is needed. Several are more hesitant, preferring existing CE policy, an industry-driven green transition, or policy combinations with existing policy packages. Consensus on need for a clear governmental vision for circular industrial transition, and need for coordination of policy packages of CE policy, green IP, biodiversity policy, etc.
Positive effects	Positive effects include: • gains in environmental protection, employment, welfare and new industries • new competitive advantages, based on existing green capabilities • benefits from existing competitive advantages, such as industrial cooperation • early mover advantages • international agenda setting and standardisation effects • benefits from resource-rich domestic economy
Negative effects	Most identified negative effects are connected to general IP risks, such as competition biaises, a "race-to-the-bottom", failed technologies and lock in effects. Also, secondary materials are not per definition sustainable.
Industrial Policy for CE – policy instruments, sectors, value chains	
Relevance of policy instruments	Most supported poliy instruments: • Taxation and VAT, notably green tax shifting, differentiated VAT for circular products and services, and taxation supporting PaaS. • Circular Public Procurement • Funding for upscaling, investment support, and for R&D (but skepticism towards state-aid) • Other economic instruments, including credits and risk-sharing instruments. • Infrastructure support and support for value chain flows and value networks. • Removal of regulations hindering CE growth
Size of public investment in CE	• More extensive public investements in CE are needed, through introducing or expanding policy instruments. New institutions are also proposed: • A public-private collaboration for sectoral roadmaps, modelled on Fossilfree Sweden • A new funding programme: "Circular Leap " • A national investment bank and/or investment fund
Horisontal or vertical policies	Both horisontal and vertical policies are needed. Policies should generally be open to all, but targeted sectoral-specific policies are necessary for technological development.
Sectoral policy focus	• Sector prioritisation can be based on i.e., level of GHG emissions, current levels of waste, or existence of particularly unsustainable practices. • Support for new technology is needed.

	• Ensure support for new actors/SME's, and for "Valley of Death" business phase. • Ensure support for "inner CE circles", such as sharing.
Value chain focus	• Upstreams policy support needed: design and raw materials processing. • Need to support recycling systems • Need to support logistics and materials flows via value chain interventions.
Policies for "inner CE circles"	• Taxation and VAT should be used to promote reuse, repair, product/service shift etc. • Reuse has larger potential in Sweden than remanufacturing. Views of environmental gains from repair policies compared to other CE policies diverge.
Criteria for policy design	
Prioritisation and criteria for policy design	• Environmental impact is the main criteria for policy prioritisation. • Alignment with EU frameworks. • Other criteria include: based on identified barriers, market creation effect, long-term conditions, measurability, comparative advantages, upscaling potential, needs of new actors, security of supply, avoidance of dependence, acceptability of policy.
Criteria for termination of support measure	When the supported company can hold its own, or when business idea turns out to be not viable.
Strategy and policy mix	
Assessment of Sweden's CE Strategy	Varying opinions: many interviewees see need for much development of both national CE Strategy and Action Plan.
Need for national CE target	Varying views on need for national CE target(s). Opinions range from that CE targets are necessary, to a preference for joint EU targets. There is a significant need for statistics and indicators on CE and RE. However, measurability is a challenge.
Coordination between policies	Closer coordination between climate, CE and other environmental policies is needed.
Trade-offs	There are many trade-offs between opportunities and risks in an industrial policy for CE. • Most trade-offs arise from conflicting economic, social or environmental objectives. • Circularity in itself does not equal resource-efficient. • Certain trade-offs arise from potentially toxic materials, affecting recycling.
Other questions	
Alignment with EU frameworks	Alignment with EU srategies and regulations is needed to create policy synergies and to avoid policy conflicts.
Lack of knowledge on CE	• The CE concept is seen as vague, and knowledge is lacking. • Need for knowledge and capacity-building in industry and government. • Broaden university education on CE.

5. Discussion

The discussion will provide answers to the thesis' research questions, placing them in perspective of earlier research and the current policy landscape and policy debate. It will also provide suggestions for key elements of a new Swedish industrial policy for CE. Finally, it will reflect on the methodology, and outline thoughts on needs for future research.

5.1. Answering the research questions

Based on the overall research question "How can a Swedish industrial policy for circular economy be formulated?", four specific research questions were formulated.

RQ1: What policy instruments are currently functioning as, or could function as, industrial policy for circular economy?

Today, only a small number of actual policies could be identified as industrial policy for CE in this fledgling policy field. This was described in chapter 3.4, with a full list of identified existing policies in Annex 4, Table 7. Most such policies are part of policy packages with other purposes, mainly green industrial policy, green innovation policy and CE policy, and could therefore be seen as "free-riders" to policies with other objectives. Most of the identified policies are recycling-related, and many are implemented by means of funding programmes. Financial IP instruments such as credit guarantees are also increasingly including CE objectives.

However, both literature and interviews provide a multitude of policies which could function as industrial policy for CE. These are described in chapter 3.4, with a full list in Table 8. While interview responses varied in terms of appropriate points of intervention in the value cycles, many focused on recycling and recycled materials. The reasons are probably manyfold. The literature concludes that recycling has been the predominant target in CE policy (i.e., Chioatto et al, 2023). Another explanation is the respondents' shifting backgrounds and experiences of CE. A third reason is probably differing definitions of CE.

When understanding the tendency to define CE mainly as recycling, the other side of this coin is awareness of the substantial attention gaps and policy gaps regarding the full range of CE aspects. This was confirmed by both the interviews and the literature review: there is insufficient policy attention to the "inner CE circles" and the prioritization following from the waste hierarchy, despite these being cornerstones of CE logic. Therefore, there is untapped policy potential in support for CBMs such as PaaS, sharing economy, repair etc. Other policy gaps, with large potential as industrial policy for CE, are using the full potential of economic instruments, capacity-building, and education, developing infrastructure such as testbeds, and extending funding opportunities in new or existing programmes.

While there are large policy gaps, right now, the public debate also sees a rapid increase in interest in circular industrial transition, and policies which can support it. This is triggered by the overall growing interest in green policies in general and CE policies in particular (Swedish Enterprise, 2022; Flack et al, 2023), but also a revival for green industrial policy (EPA & Energy Agency, 2022). CE policy is currently developing rapidly (i.e., Ministry of Finance, 2022a; Delegation CE, 2023), and green industrial policy is driven forward by both the climate transition (Tillväxtanalys, 2022; Fossil Free Sweden, 2021) and by international political developments (EC, 2023a; White House, 2023).

The interviews as well as the literature (ch.3.4) proved the multitude of potential policies, identified, and suggested by researchers or by policy practitioners, which are, or could be defined as, industrial policy for CE to fill these policy gaps (Annex 5, Table 8).

Considering the urgency to move towards more resource-efficient and circular production and consumption systems, this upsurge in interest should be used – the timing seems ripe for developing policies to support circular industrial transition. Not the least, this was confirmed by the interest shown by the experts interviewed for this thesis.

Concerning the policies proposed in interviews and in literature, there is noticeable overlap, probably reflecting those policy field exchanges that usually take place between academia and expert professionals to mutually inform policy development and policy research. So even if the academic and grey literature only provide scattered indications towards an understanding of industrial policy for CE, on the other hand, it provides good evidence on interview topics related *either* to CE policy or to green IP (ch.3.2 and 3.3). However, the interviews also provided policy proposals not already identified in literature: specific financial instruments to support PaaS business models, using regional policy instruments in support of CBM, and overall broadening of CE university education. Interviewees have a larger focus on public funding programmes than the literature, which is not surprising, since these reflect the Swedish innovation policy landscape, featuring a multitude of innovation instruments and programmes. The specific proposal for funding for the "Valley of death" is such an idea that reflects the Swedish funding landscape and the current debate (Sjögren, 2022).

RQ2: What industrial policy mix and policy instruments should be used, and what industry sectors are appropriate to target, in the development of a Swedish circular economy industrial policy?

The actual industrial policy landscape for CE is a relatively white map (ch.3.4), and this was reflected in the widely varying responses of the respondents. Many of the proposed policies were not IP, but administrative and regulatory instruments, but this could be expected. Responses are also marked by diverging ideological views on industry policy in general, with a markedly higher scepticism among the private sector. This was also to be expected, because of Swedish historical experiences of IP and the current polarisations in the media debate on green IP (see f.ex Henrekson et al, 2023).

The respondents generally had extensive and detailed insights into barriers for circular transition, and both the type and amount of barriers could be confirmed by literature (described in ch.3.2.2 and listed in Annex 3, Table 6). The primary barrier was a classic market failure (Rodrik, 2014), i.e., incorrect pricing of virgin respective recycled raw materials. Several barriers are nevertheless rarely on the political agenda, both systemic barriers such as existing linear economy and legislation, and lack of statistics and indicators, to logistical barriers relating to material flows in the value chain. An interesting insight is the economic power shifts and altered landscape of business actors that a CE will bring – this is probably a strong barrier.

Not perhaps surprisingly, the key question – is there a need for a Swedish industrial policy for CE? - received varying replies, even though the majority replied yes. Two interesting points can be made here: First, even though many respondents from industry expressed some hesitancy on this point, all wanted larger public investments in CE. Second, considering that much of today's Swedish green IP in fact falls under the green innovation policy umbrella, it would be interesting to instead ask the question "Is there a need for a Swedish innovation policy for CE?", and compare the replies.

The interviews provided a large number of policy proposals, but sometimes these were relatively vague regarding the scope and design of specific policies for industrial circular transition. This is likely because of lacking existing policy and the relatively limited public debate on CE compared to the public debate on climate.

As was clear from the interviews, the respondents also diverged in their definitions of CE. Several respondents raised issues relating to the varying definitions and perceptions of the CE concept. Regrettably, these issues spill over into complexities regarding CE policy design. As one interviewee put it: *"CE policy is about finding solutions to something not well defined"*.

The suggested policy type with the largest potential was economic and financial policies, mainly taxation, VAT and various subsidies, which is in line with the literature on IP instruments (ch.3.3.3). Interestingly, the most supported taxation policy, green tax shifting, has been on Swedish policy-makers agenda for long, but with little result (Henriksson, 2020). The same could apply to the most supported VAT policy, differentiated VAT, since, paradoxically, the only Swedish CE-specific VAT policy, the reduced VAT on repair, has recently been raised again (Ministry of Finance, 2022b). Considering the importance of economic instruments, the work of the new Swedish Committee on economic instruments for CE (Ministry of Finance, 2022a) will be highly interesting, even while taxation policy is not included in the commission mandate. In light of these complications regarding taxation policymaking, it is important to notice the ongoing policy shift in both EU and the USA towards more IP subsidies (EC, 2023a; Stolton, 2023b; Laurent, 2023), indicating higher acceptability of this policy type (cf. Nilsson et al, 2021; Cosbey et al, 2017). Other policies called for by the interviewees, such as supportive and capacity-building policies, are reflected in the literature regarding the state's role to facilitate knowledge spillover, or to correct systemic weaknesses, such as lack of connection between actors in a system (Söderholm & Frishammar, 2018).

As industrial policy for CE combines the promoting objective of IP and the sustainability objective of CE policy, the comparative advantages of Swedish industry should be promoted. Several of the sectors that the interviewees want to focus on – mining and critical raw materials, steel, clean-tech, forestry and high-tech manufacturing – are also prioritised in relevant public strategies (EPA & Energy Agency, 2022; Energy Agency, 2022). Likewise, the prioritized recycling sectors – mainly textiles, plastics, and ICT/electronics – are also reflected in existing policy (Government, 2021).

Lack of CE knowledge was a theme raised by several respondents. The lower awareness about the "inner CE circles", and the subsequent tendency to focus on recycling, is probably a result of this. But this might also be caused by the commercial value potential, which might be lower within reuse, repair, and remanufacturing. It might also result from barriers such as product/service-shifts or lock-ins in old systems.

What can be concluded from this lack of knowledge? Firstly, that agenda-setting is needed. Political visions need to be clear, but also aligned with industry's needs. Secondly, there is a need to bring forward additional CE strategies besides recycling. Thirdly, more CE knowledge is needed overall: in industry, in government, within academia, for statistics, etc. Government need CE knowledge for developing policies supporting the circular transition, and education on CE needs to be broadened, since CE skills are needed in industry. Fourthly, the CE concept needs to be clarified to facilitate marketing in circular industry.

RQ3: How should such policy instruments be prioritised and on what criteria?

There was consensus on the primary policy criteria – the environmental impact of the targeted activity and the environmental benefits achievable by addressing it. Even though there was no clear consensus on other criteria, the responses provide a relevant picture of factors to consider in policy design.

Surprisingly, policy support targeting high levels in the waste hierarchy only came up once in the interviews. Most likely connected to the strong connection of CE with recycling, i.e the last step in the waste hierarchy. But a policy targeting CE should per definition aim as high as possible in the waste hierarchy, so the results on this issue underlines the need for education and knowledge dissemination on CE

The need to design policies in alignment with EU was a clear requirement from industry respondents, both in relation to EU legislation, trade and state-aid rules. The forthcoming EU Taxonomy will be particularly important for policy design, since … will allow transparent criteria for investment purposes, and thus facilitate steering and prioritising industrial policy. In that respect, the Taxonomy will facilitate the financing of green transition through helping scale up green investments, but it will also be important for companies seeking to prove their green credentials. There are additional reasons why the Taxonomy might play a significant role. While the finance sector plays a fundamental role in industrial transition, it is generally "lagging behind" regarding CE and green growth, thus constituting a significant barrier. The Taxonomy might contribute to overcoming this. The explicit inclusion of CE in the Taxonomy is also important. Importantly, while the large EU Innovation Fund only covers decarbonisation/climate-related projects, the EU Taxonomy might give an indication of a future where EU in forthcoming funding schemes will also finance CE solutions.

Setting policies usually involves deciding targets and goals before-hand. Currently, CE is a policy field without corresponding national or EU targets. It was expected that respondents had varying views on whether specific CE targets are needed, but the main take-home message was the need for alignment with EU, even if one or several national CE targets could be merged in the existing Swedish national environmental targets system. Decisions on policy criteria, particularly environmental impact, also require relevant indicators, and the interviews shed light on the lack of CE-relevant data and statistics. Even though new statistics and indicators are currently being developed, it should be ensured that new CE indicators framework to support circular transition are broad and go beyond recycling.

RQ4: What would be the key elements of a Swedish industrial policy for CE?

To answer this question requires some reasoning, since it cannot be deducted directly from the interviews, but requires motivations based on different considerations, used as a lens through which interview findings are regarded. The first set of considerations stem from interview and research findings on prerequisites for successful policy design, as well as relevant criteria for in industrial policy for CE. The main identified policy criteria were environmental impact, and fundamental motivations for IP were market failures and market creation. Another common thread in the interviews were the vagueness of the CE concept, highlighting the need for any successful CE policy to build on knowledge-building, but also increased measurability, development of statistics and indicators, and political visions and target-setting. It would also be relevant to consider the feasibility of the suggested policies, in terms of administrative conditions but also the dynamics with existing policies, and the relative support and acceptance for specific policies. The last aspect is emphasised in the interviews: policy measures have better outcomes if they enjoy high acceptability; but also in the literature: public buy-in and sensitivity to socio-economic implications is essential (Cosbey et al, 2017; Nilsson et al, 2021). In this respect, it is also necessary to consider the diverging views on a possible industrial policy for CE.

The second set of considerations stem from the need to shape Swedish policy in alignment with EU policies, and the need for coordination with other environmental policies, which were themes emphasised in the interviews. New Swedish policies will have to be coordinated with existing environmental and industrial policies, allowing mutually strengthening policy dynamics and avoiding conflicting policies. Furthermore, they should build on upcoming EU and Swedish policy initiatives, such as new Swedish CE initiatives, including new economic policy instruments, and EU initiatives such as the Green Deal Industrial Plan, the Taxonomy, and the revised state-aid framework. In respect to this, importance should be attached not only to creating new instruments, but to maximising benefits from existing instruments.

In conclusion, the policy recommendations below are formulated based on support in the expert interviews, on potential impact in relation to status quo, feasibility, and acceptability, as well as connection to existing and forthcoming policies:

5.1.1. Recommendations

- Increase **differentiation in VAT and taxation**. Pricing is the most fundamental barrier, whether it concerns virgin raw materials vs recycled, costs of new products vs repair costs, etc, and therefore needs addressing. The specific proposal with the largest potential outcome in this respect, is probably to give the Governmental Committee on economic instruments a revised mandate, including taxation policies.
- Consider additional **green tax shifting**. Despite the political obstacles green tax shifting has met earlier, it should be placed on the political agenda, because of the large potential impact, and the broad support this policy instrument enjoys among experts.
- Address the financial and legal barriers hindering companies from upscaling **PaaS business models**.
- **Upscaling of funding** is necessary both as a driver of circular transition, and in light of the current international policy shift to increase subsidies. Implementing this requires considering how impact is best achieved. There are existing funding programmes, opportunities for credit guarantees etc, even

if mandates of existing funding programmes should be expanded to clearly include CE objectives. In addition, higher visibility and inspiration is needed to encourage uptake of CBM, and such visibility can be achieved through creation of new policy instruments or institutions, such as the proposed Circular Leap programme, a specific CE investment fund, etc. Funding must also be adapted to suit SMEs in terms of funding model and co-funding requirements.

- Set up a **public-private collaboration** modelled on Fossil Free Sweden. This organisational model has proved successful in creating collaboration and momentum, resulting in concrete sectoral roadmaps, driven by industry.
- Develop **policies targeting other CE cycles** than recycling. CE logic and the waste hierarchy underlines the importance of keeping as much value as possible. As much current CE policy targets recycling, additional policies targeting reuse, sharing, repair and remanufacturing are needed.
- Encourage improved use of **EU funding** opportunities. The literature showed that Swedish companies have relatively low uptake of IPCEI funding opportunities, while they have been successful in attracting EIF funding. Considering the speed and scope of EU development within green industrial policy, mobilisation for improved Swedish uptake is needed.
- Ensure **knowledge and capacity-building** within CE. This is needed both in industry and within public administration. Build up specific university CE education and strengthen CE-related curricula in relevant programmes.
- **Develop the Swedish CE Strategy** regarding ambition, scope and milestones planning. The Finnish CE Strategy can serve as inspiration. Ensure coordination of CE policies with climate and biodiversity policies, including green industrial policies.
- Consider setting a specific **national CE target**, in alignment with EU frameworks. Develop appropriate **indicators**.
- Consumer policies are not addressed in this thesis but play a fundamental role in addressing demand and consumer behaviour.

5.2. Reflection on methodology

The answering of the project's research questions needed to consider the lack of research on industrial policy for CE, and the large gaps in actual policy in this field, necessitating an explorative approach. The interviews and the analysis were also affected by several basic characteristics of the studied policies – the multitude of definitions of CE, the highly politicised character of industrial policy – which are complicating the analysis of the results. One conclusion from the interviews was the varying definitions of both CE and IP held by the interviewees, something which affected the analysis. However, these aspects are not necessarily drawbacks, because as Stebbins (2001) emphasizes, in exploratory research, it essential to not lose the whole picture and the original ideas brought to light among detailed data, so keeping a relatively high level of abstraction fitted well with this approach. Importantly, the method of exploration develops across several studies, and not only within a specific study (id). Considering this overall picture, the results are satisfactory, and provide an overall image of relevant aspects.

While the topic of the research project is vast, it could be approached in several ways. Several delimitations were done, and the analysis would likely have benefitted from more in-depth environmental data as base for policy prioritisation, and more in-depth analysis of Swedish industry. But with the topic's scope, the project would probably benefit from a larger format, allowing for better use of the interviews and the many relevant topics raised in these. Alternatively, the study could have been delimited to one industry sector.

5.3. Future research

As an explorative study on a topic where practically no research exists, further studies on the same topic is needed in order to strengthen and develop understanding of the research field. This would be particularly relevant considering the high activity within policy development and public debate in the policy field.

Additional research topics where more knowledge is needed and that were brought to light in this project work include how to develop indicators on environmental impact as criteria for CE policy, improving understanding of how to better integrate CE policy with climate/green policy, and how to handle occurring tradeoffs. It would also be relevant to examine how should industrial should policy be designed to support CBM for the "inner CE circles", and more knowledge is also needed on what types of changes to current linear economic, regulatory and administrative systems would bring the most benefits to promote CBM.

6. Conclusions

This thesis has contributed with initial and exploratory findings in a research field where there is practically no existing research, and in a policy field with very few existing policies. The precondition for the research project was that industrial policy for Circular Economy is needed to support the circular industrial transition, and the findings from the conducted expert interviews point in the same direction, i.e., that the development of such public policies will be necessary. While many findings from the interviews in this thesis are supported by literature, the thesis has contributed with a general overview of this policy field.

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The writing of this thesis has been a great adventure. Being able to deep-dive into a research topic on which there is practically no existing research has been a challenge, but a truly inspiring and rewarding challenge.

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Annex 1: Interview guide

Obstacles and potential for circular transition in industry:

• What obstacles exist today for a circular transition in Swedish industry?

• What barriers exist to scaling up existing circular business models?

• In which sectors there is potential for circular business models? In which processes? In which steps in the value chain?

• Where is there less potential, due to market conditions or high barriers?

Industrial policy for circular economy – general questions:

• What is your general attitude towards green industrial policy in Sweden (e.g. positive/negative/uncertain)? Why?

• Do you think a Swedish industrial policy for circular economy is needed? Why or why not? • What opportunities could such an industrial policy create in terms of benefits or scaling up of circular economy?

• What risks or other negative effects do you see with such a policy?

Industrial policy for circular economy – policy instruments, sectors and value chains:

• Industrial policy instruments can include various measures, such as: upscaling of new technologies, state aid, investment support, credit guarantees, subsidies for new circular business models, tax reductions/tax shifting, circular public procurement, investments in infrastructure. Which of these do you consider most and least relevant?

• Today, there is state funding of small-scale CE initiatives. Is this enough or do we need larger state investments in CE?

• Policy measures can be horizontal /general or vertical/sector-specific? Which do you think would have the largest impact?

• Which industrial sectors do you think state aid should focus on?

• Which steps in the value chain should be focused on?

• Which policy measures have potential for promoteion of the "inner CE circles", i.e. sharing economy, reuse, repair, refurbishment and remanufacturing?

Industrial policy for circular economy - criteria for policy selection:

• How would you prioritize policy measures in a Swedish industrial policy for circular economy?

• What criteria would the policy selection be based on? Examples of criteria: environmental impact, scaling potential, technical risks and market risks, commercial or economic potential, cost/benefit analysis, or strategic resource availability.

• What criteria should be used to terminate a support measure?

Strategy and policy mix:

• Do you think Sweden's current CE Strategy and Action Plan are appropriate, or do they need to be developed?

• Are national CE goals needed?

• How should CE industrial policy measures be coordinated with industrial policy for climate transition?

• What trade-offs between opportunities and risks do you see decision-makers needing to make in policy mix decision-making?

Other questions:

• Is there anything else you think I should ask about? Do you have anything to add?

• Do you have any suggestions for other people to interview?

Annex 2: Barriers to a Circular Economy

Table 6. Barriers to a Circular Economy
The barriers identified in literature are summarised in chapter 3.2.2. and listed here. Barriers are drawn from Mont et al. (2017), Milios (2016), Kirchheer (2017b), POLFREE (2017), Hansen et al. (2021), Lindahl & Dalhammar (2022), Domenech (2019), Flack et al. (2023), OECD (2022), Svensson-Höglund et al. (2021), DG GROW (2022), Tillväxtanalys (2022a), EC (2020), EPA (2021), and IRP (2019).
The barriers identified in the expert interviews are summarized in chapter 4.1, and listed in full in the right-hand column, to allow comparisons between findings from literature and from interview.
Framework for barrier categories based on and adapted from Mont et al. (2017), Milios (2016), and Kirchherr (2017).

Type of barrier	Barriers identified in literature	Barriers identified in interviews
Regulatory barriers:	• Lack of policies and regulation – is in itself a barrier, because voluntary initiatives are insufficient (Kirchherr, 2017a); • Existing linear economic system: laws influenced by linear thinking (Lindahl & Dalhammar, 2022) • Public policies (sectorized) into economic and environmental bring conflicts of interests and competing societal goals (Domenech, 2019) • Lack of incentives for sustainable production (EU-COM, 2020) • Lack of incentives for resource-efficient product design and design for reuse and recyclability (EPA, 2021) • Lack of incentives for production for future value preservation (EU-COM) • Lack of incentives for using recycled materials • Regulatory lock-in effects (Flack et al, 2023) – ex construction sector use no secondary material because classified as waste • Hindering legislation (Flack)	• Lack of economic policy instruments • Legislation made for linear economy, not suited for circular • Laws and rules build on linear • EU definition of CE: legislation adapted to linear economy • Difficult to regulate nationally – important to not get into conflicts with f ex EU politics • Currently no product passport • Public procurement under-used • Laws/policies for f ex company cars • Guarantee legislation for remanufactured products • Heavy reporting requirements. • Lack of established targets • Lack of measurements • Lack of indicators • ICT systems, accounting, business systems, legal, insurance, rules and regulations packages – all is built on linear economy • Legislation - ex classification as waste make use of secondary resources impossible • Many regulatory barriers

Market barriers and market weaknesses:	• Linear economy markets and value chains • Biaises in investments and consumption (OECD, 2018) • Consumer behaviour (Flack, 2023) – bc insufficient incentives for sustainability • Differing definitions: unclear for consumer, • Cheap resources and materials (IRP, 2019), mispricing of resources/underpriced externalities (OECD, 2022) • Subsidies for extractive sectors (OECD, 2022) • Market failures/polluter does not pay (IRP, 2019) • Market failures: Virgin raw materials often cheaper than recycled materials (check source Material Economics) • Cost of virgin raw materials do not reflect their full environmental impact • Generally lower envir impact from recycled materials – but often more expensive (Material Economics) • Insufficient incentives for sustainability • Lack of incentives for sustainable production (EU-COM) • Connected to above: product-related externalities not sufficiently internalised • Lack of incentives for resource-efficient product design and design for reuse and recyclability (EPA, 2021) • Lack of incentives for production for future value preservation (EU-COM) • Lack of incentives for using recycled materials • Lack of infrastructure for distribution/collection/ etc for re-use (EPA, 2021) • (Financial incentives hindering repair) • Producers can create financial incentives hindering repair by limiting access to spare parts, tools and information for independent repairers, vilket hänvisar consumers to auktoriserade, often expensive, repairers (other source than Svensson-Höglund et al, 2021; DG GROW, 2022). • Lack of recycled raw materials (Flack, 2023) • Planned obsolescence– through (imagined) obsolescence, ie. upgraded products and innovations giving the consumer the impression that his/her product is undermålig, or real obsolescence through low product (hållbarhet) and repairability (DG GROW, 2021; Svensson-Höglund et al, 2021) • Design hindering repairability and upgrading (DG GROW, 2021; Svensson-Höglund et al, 2021).	• Transition to CE implies economic power shifting, altering companies position in marketplace • Fundamental market conditions: environmental taxes, internal market trade barriers • Potentially very large transition ahead • Price difference virgin raw materials and secondary materials • Pricing of virgin raw materials: too cheap • Virgin materials cheaper than recycled • Recycled/green raw materials more expensive • Difficult compete with linear • Value of recycled mtrl too low • Value of recycled mtrl too low (and diff to recycle complex products). • Virgin plastics too cheap (and technical complexities with recycling) • Lack of recycled resources • Assymetrical market - demand higher than supply • Lack of quality recycled materials • Critical raw materials - small amount - barrier for scaling up • Volumes and quantity are barriers for CBM • Finance sector lagging behind. But taxonomy + due diligence • Lack of demand • Lacking incentives for manufacturers to design for recycling • Lack of incentives • Trade • Access to circular products • ICT systems, accounting, business systems, legal, insurance, rules and regulations packages – all is built on linear economy • Risk competition for resources, ex forest-based mtrls • Global trade structure – complicates reuse and recycling - cheap production labour, expensive repair/remanufacturing labour
Technological barriers:	• Product design (IRP) • Technological and production factors (Tillväxtanalys, 2022a) • More complex products – hinders recycling (Tillväxtanalys, 2022a)	• Lock-ins • Technical complexities with f ex plastics • Technological development - diff to recycle, ex metals • Difficult to recycle complex products
Financial and economic barriers:	• Focus on labour productivity, not materials productivity (IRP)	• Barriers for new investments – high risks, high costs • Lock-ins

	• Current linear financial and accounting systems at odds with accounting for circular output (Fischer, et al, 2023) • High costs (Flack)	• PaaS/renting => company becomes a bank (financially costly). • Many economic barriers
Business models barriers:	• Business models (IRP, 2019) • Product design (IRP, 2019)	• Benefits of CE for industry are unclear • CBM unclear – how to organise business flows • Built-in life-time: a product has to be designed so all components break simultaneously. • PaaS/renting => company becomes a bank (financially costly). • Remanufactured products - guarantee legislation • Unclear definition of circularity: difficult to market products as circular (EU taxonomy will facilitate). • Volumes and quantity are barriers for CB
Value chain related barriers:	• Transaction costs – value chains (OECD, 2018) • Trade policies restricting cross-border (OECD, 2018) • Lack of value chain collaboration (Flack, 2023) • Barriers towards CBM, incl PSS, bc fragmented incentives along the value chains – disincentivizes towards future value-retention (EC, 2020)	• Collection systems not sufficient • Agreements along value chains lacking • Logistics/value chains – ex barriers for remanufacturing • CBM unclear – how to organise business flows • Lack of logistical flows for recycled materials • Global trade structure – complicates reuse and recycling - cheap production labour, expensive repair/remanufact labour • Upstreams
Informational/knowledge barriers:	• Risks and uncertainties	• Climate higher prio than resources • Lack of knowledge of CE • Information: large challenges • Unclear definition of circularity: difficult to market products as circular (EU taxonomy will facilitate). • Benefits of CE for industry are unclear • Benefits of CE for society are unclear • Info on materials and recycling • Potentially very large transition ahead • "fat and happy" - low risk awareness. Large wave of EU policy initiatives.
Social/customer related barriers:		• Benefits of CE for society are unclear • Lack of interest • Public procurement under-used • Behaviours • Collection systems not sufficient, steered by habits etc • Lack of knowledge – ex within public procurement • Swedish consumers are picky • "fat and happy" - low risk awareness.
Organisational barriers:		• Benefits of CE for industry are unclear • Lack of interest • Behaviours

		• "fat and happy" - low risk awarenes • Lack of platform - Sw Confed of Ent not driving - mobilisation needed. Risk competition for resources, ex forest-based mtrls

Annex 3: Existing industrial policies targeting Circular Economy

Table 7. Existing industrial policies targeting circular economy
Policy framework adapted from Mont & Dalhammar (2005) and Milios (2020).
N.B. Several of these policies are under development, and are not yet implemented, particularly those included in the Swedish National Strategy for CE (Government, 2020).

Type of policy instrument	Policy instrument	Responsible actor or legislature
Administrative & regulatory	Circular public procurement	Sweden and other countries
	Policy instruments contributing to CBM – unspecified (Government, 2020)	Sweden
	More efficient environmental permit processes to facilitate sustainable production (id)	Sweden
	Policy instruments increasing supply and demand of circular products, services and recycled materials – unspecificed (id)	Sweden
	Trade in waste: “green listed wastes” have exemptions under European Waste Shipment Regulation (Hartley, 2020)	EU
Economic & financial		
	Reduction of VAT on repair services	Sweden
	Public funding programmes, funding CE or RE related R&D, technology development, pilot and demonstration projects, and CBM development Ex: Industry Leap Energy programmes Climate Leap Transition Leap (Tillväxtanalys, 2019)	 Energy Agency Energy Agency EPA
	Strategic Innovation Programme Re:Source	Sweden
	Credit guarantees (Riksgälden, 2021)	Swedish National Debt Office
	Export guarantees Programme Export Leap (source)	Swedish Export Credit
	Green export credits (EKN, 2023)	Swedish Export Credit
	Green credit market (Government, 2021)	Sweden

	A green finance market – unspecified (Government, 2020)	
	Policy instruments contributing to CBM – unspecified (id)	Sweden
	Policy instruments increasing supply and demand of circular products, services and recycled materials – unspecificed (id)	Sweden
	Support for R&D and technology development within recycling, digitalization, traceability, etc (id)	Sweden
Informative		
	Circular transition and CE counselling (RISE, n.d.)	RISE, and other actors, Sweden
Support mechanisms & capacity-building	Support in value networks and value chains, including industrial symbiosis (Södergren & Palm, 2021)	
	Support for R&D and technology development within recycling, digitalization, traceability, etc (Government, 2020)	Public agencies
	Strengthening of innovation and business climate to scale up circular business (Government, 2020)	Sweden
	End-of-waste criteria for construction and demolition waste, allowing use of secondary construction material (Flack et al, 2023)	Some EU countries
	Circular trading platform Quaero (fmr) – government -run (Hartley, 2020) Govt funding support for private platform, Circle Market (Hartley, 2020)	France Netherlands
	Eco-Industrial Parks (id): Tianjin Eco-city, Kalundborg	China, Denmark, etc
	Global material flow accounting database, UN Environment IRP Global Materials Flows Database (id)	UN

Annex 4: Proposed industrial policies targeting Circular Economy

Table 8. Potential industrial policy instruments for Circular Economy

Policy proposals identified in literature are described in chapter 3.4, and listed in full here.
Policy proposals made by the interviewed experts are described in chapter 4.3, and listed in full here.
Tabled based on own framework, with categorisation elements adapted from Mont & Dalhammar 2005, and Milios 2020.

Explanatory note: Support by interviewees

++	Strong support, several interviewees propose, no opposition
+	Medium support, at least two interviewees make proposal
?	Diverging views, with both support and principled opposition from a number of interviewees
#	Not industrial policy per se, but listed because propose in interviews

	Addressing	POLICY PROPOSALS IN LITERATURE	POLICY PROPOSALS IN INTERVIEWS	Support by interviewees	Actor responsible
ADMINISTRATIVE & REGULATORY **Public procurement**	Market-creation	Circular procurement (Steen et al, 2022; Hartley et al, 2019; Delegation CE 2021b) Green public procurement (EPA, 2021; Fossilfritt, 2022; OECD, 2022) Platform for collaboration within circular procurement (Delegation CE 2021b)	Circular public procurement	++	Regions, municipalities, state agencies
Legislation	Resource supply, market creation	Clarify classification of biproducts and waste in construction industry (Delegation CE, 2021a)	Classification waste/resources: allow more resources Avoid classification as waste to allow use of secondary resources	++ ++	
		Reduced regulations on trading and using waste (where not compromising other policy goals) (Hartley et al, 2019)	Simplify waste export		
			Remove municipalities' monopoly on waste	+	
			Adapt relevant legislation for sharing economy, ex insurance legislation		
Product regulations		Promote supply of circular products – supply-push measures (OECD, 2022) through f ex targeted R&D funding (and eco-design standards, extended EPR #)	Standards for CE labelling # Electronics – product regulation #		
	Market-creation	Promote demand for circular products – "demand-pull measures" (OECD, 2022) (ex recycled content mandates, product labelling standards)	Quotas on recycled material content # Quotas on recycled plastics # Design requirements on material content mix #	+ +	

		Minimum requirements on recycled content (Steen et al, 2022).	Fewer types of plastics # Standards for plastics #		
			Legal adaptations for PaaS	++	
			Legislation critical raw materials #		
			EU legislation on CE #	+	
			Guarantee legislation on remanufactured products #		
			Product legislation differentiating products with recycled content #		
Institutions		Credits Guarantee Board for RE (Delegation CE, 2020)			
ECONOMIC & FINANCIAL	Market failures, market creation	Raw material tax on virgin raw materials (Milios, 2021)	Pricing mechanisms virgin/recycled raw materials, incl higher tax on virgin raw materials		
Taxation	Market failures	CE-specific taxes (Hartley et al, 2019)	Green tax shifting: lower tax on labour, higher on environmental damage or resource use	++	
	CBM barriers, incentivising longer product life		Taxation facilitating PaaS BM	++	
	Market failures, market creation	Reduction of corporate taxes for firms engaging in CE-related behaviours (Hartley et al, 2019) Waste hierarchy tax (Milios, 2021)	Reductions in taxation or social security contributions for recycled resources, recycled components, or remanufacturing	++	
			Tax policies for reuse, reparation		

			Remove tax on waste		
			Increase mineral levies		
			Reduced chemicals tax for reused small electronics		
VAT	Market failures, market creation	Differentiated VAT rates (OECD, 2022) Differentiated VAT for recycled material (delegation CE, 2021a) Lower VAT for reused products and those having a certain percentage of recycled content (Hartley et al, 2019; Delegation CE 2021b) Reduced VAT on second-hand and repair (Delegation CE, 2021a; Steen et al, 2022; Milios, 2021) Increased VAT for linear products (Hartley et al, 2019)	Differentiated VAT: Reduced VAT on repair Reduced VAT on sharing economy No VAT on reused components/spare parts No VAT on second-hand Reduced VAT on reuse Reduced VAT on recycled	++ ++ +	
Support programmes incl funding and state-aid		Create a “Circular Leap” (Delegation CE, 2020) Support development of new technology for recycling of nutrients (Delegation CE, 2021a) Support upscaling of textile recycling (Delegation CE, 2021a)	• Create a “Circular Leap” • Expand “Industry Leap” (Industriklivet), or create similar initiatives: for pilot and demonstration facilities for upscaling • Expand “Climate Leap” to CE Proposed support focus – Sectors: Plastics and plastics recycling, steel, construction, process industry, small electronics, textile fiber recycling, SME’s Clothes, aluminium, concrete, agrifood, mining waste and critical raw materials, digitalisation, bioeconomy, agriculture, transport	++ ++ + ++ + + ++ +	

			Value chain: early in value chain, design, strategic access to critical resources, recycling resource extraction, traceability, domestic supply chain Proposed sector focus - CE steps: PaaS, servicitisation, reuse, remanufacturing, recycling Repair, chemical recycling Support process innovation	++ + + ++ ++	
		Increased SME funding for circular transition (Delegation CE, 2021b)	SME support Ex with more beneficial funding conditions/less co-funding than Industry Leap	++	
		New policies for market introduction phase (EPA & Energy Agency, 2022)	Public risk investment for "Valley of Death", i.e funding gap between Vinnova-funded pilot phase and bank-supported upscaling/commercialisation	+	
			Use regional policy instruments for CE support through Swedish Agency for Economic and Regional Growth		
Credit guarantees		Credit guarantees (Rodrik 2014; Fossilfritt, 2022)	Credit guarantees	+	Riksgälden, Export Credit Agency
Loans	Incentives?	Loans (Fossilfritt, 2022)	Risk loans		I.e., Industrifonden

		Loans and investing in SME's (id.)			Almi
		Specific loan product for CE (Delegation CE, 2021b)			Almi
Financial institutions		Niche public investment funds for direct investments in early stages (Fossilfritt, 2022, etc) National investment fund for CE (Delegation CE, 2021b)			I.e., Industriklivet Or new institution
		Investment bank National green investment bank (Sustainable Finance Lab, 2022)			New institution
		New credit guarantee board – covering current upscaling funding gap (Delegation CE, 2020)			New institution
Other financial instruments		Funds from sovereign green bonds channelled into green public investments (Sustainable Finance Lab, 2022)			
			Financial instruments to support PaaS BM	+	
		Road-map for sustainable investments (Delegation CE, 2021a)			
			Pricing mechanisms based on externalities	?	
			Repair checks to citizens		
INFORMATIVE	Knowledge diffusion		Business counselling on CE		
		National portal/"tool box" for CE (Delegation CE, 2021b)			
		Global material flow databases (Hartley, 2020)	Facilitate material flows and logistics		

		Promoting online material marketplaces (OECD, 2022)			
		Facilitate development of circular trading platforms (Hartley et al, 2019) Fund-matching and tax breaks for platforms VAT exemptions for sales through platforms			
		National coordination hub for CE design (Delegation CE, 2021a)			
		Develop CE indicators for CPP (Delegation CE, 2021a)	Indicators		
		Certification system for measuring of CE (Delegation CE, 2021a)			
SUPPORT MEASURES & CAPACITY-BUILDING		Improve collaboration within and across value chains (OECD, 2022, EPA 2021) Fostering industrial symbiosis clusters (OECD, 2022)	Public intervention/facilitation along value chains Support logistics chains and materials flows Development of value networks Facilitate logistics for remanufacturing Facilitate logistics for recycled materials ex charge infra for waste trucks	++ ++ +	
		Collection (and information) systems enabling secondary material flows (EPA, 2021) Infrastructure for re-use etc (EPA, 2021) Take-back systems (Steen et al, 2022)	Public support for recycling facilities - broader than today's commercial-only recycling facilities, high-level/complex recycling facilities too low capacity	+	
Infrastructure		Testbeds, innovation projects and R&D for CE design (Delegation CE, 2021c)	Infrastructure for innovation/innovation clusters – linking business and academia	++ ++	

		Testbeds, demonstration of new solutions, knowledge support (EPA, 2021) Eco-industrial parks – use best practice (Hartley, 2020)	Testbeds, real or virtual – for exchanges between academia and industry		
Education & knowledge		Introduce CE design in relevant education programmes (Delegation CE, 2021a)	Strengthen university education in CE – from accounting to technology	+	
		Method development and knowledge (EPA, 2021)	Knowledge dissemination	++	
Knowledge creation		Investigate potential for material efficiency and RE in Swedish industry (EPA & Energy Agency, 2022)			
	Knowledge diffusion	National and regional knowledge nodes (Delegation CE, 2021b)			
		National mapping of resource flows (Delegation CE, 2021a)			
R&D policy		Development of production processes (EPA, 2021)	R&D policy for industries with low R&D levels, or for process innovation	++	
		Material development (EPA, 2021)	R&D policy for product innovation, or for new technologies lacking research, i.e., materials research on recycled materials	+	
		R&D funding for demonstration projects of CE measuring (Delegation CE, 2021a)			
		R&D and pilot projects within traceability (Delegation CE, 2021a)			
		Cross-functional CE support system for SME's (Delegation CE, 2021b)			

		Guidance within national and European support systems (exists) (Fossilfritt, 2022) Matching of companies/projects with financiers (Fossilfritt, 2022)			Within existing actors
	Risks shifted to public sector through industrial support policies	Commission set up by government - responsible for public-private risk sharing (Sustainable Finance Lab, 2022)			Swedish Government
		Infrastructure – including contracts for difference aid (Fossilfritt, 2022)			
Infrastructure support			Infrastructure support for CE investments – ex transportation, electricity Infrastructure as support for industry projects – ex electricity, housing	++	
		Create equal conditions in EU market (Fossilfritt, 2022)			
Political	Decrease market risks and financial risks	Broad political agreements for industrial sectors (Fossilfritt, 2022)			
		A Swedish "Green Deal" (CE Delegation, 2019)			

Annex 5: On the CE concept

Circular Economy logic

Addressing resource use requires looking at production and consumption systems from a holistic perspective. This can be done via several perspectives, primarily Circular Economy, Resource Efficiency, or Sustainable Production and Consumption (SCP), which are similar and overlapping concepts (source). Circular economy is an umbrella term, developed over the past decades (Blomsma & Brennan, 2017), and there is no generally accepted definition (Kirchherr et al, 2017). CE has raised attention since it enables the operationalisation of the more vague concept sustainable development (Ghisellini, 2016), born from the Brundtland report (1987), but it is not until the popularisation of the concept by the Ellen MacArthur Foundation (2013) that is has achieved wider traction. SCP takes a similar approach, aiming to reduce emissions, increase efficiencies and prevent resource waste through material extraction, investment, production, distribution, consumption to waste management (UNEP and EEA, 2007). For both perspectives the need for systemic change is central, encompassing society's production and consumption systems (Bocken, 2016).

Circular economy is contrasted with the current linear economy – the "take-make-dispose" practices (EMF, 2013; Blomsma & Brennan, 2017) - which is dependent on a constant material throughput of resources and products, and where products are seldom used to their full potential (source). The linear economy results in economic pressures, loss of valuable and sometimes finite resources, large amounts of waste, and ultimately destruction of the natural capital upon which it depends (EMF, 2013).

While there is no generally accepted definition of CE (Kirchherr et al, 2017), key CE principles include i) circulate products and materials at their highest value, keeping materials and products in use as long as possible (EMF, 2013); ii) applying a life-cycle perspective, extending lifespan of resources; iii) designing out waste (id.); iv) reduce negative effects of production systems (Milios, 2019).

When implementing CE in industry or public policy, the central strategies are usually referred to as the 3R:s (Blomsma, 2015; Ghisellini, 2016):

- **Reduce** resource use and conserving natural capital;
- **Reuse** – extending lifespan of products and resources through product design, reusing, sharing, repair, refurbishment, and remanufacturing;
- **Recycle** components or raw materials.

Systemic by nature, CE thinking can be applied on all systems levels: on the micro-systems level – addressing product level changes, individual companies and consumers; on the meso-systems level – mainly the regional level, including industrial clusters and urban settings; and on the macro-systems level – encompassing the national and global levels, or overall industry structures (Kirchherr, 2017). However, in practical policy, CE has often been equalled with recycling strategies (Ghisellini, 2016; Milios 2020). But CE focus should be on keeping as high values of materials and products as possible, and as long as possible in the economy. This principle is expressed in the waste hierarchy (Kircheer, 2017, and others).

Circular flows of materials

In a widely cited framework, EMF visualizes the circulation principle and its continuous flows of materials in two main resource cycles, the technical and biological materials (EMF, 2013). In the biological cycle, the nutrients from biodegradable materials are returned to the earth. In the technical cycle, products and materials are kept in circulation through processes such as reuse, repair, remanufacture and recycling. Retaining as high values as possible is central, and it is in the inner loops where most value can be captured because they retain more of the embedded value of a product by keeping it whole. The inner loops should therefore be prioritised above the outer loops that see the product broken down and remade. These loops also represent a cost saving to customers and businesses as they make use of products and materials already in circulation. The outermost loop, recycling, is last resort in a circular economy, because it means losing the embedded value of a product by reducing it to its basic materials (EMF, 2013). The resource cycles are often described in terms of slowing, closing, and narrowing resource loops (Bocken et al, 2016).

A specific case is the bioeconomy, growing in importance for economic and ecological reasons (ex Sw gov, 2022). As the EMF framework considers the bioeconomy to belong in the biological cycle, which can be misleading, bc the technical "R" cycle loops are just as relevant for biobased products and materials (Antikainen et al, 2017).

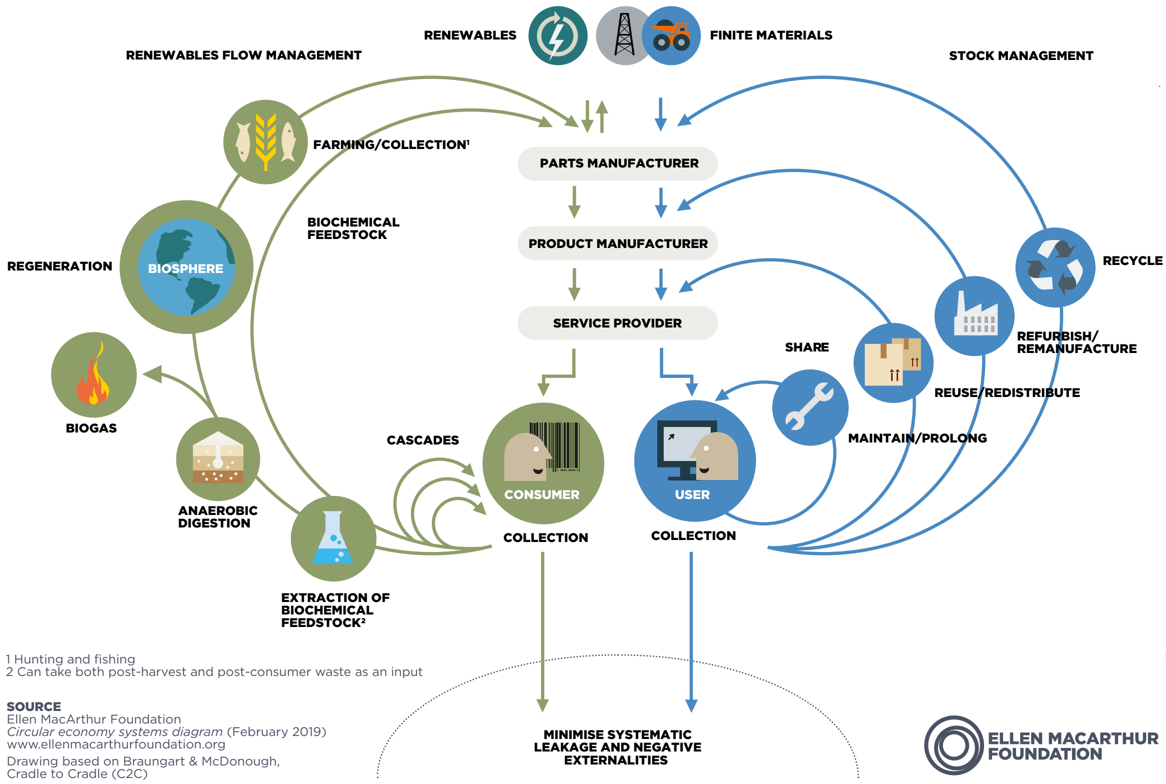

Figure 4. Circular Economy resource cycles.
Circular economy resource cycles of technical and biological resources (Source: EMF, 2013).

Annex 6: On the measurement of environmental footprint

The industrial revolution laid the ground for an economy dependent on extracting finite resources to generate economic value (EMF, 2013). Global resource use has accelerated in parallel with global economic growth and welfare, in a process called the Great Acceleration (Steffen et al, 2015b). During the past 50 years, resource extraction has tripled (IRP, 2019). The accelerating resource use has large consequences in terms of environmental pressures, such as climate change, pollution and loss of biodiversity (CE Delegation, Systems perspective, 2022).

What are resources?

Resources — including land, water, air and materials — are parts of the natural world that can be used in economic activities to produce goods and services. Material resources are biomass (like crops for food, energy and bio- based materials, and wood), fossil fuels (coal, gas and oil), metals (such as iron, aluminium and copper) and non-metallic minerals (mainly sand, gravel etc used for construction) (IRP, 2019). Extraction of resources has increased across the board over the past 50 years. Since 1970, metals increased 380%, non-metallic minerals 400%, fossil fuels 150%, biomass 170%, water withdrawal 60% (appr. figures, IRP, 2019). Global materials use is expected to double until 2060 (OECD, 2018).

Why is resource conservation needed?

Conservation of resources is necessary for several reasons: resource scarcity, economic risks, environmental pressures, and security-related risks.

For most materials used to provide buildings, infrastructure, equipment and products, global stocks are still sufficient to meet anticipated demand, but the environmental impacts of materials production and processing, are rapidly becoming critical (Allwood et al, 2011). Environmental pressures include climate change induced from Co2 emissions from materials extraction, manufacturing, transportation, end-of-life management etc, pollution of air and water from manufacturing, plastic pollution, landfill, etc. Waste generates 20% of human-caused methane emissions (UNEP, 2021)[1]. The transition in the material composition of the global economy towards minerals and non-renewables has changed the nature of our major environmental pressures (IRP, 2019). , But the production rate of renewable materials is limited and the economic cost of producing non-renewable materials is likely to increase with time, particularly if material use continues to increase (Allwood et al, 2013.). Paradoxically, since the ongoing climate transition will depend on electrification as means for decarbonisation, demand for rare earth metals is expected to accelerate, bringing with it both increasing environmental pressures and supply challenges (EPA & Energy Agency, 2022). To some extent, impacts can be ameliorated by existing or improved resource efficiency strategies, but considering the anticipated doubling of resource demand in the next 40 years, the total requirement for resources and materials will have to be reduced (Allwood et al, 2011.).

Many risks are interconnected. Over the past years, vulnerability of global supply chains has, in combination with a global pandemy, the war in Ukraine, and growing concerns over dependencies in raw material supplies, particularly innovation-critical rare earth metals, mostly mined in China, supply insecurities and sharp price rises. (WEF, 2023)

Economic growth during the 20th century has been accompanied by improvements in labour productivity (IRP, 2019), and lately also energy productivity. But the abundance of raw materials has hindered corresponding improvements in material productivity, i.e the efficiency of material use. Today, when environmental impacts and to some extent resource scarcity, are becoming the limiting factors of production – not labour – shifts are required to focus on resource productivity (IRP, 2019).

Environmental and material footprint

Environmental impact from socio-economic activities can be analysed in several ways. The Planetary Boundaries (Steffen et al., 2015) have become a well-known concept, measuring Earth's ecological carrying capacity. Thus the PB provides a science-based global normalisation reference of the risk that human actions will substantially alter the Earth system (Sala et al, 2019). Already today, anthropogenic perturbation levels of five of the ES processes/features (including climate change, biosphere integrity, biogeochemical flows, and land-system change) exceed the proposed PB (Steffen et al, 2015). Of these, climate change and biosphere integrity are recognized as "core" PBs based on their fundamental importance for the Earth system. Recently, new research showed that the PB related to environmental pollutants and other "novel entities", including plastics and chemical pollution, has been exceeded (Persson, et al, 2022).

[1] Methane has been second only to CO2 in driving climate change during the industrial era (Myhre et al. 2013 or other source).

Resource use is the largest single impact sources for biodiversity and climate change, in terms of extraction of primary resources and energy consumption for material production, respectively (IRP, 2019). However, detailed statistics on environmental impact from resource use is only available to certain extent. A relevant picture of Swedish industrial production therefore has to be assembled by drawing from several sources.

Overall environmental footprint of a country's production and consumption is usually evaluated with LCA methodology, differentiating between domestic, production, consumption[2], respective consumer environmental footprint (Sala, et al, 2013). This allows the environmental pressures of a whole economy to be viewed according to two complementary perspectives: a production perspective (i.e. which industries are directly causing environmental pressures), and a consumption perspective (i.e. which consumed products directly and indirectly cause environmental pressures) (EEA, 2013). It should be noted that trade contributes to "outsourcing" of environmental footprints, and that the domestic footprint, which is an internationally established measurement in f ex the UNFCCC climate negotiations, only gives part of the picture. Environmental pressures activated by domestic production can differ significantly from environmental pressures activated by domestic consumption (EEA, 2013). This is particularly important for Sweden and similar countries, where most of consumer products are manufactured abroad (EEA, 2013).

Environmental and material footprint of Swedish industry

Measuring environmental impact from Swedish industrial resource use requires combinations of environmental and economic data, which is assembled in the national environmental accounts (SCB, n.d.a). The statistics include air emissions, energy consumption and waste resulting from industrial sectors, private and public consumption, but it does not include environmental impact from resource use, which is fundamental information for CE policymaking.

Swedish national statistics on CE is focused on recycling and waste. But as CE is a policy area under development, development of new public CE indicators is ongoing both in Sweden and within the EU.

The material footprint is a relevant indicator. Swedish material footprint has increased around 25% during the past decade (SCB, ndc), reflecting both increased domestic biomass, metal and non-metallic mineral extraction (SCB, ndc), and upstreams resource use from global imports (SCB, n.d.d). Waste generation per capita is also increasing with the same rate (SCB, nd.e). When considering the increase in

[2] LCA terminology sometimes differ. The term production is calculated as Domestic environmental footprint + export, to give a basic picture of direct pressures arising from economic sectors and their economic output (EEA, 2013). The term consumption is calculated as Domestic environmental footprint + imports – exports (Sala et al, 2019).

material efficiency, domestic material consumption has in fact grown 40% over the past two decades (SCB, ndf). The driving force behind this is mainly GDP growth (id.), which is in line with (principles) identified in research, such as The Great Acceleration (Steffen et al, 2015b). In conclusion, Swedish resource use continues to grow, despite efforts to promote circularity in production and consumption. But the Swedish environmental footprint is hardly only relevant in international comparison,

Decoupling of resource use from economic growth

As growth in resource use is strongly connected to economic growth, decoupling is a key concept in CE thinking, i.e. breaking the link between environmental pressures and economic growth (EEA, 2013). Decoupling resource use and accompanying environmental pressures from economic growth is a central element in the EU resource efficiency strategies (EC, 2011b). Decoupling can be assessed in absolute terms - where environmental pressures are stable or decreasing, despite economic growth - or in relative terms – where environmental pressures are still growing but less rapidly than the economy (EEA, 2013). The EU Resource Efficiency Roadmap (EC, 2011a) measures RE as relative decoupling, or "resource productivity" [3]. While this provides relevant data, it does not however give the full picture, since it is based on the domestic footprint, and fails to account for environmental pressure from imported products. The consumption footprint tends to be significantly higher - in the Swedish case, it increases GHG emissions with 65% (SCB, 2022). Therefore, while the domestic footprint of Sweden shows absolute decoupling, the more relevant consumption footprint shows relative decoupling or no decoupling at all (Sala et al, 2019a; SCB, n.d.b). This means that environmental pressure from domestic production shows some decrease, but environmental pressure from imported goods shows no decoupling.

Different environmental impact categories show differing levels of decoupling from economic growth. The environmental footprint calculation method developed by the EU (Sanyé Mengual, et al, 2023) features 16 impact categories: Climate change; Ozone depletion; Human toxicity, non-cancer; Human toxicity, cancer; Particulate matter; Ionising radiation; Photochemical ozone formation; Acidification; Eutrophication, terrestrial; Eutrophication, freshwater; Eutrophication, marine; Land use; Ecotoxicity freshwater; Water use; Resource use, fossils; and Resource use, minerals and metals. Those impacts might in turn lead to impairment of human health, biodiversity and natural resource provision, e.g. climate change, land use, water use, etc. may lead to biodiversity loss. Regarding resource use, while imported resources grew as rapidly as the economy, EU resource use show only relative decoupling (Sala et al, 2019; EEA, 2013).

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[3] GDP/Domestic Material Consumption

Two key factors lie behind the relative decoupling in several production processes: improvements in production processes through ecoefficiency measures such as improved material efficiency, energy savings, improved production processes, and end-of-pipe technologies; and changes to national industry mixes over time, mainly driven by "outsourcing" of industrial production with high environmental pressure to non-EU countries (EEA, 2013). Importantly, the relative small levels of decoupling seen in Sweden and other EU countries can therefore lead to increases in global pressures (EEA, 2013). The challenges for reductions in material resource use and GHGs in the future to meet SCP and climate change goals are considerable.

Environmental footprint of Swedish industry – impact categories and sectors

Sweden's environmental footprint does not stand well in international comparison. Firstly, Europe's and North America's per capita environmental impact from resource use is significantly higher for all impact categories (climate change impacts, particulate matter health impacts, water stress, and land-use related biodiversity loss) than in other world regions (IRP, 2019). Then, Sweden's environmental footprint per capita is significantly higher than the EU average (Sala et al, 2019). Sweden's environmental impact from resource use is among the highest in the EU. Overall, Sweden is high above the EU average, and specifically, Sweden has the highest environmental impact from mineral and metals resource use of all EU countries, and is among the seven EU countries with highest impact from fossil fuel resource use (Sala et al, 2019)[4]

As a Member State with a high GDP per citizen, Sweden also present high impact per citizen (e.g. for climate change, marine eutrophication and fossil resource use). (Sala et al, 2019a). However, in terms of decoupling, Sweden's ranks better than the EU averages. Sweden's domestic environmental footprint has decreased more than the EU averages for most impact categories, including climate change, eutrophication, and acidification, between 2000 and 2014. Compared to Swedish GDP growth of 31% during this period, a relative decoupling has take place. (Sala et al, 2019). Resource use is an exception: Swedish environmental impact from resource use is instead increasing: fossil resource use +13%, minerals and metals resource use +1%. (Sala et al, 2019)

Sectors

Swedish statistics cover sectorial GHG emissions (EPA, 2023), but not other environmental impacts per sector. In European production, material extraction is dominated by agriculture and forestry (25 %) and mining industries (75 %). GHG emissions is mainly (75%) arising from agriculture, the electricity industry, transport services and some basic manufacturing industries (refinery and chemical products, non-metallic mineral products, basic metals) (EEA, 2013).

[4] Outside of this LCA framework: marine litter, overexploitation of wild resources, noise, artificial lights, spread of invasive species, etc (Sala et al, 2019a)

Importantly, the sectors which dominate environmental pressures are not the ones contributing most to the economy. Agriculture, the electricity industry and transport services are environmental hotspot economic sectors, but contribute relatively little to economic output and employment. (EEA, 2013)

Product groups

Appliances and mobility (passenger cars are the product groups being the main drivers for resource use, specifically mineral and metal resource depletion), because of the extraction of precious metals used in printed circuit boards (Sala, et al, 2019).

Footnotes

[i] Resource use (fossil fuels, minerals and metals), particulate matter, land use, climate change, freshwater eutrophication, photochemical ozone formation (Sala et al, 2019).
[ii] There are significant overlaps with green growth perspectives - economic development based on sustainable use of now-renewable resources, which fully internalises environmental costs (Rodrik, 2014) - and with industrial renewal and/or green transition policies (Tillväxtanalys, 2018).
[iii] With this definition, biofuel policies in USA and France are green industrial policies, since they combine a greening industrial objective, and support to domestic producers, aiming to develop a domestic industry, while biofuels policies in Sweden and Portugal were only qualified as green policies, since they were limited to consumer mandates (Hallegatte et al, 2013).
[iv] It should be noted that this economic perspective only considers mispricing of environmental aspects currently included in production-consumption systems, such as CO2 and other GHGs, but does not consider the absence of generally agreed pricing mechanisms for other types of environmental impacts, such as impacts on biodiversity (see f ex Dasgupta, 2021; IPBES, 2022).
[v] Relevant agency programmes and similar funding mechanisms include:

- *Climate Leap*: investment support for GHG emissions reductions projects (EPA, n.d.a).
- *Industry Leap*: funds prestudies, R&D, pilot and demonstration projects, and green technological investments, which include circular projects. Part of EU recovery and Resilience Facility (Energy Agency, n.d.).
- Other Energy Agency funding programmes for energy R&D and demonstration projects (Energy Agency, 2023).
- Vinnova programmes – i.e. on green and digital solutions
- *Transition Leap* – capacity-building and skills
- Export credit programmes run by the Swedish Export Credit Agency, such as the *Export Leap*

[vi] I.e., the Stenungsund plastic recycling refinery, the Stena Recycling lithium battery project, the ReNewCell project for chemical textile recycling, but also CBM-related projects such as the Axel Johnson system for circular e-commerce deliveries, the Filippa K Circular PLM project, CBM for Houdini sportswear (Energy Agency, n.d.b.).