Barriers for industrial waste recycling in the context of circular transition: lessons from Mistra Closing the Loop

Authors: Fredric Norefjäll, Elena Talalasova, Haben Tekie
Summary

This is the final deliverable of a task within the national research program Mistra Closing the Loop (CTL). It aimed at analysing the barriers and drivers for industrial waste recycling as a part of transition towards a circular society. In doing so, we drew on the experiences from five projects participating in CTL. Found below is a graphical abstract capturing both of the logic behind the research and the main results.

Industrial recycling as part of a broader transition towards a more circular society faces an overwhelming number of obstacles on all system levels. Apart from being a source of despair, long, unprioritised lists of barriers can lead to diffusion of efforts and resources while attempting to tackle them all at once. In addition, these barriers have traditionally been regarded as separate entities, and little is known about the relationships between them. In this report, we argue for a shift in how we study and act on the barriers for circular transition. More specifically, we call for:

- a need to better understand the links, relationships and dynamics between different barriers and barrier groups
- a need for methodological experimentation and more action-oriented research
- a more targeted approach, where resources are pulled towards tackling a few barriers with a scientifically demonstrated potential to accelerate the change
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Preface

In this study, we analyse the barriers and drivers for industrial waste recycling as an important part of circular transition. This was done using some of the projects participating in Mistra Closing the Loop – namely, Cimmrec, Constructivate, Ebar, Explore and Glad\(^1\) – as case studies. More specifically, we tried to answer the following questions:

1. What can be said about the drivers and barriers to material recycling and circular economy in Sweden, drawing on the participating projects’ experiences?
2. What barriers are worth focusing on in order to bring about the change?
3. What methods and tools can help answer the questions above?

The study is highly exploratory and action-based, with creation of methodology and barrier analysis as equally important results. An additional, less tangible but perhaps even more important result is facilitating the exchange of knowledge between the projects participating in the program. This was primarily done through three workshops centered around preliminary and final results, but also through scoping meetings, where we got a chance to test and adjust our methodology while challenging the projects with our questions (see Appendix 1 for an overview of the process).

The research design followed the double diamond model (Figure 1), a popular concept from design thinking characterised by constantly shifting between the phases of searching and narrowing down, between divergent and converging thinking (Design Council, 2004).

![Figure 1 - Double Diamond Model as applied in this study](image)

The first “diamond” is problem oriented. Here, we started with expanding the projects’ focus and broadening their perspectives, while simultaneously discovering and testing different methods and tools for identifying the barriers in a holistic way. As the next step, we narrowed it down to one method, which we eventually used to define a list of barriers. The second diamond is solution oriented. There, we first developed a methodology for analysing these barriers. The analysis then concluded in delivering a narrowed down, targeted set of leverage points – barriers that have the biggest effect on the system.

Several trade offs and limitations of the study need to be outlined. First, focus on the big picture comes at the expense of the depth with which we looked at each participating project.

\(^1\) An overview of the projects can be found in Appendix 1. For a more detailed overview consult with other Mistra CTL reports
Second, given the nature of the projects, the identified barriers often relate to material recycling, and not necessarily other pillars of the circular economy, such as reducing or reusing. In addition, since the policy overview is a separate part of the program activities (see report by Naoko Tojo), in this report we focus on other, non-policy related, barriers, particularly when describing potential solutions.

The report is structured as follows. First, we provide a brief overview of other studies dealing with similar issues and describe their methods and main results. Then, we introduce our toolbox – a set of methods that we used to answer research questions 1 and 2, building on the existing theories and practices in the field of circular economy and broadly, sustainability. As the next step, we provide a brief overview of the barriers identified at the information collection stage. In the next chapter, we present the leverage points identified through the information analysis, as well as briefly suggest actions to realise these leverage points. The final remarks represent our reflections on the process and the outlook. Finally, we invite the reader to go through our reading list, structured by the themes.
1 What have others done?

At the discovery stage of our study, we looked at some of the latest (2017-2019) reports and academic articles targeting circular economy barriers from a systems perspective. Below is a brief overview of the methods they used and their main results.

<table>
<thead>
<tr>
<th>Study</th>
<th>Scope</th>
<th>Method and framework</th>
<th>Results and themes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kirchherr, Piscicelli and Hekkert (2018)</td>
<td>EU</td>
<td>Grouping of barriers to cultural, regulatory, market and technological. Chain reactions identified. Survey, interviews with businesses and policy makers.</td>
<td>Chain reactions stressed. Cultural barriers prevail (corporate culture, consumer awareness), are driven by market barriers (virgin material prices, capex costs), which in turn are driven by policy barriers (underlying barriers). Technological barriers did not rank high.</td>
</tr>
<tr>
<td>Tura et al. (2019)</td>
<td>Business perspective, no geographic scope</td>
<td>Framework consisting of environmental, economic, social, political and institutional, technological and informational, supply chain, and organizational barriers. Interviews.</td>
<td>Internal barriers: lack of financing and infrastructure, perceived consumer demand, resistance to change, product design, absence of market. External barriers: taxation and regulation, lack of harmonization in the EU, public procurement, lack of goals.</td>
</tr>
<tr>
<td>Houston et al. (2018)</td>
<td>EU, business perspective</td>
<td>Internal (corporate, value chain) and external (EU, local policy) barriers.</td>
<td></td>
</tr>
<tr>
<td>Hart et al. (2019)</td>
<td>Built environment</td>
<td>Cultural, regulatory, financial, sectoral barriers.</td>
<td>Design, knowledge, not embedded in the organisation, financing, silos, no sense of urgency, lack of reverse supply chain, lack of data, legislation, trade agreements, lack of financial incentives, externalities not internalised.</td>
</tr>
<tr>
<td>Pheifer (2017)</td>
<td>Circular business models, business perspective</td>
<td>Barriers on micro (company), meso (value chain) and macro (society) levels.</td>
<td></td>
</tr>
<tr>
<td>Govindan and Hasanagic (2018)</td>
<td>Supply chain perspective</td>
<td>Multi perspective framework – external (government, society), internal (consumer and supplier perspectives). Categories: governmental, economic, technological, knowledge and skills, management, circular economy framework, culture and social skills, market.</td>
<td>Framework is the main result. Consumer related issues (acceptance and awareness) and technological barriers prevail as a focus in the literature studied.</td>
</tr>
</tbody>
</table>

Most of the studies are inductive, meaning that the frameworks came after the results were collected and that creation of methodology was part of the study. Many categorised barriers across several systemic levels, e.g. external-internal or macro-meso-micro. The empirical results seem to point towards the importance of "softer", non-technologic barriers. There were few brief mentions of the interconnectedness of the barriers, and only one article outlined potential interactions and negative chain reactions across barriers and barrier groups.

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2 Where the framework represents the main result of the article, the last two columns are merged.
A similar overview of theoretical and methodological approaches to analysing the barriers, but focused explicitly on circular business models, is provided by Babri et al. (2018). Their overview suggests similar results.

2 Our toolbox
This chapter describes the tools developed to collect and analyse the information for the report, including their theoretical foundation, benefits and limitations, and potential for application in other projects.

Circular economy is a complex issue, with many actors, institutions and artifacts affected by the development. Thus, there is an inherent value in developing and applying tools and frameworks that help deconstruct and make sense of this complexity, with the ultimate goal to come up with a set of tangible actions. An important result from the project is the two frameworks that were developed based on the existing literature and our previous experiences and used to analyse the barriers from the systems perspective. The frameworks were specifically adjusted to fit the purposes of the study, but the authors invite other projects or applied researchers studying similar issues to test and adapt them for their own needs.

The frameworks fit different purposes and came in at different stages of the project – the first one was used for information collection, and the second one – for information analysis. Table 1 features a brief overview of the two. A detailed description of each framework follows.

<table>
<thead>
<tr>
<th>Tool</th>
<th>Goal</th>
<th>Stage</th>
<th>Methods</th>
<th>Result</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Context and Critical Conditions (CCC)</td>
<td>To identify and provide an overview of the barriers across two dimensions – time and system level</td>
<td>Information collection</td>
<td>Interviews, workshops to confirm the findings</td>
<td>A list of barriers</td>
<td>Comparison Discussion Getting the full picture Exchange of knowledge Categorisation Visualising the complexity</td>
</tr>
<tr>
<td>Leverage points for action (LPA)</td>
<td>Identify which barriers the project could focus on solving</td>
<td>Information analysis</td>
<td>Desk research, potential for applying a workshop format</td>
<td>A prioritised list of potential bottlenecks - intervention points</td>
<td>Prioritising Visualising relationships and interactions Targeted intervention Narrowing down the complexity Diving deeper</td>
</tr>
</tbody>
</table>

Context and Critical Conditions (CCC) – information collection
The framework predecessor was developed in The Ecopol project and is based on a manual of the University of Applied Sciences, Graz, Austria, which in turn relies on the “9-windows tool” of the TRIZ method (Souchkov, 2019, Ecopol). The framework (Figure 2) and the underlying questionnaire were significantly adjusted, primarily to fit the context of the circular economy and material recycling, and the structure and nature of the research programme Mistra Closing the Loop.
The thinking behind the framework is that it is essential to understand that a project or change process cannot be seen independent from the contextual system it is embedded in. For each project, the framework is looking at the full “context” but focusing on the “critical conditions” that ensured the success of the projects and of the change they are aspiring to do – the key success factors. The mindset is to focus on the change (transformation) the project aspire to contribute to – circular transition in our case. The main idea is that the whole is greater than the sum of its parts, and that by deconstructing the complexity into smaller, more tangible components, we expand our knowledge of the whole.

In the middle of the framework is the project itself. The framework then moves beyond the current state of the project – to the past, where the driving forces for the project emerge, and to the future – upscaling of the project solution, where most of the barriers will arguably occur. In addition to moving in time, the framework strives to cross the system levels – by elevating the projects and looking at the “super-system”, or society, they operate in; and by dissecting the projects and looking at the particularly problematic areas, such as business model or technology.

By deconstructing the barriers across two dimensions – time and system level, we help projects make sense of the complexity, while making sure that we cover all possible barrier areas, even if they have not manifested themselves yet. But it can also facilitate and guide the action. The underlying logic there is that solving the barriers at the super system level likely requires a different actor constellation, and a usually broader societal agreement than solving the barriers on the sub system level. The super system is also where projects will have most of the similarities, and where the potential for joint action is the highest. This brings about another possible value of applying the framework – a comparative one, if applied across multiple study objects. The comparison is not limited to “vertical” dimension. Exploring the past and the potential futures for several study objects can provide equally valuable insights and lessons as one project’s past is often another projects present, or even future.
A softer value of the framework was pointed out by the participants themselves. Answering the questions asked by this tool was perceived as a mental exercise, helping broaden the perspectives, and potentially stimulating ideation for future projects, initiatives or follow ups.

Essentially, the framework is a way to understand the specific contexts of the projects, while simultaneously getting a full picture of the barriers they are facing and creating stimulating discussions.

**Leverage Points for Action (LPA) – information analysis**

The method is inspired by systems theory, particularly the concept of leverage points and the cross-impact method of forecasting. A similar principle lies behind several recent studies in the field of sustainability, see, e.g., SEI's study on the relationship between Sustainable Development Goals (SDG) and NDCs (Weitz et al., 2019, Nilsson et al., 2019) or a study by Abson et al. (2016) on applying leverage point thinking to sustainability transitions.

Applying the systems theory permitted the authors to grasp and visualise the complexity of relationships between different barriers and barrier groups. This, in turn, is a key step in identifying **leverage points** - barriers that, once solved, can have a positive effect on the whole system. These leverage points are central to the study as they mark the most impactful points of intervention across the projects and justify the targeted approach of the rest of the report.

Central to the LPA assessment is weighing of the barriers identified at the information collection stage, according to several criteria.

The following criteria served as the basis for the weighing exercise:

- **Importance**: perceived importance of the barrier for the projects
- **Instances**: prevalence of the barrier, number of projects experiencing the barrier
- **Interactions**: the degree to which solving the barrier can affect other barriers
- **Influence**: potential to act on the barrier within certain actor groups

These criteria and their use can be adjusted depending on the goals and structure of the research program. For instance, if the program’s goal is to identify tangible actions that the program participants themselves can contribute to solving, the latter criterion (**Influence**) needs to be included. Such was the case with Mistra Closing the Loop. On the other hand, it also means that some of the “super system” barriers that score high on **Importance** might not make the cut to the final prioritised list, since they are perceived as impossible to act on. Similarly, the criterion **Instances** is only relevant if there are many different study objects – such as projects in case of Mistra Closing the Loop; otherwise it can be omitted.

For Mistra CTL we used a numerical scale from to assess the **Importance** and **Interactions** of the barriers. Criterion **Influence** was applied to filter the barriers to be included in the assessment (binary, 1 or 0). Criterion **Instances** was embedded into the **Importance** criterion, since it reflects the importance of the barrier for the programme as a whole (the “change”, circular economy). The logic can be summarised in the equation below:

\[
\text{Leverage point strength}_x = \sum_{i=1}^{n} \text{Interactions}_{x \rightarrow i} \times \text{Importance}_i
\]

\[\text{where } x \neq i; \text{ Influence}_x \neq 0\]

Results from the assessment can be presented in a matrix form as illustrated below (Table 2).
Table 2 - Leverage points assessment

The table is best read horizontally, with the number in the Sum column representing the potential of the corresponding barrier in the first column to be a leverage point (color coded from yellow = low potential to dark red = high potential).

It is important to note that this is a rather subjective assessment. No statistically relevant correlation analysis was performed due to the scope of this study but can be embedded if deemed fitting to the goals of your assessment. In other studies, corresponding assessments were performed through workshops with a diverse group of stakeholders (SEI for mapping SDG interactions).

An alternative – or complementing - way to present the results is through simplified systems dynamics diagram, where the thickness of connections represents *Interactions*, and the size of the barriers represents their *Importance*. See example on Figure 3 below.

Figure 3 - Alternative visualisation of LPA analysis

Several limitations in scope prevent the opportunity to use a full-scale system dynamics diagram and identifying feedback loops (as, for instance, in the latest World Energy Scenarios update by the World Energy Council, 2019). First, the list of factors from the information collection stage is not – and cannot be – exclusive due to, not the least, the nature of the topic,
and any such attempts can easily fall under the label of false precision. In addition, second hand – or cascading – effects, where the affected barrier affects other barriers, are not accounted for. Finally, only reinforcing relationships are accounted for, representing an important and perhaps contestable assumption that there are no conflicts between the barriers.

3 Overview of the barriers

This problem-oriented chapter describes the main barriers faced by the projects of the programme, grouped by barrier types and focusing on barriers shared by several projects.

Presented below (Table 3) are results from the CCC analysis. For the purposes of this report, we aggregated them and structured according to the barrier types: policy, market, behaviour, actors, technology and product properties. These types represented reoccurring themes in interviews with project participants.

Table 3 - Overview of the main barriers and drivers

<table>
<thead>
<tr>
<th>Barriers</th>
<th>Drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Policy</strong></td>
<td><strong>Drivers</strong></td>
</tr>
<tr>
<td>Missing economic policy instruments</td>
<td>Circular Economy package</td>
</tr>
<tr>
<td>Requirements and goals not stringent enough</td>
<td>High level goals for recycling</td>
</tr>
<tr>
<td>No Extended Producer Responsibility (EPR) for some product groups or EPR not stringent enough</td>
<td></td>
</tr>
<tr>
<td>Standards and quality assurance missing</td>
<td></td>
</tr>
<tr>
<td><strong>Market</strong></td>
<td><strong>Drivers</strong></td>
</tr>
<tr>
<td>High transportation costs</td>
<td>Mature market for metals</td>
</tr>
<tr>
<td>No established logistics</td>
<td>Big potential quantities available</td>
</tr>
<tr>
<td>Fragmented market</td>
<td>Big players starting to shape the market</td>
</tr>
<tr>
<td>Lack of risk sharing mechanisms</td>
<td></td>
</tr>
<tr>
<td><strong>Behaviour and actors</strong></td>
<td><strong>Drivers</strong></td>
</tr>
<tr>
<td>Low collection rate</td>
<td>Increased interest in using recycled materials in production</td>
</tr>
<tr>
<td>Lack of capacity among actors directly involved in collection</td>
<td>Awareness of emission reduction potential</td>
</tr>
<tr>
<td>Hindered information exchange</td>
<td>No direct opposition by actors</td>
</tr>
<tr>
<td>Lack of trust</td>
<td>No behavioural change needed</td>
</tr>
<tr>
<td>Collaboration hindered by silos</td>
<td></td>
</tr>
<tr>
<td><strong>Technology</strong></td>
<td><strong>Drivers</strong></td>
</tr>
<tr>
<td>Early development stage of some technologies</td>
<td>Emerging technologies for sorting</td>
</tr>
<tr>
<td>Failed previous trials</td>
<td>Developed recycling infrastructure</td>
</tr>
<tr>
<td><strong>Product properties</strong></td>
<td><strong>Drivers</strong></td>
</tr>
<tr>
<td>Material complexity</td>
<td>Variety of types and applications</td>
</tr>
<tr>
<td>Lack of design for recycling</td>
<td></td>
</tr>
<tr>
<td>Light weight – less prioritised</td>
<td></td>
</tr>
</tbody>
</table>

Early on at the information collection stage, it became clear that barriers received significantly more attention than drivers. While our questionnaire included questions related both to barriers and drivers, the interviewees eagerly dived into the former, while the latter was either explained in very general terms, or was equaled to the absence of a barrier (e.g. technologically feasible → no technology related barriers; does not require behavioural change → no behavioural barriers). Such imbalance is a learning in itself, and hints at predominance of problem-oriented thinking. From now on in this chapter of the report, we describe the *barriers* in detail, while the drivers are explicitly or implicitly referenced in the solution-oriented chapter.
Figure 4 features an alternative presentation of the barriers that demonstrates relative perceived importance of different barrier groups, split by project and barrier type. A detailed description of each group follows.

<table>
<thead>
<tr>
<th>Policy</th>
<th>Market</th>
<th>Behaviour</th>
<th>Actors</th>
<th>Tech</th>
<th>Product Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic film</td>
<td>CONSTRUCTIVATE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mn, Zn</td>
<td>EBAR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GLS</td>
<td>GLAD</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>plastic</td>
<td>EXPLOR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>plastic</td>
<td>CIMMREC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

![Figure 4 - Overview of the barrier groups by project and significance](image)

**Policy**

When it comes to policy, both the lack of instruments and the design, choice and level of ambition of the existing instruments acted as barriers for the projects.

According to the projects, economic instruments are not used to their full potential, thus hindering the development. Explore and Cimmrec both pointed out the importance of the taxes for virgin plastic, while Glad attributed general lack of incentive for the use of GLS to it being exempt from the landfill tax.

Regarding the administrative instruments, the perceived issue was their level of ambition and scope. For instance, Constructivate pointed out that weight-based requirements and goals prevent recycling of low weight plastic, such as plastic film. Somewhat similarly, Explore noted that the way recycling rate is calculated – through collected volumes, represents an important barrier. Low level of ambition in setting political goals for circular economy was picked up by both Constructivate and Cimmrec, while Glad faced the issue of the definition of waste and end-of-waste criteria. Since GLS is classified as waste, there is both significant resistance to its use and stricter regulatory framework applied. In addition, and as a way to counteract some of the regulatory hurdles, the importance of establishing the quality assurance system was picked up by many projects.

A closely tied barrier is the level of ambition in the Swedish EPR system. One part of the issue is the scope – or the material streams – included in the system. Another is stringency of the goals for material recycling. Yet another is the fee modulation, where the classic weight/sales/type of material fee is applied. While it has achieved significant results, some projects pointed that it was not enough to create incentives for material recycling of the waste streams they are
tackling. More advanced EPR systems start to emerge in other European countries, particularly Germany. These take into account other criteria, such as recyclability, reparability, the presence of hazardous substances, were suggested in this regard (Watkins et al., 2017).

As mentioned earlier, this summary was fed into the other part of the project to act as a starting point for the policy overview, so this section marks the end of the policy discussion in this report.

**Market**
Consistent with other studies on industrial waste streams, market related barriers were experienced by all the projects, albeit to a different extent and in different forms. Costs, value and competition represent reoccurring themes, where issues either resulted from the fragmentation – or absence - of the market, or competitiveness in the presence of cheaper alternatives.

Several projects noted low value of the material as one issue (Constructivate – plastic film, EBar – Zn and Mn, Cimmrec – plastic). Explore expressed the same issue in relative terms and said that in composite products – such as cars, the focus naturally shifts to the metals, that are easier to recycle and bring higher income than plastic.

Furthermore, cost structure, lack of infrastructure and market for recycled materials represented another hurdle. In Constructivate’s case, the market for recycled construction products was largely inexistent, likewise for Glad/GLS, where one of the central market elements - pricing mechanism - was missing. The prices were decided on a case to case basis, depending on availability of deposits and distance, which increased the transaction costs. Glad and Explore both pointed out prohibitively high transportation costs in the absence of an established and optimised infrastructure. High investment costs were picked up by Ebar, while Explore raised the issue of high labour costs for dismantling of cars.

For projects dealing with plastic material streams (Constructivate, Explore, Cimmrec), the biggest perceived barrier and the factor aggravating both the cost and the value issues was competition. Low prices for virgin plastic made it near impossible to compete. In fact, according to S&P’s\(^3\) annual commodity report, virgin plastic has recently become cheaper than recycled plastic, worsening the situation.

Virgin materials have been establishing their value chain for many years, decades or sometimes centuries. With source materials highly concentrated in space, the production facilities evolved to accommodate for this large volumes and short distances, and the economy of scale was the result. Recycled materials are facing the opposite situation. In the absence of scales comparable to those of virgin materials, distributed infrastructure, or absence of thereof, and market fragmentation means that the costs are higher, while the volumes are lower. The issue manifests, among others, in prohibitively high transportation costs and comparatively high investment needs.

The investment costs are an issue due to, not the least, undefined risk ownership and lack of risk sharing mechanisms, another issue picked up by the projects. In a prisoner’s dilemma with a circular twist, self interest manifesting in risk aversion leads to lack of any development, as no one actor is willing to assume any additional risk.

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\(^3\) S&P Global Platts is a provider of energy and commodities information and a source of benchmark price assessments in the physical commodity markets.
The conversation on risk in the context of circular economy has been gaining ground for several years, often with somewhat negative connotations and centered on toxicity and hazardous substances reduction. The perceived conflict is grounded in precautionary principle taken to its extreme. However, we are convinced that, while chemical safety represents a natural limitation and a necessary pre-condition to the circular economy, bans, full restrictions and prohibitively high limits represent albeit effective, but often not efficient interventions. Alternative interventions are presented in the next chapter.

**Actors, networks, behaviour**

Actors group manifested as both driver and barrier. In the projects themselves, no problems with the actors were noted – rather indicative of the self-selection bias than the general situation. For the upscaling (the future dimension of the CCC framework), barriers such as lack of information exchange and trust (Cimmrec, Glad) and limited collaboration and silos across industries (Explore, Cimmrec, Constructivate) were named. For many projects, implementing circular economy meant establishing direct contacts with other industries (Glad – construction and paper industries). These types of exchanges – intersectoral - represent both a hurdle and an opportunity. A hurdle because the collaboration channels are not established as the actors are not used to work with each other; an opportunity because there is no direct competition between the actors, so information can more easily be shared, given that the trust is established.

Constructivate pointed out that one pre-condition is a better understanding of the needs of different actors in the value chain, particularly the buyer industries. Explore pointed out that the actor issues may arise in the future with construction of a large-scale facility that could decrease the need for car dismantlers and damage the existing actors.

Since the projects deal with industrial waste, behavioural barriers were not as pronounced. Some relatively minor issues included lack of knowledge for the collectors of waste on the construction site for Constructivate, and issues with collection incentives for Explore.

**Technology**

The main types of barriers identified can be grouped into the following categories:

- Low maturity levels for technologies and processes (Cimmrec, Ebar, Glad)
- Absence of technology easily available in Sweden (soft plastic washing for Constructivate, plastic sorting facilities for Explore, black plastic unidentified by the dominating sorting systems for Cimmrec)
- Failed previous trials that affected the development in a negative way (Glad)

The technological barriers are most evident in the case of Ebar, where a new process for recovery of Mn and Zn needs to be developed. The development stages for the technologies relevant for the projects – as perceived by the projects themselves - can be seen in Figure 5 below:

![Figure 5 - Technology development levels for the technologies involved in the projects](image)
As can be seen from Figure 5, the technological readiness level for the technologies or processes needed for the projects vary from project to project, and within projects. Despite this variety, the consensus was that technological barriers are easier to overcome than other barriers. In many cases, there is a fine line between a technological and a market barrier: even if a technological barrier is named, it often relates to the infrastructural setup and the context. An example is soft plastic washing (Constructivate) – a technology that is readily available, but represents a barrier in the Swedish context as no facilities are available that could shorten the distances and cut the costs.

Product properties
In many ways, this category acts as both a natural limitation to the circular economy and a root cause of many of the other barriers. The main types of the barriers associated with product properties are:

- Material properties
- Material and product complexity
- Product design
- Use characteristics and time perspective

Plastic and metals have completely different properties at the material level, partially explaining the relative easiness of recycling metals compared to plastic. However, the current system is characterised by a complete mismatch of the uses and the type of plastic used, where higher quality pure plastic is used where lower quality or higher impurities level plastic would have sufficed.

A limitation that does not get enough attention is the time perspective. Two of the Mistra CTL projects are dealing with products with longer use phase (buildings for Constructivate, cars for Explore). These products were not developed with sustainability and recyclability in mind, often consist of non-traceable or mixed materials, and, due to their longer use phase, will continue setting limits, defining the challenges and justifying no one-fits-all principle for circular economy for many years to come.

Another issue is material and product complexity, brought up by Explore. Material complexity can hinder dismantling and material recycling, especially when paired with lack of design for recycling. At the same time, in case of Explore, it is also harder to avoid due to the purpose of the product and the associated properties of plastic and metal (lightweight and durable plastic, collision proof metal, no accepted compromise on safety).
4 Leverage points for action

This solution-oriented chapter describes a selection of barriers that can act as strong leverage points for change and suggests what can be done to help realise their leverage point potential.

Figure 6 - Results of the LPA assessment

Figure 6 presents the results of the leverage point assessment. Market group and Actors and networks group present the biggest potential for acting as leverages, with policy a close third. As previously noted, the policy barriers are outside the scope of the solution-oriented analysis. In addition, their leverage point potential was most likely toned down by the Influence criterion. The barriers we will focus on in this chapter are the following:

1. Lack of risk sharing mechanisms (and broadly, risk management for recycled materials)
2. Fragmented markets
3. Lack of collaboration and exchange of information

When the results of this assessment were presented at Mistra Closing the Loop conference 2018, we noticed that it was lack of risk management that resonated the most with the participants. Therefore, more attention in the following chapter will be dedicated to this topic. However, we still touch upon number two and number three, as the three barriers described above are interlinked in a potential positive feedback loop, where targeting one of these barriers has a snowball effect on the other two.

The chapter is structured as followed. For each barrier, insights from LPA assessment are first summarised through explaining how targeting this barrier is likely to affect the system. Then, a brief set of actions is suggested to contribute to solving the barrier.

Risk sharing and risk management

Establishing risk sharing mechanisms and embedding risk management principles into circular economy has potential to improve both the demand and the supply of secondary materials. On the demand side, an established society-wide risk management system means easier introduction of secondary materials on the market, a better understanding and communication of their value and a potentially higher willingness to pay. On the supply side, risk sharing across and beyond the value chain can help secure funding of the circular economy initiatives and level the playing field. Additional benefits include improving information exchange and collaboration between the actors through discussing and negotiating risk sharing arrangements, and contributing to the “defragmentation” of secondary materials market through establishing tangible links between the actors.
**Risks mapping and clear risk distribution**

As previously implied, risk sharing and risk management for circular initiatives is needed on both macro (societal) and micro (industry and value chain) levels. Here, macro level risks include societal acceptance, political landscape, environmental and health and safety risks. Micro level risks include the market (demand, competition), organisational (intermediary, missing link, actor roles), financial (lack of financing, default) and technological (integration into production processes) risks.

**Risk aversion as an excuse for business-as-usual?**

Perceived financial, performance, time and social risks are frequently mentioned as potential barriers to the uptake of remanufactured products or products with remanufactured parts by the consumers - see summary by Milios and Matsumoto (2019). But in some sectors, the consumer risk aversion might be overestimated and not grounded in scientific studies, customer surveys, or other empiric evidence. The same study found out that, while there is limited consumer awareness on the use of remanufactured car parts among the Swedish consumers, there is also no significant risk aversion associated with their use. In addition, the consumers recognised the value of using secondary materials in car production.

Different types of risks require different types of measures and different actor constellations to successfully manage them. But central to any risk management endeavour is a common understanding of all risks that might arise. A successful risk mapping exercise would include identification of the sources, aspects and types of risks throughout the value chain and beyond.

After the risks have been properly identified and valued comes the stage of risk distribution. It is crucial that ownership of every type of risk is clearly defined. The general principle is that industrial partners – or partners closest to the development - allocate as much as possible between themselves, followed by the financial institutions, the government and the society/consumers. Creation of joint ventures is one way of distributing the risks and profits across multiple actors benefiting from the development. But regardless of the arrangement, there is often need for additional external funding, justifying the inclusion of the financial institutions, a topic discussed below.

**Involving the financial institutions**

Goovaerts and Verbeek (2018) conclude there are two main ways financial institutions can contribute to circular economy: through providing with financial and legal structures, and through adjusting their own risk assessment frameworks to balance linear and circular risks. ING⁴ provides a similar but more detailed overview, written from the perspective of financial institutions themselves (Hieminga, 2015).

Both studies conclude that significant adjustments need to be made in the ways the traditional financial institutions operate in order to effectively capture the circular economy potential. Indeed, circular economy projects are strikingly different from linear projects, and cannot be evaluated in the same way the linear projects are evaluated. Differences vary from time distribution of operational costs and benefits, to potentially higher capital expenditure, to a complicated market assessment. The adjustments need to be made to make sure that circular

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⁴ The ING Group is a Dutch multinational banking and financial services corporation
initiatives do not pay discriminatory premiums that reflect the added risks but fail to encompass the added benefits of circular alternatives.

It is worth pointing out that the scope of the adjustment will depend on the type of project. There is a need for a variety of capital types to finance the circular economy transition, and thus, a broad range of financial institutions to engage. Initiatives for increasing the resource efficiency can be relatively easily financed, while other initiatives associated with completely changing the business model are riskier and less fit for low-risk funding. For these, there might be a need for creating new financing models and financial institutions, such as dedicated circular economy funds.

A crucial and non-negotiable condition to the participation of the financial institutions is stimulation of demand. This is done through both a shift in how we define the value at the societal level and through concrete business model arrangements. Both are discussed in the following section.

**Demand commitment**

Two risk categories are directly related to the fact that the market for circular products is not fully established – namely, market and financial risks. In such situation, it is hard to estimate the demand for the product, appropriately finance new infrastructure and estimate the capacities required. One potential arrangement is various forms of demand commitment from the buyer’s side, the most common form being an offtake agreement. Offtake agreement implies that the buyer of the material commits to purchasing a certain amount of this material in the future, often before the infrastructure is built. Thus, demand commitment secures the cash flow for the material and simplifies financing of the facility. Other, less binding forms include setting corporate goals. In our conversations with project managers, it was named that Volvo’s commitment to recycled materials acted as an important driver for the project. Other market players such as Ikea start to drive similar initiatives in other markets.

There are several important preconditions to such arrangements. One is quality assurance; another is existence of a broad societal understanding of the value of recycled materials which would motivate the companies to commit.
Societal shift for redefining the value – the role of metrics

Producers engaging in recycling and dealing with circular raw materials will strive to cover the remaining risks through pricing mechanisms, passing the bill to the final customer. For this to be a viable business endeavour, there needs to be willingness to pay for circular products. The societal value of circular products thus needs to be clearly articulated to consumers.

Redefining the notion of material quality and setting it in relative rather than absolute terms – in relation to the function of the product instead of fixed values – can help to shift consumers’ perspective. A 100% quality must mean that the material satisfies the need of this particular application to a full degree, as opposed to it being 100% strong or 100% pure. In other words, value should be a function of application, where good enough is the absolute best.

The corporate world has long seen the need to be able to capture and communicate the non-monetary value that they bring in clear and understandable terms. One of the most prominent examples of such attempts is corporate monetary evaluations of the environment, popularised by Kering about a decade ago with the introduction of their Environmental Profit and Loss methodology. Monetising the environment made natural capital more easily comparable to financial capital, and thus more understandable for the board, and helped justify investments in sustainability. Monetising the benefits of the circular economy has potential to help justify the circular transition and enable circular investments, lay the ground for internalisation of external costs and facilitate a dialogue with financial institutions.

Defragmentation of the market

Improving the logistics in secondary materials supply chain has its primary effect in stimulating the demand by driving down the prices of secondary materials - through lowering the costs, securing stable supply and allowing for bigger production volumes.

New intermediaries and value chain innovation

With traditional distribution and selling channels seemingly failing to accommodate for the distributed nature of circular material flows, new types of marketplaces and value chain arrangements need to be established. The role that was sought after the most in the participating projects is an intermediary that facilitates the transactions.

The type of the intermediary needed, and their primary role, depends from case to case. For some types of circular economy transactions, a direct business to business exchange might be preferable. This is especially the case where the potential use/function of the material is narrow and well defined (as in Glad), and where limited to no additional processing at the buyer’s side is required. In these cases, the role of the intermediary is primarily organising the transportation. In other cases, where the recycled material has many potential applications, the role of the intermediary is to aggregate the offers and match them against the existing needs. In these cases, there is a need for an intermediary that operates as a marketplace. These differences are key to defining the actor best equipped to assume the new role, e.g. a waste recycling company, the buyer(s) or the seller(s) of the materials, an industrial association or a completely new actor.

Introducing a new role in the value chain can lead to a cost increase. Some of these costs can be cut through optimising transportation and digitalising the transactions, as well as through attracting a critical number of players. Diversity of materials and volumes means that the possible losses from low volumes for some deliveries can be balanced out by other, bigger, deliveries. In cases where a platform is co-funded by several actors, the general financing of the
initiative can be arranged through joint ventures, where risks and benefits are shared between the participating parties. Potentially beneficial is the establishment of a contact node in each of the participating companies. Such a role would stretch across the areas of business development, logistics and purchasing, sustainability and quality.

As pointed earlier, digitalisation is one way to compensate for the negative cost effects of redesigned value chains. Linked to this suggestion is our next one, that revolves around the added value of digitalisation in the context of the circular economy.

**From digitalisation to digital transformation**

AI and digitalisation can help manage the complexity embedded into the distributed circular value chains. In fact, the digital dimension should be seen as a natural part of the circular transition. There is a growing number of studies attempting to establish the links between the two megatrends of circularity and digitalisation. One notable example on AI in particular is a report by Ellen McArthur Foundation (2016) that conceptualised the value creation potential of AI for circularity to consist of providing information on the location, condition and availability of the asset.

However, there is indication that the full potential is not yet reached (Antikainen, et al., 2018). A study by the German Economic Institute (Neligan, 2018) concludes that most of the “digitalisation for circularity” in the German manufacturing sector occurs at the process optimisation stage, and significantly less at product design stage. Since AI is a more advanced stage in the digitalisation work, one may assume that the number of actors that work with AI for circularity is even lower.

Circular economy stretches well beyond optimisation of the processes and encompasses design of the product and increasing the useful lifetime, to name a couple. In order to capture these and other pillars of the circular economy, there is a need for a comprehensive inventory and gap analysis of the circular digitalisation work done within the companies, for instance using the framework described above.

Both distributing the risks and building new value chains require collaboration and exchange of information to properly function. In a way, collaboration acts as a key enabler for all the solution groups named above.

**Collaboration and exchange of information**

As pointed out by Farooque et al. (2019), circular supply chain collaboration is an increasingly important field for circularity, characterised by a “critical” potential impact and utmost urgency, but also very high knowledge gap. It is linked to a range of benefits, from more tangible such as market creation, to strategic gains such as joining the forces and lobbying for circularity, to softer factors such as creating awareness and breaking the silos.

One success factor for a collaborative network is the presence of a central node - an actor that coordinates and facilitates the collaboration. In studying non-alloyed steel supply chain, Berlin et al. (2019) derive the informal and formal coordination mechanisms and identify the main collaboration node for the industry, which in their case was a procurement intermediary. Identifying the actor that could act as such a node for other circular economy industrial initiatives is the first step in the right direction.

However, establishing a collaboration node and a platform is not enough to build a successful network. Equally important is the presence of a common goal and the sense of the progress towards this goal. For this, it helps to look at collaboration as a stepwise process, with clearly
defined input, process, outcome and output. One suggestion that ticks many boxes of a potentially successful collaboration is featured below.

Roadmaps and strategic network building
As demonstrated in the problem-oriented section of this report, many of the challenges are explained by the material type. We see the need for facilitating a dialogue between industries that deal with similar raw materials, while at the same time, broader circular economy clusters are also needed for the purposes outlined above.

A way to unite these perspectives is through establishing an initiative similar to Fossil Free Sweden, where industrial actors come together to develop roadmaps to carbon neutrality. In Fossil Free Sweden, the roadmaps are linked to industries, with the industrial associations responsible for each industry’s roadmap. In a circular roadmap, the discussion could instead revolve around the material type, where separate roadmaps are developed for circular types of plastic, circular metals, circular textile, et cetera, and could be extended to include other actors such as municipalities and financial institutions. A collaboration of this type can bring about several benefits:

- Breaking the silos – creating new communication channels and facilitating the dialogue between actors that otherwise do not collaborate
- Creating accountability and ownership over societal issues through transparent commitments and clear responsibility distribution
- Accelerating the transition through future and action-oriented perspective
- Gathering the critical mass for the transition

However, there are several prerequisites for this exercise to become a successful collaboration initiative. First and as mentioned earlier, there is a need for an intermediary (a collaboration node) that takes up the facilitating and coordinating role. This task could be a program legacy of Mistra Closing the Loop, but otherwise a governmental initiative such as the Delegation for the Circular Economy could be an appropriate platform. Next, there is a need for at least some level of political support and timeline anchoring. Ideally, the roadmaps would be linked to high level – but tangible and measurable - societal goals (equivalent of zero net emission 2045 for Fossil Free Sweden). In the absence of such goals, the timeline can be linked to EU circular economy goals or include definition of the goals and the timeline as part of the exercise.

In developing the concept for such a roadmap, experience from other countries should be considered. An initiative that has recently been gaining international attention is the Slovenian roadmap towards circular economy (2018). Table 4 summarises how Fossil Free Sweden and Circular Slovenia fit the criteria of successful collaboration mentioned above and briefly suggests what a Swedish national initiative for closing material loops could improve on to have the biggest effect.
Table 4 – Comparison of the initiatives with regards to the criteria for a successful collaboration identified in this report

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Fossil Free Sweden</th>
<th>Circular Slovenia</th>
<th>Roadmap for circularity (suggestion)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presence of the collaboration node</td>
<td>Fossil Free Sweden acts as a coordinator, with appointed project manager and a spokesman</td>
<td>A consortium of research institutes, public agencies’ representatives and NGOs</td>
<td>Potentially: delegation for the circular economy, Mistra, Circular Sweden initiative, Återvinningsindustrierna</td>
</tr>
<tr>
<td>Legitimacy</td>
<td>Initiated by the Swedish government</td>
<td>Initiated by the Slovenian government</td>
<td>Depends on the node chosen</td>
</tr>
<tr>
<td>Accountability</td>
<td>Industrial associations are responsible for each industry’s roadmap</td>
<td>The consortium of non-industrial actors</td>
<td>Industrial actors</td>
</tr>
<tr>
<td>Inclusiveness and diversity</td>
<td>Several industrial associations consisting of private companies. Limited exchange between industries. No other actor types included</td>
<td>Broad range of stakeholders involved throughout the process</td>
<td>Can be extended to include municipalities and financial institutions</td>
</tr>
<tr>
<td>Tangible goals</td>
<td>Achieving carbon neutrality for the participating industries</td>
<td>Loosely based on SDGs and Slovenian development strategy 2030, stresses the importance of establishing national goals</td>
<td>Must be set in relation to each material (not possible to become 100% circular for all material streams)</td>
</tr>
<tr>
<td>Anchored timeline</td>
<td>2045 linked to the nationwide goals</td>
<td>No clearly defined timeline, besides 2030 for the development goals</td>
<td>High level national goals missing, EU goals and targets not ambitious enough for Sweden</td>
</tr>
<tr>
<td>Commitments and rewards</td>
<td>Actors commit to a set of actions in exchange for policy support</td>
<td>Visibility and networking, policy recommendations</td>
<td>Actors commit to a set of actions in exchange for policy support</td>
</tr>
<tr>
<td>Transparency</td>
<td>The resulting roadmaps are publicly available</td>
<td>Both process and results, included public consultation</td>
<td>Process and outcome transparency, evaluation and quality control crucial</td>
</tr>
</tbody>
</table>
Final reflections

Revisiting our literature review, we noticed that the barriers identified are mostly similar to ours - there seems to be a fairly comprehensive picture of the flaws of the current, linear system. This similarity can serve as a strong research foundation for building solution-oriented coalitions; but arguably, we are approaching the point of saturation in our understanding of what the obstacles are. Our study calls for a shift from mapping the barriers to acting on them. Against this action-based background, this report marked an attempt to provide tools to not drown in complexity and not attempt to target everything at once, through identifying a set of intervention points that can accelerate the change.

In doing so, we were limited both by the nature of the task, the context of forming part of a research programme, the focus on material recycling, and the methods and contact points that were available, leading to some barriers receiving more attention than others. For instance, business model perspective was not as pronounced as in other studies we looked at, and internal, corporate barriers to circular transition were not explicitly stated. Very soon we realised that the drivers were less pronounced than the barriers, and a lot less tangible, which can relate to the lack of articulation of the value of circular economy. Throughout the report, we have tried to be as transparent as possible with these and other limitations, so that scholars and practitioners can build and improve on our results.

Despite these limitations, we were able to identify a variety of barriers that reside on all societal levels and range from market to policy to behaviour to technology. Our analysis proved that market-related and actor-related barriers had a significant effect on the system studied, while technological barriers were either not as pronounced, or not as hard to tackle. Within the market and actor categories, we suggested that fragmented logistics, lack of risk management approach and lack of collaboration and exchange of information should be targeted, for example through a set of interventions outlined in the last chapter.

To arrive at these conclusions, we applied and tested various concepts from design thinking and systems thinking, through action-oriented research. We are convinced that the two frameworks we settled for – Context and Critical Conditions and Leverage Points Assessment - have a significant potential to be used in other circular economy or broader sustainability transitions studies.

The urgency and state of the planetary boundaries, as well as the ambition and timeline of the SDGs call for a swift systemic shift, where transitioning to a more circular economy is an important pillar and where business as usual and research as usual can only take us so far. Circular transition may require technological innovation, but arguably more importantly, it calls for value chain, business model, social and methodological innovation. Only combining these can we truly transform our society, rather than being complacent with incremental improvements.
Reading list

**Barriers and drivers for circular economy and circular business models**


**Digitalisation and AI for closing material loops**


**Risk sharing in the context of circular economy**


**Circular supply chain collaboration**


**Analytical tools**


Design Council. (n/a). *What is the framework for innovation? Design Council’s evolved Double Diamond*


**Other references**

Appendix 1 – Overview of the projects and the process

The figure above illustrates the diversity of the material loops that the projects analysed in this report aim at closing. The projects cover several industries – from alkaline batteries production (Ebar) to construction and demolition (Constructivate), to paper production (Glad) to car manufacturing (Explore). In addition, the last project, Cimmrec (excluded from the figure) aims at comparing plastic and metal material recycling loops. Both post-consumer waste (Ebar, Explore, Constructivate) and industrial waste (Constructivate, Glad) is studied. Different types of plastic (Constructivate, Explore, Cimmrec), metals (Ebar, Cimmrec) and other materials (Constructivate, Glad) are included in the studies. Some of the projects deal with a pre-defined buyer (Glad, Ebar), others imply a variety of potential applications (Constructivate, Explore). Some deal with existing well-developed technologies (Constructivate, Cimmrec, Explore), others aim at developing or improving a technological process (Ebar, Glad).

Such variety comes both challenges and opportunities for a systemic study. Different lengths and types of material loops represented provide a gold mine of information, but this information is hard to generalise without experimenting and reiterating. Listed below are the main activities that formed part of this analysis and that tried to address this complexity.

1. Scoping meeting
2. Introductory interviews with project representatives
3. Method development
4. Literature review
5. Developing the questionnaire
6. Test of the questionnaire on one of the projects
7. Making the adjustments and additions to the questionnaire
8. Workshop 1 – presenting CCC, actors and networks exercise
9. Analysing the questionnaire results
10. Workshop 2 – presenting the results of the barrier analysis (CCC)
11. Workshop 3 – presenting the results of the LPA analysis
12. Summary and final meetings
13. Report writing