Knowledge transfer for spurring transitions to circular business ecosystems

Project summary report: Kunskapsöverföring för cirkulära affärsekosystem
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This project aimed to **accelerate the shift** towards more resource-productive circular business models of companies in the textile, furniture, and automotive in West Sweden.

**Background:** Our production system utilises significant amount of material and produces tons of waste. This results in both dramatic ecological problems and value loss.

**Approach:** RISE facilitated meetings between various actors to spur dialogue and collaboration on areas of possible common interest (matchmaking).

**Results:**
- Helped initiate the start of one new value chain that involves the recycling of vehicle bumpers, a component that represents an immense flow of polymer materials that is currently incinerated. Actors involved in this collaboration continue to coordinate to expand the value chain and its infrastructure and prepare for handling larger volumes.
- 7 pilot projects were initiated including recycling of polyester textile waste for new fabric production, decrease of waste in leather production, and upcycling of idling materials for product longevity.
- Learnings: We identified examples that display the possibility for closing material loops within and between different sectors.
- A improved methodology for how to work with circular transitions in business ecosystems.

To conclude the project resulted in creating several new collaborations and ideas for circular business propositions, that in several cases has started to be further explored.

**Suggestions for future projects** related to matchmaking and development of material palettes for circular product design.
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Introduction
"They and their production system are very peculiar. They have a burn-centric society.

Like us, they invest much time and energy into materials and objects. However, they take those same materials and objects and burn them or fragment them and instead, acquire, toil with, and use more materials and objects. Objects and materials that require 100s of steps to make are merely discarded.

They say it's too difficult to sort and handle used objects for re-production even though they have devised other technological solutions that are much more advanced.

I (an explorer, not an engineer) estimate that I could do something with many of the materials and objects myself. Instead, they start over with raw material instead. Yes, odd indeed".

*Journal entry, Unknown observer from another time or planet*
This project aimed to accelerate the shift towards more resource-productive circular business models with companies in the textile, furniture, and automotive sectors in West Sweden.
Material use and value losses in the contemporary production system are enormous

"three dollars’ worth of precious metals (gold, silver and palladium) is all that can be extracted from a mobile phone that, when brand new, contains raw materials worth a total of US$ 16.81 (Ellen MacArthur Foundation, 2014)
Three sectors & a lot of waste

500,000 Tons of furniture
RISE project "Affärsmodellsinnovation för Cirkulära Möbelflöden", 2019

170,000 End-of-life vehicles
Den samhällsekonomiska kostnaden av skrotbilar Bilsveden, 2017

135,000 Tons of textile
IVA, 2020
The role of a circular economy to mitigate climate impact

Ellen MacArthur Foundation, Financing the Circular Economy: capturing the opportunity (2020)
www.ellenmacarthurfoundation.org/publications
Potential related to extending product life:
Possible impact reductions for Vehicles, Furniture, Textile

- **Office chairs**: >(-)30% CO₂e
  - [Link](https://cirkularitet.se/wp-content/uploads/2019/02/H%C3%A5llbarhetsanalys-av-cirkul%C3%A4ra-m%C3%B6belfl%C3%B6den.pdf)

Electric vehicles
>(-50% CO₂e
  - [Link](https://cirkularitet.se/wp-content/uploads/2019/02/H%C3%A5llbarhetsanalys-av-cirkul%C3%A4ra-m%C3%B6belfl%C3%B6den.pdf)

Clothing
>(-50% CO₂e
  - [Link](https://www.naturvardsverket.se/Om-Naturvardsverket/Publikationer/ISBN/6900/978-91-620-6971-1/)

RISE Sustainable Business, FADEV Project material, 2021
Goals & Scope
**Goals**

**Identify** strengths, experiences and lessons learnt on both business **opportunities** and **barriers** within each of the 3 participating industries regarding the transition to circular business models.

**Strengthen** the participating actors’ **ability to design** for circularity and **ensure** that actors increase their **awareness** of the **connection between business model and design**.

**Share** experiences with other industries / stakeholders.

**Elaborate** findings in an **intuitive and accessible way** for external actors to enable them absorb and apply the knowledge and experience developed in the project.
**Scope**

The project intended to better understand how circular strategies can be attached to large, well-established manufacturing companies by examining how *circular business models and design strategies for closing material loops*, streamlining material use and extending component life can lead to increased resource productivity over a vehicle life cycle, with a theme of “circular seating”.

**Key focus aspects:**
- Business and organisational issues, including collaboration within business ecosystems
- Appropriate material choices.

A scenario for exploration was a change in business logic from a goods to a service dominant logic with focus on providing products as a service, where focus from a service provider will be to keep total cost of ownership. In such a scenario, vehicle interiors may be exposed to more wear and tear and keeping them comfortable and aesthetically appeasing to customers will be a primary concern. More durable or more easily exchangeable components are just a couple of the solutions that could be utilised in such a scenario.
Participating companies & organisations

[Logos of various companies and organisations]

Financed by
Method

Data collection:
Interviews/discussions with company representatives representing one or multiple firms

Coordination in business ecosystem
• Match-making facilitation
• Continuous networking with external stakeholders

Continuous analysis
• Shifting between perspectives / using different lens for analysis
• In-depth analyses and methodology testing and development

Preparation for further research development and pilots
The project demanded moving between different perspectives, from introduction of *planetary boundaries* as guiding principle for how to make circularity happen at the substance level.
Inventory of the business ecosystem

What do you have?
- Material/waste streams
- Existing business logic
- Increasing customer demand for circular products & services
- Knowledge
- Existing actors in the value chains
- Paying customers

What do you need?
- More information
- A new business logic, business model
- New knowledge
- Different competences
- New collaborations

What do you want?
- A more circular logic
- Explore circular business potentials
- Paying customers

With such an inventory, it is possible to create new value chains by combining different actors and their resources. Material/waste streams, knowledge, infrastructure, outputs and customers represent tangible aspects that make desired circular outcomes possible. Given many actors, there are many solutions or ways forward. This project capitalised on this potential and helped make matches between actors that could work together to make circular outcomes.
Exploring circular possibilities together

- About 80 matchmaking sessions
- Almost 100 people involved
- From almost 30 different organisations
**Conceptualising the circular business ecosystem**

**Data collection & matchmaking:**
Displaying the spheres of functions / foci of the business ecosystem, classifying actors not by sector, but according to life cycle phase. While coming from 3 main industries, these delineations are not of utmost importance when trying to achieve circularity, whether it be circular flows of material or longer product life. Matchmaking was focused on matching actors between spheres, but also within spheres of focus. Each actor has a particular focus in mind, but all have one thing in common (hopefully), achieving circularity. **Circularity** is inherently seen as different for different actor with different foci. Material circularity is common to all, while in theory, the highest aspiration for the system is value preservation in the utilisation, i.e., keeping products in use longer.
Theoretical background
Circular principles, from theory to applicable business and design strategies

The circular economy has been proposed as a promising route for manufacturing companies to do business that could achieve both profitability and larger steps towards eco-sustainability [1]. However, with hundred different definitions of CE today [2], it can easily result in different world views and what actions to take, and without implementing CE principles in a specific hierarchical order, there is a risk for circular approaches only leads to incremental improvements, just as eco-efficiency approaches in industry long time have been criticised for [3].

One way to simplify, a circular economy can firstly be divided into different visions of how much closeness of material and resources a system theoretically can achieve [4]. Based on figure 1 this view can be described as a relative circular system, where waste is reduced, vs an absolute circular system to reach a system that does not create waste at all.

To reach such visions three main principles that can manipulate the ingredients, amounts, clock speed, and closeness of material and resource flows can be applied: Closing, narrowing and slowing down of resource loops [5] (fig. 2). According to these principles, closing loops are achieved by material recycling that can circulate virgin and post-consumer materials back with a high threshold, and is a prerequisite for creating circularity. Narrowing loops is achieved by resource efficiency, such as using fewer resources per product produced, or during usage. This includes using fewer consumables, water, chemicals, and energy. Slowing material flows is achieved by reuse and remanufacturing, extending product life to keep products at, and in their highest utility for as long as physically possible by reuse, upgrade, sharing, adapt, and recontextualisation. For most passive (none energy using) products, as furniture, and fixed installations, extending longevity has the potential to lead to the biggest climate/ environmental reductions. Also for energy-using products run on renewable energy and with high thresholds as e.g. electric vehicles, extended longevity is a promising approach.

Moreover, a circular system should be regenerative meaning that the system preferably should be run on renewable energy, and materials and resources used should be used and circulated in a way that is safe for humans and the rest of the living things in the ecosphere [1, 6]. Also using and providing reliable information to be able to acquire, monitor, and track materials and products during all life cycle phases from extended longevity and circularity is crucial for harvest potential climate / environmental benefits.

Fig. 1 Three different approaches to circularity were type II and II represent different targets for a "relative" versus an "absolute" vision for a circular system [4].

Fig. 3 Potential for reduced greenhouse gas emissions if circular strategies are applied globally is estimated to be 40% less, annually, based on today's scenario [1].

Fig. 2. A vision of an “absolute” circular system by a type II-III ecology can be explored by three main interconnected strategies for; closing, narrow and slowing down material & resource flows. [3] adapted from [5].

Fig. 4. Strategies for slowing down resource flows, i.e., prolonging the time from extraction (A-B) to a closed loop is achieved (B-H) for the resource used, by reuse, repurpose & remanufacturing.

References:
How to apply circular principles in practice
Designing business models and products to:

- **Slow down of materials & resource flows**
  Extend the longevity of products by reusing, repairing, upgrading, adapting and recontextualising.

- **Narrow flows**
  by using fewer materials, energy, water, chemicals by efficient technologies and production processes, during product usage and recirculation.

- **Close material loops**
  by material recycling of surplus materials from production or post-consumer usage and circulating them so that they can preserve their material properties and economic values.

- **Use renewable energy**
  to run the circular products and services throughout their lifecycles as solar, wind, water, etc.

- **Regenerate materials**
  by adding or substitute problematic ingredients with safer ones for materials and production processes, product usage, and when closing loops.

- **Use information**
  about financial, ecological, and customer benefits from your circular products and services.

- **Keep track of data**, including health and health history of circular products and services.

**Sources:**
Circular principles adapted from (Konietzko et al., 2020; Bocken et al., 2016)
For the longevity potential for electric vehicles see e.g: [https://www.youtube.com/watch?v=2SQ5PoV1hYY](https://www.youtube.com/watch?v=2SQ5PoV1hYY)
What is a Business Model?

Business Models...

- Have many definitions, examples and taxonomies
- A BM “Describe the rational of how an organisation creates, delivers and captures value” (Osterwalder and Pigneur, 2010)
- Few companies understand their BM, strengths and limitations (Johnson et al., 2008)
- Are better predictors of financial performance (Weill et al., 2004)
- Can inform innovation process
- Key for business success (Casadesus-Masanell and Ricart, 2011)

Source: https://trainertushar.in/author/siteadmin/
**What is a Circular Business Model?**

CBMs are expression of a “stock-based economy” that is an economy that builds on a different profit-making logic than the “linear flow-based economy”.

Profit is generated by providing access to a stock of products or by the utility that a stock of products can deliver. Therefore, the stock has to be considered attractive for as long and for as many users as possible.

The longer time each unit in the stock can deliver utility, the higher the revenue and profit will be generated. Hence, it is paramount that the designers are incentivised to make products desirable over time.

An extreme situation would be that manufacturing companies stop producing products, retain their ownership until their end-of-life and instead merely sell their access or performance. To know more about other ways to design stock-based (circular) business models, see “The Performance Economy” by Walter Stahel (2010).

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Today there are a plenty of definitions of CBMs (*Kirchherr et al., 2017*). However, common key features can be identified:

1) **Circular supply**: material recycling via renewable energy
2) **Resource recovery**: substitution primary material input with secondary production;
3) **Product life extension**: extending the useful lifetime of products through design for longer average lifespans and enabling second life (e.g., repair or remanufacturing);
4) **Sharing**: enable increased utilisation rate of products via shared use/access/ownership (often though digital platforms)
5) **Product as a service**: product access and retained ownership to internalise benefits of circular resource productivity (e.g. renting).
What is a Business Ecosystem?

The shift from a linear to a circular economy is a complex problem and timely success requires joint effort from multiple stakeholders towards achieving higher resource efficiency and effectiveness in production and consumption cycles. Given the systemic nature of the implied change, the business model as a firm-level construct is no longer adequate to serve as the primary unit of analysis. One of the main challenges in circular transitions for corporations is to manage the distribution of new activities required for resource optimization within their established value chains and many times new partnership and orchestrations are needed. proposition for the customer that any single firm. The ecosystem concept is centered on the creation of a joint value in the constellation cannot achieve in isolation (Lingens et al., 2021; Adner, 2017; Jacobides et al., 2018).

The business ecosystem view provides another perspective, arguably more tailored to systemic change. Descriptions of business (or innovation) ecosystems place increased focus on the system around the firm and its dependency on actors around it with a few principles emphasized including: the shared outcome organised around a focal firm (Autio & Thomas 2014), the symbiotic relationship between a set of actors (Basole & Rouse 2008), or the value flows of products and services, data, payments and intangibles (den Ouden, 2010).

As such the business ecosystem view lends itself to focusing on the system as a whole, and in its most extreme forms, the roles of actors – product/service provider, suppliers and customers – become essentially equalised. In case of systems transitions (or change and learning in complex systems) like the one suggested by circular business logic, such an equalised view of actors is valuable as it can reveal some of the very relationships and competences that may restrict change. While a complete mapping of an existing business ecosystem can be also seen as a static picture, in its best form, it can facilitate redefining needed competences or relationships often determining the need for completely new competences or to include new actors (Adner, 2012). In the case of implementing a circular business logic (or model), a redefinition is invariably needed as a change in logic means that system rules are changed.
Design for circular business models built around long-lasting products

Product life extension is for many products the circular strategy that has the potential to yield climate / environmental benefits, and there is a growing toolbox for product designers to make it happen. However, due to the intertwined relationship between business and design logic, product life extension is not just a product design activity.

From a product design perspective, slowing resource use is relatively straightforward and already available through design tools, such as the DfX-methods [1] focused on easy disassembly, recycling, modularity remanufacturing, upgradability, etc. These tools offer support to designers with practical guidelines for designing products for desired characteristics. Thus, changing design logic for slowing resource use (e.g., product longevity) is well-supported by previous work and could be seen as a doable engineering activity. However, even if the product design is responsible for the major climate & environmental impacts over the lifecycle of a product, designers cannot control what happens with the product in real-life usage, if this has not been supported by business logic that actually can enable the product to realise its embedded potential. Although, even if products can be designed for longer life they will inevitably be exposed to changes in the surrounding world that will risk making them premature obsolete.

Products that cannot withstand changes during the usage period risk becoming outdated prematurely and thus their economic value is reduced. A great amount of money for functional and timely products are then reduced to a little money for material recycling. At the same time, an extended service life provides great climate and environmental benefits. The reasons why products are outdated prematurely can be due to one or combinations of the four changes described in the table to the right. With such outcomes, the owner or user of the product may judge it to be unsatisfactory and put it in storage, discard it, and replace it with a newer one.

Four basic reasons why products can become obsolete, i.e., unattractive and lose their embedded value(s)

- Aesthetic changes where fashion and taste change. Customers and users value different types of aesthetics and intangible values that are associated with products in different ways, such as shape, colour scheme, materials, or brand values.
- Technical changes and wear that cause existing products to be perceived as low-performing or that they wear out too quickly. For example, a fairly new mobile phone may be fully functional but still considered bad in comparison to the new model – or a glued chair leg may break off and make the chair unusable.
- Functional changes where new needs can not be met. For example, the large sofa in the new, small office may not fit; or new work routines are introduced, disabilities arise or physical dimensions change.
- Social changes, such as new certification rules and legislation regarding material content, can affect interest in certain types of products - or even make them prohibited from selling. Customers can also change their attitudes as e.g towards owning products.

References:
Product design strategies to prevent premature product obsolescence

During circular product design, envision:

- A system with a product architecture of individual modules, being separable in interconnected layers
- Different life-lengths of these modules due to aesthetical, functional, technical and social changes
- The factors that could make modules prematurely obsolete
- Potential customers for the various modules in a sequence over time
- The costs to realize a product architecture that is based on circular principles

Products suitable for circular business models must be aligned with both a circular business and design logic, that are co-developed in early development phases. An important starting point is setting a vision that based on circular principles can be used as a platform to backcast a desired future state of the company and its products, together with the value chain. Read more in appendix: Accelerating System Transition Towards Circularity (RISE REPORT 2021:41). P 60. Available at: http://ri.diva-portal.org/smash/record.jsf?pid=diva2%3A1597861&sid=8977

Read more about design for future adaptable products at: https://www.ri.se/en/what-we-do/expertises/future-adaptive-design-circular-economy
Materials in a circular economy

The choice of material controls the product’s aesthetic expression, wear resistance, energy, water, and chemical ingredients and consumption in production and affects the technical and economic possibilities for reuse and material recycling. Material choices need to be made from a multiple-use cycles perspective and as part of a chain of interconnected circular design activities in the development of a circular business model and suitable product design, to enable material functionality for a long time through several cycles of usage.

Why not be inspired by nature’s production workers who are both simple, efficient, and proven to be sustainable? With combinations of only a few elements everything living in the biosphere is built, i.e. the concept of “Less is more” applied [1]. This stands in strong contrast to today’s material design and usage, combining significantly more of the periodic table’s hundreds of elements in many products.

To develop a circular material palette for your products, the first basic criteria is to divide into two material categories; technical and biological materials [3], which can be combined but must be easily separable during the overall life cycle of a product. However, due to wear and tear, materials in these cycles can have a different usage time. Consumables could have a faster circulation speed and should preferably be made of materials and require less energy and resource than technical materials with more embedded energy and resources.

Technical materials such as iron, metals, electronic components, fossil-based polymeric materials, adhesives, and chemicals, should preferably be designed to have a long usage time and to be circulated with minimal leakage to the environment.

Bio-based materials, such as wood and wood fibre-based materials, textiles, bio-based polymers, and rapidly degradable chemicals, should be designed to fit in with nature’s principles for the circulation of nutrients. In the end, choosing the right materials for the right usage times could save significant energy and resources from a total lifecycle perspective.

Circular principles
- Slowing flows
- Narrowing flows
- Cloosing loops
- Use renewable energy
- Inform

The choice of material needs to be made from circular principles and as part of a chain of interconnecting circular design activities that can increase the potential for value preservation over a long usage time through several use cycles of a product. A starting point is to explore how a circular material palette could be assembled with ingredients that are safe for humans and the planet, have the desired aesthetical and technical properties that also can be circulated back through material recycling without losing its properties.

References:
Some promising circular solutions in the automotive, textile & furniture industry
Promising circular approaches in the textile industry

In recent years the focus on circular initiatives in the textile industry has increased rapidly globally. The challenges to transform the industry are plentiful of intertwined sustainability challenges related to e.g. production of natural fibres, chemical usage in farming, non-renewable ingredients for synthetic fibres, chemicals for surface treatment, short product life for fast fashion clothing, lack of return logistics. Or end-of-life treatments that lead to downcycling, stockpiles in landfills, or evaporation of values as incineration.

Regarding longevity, many efforts have been made, and are made to extend the usage time of clothing and in Sweden, the second-hand market is increasing. More OEMs and resellers are also testing to include used products in their offerings.

Textile material recycling in a CE context could be divided into two main tracks for mechanical recycling versus chemical recycling with pros and cons. In mechanical recycling, textiles are shredded or carded, to extract fibres of the right sizes that could be spun into new garments. Advantages are low complexity in technology and low energy usage. The challenge is to extract fibres of the right quality to keep the original technical properties. In chemical recycling, mixed garments of natural and synthetic fibres are dissolved or de-polymerized into monomers, and for the latter then turned back in a re-polymerisation process.

The advantages of chemical recycling are that material properties can be preserved if turned back into textile fibres. Also, the monomers produced can have a wide variety of usages in the chemical industry. Challenges are impurities of the constituent material and that the process is energy-intensive to run. Several ongoing research attempts are promising, where some have been implemented on the market as with Renewcell that with paper production technologies convert used cotton into a pulp that can be turned into new fabric, i.e. lyocell or viscose. RISE have made many trials that show promising results from both de & repolymerisation, as well as mechanical recycling.
Promising approaches towards circularity in the furniture industry

Sweden has a strong furniture industry with a proud tradition of manufacturing timeless and high-quality furniture, which in 2018 had a turnover of 177 billion SEK [1], where the region of West Sweden has many producers of high-quality furniture for the public sector. Many of these firms strive towards increased circularity in their products and their value chains. However, there is a large amount of office furniture that is prematurely scrapped when businesses move, or when needs changing. At the same time, there is a clear trend towards customers increasingly asking for reused or renovated furniture as part of their sustainability work, the commercial second-hand market is growing and new furniture brokerage companies are established. It is a market in change, where new ways of doing business take shape [2]. However, there are several challenges along the way. Many furniture products are foremost designed for cost-efficient production and not to be upgraded or renovated, e.g., products with laminated chipboards, that in combination with fast fashion trends risk making products premature obsolete. Also, low price furniture might not be considered to be valuable enough to justify repair or renovation, compared to new furniture.

Moreover, a CE will require new routines and processes for repurchases, return handling, remanufacturing on a larger scale, and new forms of collaborations between manufacturers, dealers, customers, and other parties, to find incentives that reward renovation upfront new sales.

Also, chemical ingredients for flame retardants, textiles, foam, and surface treatments are important issues in the industry, where e.g. substitution of polyurethane foams, fake leather, emissions in chipboards, and search for surface treatments that can withstand continuously disinfection with alcohol is some of the most discussed [3].

Although many challenges, there is an ongoing shift in the furniture industry with OEMs, subcontractors, resellers that together with public and private customers have to join forces to implement circular business models and offerings in their value chains. Examples could be found from applied research projects and actors that have set ambitious targets for to be 100% circular as e.g., IKEA.

References:
[3] Examples of furniture OEMs with ambitious targets for CE are e.g., IKEA and FLOKK.
[4] RISE Substitutionscentrum can provide information about alternative chemicals https://www.ri.se/sv/substitutionscentrum.
Promising approaches towards circularity for interior materials in the automotive industry

Contemporary cars and lorries contain a myriad of material types and only some of these types are functionally recycled. Fortunately, metals represent the highest weight percentage in the vehicle and also the highest material recycling rate. However, materials in vehicle interiors, which represent a much lower weight percentage, are commonly incinerated, resulting in losses of valuable materials. Vehicle interior materials are mostly combinations of various polymers, elastomers, textiles, foams, and glues (often in composites), mostly from fossil-based ingredients, representing much embedded energy, hazardous chemical substances that contributing to CO₂ emissions.

Even if reuse and refurbishment are established for vehicle interiors, the vehicle design focused on cost efficient production often makes activities like replacing carpeting, cleaning and repairing seating or scratched plastic panels or updating vehicle controls, time-consuming and less profitable. However, refurbishment of vehicle interiors is doable both from a technical and financial perspective for some vehicle types and many OEMs are planning to scale up their remanufacturing operations. There is also an ongoing shift to implement materials that are recyclable and that are based on recycled ingredients. This is done by e.g., using mono-material solutions. Here, the use of polyester fibres (PET) enables mechanical recycling with a reasonable downgrading or chemical recycling to rebuild the polyester from its building blocks. Although replacing foams of PUR in seating is still difficult due to maintaining material properties over time, a modified material specification to allow the replacement of PUR is technically possible. Moreover, even if the use of natural materials is being widely debated, components made of natural fibres such as kenaf, wool, or wooden veneers made from for ex., eucalyptus or bamboo, have been implemented in the production of vehicles. Leather, on the other hand, is questioned due to toxic ingredients in the tanning process and climate/ethical reasons. While some OEMs have introduced naturally tanned leather with olive leaves, others have abandoned or, plan to substitute natural leather in favour for vegan leather (usually made of PVC or PUR).

In their Flint site, Renault will open what they describe as their RE-factory, with the aim of experimenting with circular strategies as retrofitting vehicles, second life applications, material recycling, etc. https://www.renaultgroup.com/en/news-on-air/news/re-factory-the-flins-site-enters-the-circle-of-the-circular-economy/. Fisker Ocean claimed to be worlds most sustainable vehicle. Features include Full-length solar roof, Interior textiles made from recycled ingredients. https://www.fiskerinc.com/. Polestar experiments with bio based interior materials from flax and seat fabrics from discarded PET bottles and 3D knitted yarns to reduce waste. https://www.polestar.com/. BMW is sourcing natural tanned leather with olive leaf extract to reduce chemicals. Although leather is a durable material that can be more valued after wear, there are still some questions about some environmental aspects. https://www.press.bmwgroup.com/. National Halmstad, manufactures insulation components built up of several types of PET fibres with different properties that are both partly based on recycled ingredients, and that can be mechanically or chemical recycled. https://nationalsweden.se/material/polyesterfiber/. BMWs I3 model has been a benchmark for novel circular interior materials, such as recycled fibres & wool in seats, kenaf fibres in door panels, eucalyptus as surface materials in the instrumental panel, etc. http://www.bimmerfile.com/2014/06/25/bmw-i3-wins-automotive-interiors-expo-award-2014/. Scandinavian Enviro System together with rubber producer Anva produces rubber components with 100% recycled carbon black from discarded tyres. For interior applications, floor mats could be a possible application. https://www.envirosystems.se/en/.
Results
Based on the inventory (described in slide 19), simple descriptions of what each actor wanted / needed and what they had to offer the ecosystem are presented here. Matches were made based on more detailed wants and needs.

**Product focus:** How to produce a circular product

**Material-product focus:** How to produce a circular material

**Value focus:** How to deliver value to the user over time

**Raw material focus:** How to yield material that can be recirculated

**Knowledge focus:** How to create and share information that is needed to achieve circularity

**Principle material flows**

**Principle information flows**

- **Have:** Market
  - **Want:** Circular interior solutions

- **Have:** Circular interior solutions
  - **Want:** Materials, Market

- **Have:** Infrastructure
  - **Want:** Materials

- **Have:** Dismantling knowledge
  - **Want:** Increased price for components

- **Have:** Processes, Material bi-products
  - **Want:** Materials

- **Have:** 3D printing process
  - **Want:** Quality materials

- **Have:** Market
  - **Want:** Circular upholstery
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<td><strong>Purpose:</strong> Project kick-off</td>
<td><strong>Purpose:</strong> To explore specific problems &amp; solutions</td>
<td><strong>Purpose:</strong> Deep dive into CE KPIs and indicators</td>
<td><strong>Purpose:</strong> Result dissemination</td>
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<td>- To meet all the project partners and setting a common ground on challenges and possibilities for reaching more circular value chains.</td>
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Summary of main findings: Barriers and enablers in relation to circular principles in the three studied sectors

Background: The purest vision of circular economy (CE) is aimed at a closed system in which less material deliver equal or more function thus reducing material resource demand (Cullen, 2017). There are many factors that make it difficult for furniture, textile and automotive manufacturers to implement steps towards a CE.

Main barrier: The dominant business logic in each sector involves selling many units of product and this demands a continuous flow of virgin resources into manufactured products. Other contributing factors:

• The sheer diversity of material types used in each sector, whether it be in vehicle interiors or for furniture coverings, make achieving circular outcomes more demanding.
• Existing material specifications with tough criteria for e.g. UV, resistance to wear/tear create lock-ins to certain material combinations and ingredients that are problematic e.g. surface treatments for textiles.
• Toxicity rules make traceability and identification near necessary, something that is often difficult to achieve.
• Tough visual criteria in combination with penalties for variations increase production waste
• Component costs often include the cost of waste, which reduces incentives to reduce waste.
• Customers are sensitive to visual variations
• There is a trend in the automotive industry towards assemblies that are more difficult to dismantle, hindering reuse and clean material fractions for recycling.
• Criteria for component certification make production waste difficult to reuse in automotive components
• Competing goals (even climate change) can create goal conflict and add complexity to assessment and decision-making, potentially reinforcing inaction.

Main enabler: Waste and value loss seen in the steep value hills of products and incineration of materials create interest and incentives for companies to capture lost value. Others include:

• Companies have many goals in common related to CE and climate action.
• There is a wide diversity of material criteria demands meaning that finding a reuse opportunity is merely about finding a match.
• There is a wide diversity of processing competences among companies, both knowledge and machines for different processes and outcomes.
• When companies across branches meet there is a huge interest in finding practical CE solutions
• Companies in the consortia demonstrated a willingness to share and do tests together. In addition, there are many entrepreneurs trying to make circular outcomes happen. They play an important roles as frontrunners and disruptors.

There are activities that aim to capitalise on these enablers and to facilitate change including:

• Review and update of material specifications to identify criteria that might be lowered or altered to enable recirculation
• Explore if certain aesthetic requirements could be eliminated, thus reducing production waste associated with visual variations.
• Initiate collaboration between OEM and subcontractors in finding use of production waste in own or other products, that could provide additional revenue streams.
• Provide customers with background information and a history of why there is a visual variations.
• Include product dismantling workshops already at the design stage.
• Explore how re-certification can be done onsite to re-use production waste.
Summary of promising pilot trials
Background: The Swedish textile industry generates over 6,000 tonnes of waste (estimated to be as much as 14,000 tonnes) per year. Eliminating the origins of this waste is naturally the most direct solution. Beyond this, turning this waste into value beyond its caloric value in incineration is a natural objective in any reasonable circular economy plan. Industrial symbiosis – simply stated, sharing waste or bi-products between industrial actors – has been identified as a key approach (IVA 2019).

Promising solution(s): The collaboration described here focused on recycling of polyester textile production waste. The firms exchanged polyester textile waste to attempt to create fabrics from each other’s bi-products. Since each firm has at least a few main methods of making fabrics from textiles, there were a few avenues to try. Potential products were yarn, insulation or cushion material.

Circularity: This case illustrates how circular principles of closing material loops / flows could be applied. In a broader sense, the case represents how merely shifting waste context has the potential of leading to more circular outcomes. In this case, each entity could not handle its own waste in a different way but could – with its knowledge, machines and customer network – imagine and start to work towards another outcome.

Retained values: Waste textiles represent an undisclosed cost for the entities involved. Incineration does not yield enough energy to offset and justify a payback for containers and transport to waste handling. On the other hand, a recycled yarn product could yield normal market prices as long as it meets specifications. Moreover, in terms of carbon footprint and other environmental impact categories, polyester production represents the most dominant phase of the textile life cycle (as much as 50% when not used in wash intensive settings). Avoiding incineration saves this already invested environmental impact.

Current status: The parties agree that the initial tests were promising. However, they did not result in yarns that do not meet the specifications of the most immediate applications in mind. While the yarns may be acceptable in other applications, test textiles contained loose fibres that would likely be released during use, raising questions about their environmental viability regardless of application. More tests are to be conducted to attempt to improve quality. Chemical recycling is still a consideration. Direct use of the discarded textiles by cutting and sewing into usable fabrics is the final option. This would likely involve the least environmental burden but requires a new process and to find an appropriate application.

Actors involved: Dual Borgstena Sweden, National Sweden, RISE.
Closed loops with increased material values, the “BUMPER” case

Background: The rate of material recycling for nonferrous materials from EoL vehicles (ELVs) is today very low, usually polymers are produced with virgin resources and are being incinerated after use. Moreover, these automotive-grade components rapidly drop in value at end of life due to complex designs being difficult to disassemble. Bumpers from cars is an example of a component type that for most brands are produced in a combination of PP / EPD mix with various levels of talc that are possible to circulate back into new bumpers or used as feedstock for other products. However, this is not the case in Sweden and most markets today.

A promising solution: A consortium in the automotive industry, with OEMs, dealers, repair shops, insurance, material recyclers & branch organisations, had previously investigated and identified components and actors that could circulate ELV components. However, an entity was missing that could make the material into a viable end-product and business model. RISE Sustainable Business connected the consortium with the start-up Sculptur, producing 3D printed high-end furniture from circulated materials. The first prototype of a furniture series was developed and test printed, intended for showrooms at car dealers, as a way to illustrate circular principles to their organisations and customers adding a rich history of materials by traceability.

Circularity: This case illustrates how circular principles of closing, narrowing, and slowing down of material loops / flows could be applied in conjunction. Closing: by using the PP / EPD blend car bumpers can both meet automotive specifications and be recirculated into furniture products, that after many years as an item of furniture, can be ground into pellets and 3d printed back into new products. Narrowing: 3D printing is a very resource-efficient production method using only the material needed for each component. Slowing: Cars have an average life of 10-16 years in Europe, and by adding a use cycle as a piece of furniture with a rich history (from the origin as car components) the chances for many years of usage increases.

Retained values: A discarded bumper has no or negative value (disposal fee), while the recycled outcome chair has a value that is comparable or more than that of the bumper. Moreover, recycling a bumper also offers a reduction in material usage and carbon emissions, closer relationships with customers, more profits, and a more secure material supply chain.

Current status: During 2020 material tests as sorting and cleaning of components and design/prototype work has been carried out. In 2021 market materials and initial customer conversations will be carried out for test sales.

Actors involved: Volvo Cars, Volkswagen, Sculptur, MRF, IF, Stena Recycling, BilSweden, RISE.
Reducing production waste in leather production

Background: Nordic Leather Group (NLG) is a Swedish subcontractor that produces many leather accessories, but makes mostly leather belts. Because the design of leather belts is typically of a rectangular shape and cowhides do not come such a shape, in combination with natural variations in the leather surface and deviations of colour inevitable results in waste. The fashion industry in which NLG operates is characterised by large production volumes within tight timeframes, making the sourcing of hides and time-efficient production crucial. Key current issues include: A) sourcing of extra hides to reduce risks for material shortage since cowhides are mainly sourced from southern Europe and delivery times could greatly vary; B) The amount of waste (30 tons of leather waste was sent to incineration in 2020) represents lost values. Based on NLG's ambitions for sustainability and circularity, together with increasing demands from NLG's customers setting ambitious circular goals for zero waste, strategic ways to reduce the company's waste have been explored.

A promising solution to narrow material flows: Today the main production method at NLG is machine cutting, where hides are fastened to a flat cutting table and then cut. Before cutting, the cuttable part of the hide is identified and distributed (Figure 1). By optimising the cuttable portion by mixing components for several customers (figure 2), products can be jointly cut in the same area. With such an approach, NLG could both meet just-in-time customers and produce components to put in stock for customers that are less dependent on just in time delivery schedules.

Circularity: Leather is a material that provides many valuable properties in product design as giving a natural expression for fashion, furniture, and automotive applications as well as good properties for wear and tear, which can make leather products usable for many decades with the right maintenance. Foremost, leather as a material meets circular criteria for product longevity. Additionally, leather represents the narrowing and closing principles as hides - by definition - are waste material from meat production. Environmental impacts of leather include a share of that from meat production and in particular, impacts from the tanning process, which is commonly chemical intensive.

Retained values: As all material costs are comprised in the component price including waste, there are no additional costs for producing components for stock. Rather, costs could be reduced by avoiding waste-handling costs.

Current status: RISE has supported NLG in exploring ways to design out waste by facilitating a range of contacts with new actors and ideation of activities. Some ideas have been tested and several discussions with stakeholders have been initiated. These include collaborations with small niche producers and designers exploring upcycling, and the design of long-life leather products, to large OEMs, where leather waste could be integrated into existing products. Also, internal efforts at NLG have been carried out to use hides more efficiently in the existing process.

Findings: It may seem surprising that materials representing large economic values are routinely disposed, but NLG is far from being the only subcontractor having significant waste streams within the current linear logic. Generally speaking, reasons for today's situation in the production industry can be found in a combination of elements such as the purchasing logic from customers, with a focus on just-in-time delivery, high-quality demands, and often with penalties if the quality is not met. Also, the component price in most cases includes waste and waste handling and waste could be difficult for OEMs to factor in, if targets for reduction in value chains are not actively set up. Also, the ownership of materials could be an issue as NLG is not allowed to use materials that are closely related to a specific OEM brand, e.g., with specific colours, shapes or logos. However, in this case, NLG has ownership of the waste material which allows them to make new products. Moreover, as NLG traditionally has produced only based on customers' orders, there has been no prior experience of producing components to put in stock. However, this pilot has shown that this could be done.

To sum up, this change to combine several customer products into the same hides requires NLG to add extra time and requires more operator skills in the pre-production. In addition, it requires planning and forecasting not currently done. Nonetheless, a further development based on such approach could be to open up for available free production areas to other NLGs customers. Also, it would be worth considering ways to further find cascading usage applications for leather waste still remaining after production optimisation.

Actors involved: Nordic Leather Group, RISE.
Upcycling of idling materials into design for product longevity

**Background:** After a career as an architect, Cecilia Eduards left the building industry with the idea to merge the qualities and materiality of good classic architecture with a design philosophy for creating durable and aesthetical long-lasting fashion accessory bags. Her company, Eduards Accessories (EA), was founded and launched in 2013, and products are now presented in selected design and fashion stores in Scandinavia, Europe, Australia, and Japan. All items are handmade in Sweden exclusively from vegetable-tanned leather of top quality by skilled craftsmen. As a designer, Cecilia has the intention to design products that can meet customers’ aesthetical and practical needs over time. Even though Cecilia foremost uses classic designs for new styles combined with a slow change pace of models as an enabler for longevity, it is still hard to monitor customers’ purchase and disposal behaviors in detail. However, Cecilia can control how the EA brand communicates novelty versus existing products, and here she deliberately uses storytelling and brand-building through social media that show only used products. With this strategy, customers get used to a story about already used products that become more personal by allowing traces from usage to be visual, which thus could help create stronger attachments to the owners.

**A promising solution to narrow and slowing down material flows:** During discussions with RISE, several areas for exploring circular business models have been identified such as buyback offerings, providing products-as-a-service, or upgrade offerings, if the customer functional requirements of carrying space changes. However, a promising area of exploration where the potential for both improved market values and profitability has been to identify idling materials at the subcontractor Nordic Leather Group (NLG). As NLG mainly produces leather accessories in very large volumes and with strict just-in-time deadlines, they often have materials left over from large customers that end up idling in stock. Retained values: As just-in-time production requires careful planning in the sourcing of materials, adding material becomes insurance for NLG to not face a material shortage, although the result is often surplus hides of very high quality and economic values that become idle in storage. Here, smaller OEMs such as EA play a role that can use such idling resources in low quantities to do exclusive and limited editions where unique colours, pattering, and information of origin becomes important components in the storytelling. Moreover, these idling hides could also create a financial win-win for both NLG and EA as there are both incentives to free up NLG storage space, as well for EA to get access to premium hides at a lower price than if sourced directly from the tannery.

**Current status:** During the first quarter of 2021, EA has developed a limited bag collection based on leather from assorted idling hides under the name the “Leather archive project”. EA sees this collection as an important statement to communicate the company’s design and sustainability philosophy.

**Findings:** At first sight, this case could illustrate something obvious in the traditional thrifting industry logic, as treating valuable materials that become production waste as fuel for incineration, as an expensive way to create heat and evaporate embedded economic values. However, due to mismatches between different sizes of actors, volumes and requirements for delivery on time and production cost, significant economic values, and climate/environment impacts that today are lost or become idle, could be better utilised in many industries. If circular business ecosystems would be built by continuously matching actors with various needs and wants, material resources could be significantly optimised. What is too small for one actor could be just the perfect size for another one. Here, we see a huge opportunity for creating ways for matchmaking and collaboration across and between various industries and types of actors. Just as in nature, where ecosystems consist of a plentiful of organisms that thrive in symbiosis over time.

**Actors involved:** Eduards Accessories, Nordic Leather Group, RISE.
Improving circularity for child seats

Background: Artex is a product development and manufacturing company in the textile industry focused on the design, production, and refurbishment of used seats for mainly public transports. Artex operates in branches, such as railway, buses, transport vehicles, cars with many large customers as for ex., Bombardier, Scania, Volvo, as well as components for the furniture industry. Artex sees a strong business case in their refurbishment activities where customers can save both money and environmental gains e.g., by updating their existing train or bus seats instead of buying new ones.

Artex core business is built around the design and craftsmanship of textile materials, but includes many other materials, such as foam, felt, leather, wood, steel, and various polymers. In many of their projects, Artex often takes overall responsibility for product development, including design, pattern construction, material choices, sourcing, and production of complete products.

Artex is striving to improve circularity for its materials and products from the design stage, i.e. where they have control. Examples include modular designs that make refurbishment easier, or sourcing of materials with recycled ingredients. Or substituting materials with problematic chemical substances. However, design for refurbishment is sometimes challenging to implement, especially for large public customers where purchase strategies that promote refurbishment, not always are followed up in the existing component designs. For ex., seats in public transports. As Artex today uses a wide variety of materials in its current material library, with difficulties to judge the potential for circularity during its product’s different life cycle stages, an exploration to develop a process for categorising more circular materials has been launched.

A promising solution: Artex is the producer for Volvo Cars (VCC) integrated child seat, tailor made for Volvo Cars models. This product was chosen for the first analysis for improved circularity, and the current leather substitute and the PUR foam in the upholstery were judged difficult to meet circular criteria of closing loops, and regeneration. Regarding PUR foams, the debate and search for replacement materials have been going on for decades in the furniture and automotive industries, due to environmental concerns in the production and end-of-life phases. However, PUR foams are still very much appreciated due to form stability, manufacturability, and price. Moreover, in ongoing research biobased PUR foams are under development that can reduce fossil dependency for polymers [1]. There are available substitute materials to PUR foams as Polyester (PET) fibres as e.g., [2], and production methods to go along with it [3]. However, with PET-based foam, there could be issues with sag over time, and comfort issues that have to be considered in the design. Regarding leather substitutes, there are several biobased alternatives on their way to the market that are promising [4].

Circularity
If (as has been discussed ) PET can be used both in the outer fabrics and in the foam, there is a potential to create a product that is recyclable by mechanical or chemical methods. Also, as there today is good availability of PET fabrics and fibres based on recycled ingredients this could narrow resource flows. However, as a long usage time will give the biggest environmental gains, spending careful thoughts about the choice of the outer fabric visual and tactile properties, and design for ease of disassembly for cleaning and refurbishment, will be important to prevent premature obsolescence.

Current status: The work started in early 2021 and is ongoing

Actors involved: Volvo cars, Artex, RISE

References:
[2]https://steps-mistra.se/
Improving material circularity for service vehicles

**Background:** Modulsystem is a producer of interiors for Light Commercial Service and delivery vehicles. They take full responsibility for rebuilding standard Light Commercial Vehicles (LCVs) to meet customer needs for storage, lighting, energy support, etc. LCVs are mainly bought under leasing agreements where the interior cost is embedded. After the lease period, the interior (that often can survive the life length of the vehicle) sometimes are reused and put in the customer's next vehicle for another usage period. Alternatively, they are sent to material recycling and disposal. The components in the interior, mainly drawer and shelves are built up by a modular system where the whole interior is slid in on racks and mounted to the vehicle body. The materials for the interior shelving are mainly steel, but there are also floor, wall, and insulation materials included in the complete installation. These materials could be combinations of e.g., plywood, aluminium, sandwich laminates, polystyrene (EPS) insulation, and acrylic or polypropylene (PP) wall coverings.

Several areas for improved circularity have been identified, from a refurbishment offering of complete interiors to including installation of renewable energy powered auxiliary power units, to choosing materials based on recycled ingredients, due to increased demands from customers in the automotive industry.

Also, improved insulation for battery electric vehicles (BEVs) is an emerging customer requirement. For traditional LCVs, tougher emission regulations will prohibit idling with internal combustion engine vehicles (ICEVs), but BEVs are also somewhat ill-equipped to deal with cold temperatures. If BEVs are not equipped with an extra power unit or range extender and if there is no access to a charge point or diesel heater, generating heat will affect vehicle range and will add complexity in route, and work planning. Thus, finding a suitable insulation material has become an important issue for Modulsystem to further explore.

**A promising solution:** The most commons solution for insulation in LCV’s is to use various boards of EPS insulation, but this solution does now provide enough thermal properties and is time-consuming to assemble. Moreover, gluing EPS blocks to the car body and wall panels makes disassembly at end-of-life difficult.

During a matchmaking meeting with the actors in the circular knowledge transfer project, National Sweden presented their solutions for insulation of vehicle cabs for vehicles operating in a winter climate, e.g., in the north of Sweden. The material used in the vehicles is soft Polyester (PET) fibres that are bound on an outer carrier of harder PET, creating both insulation and wall panel modules of various densities that are mono materials. In National’s current production process there are a lot of EPS cuts that today are wasted and incinerated. There are several ongoing research initiatives where this waste material could be chemically recycled and there have been trials to recomb these waste cuts and form them into coherent insulation blocks again. In this case, these possibilities will be further explored together with actors that can provide a cost-effective combing process, that can result in the right technical properties similar to the virgin PET fibres.

**Circularity:** The suggested wall and insulation panels in PET are fully recyclable, and if production waste from production cuts could be repurposed into insulation for service vans, there is a potential for saving valuable materials that today are being incinerated. Moreover, by improved insulation properties, energy needed for heating the vehicles could be lowered, reducing emissions from diesel heaters.

**Current status:**
Due to the Covid pandemic, the practical hand-on work with vehicles and products started during early 2021, and will, in a first phase, focus on finding the right thermal effects with test of various PET insulation types, before exploring production waste.

**Actors involved:** Modulsystem, National Sweden, RISE.
References


Appendix
**Supportive Methods and Tools**

- A managerial toolbox that theoretically outlines how sustainable system transition links in with BM and CBM with the use of the Multi Level perspective
  - As representation for Industry logic
  - Devices to commercialise technology
  - Subject to innovation
- Strategically framed how the Toolbox can be used as an enabler for system thinking and sustainable transition to CE.


- A selection of easy-to-use methods for diagnosing and facilitating organisations and business ecosystems in managing change particularly towards a higher degree of circularity
- Audience: primarily for change agents
- Content
  - Key concepts: CE and System Transition
  - 15 methods for diagnosing change
  - 9 facilitation tools at organisational level
  - 9 methods for facilitating business ecosystems creation and development.

Sustainable Business is a group of researchers within RISE, that since 2013 has systematically worked with knowledge building in Circular Economy with a focus on circular business models, business model innovation, business ecosystem measurability, product-related business risks, environment, and climate benefits, etc. We believe that more resource-productive circular business models can accelerate the transition in society to radically reduce the climate and environmental impact.

For more information, please visit www.ri.se