CLOSING THE LOOP

TOWARD CIRCULARITY IN THE SUPPLY CHAIN

MIT Center for Transportation & Logistics

Roundtable Report

Winter 2019/2020

Sustainable Supply Chains

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Why Circular Supply Chains?

4.6
Pounds of waste per person, per day in the U.S.

25%
Percentage of consumer waste recycled

8%
Percentage of consumer **plastics** recycled

20%
Product return rates for e-commerce are **double** that of brick-and-mortar retail

U.S. HOUSEHOLDS

BARRIERS

Companies are currently wired for linear supply chains.

Fragmented or missing standards work against circular supply chains.

Consumers need recycling education to improve the recyclability of the stream.

Motivators to Solving the Challenges

REGULATION

CONSUMER PRESSURE

NGO PRESSURE

Bottom Up

Employees who see a way work better or managers looking to see waste as a value stream

Top Down

CEO passionate about the environment, or corporate directive to improve

Images of a brand's iconic products or packaging washing up on beaches or appearing in horrific images of e-waste processing situations creates a pressure to take control of end-of-life items.

> "If the conversation is only about cost, you're dead in the water"
>
> *- Apparel Manufacturer*

> "We announced goals on plastics because people expect it now."
>
> *- Computer Manufacturer*

> "We have an outcry from consumer youth—Gen Z wants this."
>
> *- Apparel Manufacturer*

Mechanisms for Circular Supply Chains

Ecosystems of partners
- -Public-private ecosystems
- -Supply chain ecosystems
- -Pre-competitive collaboration

During the roundtable, groups considered 18 circularity mechanisms (shown randomly at right)

Groups converged on:

- Industrial symbiosis
- Product design
- Reverse logistics

as primary mechanisms to drive circular supply chains

In every ecosystem, all partners must be viable and motivated in order to play their role.

> "The future is a circular economy, and the heart of that is collaboration on future technology and additional research."
>
> *- FMCG Retailer*

Extend lifecycle

Energy recovery

Dematerialization

Production on-demand

Closed-loop supply

Secondary markets

Down-cycling

Sharing platforms

Product design

Tracking assets

Recycling

Upgrade and repair

Pay per-use

Sell and buy back

Refurbish resell

Manage assets

Industrial symbiosis

Reverse logistics

Activity adapted from materials from the Ellen McArthur Foundation, ellenmacarthurfoundation.org

Examples of Circular Supply Chains

Servitization

Consumers get a lifetime membership and their first organic cotton shirt by paying a deposit. They get a new shirt for nominal fee, any time, for any reason when they return an old one in any condition. The company recycles returned shirts and encourages customers to include other end-of-life apparel in the return envelope. More than 20,000 people were on the waiting list to join the service.

Reverse Logistics

Two companies said they have recycling initiatives that generate more revenue than they cost. Interestingly, although recycling is profitable at both companies, they don't book these profits. Instead, they prefer to reinvest the gains in further circularity efforts such as training, investment in recycling equipment, and other opportunities.

Industrial Symbiosis

"Industrial symbiosis" eliminates waste by finding a partner who would use the "waste" as input for their own product. Byproducts become products. Materials suppliers, competitors, and companies in other industries can help close the loop. For example, using carbon fiber scrap from the aerospace industry to make high-performance laptop parts.

Product Design

Better designs might also steer products away from "monstrous hybrids" that are hard to disassemble and recycle. Designing multi-use, concentrated products helps enclose more product in less packaging and reduce the total number of different products consumers must buy.

> "Only go after partnerships that will move significant volumes of waste."
>
> *- Apparel Manufacturer*

Cloaing the Loop - Toward Circularity in the Supply Chain, Roundtable Report Highlights

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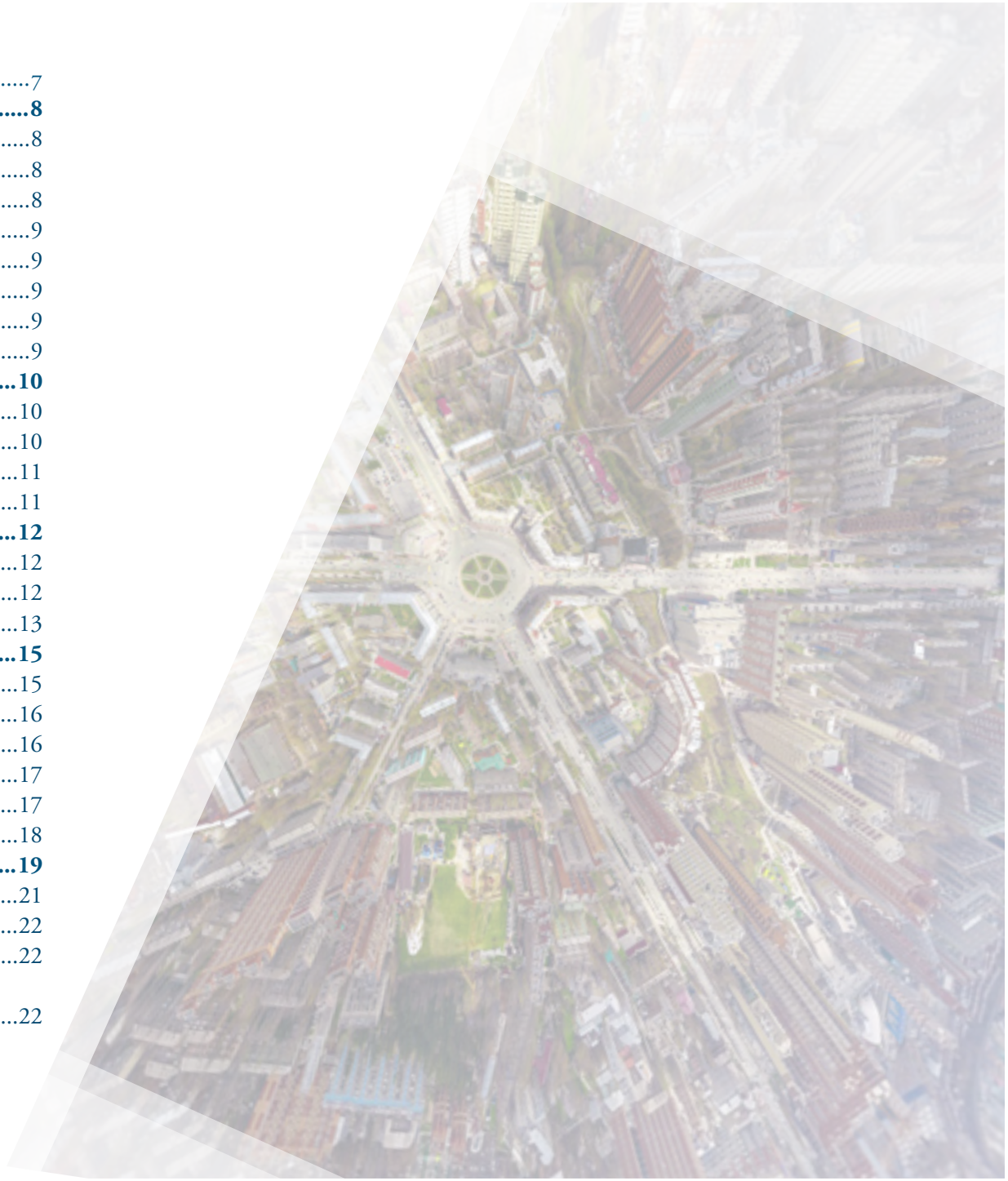

Executive Summary

The MIT Center for Transportation and Logistics (CTL) convened participants from industry, non-profits, and academia to discuss circular supply chains during the December, 2019 roundtable. Participants came from industries spanning technology, apparel, food, beverages, finance and furniture as well as from product makers, retailers, and carriers. Despite the diversity of participants, the day revealed that they faced similar challenges. The five sessions of the day-long event covered the following topics: e-commerce consumer channels, managing end-of-life products, business and government ecosystems, a business model brainstorming session, and discussions of the future of circular supply chains. This report used Chatham House rules to ensure the candor of participants in sharing their best practices, ideas, and issues.

Companies cited seven drivers for their circular supply chain efforts: motivated employees, mission-driven leaders, high-level sustainability goals, waste stream economics, access to materials, customers' demands, and regulation. All these drivers were important because "if the conversation is about cost, you've already lost." Participants advocated a systems-level view.

Growing e-commerce consumer channels affect circularity in positive and negative ways. Increased last-mile product deliveries offer new opportunities for reverse logistics even as they have increased product returns and packaging waste streams. Companies can partner with retailers for collection of returns, used goods, and end-of-life products. The sharing economy dovetails with the circular economy through renting, sharing, and reuse of products.

A key insight was, "Waste is just a resource in the wrong person's hands." Many companies were turning what had seemed like waste streams of materials, packaging, and products into value streams. For example, plastic bottles become shoes, shoes become playground surfaces, flex film becomes decking material, food waste becomes electricity, and so on. Making waste tangible to those who affect its creation helps get that wasted resource into the right hands.

The circular economy depends on building ecosystems of partners. The group discussed three such ecosystems: public-private ecosystems comprised of consumers, municipal waste collectors, waste haulers, materials recovery facilities (MRFs), and materials processing firms; supply chain ecosystems of individual corporations that provide (or accept) diverse recycled materials; and industry ecosystems for pre-competitive collaboration on standards for circularity at scale. In every ecosystem, all partners must be viable and motivated in order to play their role.

A brainstorming session asked independent breakout groups to pick seven business model elements from a list of 18 that will be essential to circular economy businesses. The groups converged on three universal elements: first, product design for circularity reduced waste, increased recyclability, and extended the life cycle; second, reverse logistics (e.g., last-mile returns and municipal recycling programs) recovered end-of-life packaging and products as a prelude to reuse and recycling; third, industrial symbiosis created webs of companies to convert byproducts to products and convert waste into assets across a multi-industrial ecosystem.

The future of the circular supply chains depends on economic ecosystems, pre-competitive standards, and matchmaking to find new uses for old materials. Thus, ongoing collaboration will be a key element of building the circular economy. Inspired by this desire for collaboration, MIT CTL is currently in the process of creating a consortium for shared research, conversation, and roundtables that help develop and adopt best practices for the future.

1. Drivers for Circularity

Dr. Alexis Bateman, Director of MIT Sustainable Supply Chains, opened the roundtable with four trends that highlighted the need for circular supply chains at the societal level. The first trend is the ongoing accumulation of waste—an average of 4.6 pounds per person per day—of which only 25% is recycled. Second, China's refusal to take US plastics recycling materials puts pressure on developing in-country infrastructure and materials recovery facilities (MRFs). Third, growing concern about the impact of discarded plastics, bans on single-use bags, and a war on disposable straws underscore the threat of regulation of supply chain packaging and as well as the opportunity for new solutions. Fourth, the explosion of e-commerce has brought a concomitant explosion of both packaging in municipal waste streams and product returns in retail supply chains.

At the company level, the participants cited a wide range of drivers (and some challenges) to pursuing circular economy initiatives. The examples they gave showed how the motivation to pursue circularity initiatives can come from within the company or external sources. Internally, the effort can be started top-down or bottom up, with reasons ranging from philosophical conviction to economic reasons to material access practicalities. Externally, motivation can come from regulation or from consumer/NGO pressure. One of the overall insights from the roundtable was that internal motivation, not just external pressure, was driving numerous circularity efforts.

1.1. Challenge: Going Beyond Cost

In talking about justifying corporate circular economy initiatives, one participant said, "If the conversation is about cost, you're dead in the water." The reason is that many, but not all, initiatives do come with a financial cost either up front (e.g., investment in equipment) or on an incremental basis (e.g., higher prices for a recycled material). Currently, the low price of landfills and fossil fuels makes them attractive to those focused only on the bottom line. Thus, several participants said companies need other motivators beyond short-term cost to drive circularity efforts. These motivators include the value of circularity for resilience and license to operate.

1.2. Employees Make it Happen

Three companies had employee-driven circularity efforts. At one shoe company, the motivation for recycling came from the employees who saw the waste and wanted to do better. The company's culture emphasizes taking action. When employees discovered there were no recycling opportunities for their company's products at end of life, they decided to take it upon themselves to repurpose the materials. In other cases, mid-level managers found ways to motivate employees to see waste and think of creative ways to do something about it, such as turning recycled materials into limited-edition runs of products that tell a story. The challenge with bottom-up initiatives is in harnessing them for replication at scale.

1.3. Leaders with a Mission

At some companies, the drive for circularity comes from the top. That might be through a CEO who is intrinsically passionate about the environment. Or, it might be leadership that sets aggressive sustainability goals, such as achieving zero waste by 2030, that drive company actions. At least one company at the roundtable was a certified B Corporation. This legal structure enables a company to balance fiduciary responsibilities to shareholders with other social or environmental priorities.
The B Corporation at the roundtable said they balance the needs of six stakeholders: the company, customers, employees, suppliers, the community, and the earth.

1.4. Waste Stream Economics

In some cases, a focus on costs can help circularity: "Waste costs money, so we can save the earth and save money at the same time," a manufacturing company said. Similarly, raw materials cost money, and therefore reusing scrap saves both disposal costs and avoids the costs of additional virgin raw materials. A food retailer has an anaerobic digester for food scraps that not only avoids the cost of waste disposal but also generates electricity. Although the company does not sell the digested material, the material could be sold to farmers or gardeners.

Two companies said they have recycling initiatives that generate more revenue than they cost. Interestingly, although recycling is profitable at both companies, they don't book these profits. Instead, they prefer to reinvest the gains in further circularity efforts such as training, investment in recycling equipment, and other opportunities. That is, the companies use circularity for the internal finances of circularity.

1.5. Recycled Supply Stream Economics and Risks

Supply-side issues also drive investments in circularity. A representative from a circular economy investment firm raised substantial funds from large brand-name companies. These companies want to finance startups to help create the supply base and services needed for circularity.

For example, if only 8% of consumer plastic is recycled, then only 8% of "new" plastic items can be PCR. Therefore, large companies who want to reach their green goals, such as PCR content, need viable recycling at scale.

Risk of access of vital raw materials also encourages circularity, such as when China restricted access to rare earth materia. Recycling or urban mining offers a safe second source for materials that mitigate risks of resource nationalism and commodity price fluctuations. As MIT CTL Director Prof. Yossi Sheffi pointed out, Johnson Controls recycles 99% of its car batteries, insulating the company from price fluctuations in lead.

1.6. Consumers, Customers, and NGOs

"We have an outcry from consumer youth—Gen Z wants this," said one company. Images of a brand's iconic products or packaging washing up on beaches or appearing in horrific images of third-world e-waste processing situations creates a pressure to take control of end-of-life items. Some customers may also pressure well-known brands, particularly ones seen as forward-thinking, to take the lead on sustainability issues, pushing those companies to do more than the minimum and become role models for recycling efforts. A technology maker admitted, "We announced goals on plastics because people expect it now."

A computer maker called EPEAT—an environmental product certification—an "easy button" for consumers and organization customers (e.g., the US government) seeking sustainable products. Among EPEAT's 51 criteria for achieving Bronze, Silver, or Gold level certification are circular economy properties such as recycled content, recyclability, product longevity, and end-of-life management, among others. The company said making products to the EPEAT standard was a good way to address customer "care-abouts" and boost sales to these customers.

1.7. Regulation: Sticks and Carrots

Finally, government regulations can drive initiatives on circularity. Regulations such as Extended Producer Responsibility (EPR) put the burden back on the product's producer to be responsible for its end-of-life disposal. EPR regulations are common in the EU but are found in only 10 US states. Similarly, bans on products such as single-use plastic bags push companies to consider alternatives or consider proactive self-regulation to reduce the chance of more forceful government regulation.

1.8. Goals Take On a Life of Their Own

Several organizations expanded on the topic of setting high-level goals that then become drivers. Goals targeted areas such as levels of post-consumer recycled (PCR) content in products, zero waste, greenhouse gas (GHG) emissions, and wastewater. Such goals put a stake in the ground that can galvanize the company to address tough challenges, such as investing in the infrastructure or working more closely with supply chain partners. Goals also help create a common language and drive alignment of circularity efforts.

2. Consumer Channels

The rise of e-commerce creates a double challenge to circularity, but also an opportunity. First, it creates an explosion in the packaging in the post-consumer waste stream. The boxes and void-fill required for damage-free last-mile deliveries by parcel companies, couriers, and the postal service mean that corrugated paper is now 50% of consumer waste. Second, product return rates for e-commerce are double that of brick-and-mortar retail (20% versus 8 to 10%). This poses a waste and refurbishment challenge in managing returned products for resale, reuse, or recycling. Some evidence suggests that many of these returns are adding to the waste stream.

This retail trend and its impact spurred a roundtable session on how companies currently use or could use new channels in the forward supply chain to improve circularity for used products and packaging.

2.1. Challenge: Consumer (Mis)behavior

Several discussions during the day highlighted how some consumers' behaviors make circularity harder. Although some consumers do seem to care about the environment, several participants were skeptical about mainstream attitudes and actions. Although a solid 60 to 70% of consumers claim to support sustainability when surveyed, they vote with their wallet in retail. Only a niche percentage of consumers—perhaps 5% to 10%—are actually willing to pay more for sustainability. "I don't think we can expect consumers to fundamentally change their mindset or behavior," said one participant.

Similarly, planned obsolescence and consumers' preferences for newer, cooler products in technology and fashion seem to contribute to the volume of waste. Fast fashion has gone to a 52-season cycle, with garments being worn for only nine months before being donated or discarded.

Many participants advocated more consumer education. A nonprofit focusing on municipal recycling noted that first people must be trained to recycle. Next, they have to be trained to recycle well. Education might include putting an "Oops!" tag on a mis-filled recycling bin, encouraging consumers to take the extra step of taking empty bottles from the bathroom to the kitchen's recycle bins, or educating consumers on recycling codes for plastics. Although unlikely to be copied by the US, China's Social Credit System motivates citizens to recycle properly (along with many other appropriate social behaviors) to ensure consumers get access to get loans and other things.

2.2. Solution: Easy Last-Mile Takeback

A retailer noted how online retailers strive to reduce friction for consumers. E-tailers make buying items as easy as possible and make returning them easy so that consumers order more and are likely to spend more. Similarly, many sharing economy mobile apps try to eliminate the friction from activities ranging from bike sharing to software updates. The opportunity comes in the fact that the easy-buy/easy-return model of online shopping habituates consumers to reverse logistics. Thus, it may offer a convenient way for handling end-of-life products as well.

This idea can extend to packaging. Companies who do last-mile delivery have a great opportunity to take back materials and to use reusable totes instead of bags. With enough delivery density and frequency, they could readily retrieve empty totes left by customers on the doorstep. At least one major online retailer does this, closing the loop by taking the reusable plastic tote at the next delivery or collection round. Another company was developing refrigerated cooler boxes for households that could be used by last-mile companies to deliver perishable groceries rather than wrap every order in non-reusable insulation. These cooler boxes could be electronically lockable.

2.3. Solution: Creating Collection Partnerships

The high cost of visiting individual households and handling individual parcels motivates companies to somehow consolidate items rather than bringing them back one at a time from customers. For example, a computer maker partnered with a large nonprofit to handle the challenge of end-of-life PCs and related technology products. The nonprofit operates 3,200 thrift stores around the US that specialize in hiring the disadvantaged who then refurbish donated goods for sale.

Under the partnership, consumers can drop off old PCs, laptops, printers, and other technology products (from any maker) at the nonprofit's drop-off locations. The nonprofit refurbishes and resells working products, extracts and resells useful internal components if possible, and sends the rest to partner recyclers who break down the products into raw materials. Similarly, other companies were arranging partnerships with retailers and shipping stores: A shoe manufacturer accepts drop-off of its shoes and competitor shoes at its retail locations.

Several participants noted the lack of control they have over the fates of their products once they leave the factory or warehouse. An environmentally conscious firm gets consumer complaints about excessive packaging added by downstream e-commerce outlets but has little influence on these retailers. Customers and consumers can do anything they want with the product. The challenge for companies is to ensure responsible behavior to get the best use, reuse, and end-of-life handling from their products.

For example, financial incentives can also spur both higher rates of consumer recycling and cost-effective consolidation. Some US states and some countries levy refundable deposits on bottles or other products. Consumers can get a refund if they return the end-of-life product to a collection center or participating retailer. The retailer may have incentives to participate in collections because the refund to the consumer is in the form of a voucher for that retailer. US states that offer 5¢ a bottle have 60% return rates on bottles, Prof. Sheffi said.

2.4. Solution: From Products to Services and Sharing

Another solution to controlling the fate of end-of-life products is to switch from a product sales model to a leasing or rental services model. For example, a circular economy investment firm described a startup's circular business modelfor t-shirt rental. Consumers get a lifetime membership and their first organic cotton shirt by paying a deposit. They can get a new shirt any time for any reason (and then return the old one in any condition) for nominal fee, usually less than the cost of a t-shirt at retail. The company recycles returned shirts and encourages customers to include other end-of-life apparel in the return envelope. More than 20,000 people were on the waiting list to join the service.

Other discussions highlighted the potential role of sharing economy apps as a consumer channel for extending the life of products. The sharing economy pairs well with the circular economy because sharing extends the life of a product, often in the context of local peer-to-peer transactions that minimize transportation distances (and their costs and impacts). For example, two participants mentioned platforms for sharing-type reuse of children's wear, cribs, car seats, and other kids' products that children quickly outgrow but that are reusable. Traceability solutions can help manage tracking of service or shared assets through cycles of use, reverse logistics, refurbishment, and redeployment. Items can be collected by last-mile networks, collection partnerships, or by a circular economy startup and, as one traceability solutions provider discovered, can be used 15 to 20 times before reaching end of life.

3. End of Life: The Beginning of New Life

"Waste" has a negative connotation. However, one participant suggested, "Waste is just excess material in the wrong person's hands," A quotation attributed to Oliver Waddington-Ball, Founder of Goldfinger factory. Most people might think that discarded water bottles are waste, but they may be pure polyester, which some manufacturers want and would pay for. Once a material has been made, most of the environmental damage (water, energy, materials, etc.) has been done. All that can be done then is to make the best use of that material, extend its life as far as possible, and minimize the further impacts of its disposal.

Some participants advocated avoiding waste in the first place; a product or material that never needs to be made saves the most in cost and environmental impact. For example, an apparel maker noted that the rising use of digital product samples can avoid the waste and costs of physical product samples during the product development and sales processes. A grocer works to minimize waste of fresh products by reducing the days on hand and coordinating movements of products. A fashion product maker sought to reduce forecast errors that create wasteful excess inventory by reducing the number of color options or embellishments on those products.

The Ellen MacArthur Foundation's "butterfly diagram"* illustrates the many possible circles of the circular economy with end-of-life materials circling to other users or a spectrum of upstream supply chain locations. Under the butterfly framework, tighter circles provide better circularity by finding a more valuable reuse of the item and fewer steps to recycling the material. The roundtable's session on managing the end of life in supply chains focused on the various ways companies can make that lifespan almost endless through reuse and recycling. The examples shared during the session and the rest of the day could be viewed as a quadrant of circularity scenarios. One dimension of the quadrant contrasted products and packaging. The other dimension contrasted post-industrial recycling and post-consumer recycling scenarios.

3.1. Best Practice: Make Waste Tangible

People can't see CO_2, but they can see waste. Some companies shared ways to make waste more visible to employees and decision makers in order to spur more ideas about its elimination or repurposing. For example, a maker of cleaning products has a zero waste goal that they will likely meet in 2019. To help drive the effort, they hold an annual dumpster dive to show people what is being discarded and get them to think of how to reduce, reuse, or recycle it. The company also moved all the trash bins from individual offices to a central location to make people more conscious of discarding things. Another shoe maker brought designers to the factory floor to see the waste created by inefficient designs or wasteful embellishments. Indeed, employees at all levels need to see the waste that their decisions may be creating if they are to either eliminate it or find a use for it. Seeing the waste could help shift the mindset from linear thinking to circular thinking in which downstream is not over the horizon and out of sight. In closing the loop, what goes out the factory door as product or waste eventually returns to the inbound side, either at the company or at another company.

3.2. Best Practice: Treat Waste Like an Asset

Many companies gave examples of creating value from waste rather than treating it like a financial and environmental cost. For example, a CPG maker found a solution for the empty corrugated boxes that were just being thrown into landfills. In 2014, they looked for ways to give the boxes extra life. To create the biggest environmental benefit, they partnered with a company who could reuse the boxes as boxes. Moreover, they pursued similar efforts to reuse or recycle shrink-wrap and tie downs.

*https://www.ellenmacarthurfoundation.org/circular-economy/concept/infographic

Treating the boxes like an asset, not trash, required a big change in how workers handled them. The company had to train workers to open the boxes carefully, not cut them, and to fold and stack them on pallets to the correct height for shipment. Other companies commented on how the trend from waste to assets affects procurement and design—higher-quality packaging might be designed for longer life rather than lowest-possible cost. Beyond that, participants mentioned the next stage would be purposely-made reusable packaging.

A technology product maker said it sees its end-of-life products as a valuable asset to take back—it shouldn't be a burden. After one customer is done with a product, there's often additional use and value in it. Old equipment such as computers can be refurbished and resold by wiping the previous customer's data and ensuring the product is functional. The manufacturer also gave examples of leading outdoor apparel retailers, such as Patagonia and REI, who welcome returns and used merchandise as an opportunity for reselling used equipment and apparel. People recognize that old products can be refurbished, making old products, in fact, assets.

In some cases, refurbishment and resale isn't possible. For example, in 1990, employees of a shoe maker wanted to find a better solution to handling returns of sampled, defective, or end-of-life shoes instead of dumping them in a landfill. They encountered a difficulty, however: Shoe makers create very strongly bonded amalgams of many different materials for a long-lived product—good for the environment—but also one that is very hard to recycle—not ideal.

The key to finding value in end-of-life shoes was in inventing a way to separate the materials to make something useful for other applications. The company's employees experimented with various water jets, cheese graters, and other ideas until they designed a functional grinding machine. The machine produces relatively pure fragments of rubber, foam, and textiles. They then found uses for the material, which offers a combination of moisture-wicking, noise absorption, or rebound properties. They sold ground-up shoes to makers of sports surfaces, playgrounds, carpet padding, acoustic dampeners, and car interiors. The company partners with other industries to reuse materials and also recycle some of the grind back into its own products. Today, the company operates grinding centers in the US and Belgium that have recycled a total of 100 million pounds of footwear and scrap. The example shows two of the key challenges of recycling: converting the original items into something useful and finding the people who want to use it.

Companies identified many diverse ways to convert waste into value. One shoe company representative was wearing patchwork-colored shoes made as an experiment in using the leftover materials from other shoe models. The company also had created a limited-edition yellow and green jersey with a story behind it for teaching moments in circularity. Another example was a liquor company that encourages customers to return its glass bottles for conversion into commemorative glassware. Even food waste can be converted into electricity and compost cake for farmers. Finally, the use of shoes to make flooring shows how materials can flow from industry to industry.

3.3. Solving Challenges to Finding Value

Eventually, however, finished goods products do reach the end of their usable lives. Compared to the recycling of packaging and industrial scrap raw materials, several participants said recycling of finished consumer products is much harder due to the complexity of products and the many different materials they contain. In some cases, product makers can refurbish and resell products. In other cases, the product cannot be reused, and recyclers face the bottleneck of breaking apart a durable good into the most useful components or materials. Even textiles are hard to reuse if they contain different materials; stitching, zippers, and tags must be cut off.

Yet some companies find that even truly unusable end-of-life products can still be an asset. Their key challenge is that the recovered components or materials must have enough value left to be reused for some other purpose. Handling, consumer use, and recycling processes can contaminate or damage some materials. For example, the processing of recycled fabric shortens the fibers, which reduces their value. Contamination of plastics and metals can limit their further use to lower-value applications. Much of the time, participants said products are down-converted into a raw material (e.g., plastic, metal) to be reused as a pure input to something else. An electronics maker noted that for electronics, recycling itself comes with costly environmental, health, and safety concerns given the toxicity of some of the materials.

Finding value in waste such as post-consumer plastics can also take investment. A maker of cleaning products wanted to increase the sustainability of its business by closing the loop on the plastics used to package their liquid products. In 2003, they committed to create and use recyclable plastic bottles made from PCR (Post Consumer Recycled) plastic for products, which encompassed 67% of the company's total sales. As a smaller company, one challenge was in finding a bottle supplier willing to try to make the bottles from PCR plastic. The supplier demanded that the company pay for the dyes and molds as well as guarantee a minimum volume of bottle production. Because the company was committed to improving circularity, it bore the added costs of large inventories of bottles.

Although the company's use of PCR plastic extended the life of that material for another cycle, continuing the circle has been a challenge. The bottle's label has so strongly adhered that it interferes with further reuse and recycling; less than 25% of the company's PCR bottles loop back for another round of recycling. That rate is much higher than the US average, though. The US recycles a mere 8% of its post-consumer plastics due to contamination by food, labels, or mixed content that can't be re-processed. Rates are even lower for plastic film and flexible packaging: only 4% for polyethylene monolayer and 0% for multilayer films.

This issue with low rates of recycling by consumers highlights a difference between PCR and PIR (Post Industrial Recycled) materials. A manufacturer noted that post-industrial waste, such as raw materials scrap and packaging, has two big advantages over post-consumer waste. First, it often contains relatively pure materials, which have high value. Second, it can be collected in large volumes at a relatively small number of locations—a few factory sites rather than millions of households. Collectors can pick up these pure materials and consolidate them at recycling centers that are co-located near the overseas factories of the manufacturer. The reprocessed materials then circle back to the manufacturer's factories to be reused in their products, or they go to partner companies that can reuse them.

The challenge of product recycling complexity grows even harder if a company accepts competitors' products for recycling. A manufacturer noted that they know the raw materials, adhesives, chemistry, and construction of their own products but not those of other makers. They have a restricted substances list for their own products, but they don't know what's in competitor's products. No single company can solve the problem of complex, unknown, post-consumer products; it takes an ecosystem approach.

Finally, some end-of-life products or materials are too contaminated or degraded for any further use of the materials in products. A participant cited a podcast that explained the controversial practice of incineration as a way to at least get energy from waste. The EU is especially advanced in its waste-to-energy systems that help offset coal use. Incineration isn't ideal, but it may be better than landfill.

4. Ecosystems

"One company can't do it alone. A whole ecosystem is needed," said two participants. For example, a CPG company invented a recyclable toothpaste container, but the container can't be distinguished from non-recyclable ones. Thus, it would be discarded along with all the other non-recyclable toothpaste containers. To be viable, a circular economy solution needs an ecosystem to support all the arc segments of the circle of manufacturing, distribution, end-of-life collection, materials recovery, and reprocessing to loop back to manufacturing.

Overall, the group discussed three key ecosystems that have the largest impacts on circularity. Discussion began with the public-private ecosystem associated with the post-consumer recycling collection networks that are managed at the municipal level in conjunction with private waste haulers and MRFs. This ecosystem aggregates, separates, and enables conversion of post-consumer materials into new products. Second, the supplier ecosystems of individual corporations that work to bring recycled materials into products. Third, industry ecosystems composed of competing peer companies collaborate at a pre-competitive stage to create standards and practices that enable efficient scale of circular activities.

4.1. Boosting the Municipal Collection Infrastructure

Municipal recycling programs could be the dominant way to aggregate end-of-life materials from individual consumers so that these materials are recycled to provide sufficient supply of PCR materials to companies. A nonprofit focused on municipal recycling described the challenges of and solutions for the collection end of post-consumer recycling. The first challenge is that 50% of US households don't even have access to municipal recycling.

The uneven infrastructure arises because each of the 21,000 independent municipalities make their own waste collection arrangements. This is not just a US problem. A manufacturer reported that recycling infrastructure for post-industrial recycling varies by country, too—China can handle it but Indonesia can't, for example.

The nonprofit helps grow municipal recycling infrastructure through a model they call "voluntary producer responsibility." It accepts corporate donations that it uses to fund grants for recycling carts, technical assistance, consumer education, and recovery infrastructure development. One unusual challenge the nonprofit faced was just trying to give municipalities money; many local governments lack any official process for taking money from third parties outside of normal streams of government revenues such as taxes, fines, and fees.

Simply providing access to recycling alone is not enough to solve the problem. First, consumers need encouragement to recycle. Encouragement spurs volume, but it can also bring contamination problems. Therefore, consumers also need education on how to recycle well to improve the quality and recyclability of the stream.

The nonprofit thus also supports consumer education and outreach for recycling with open-source solutions. Online instructional material is inexpensive but not very effective because it requires consumers to actively seek it out. Unfortunately, many municipalities only have a budget of $1 per household per year for education—only enough to mail one postcard a year. Overall, changing consumer behavior involves some combination of education, incentives, and regulation, said an MIT researcher.

4.2. On the Road to Recovery

Takeback is expensive, but is only the first part of the story. Some participants wondered whether companies that tout reusable and recyclable items actually succeed at reuse and recycling. "I'd like to know what do they do once they get the product back," said one participant. As mentioned in the context of recycling clothing, shoes, and computers, recycling finished goods can be challenging owing to the many diverse materials in the product and the challenges of separating parts that were meant to stay together to ensure the life and performance of the product. If the collected materials can't be separated and converted to something useful, they end up in a landfill or incinerator anyway.

The recycling nonprofit also helped with the second layer in the municipal recycling collection ecosystem: the MRFs that aggregate and separate recycling streams into bulk quantities of single materials, such as bales of plastic bottles of a specific type and color. MRFs tend to be large, privately run facilities that aggregate recyclables from many municipalities in a region—what could be called a "recoveryshed." The nonprofit created an initiative to bring representatives from 50 cities together to learn best practices and create common solutions to help standardize the fragmented policies of municipalities in each recoveryshed.

Next, recovered materials need conversion into a usable form for making the next generation of products. For example, synthetic leather cannot be simply collected and re-used directly, nor can plastic. Plastic, for instance, may need to be melted and formed into pellets before it can be incorporated into a new product. Specialized processing facilities take the sorted materials and convert them into a raw material that is compatible with the typical equipment used to manufacture products from virgin materials. This brings the recycled materials back into the upstream end of product supply chains.

MRFs and processing, however, require substantial investment, which requires confidence in demand for recycled materials and a stable supply of incoming materials. Offtake agreements are a best practice that can both motivate construction of recycling and conversion infrastructure and ensure a supply of recycled materials or demand for recyclable waste streams. These agreements with a MRF or recycled material processor provide a guaranteed long-term customer (say, seven years of purchase commitments) contingent on the facility meeting performance requirements such as low contamination. The offtake agreements stream down from top brands, who are funding the infrastructure. They recognize the need for more capacity so they signal to the market that they will buy the output of this part of the circular supply chain.

Another solution to encourage funding of costly infrastructure is tradable certificates. In the sustainable energy space, RECs (renewable energy certificates) have created a tradable commodity out of renewable energy capacity that creates a market for renewable energy and encourages both investment in large-scale renewable energy projects and reduces friction in using renewable energy. ARCs (attributes of recyclable content) would be the recyclable materials equivalent of RECs. Three participants mentioned that tradable certificates in these materials would help develop the industry.

4.3. Building Recyclable Supply Ecosystems

A supplier to a computer maker made an offer to close the loop on plastics collected by the maker's nonprofit recycling partner. The supplier said, "We would like to take your plastic and put it back into your product." The computer maker agreed. So, now, plastics from old unsalable computers and equipment are sorted by type, ground into pellets, sent to Asia, and re-molded into cases for displays and desktop products that are sold as new products. At end of life, they can again be donated back to the nonprofit. Everyone in the full loop benefits: the computer maker, the nonprofit, the recycler, the re-grinders, the resin supplier, and so on. An independent third-party life-cycle analysis (LCA), environmental analysis, and water-shedding analysis found that this loop beats using virgin raw materials and landfill dumping of end-of-life products, even when factoring in the transportation.

Building the loop took two years. In some cases, recycling involves even more complex ecosystems with cross-industry connections. For example, a computer maker is taking scrap carbon fiber from aerospace firms to make stronger carbon-fiber reinforced parts for lightweight laptops. The question is: What will happen to those carbon-fiber reinforced laptop parts at their end of life? The answer to that might entail further cross-industry connections, such as talking to carbon fiber producers and partnering with them to reach customers in other industries that might have a use for PCR carbon-fiber reinforced polymers.

As the carbon fiber example shows, part of the challenge for companies looking to improve circularity of either raw materials or their end-of-life products is finding matching partners who might be in very different industries. For example, packaging industry shrink wrap from a grocer can become housing industry deck planking, and beverage industry plastic bottles can become apparel industry shoes. The US Business Council on Sustainable Material can help match industrial materials to those who need them.

One challenge with these circular supply ecosystems is the well-intentioned regulations around international shipping of materials that many deem to be waste. Transportation of recyclable materials between countries can be a challenge because companies can't ship "waste" to China or Korea. The material needs to be coded as a raw material or feedstock instead. That requires partnership with these governments to enable this coding, so that the raw material can get back to the manufacturing facilities.

4.4. Creating Value for All Stakeholders and Incumbents

With ecosystems come stakeholders and incumbents. And with any proposed changes in practices to create circular supply chains come questions of adoption by stakeholders and reactions by incumbents. Change brings the tough issue of who bears the costs and who reaps the benefits of circularity. The most salient challenge in any of these ecosystems was that the circle fails if any link in the cycle isn't viable to all participants' need to get some value, incentives, or motivation for their efforts.

For example, several participants mentioned refillable products as one solution for extending the life of consumer packaging. However, they also noted how this requires changes for at least three categories of stakeholders. First, it requires product makers to offer appropriate bulk-quantity versions of their products for replenishing the refilling station. Second, it requires retailers (or third-party merchandisers) to manage the refill stations. This adds complexity and labor over the current practice of simply restocking more bottles on the shelves, and it also requires rolling out new processes across large retail networks. Finally, it asks consumers to remember to bring empty bottles back to store and refill them. Consumers, product makers, and retailers all need incentives to ensure all three adopt the solution.

One key takeaway was the observation that companies are currently wired for linear supply chains. Many key performance indicators (KPIs) focus on the performance of individual departments or silos. Thus, a department that currently makes money from selling surplus cardboard might fight the move to reusable containers, even though reusable containers would be best overall. Transforming the linear chain into a circle requires different, more holistic KPIs. This observation extends to society, too. The economic focus of GDP growth prizes consumption over more balanced measures of quality of life and the environment.

The solution to these challenges is a systems-level view, which helps everyone see the value that can benefit the whole company, supply chain, community, and partners. Recall the admonition of moving beyond just "cost" as the decision-making variable. The systems view moves beyond concerns about short-term costs to one part of the organization to ensuring the viability of supply chains and demand in the long-term.

An investment firm focusing on circular economy targets all parts of these various ecosystems. The firm said, "We look at the system and all the players—the collectors, haulers, sorters, haulers again—each one of the players has to find value in their process and content." Each of the firm's investments targets some key gap in creating the circular supply chains in fashion, food, electronics, and other industries.

It might be an artificial intelligence (AI) robot that sorts recyclables, or systems to improve transparency, or enabling technologies that overlay the whole circle. As with the nonprofit, much of the investment firm's funding comes from very large companies that need circular supply chains to reach their sustainability goals at scale.

4.5. Achieving Scale

Some participants worried about the small scale of many of the efforts mentioned at the roundtable. For example, a shoe company made a shoe completely from one material, which certainly makes recycling much easier, but they only made 200 pairs in total. Also, a circular business model shirt company might have what seems like a huge waiting list of tens of thousands, but it's tiny compared to the total market of billions of shirt-wearing consumers. A parcel delivery company once offered a consolidated waste program but never got the volumes needed to make it viable. A different shoe company described the financial magnitude of their revenues from recycling as a rounding error on the company's balance sheet.

However, if the global economy is to become truly sustainable, then all these circular initiatives will need much more scale. As mentioned earlier, since consumers only recycle 8% of plastic bottles, bottle makers can only have 8% PCR content in new bottles. One of the big companies at the roundtable said big companies have a big opportunity to drive solutions at scale. Smaller brands might be nimble in trying new ideas, but they have limited resources and impact by themselves. The large company said, "We can't wait for little experiments."

Instead, the company suggested an approach in which each large company picks their top five materials that create the most waste and works to move the needle on them. "Only go after partnerships that will move significant volumes of waste. Treat it as a pre-competitive space to get to scale." For example, a global grocery chain suggested they could drive scale to their anaerobic digesters by including other companies' food waste, too. This type of sharing of ideas and capacity dovetails the sharing economy and the circular economy.

4.6. Peer Ecosystems for Pre-Competitive Standards

Many participants extolled the virtues and opportunities in pre-competitive collaboration for finding cost-effective solutions in circular supply chains and driving scale. These shared solutions would probably take the form of standards that companies implement in their own processes, expect from suppliers, or offer to customers. More specifically, companies wanted standards for materials and audit processes.

Fragmented or missing standards are a problem for circular supply chains. A food company that was working on compostable packaging highlighted the challenges of fragmented standards. For materials, the ASTM (American Society for Testing and Materials) standard for compostability specifies an 84-day digestion period. However, commercial composting facilities use a 45-day period to ensure viable economics. This difference implies that materials that might meet the ASTM standard might fail to fully digest within the shorter period used by commercial digesters. Undigested materials make the resulting compost cake unacceptable to farmers who don't want fragments of undigested trash blowing around their fields. To add further confusion, some states are proposing their own composting standards. Joint coordination between compostable materials makers, composters, and regulators would help find a standards definition that is viable for all and enables earth-to-earth cycling.

Participants mentioned two materials-related standards that could help create circular supply chains. A first standard—a "materials passport"—would enumerate the materials in a product in a standard way. Knowing the content of the item would help guide recovery processes and enable the highest value of recovery from that product. Second, standards on restricted materials would reduce the risk of toxins in the waste stream and recycled materials and reduce the risks to firms that handle post-industrial and post-consumer items. Together, the two standards help the viability of recovery facilities and the attractiveness of recycled materials.

Some industry-specific groups such as the Sustainable Apparel Coalition are already working to encourage and develop standards.

Participants also wanted standardized audit processes for circular supply chain partners to help reduce the costs of compliance and the risks of noncompliance. On the upstream side, audit processes ensure that suppliers and contract manufacturers use the materials they claim to use (e.g., a certain percentage of PCR), avoid restricted materials, and operate in a sustainable fashion. On the downstream size, audits ensure that collectors of PIR and end-of-life products handle the materials—especially e-waste—in a sustainable way. Standardized audits would help companies with due diligence and reduce suppliers' cost in complying with fragmented audit processes. All of these standards would reduce friction in circular supply chains, enabling the circular economy of the future.

5. Brainstorming the Circular Economy of the Future

In the afternoon, the group divided into five independent subgroups of about a half-dozen people each to brainstorm business models for the circular economy. Each group was given the same set of 18 business model building blocks: cards printed with a business model element, definition, and examples of it. They were told to pick the seven cards that had the most potential for creating a circular business model. The questions to be answered by the exercise were twofold. First, if companies start with no constraints, what are the core practices they might use to drive a circular economy? Second, would the different groups independently converge on similar solutions?

The 18 building blocks (and corresponding definition and examples) were:

1. **Industrial symbiosis**
   - Partner to convert waste streams from companies to raw materials
   - Timberland uses old tires to produce new shoe soles

2. **Product-life extension**
   - Repair, upgrade, remanufacture, or remarket products for longer life
   - Caterpillar upgrades and repairs their products throughout the lifecycle

3. **Sharing platform**
   - Utilize idle assets by offering their use to others
   - Airbnb, GetAround car sharing, FLOOW2

4. **Leasing/pay-per-use services**
   - Offer products as a service
   - Avis car leasing

5. **Product design**
   - Design for durability, upgradability, maintenance, and repairability
   - Miele washing machines, Fairphone

6. **Sell and buyback**
   - Sell a product with an agreement to repurchase it at the end of use
   - Vodafone Red-Hot scheme

7. **Reverse logistics**
   - Collect and move used materials, products, and components from user
   - DHL reverse logistics for products

8. **Facilitating and operating secondary markets**
   - Host a venue/platform for resale of used or surplus products or parts
   - Ebay, US Materials Marketplace

9. **Tracking assets**
   - Collect information to enable maintenance, ecovery, reuse, remanufacture
   - TROMA: sensor-based tracking for collecting, tracking recyleables

10. **Refurbishment and reselling of used products (third party)**
    - Collect, refurbish, and resell another company's used products
    - GameStop: refurbishing and reselling electronic equipment

11. **Support lifecycle extension**
    - Sell consumables, spare parts, and add-ons for product life extension
    - Car repair and servicing, Splosh refills

12. **Downcycling**
    - Turn materials from used products into new products with lower quality
    - Nike: shredded shoes become sports flooring

13. **Recycling**
    - Turn materials from used products into new products of similar quality
    - Plastic bottle recycling/reuse schemes

14. **Internal asset management**
    - Optimize equipment lifetime, track assets, promote lean strategies
    - GM's landfill-free product sites program; Unilever's Zero Waste program

15. **Product demand**
    - Produce only after orders have been placed (personalization components)
    - SWOON: produces furniture after reaching a set amount of orders

16. **Dematerialized services**
    - Shift from physical products to physical or virtual services and processes
    - Netflix, Spotify

17. **Closed-loop supply chains**
    - Enable multiple uses of resources and materials to minimize virgin material
    - Braiform: loops garment hangers through makers, retailers & reuse centers

18. **Energy recovery**
    - Convert waste into useful heat, electricity, or fuel
    - Kroger: food waste into biogas; Copenhagen: municipal waste for heating

Activity adapted from materials from the Ellen McArthur Foundation
ellenmacarthurfoundation.org

5.1. Key Business Model Element: Product Design

All five groups started with product design as the key enabler for circularity. Two apparel industry participants stressed the need for new designs as a prerequisite for circularity. Over half of waste created by a product is embedded in the design decisions. "To change at scale, we need to start with different design," was the consensus rationale.

New designs might mean using new materials, such as upcycling postal envelopes into shoes or creating new manufacturing technologies that reduce scrap. Or, designers might use modularity to help extend product use and manage the trade-off between separability and complex components. Better designs might also steer products away from "monstrous hybrids" that are hard to disassemble and recycle. Designing multi-use, concentrated products helps enclose more product in less packaging and reduce the total number of different products consumers must buy.

An organic food company shared their story of designing for circularity. They wanted to design a substitute for the product's plastic thin-film wrapper that kept food favors in and outside odors out—essential to extending the shelf life of the product. In particular, they wanted to design a thin film from PCR materials that was also compostable.

They started an industry group to make the volume attractive to material manufacturers and found a partner to help design candidate materials. However, some candidate PCR materials didn't work on the manufacturing line, some PCR materials weren't compostable, and the suppliers of PCR materials could not guarantee the uniformity of properties. Each trial took four months just to test for compostability. After five years and six trials, no solution had been found. In the end, the company decided to design a plant-based material solution instead of PCR. Although different from the initial PCR vision, the plant-based product did reduce reliance on fossil fuels and offered earth-to-earth circularity.

This example shows the challenge of trade-offs for design for circularity. Another food maker noted other competing demands for these kinds of wrapping materials. The packaging of a food product needs to provide a good consumer experience: being attractive in the marketing sense and feeling good in consumers' hands. Reducing the weight or composition of the packaging may make it feel too flimsy and lessen the product quality in the consumer's eyes. Similarly, the earlier example of the challenge of recycling shoes highlights the design challenge of making strong products that stay together (long life) versus products designed for disassembly. All of these examples illustrate the broader design challenge of creating what's good for product performance (and sales) and what's good for the planet.

One suggested design solution was to embed software-driven functionality into the product such that it extends product life. For example, shoe makers might design a shoe that contains software to control and change the color of the shoe. That would solve the fast-fashion waste problem. Or, the software might change the stiffness so that one pair of shoes works for both walking and running. The idea is analogous to what Tesla does now: downloading new software into all cars every week.

Some participants argued that product design wasn't necessarily the required starting point and might even be a holdover from linear thinking. For example, perhaps a company could begin by building services around existing products. In a truly circular system, a company could start anywhere, reframe the interconnected webs, enhance the undeveloped pieces, and maybe free up different possibilities for new directions. Two participants suggested focusing on what is relevant to the company and what can have the most impact. That focus might extend beyond the product to look at the whole loop.

5.2. Key Business Model Element: Industrial Symbiosis

"Industrial symbiosis" eliminates waste by finding a partner who would use the "waste" as input for their own product. Byproducts become products. Materials suppliers, competitors, and companies in other industries can help close the loop. For example, using carbon fiber scrap from the aerospace industry to make high-performance laptop parts that could then be recycled into still other products illustrates the potential power and complexity of industrial symbiosis.

5.3. Key Business Model Element: Reverse Logistics

All groups also picked reverse logistics as a key business model component. The day's discussions of municipal collection, e-commerce returns, and end-of-life product takeback highlighted the essential role of reverse logistics. In the butterfly diagram, reverse logistics helps loop downstream resources back to upstream players. A logistics provider said they could meld the various distribution networks that they service to create more shared trucks and distribution centers to enable less costly reverse logistics.

The group commented on some of the other business model options that were used or not. For instance, the leasing and pay-per-service elements were also powerful for creating alternate product life cycle management schemes. Recycling was suggested because there was always some material that spilled through. No one chose sharing platforms, refurbishment, or downcycling. Why weren't these considered fundamental? Participants replied that those elements overlapped with other multipurpose components (e.g., downcycling could be handled by recycling).

Some of the group discussions revealed that circular isn't a strictly a circle of repeating birth and death of products. It's more of a web of connections that can cut across many directions. If waste is a resource in the wrong hands, then the right hands might not be further along the circle. They might be in another industry's circle.

5.4. Best Practice: Research, Learning, and Collaboration for Circularity

Many of the discussions and key takeaways called for knowledge creation and sharing to help solve the challenges of circularity and spread them across supply chains. For example, plastics recyclers are trying to solve the challenge of de-inking. However, the paper recycling industry has already succeeded in solving the de-inking problem. Paper recycling has low margins, so its solutions need to be inexpensive. Recyclers of other materials could learn from the paper industry. Similarly, glass recycling has reached a tipping point for scale, so recyclers of other materials could learn from these pioneers.

Several participants advocated for creating more knowledge through research, such as on better circular materials, technologies for material segregation and conversion, and recovering CO_2 from the atmosphere. That new knowledge could form the basis for shared standards, practices, and toolkits. These cross-industry solutions would enable scale better than fragmented individual brand solutions.

One key challenge for collaboration is finding a platform that continues the conversation started at this roundtable. **As a result of this roundtable, the MIT Center for Transportation & Logistics is creating the Consortium for Circular Supply Chains** to pool resources for research and to support many opportunities for collaboration across organizations who share the same vision. The consortium will bring together different people from across the circular economy, such as suppliers, product makers, retailers, and carriers, procurement managers, and waste managers; or private companies, municipalities, regulators, and NGOs. Such a consortium could extend the conversation to create a continuous discussion supported by research and roundtables. "The future is a circular economy, and the heart of that is collaboration on future technology and additional research," concluded a retailer.

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Sustainable Supply Chains

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