Circular Economic Surplus Asset Management:

A game changer in Life Sciences

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Abstract

The integration of Surplus Asset Management (SAM) with the Circular Economy (CE) provides a solution to optimize the use of resources, assets, and equipment, throughout their life cycle enabling new business models, increasing profitability, achieving sustainability goals, plus reducing obsolescence and waste. We introduce the Circular Economic Surplus Asset Management (CE-SAM) as a business approach to create value by extending the life cycles of discarded useful equipment. We distinguish four types of value: sourcing value, customer value, information value, and environmental value. Carbon footprints can be reduced by up to 80% by redeploying equipment depending on residual value and customer needs. CE-SAM can be a business game-changer if it is integrated as part of the business strategy. The implementation challenges can be best tackled through the collaboration of different actors along the value chain, depending on their capabilities and capacity. REUZEit, a case study company, provides a feasible case study that services life science and pharmaceutical companies to optimize the use of their resources, assets, and equipment, to reduce obsolescence, waste, and increase profit at the same time.

1. Introduction

Businesses need resources to produce goods and services. By resources, we mean materials, water, and energy, among others. From the point-of-origin to the point-of-consumption or usage, raw materials feed supply chains; also, energy and water are indispensable for the production and distribution of goods and services. For example, 70 to 80% of the energy footprint of personal electronic devices occurs during the manufacturing phase[1].

Recent studies show that many natural resources are becoming scarce such as rare earth minerals. The consequences of resource scarcity include volatile and rising commodity prices and supply disruptions. Hence the resource consumption of supply chains must be reduced. Additionally, we must deal with climate change, partly caused by GHG--greenhouse gas—emissions of supply chains. Since most GHG emissions result from resource consumption, in particular energy, reducing natural resource consumption and reducing GHG emissions go hand-in-hand (Krikke, 2011). Finally, waste streams such as discarded electronics and marine litter are polluting our planet.

Circular Economy (CE) provides a solution to both resource scarcity and GHG emissions through the reuse and recycling of discarded products and packaging. CE is a model of production and consumption, which involves sharing, leasing, reusing, reconditioning, repairing, refurbishing, and recycling existing materials and products as long as possible. Jacqueline Cramer (2017) describes 10 possible circular "R" options (Figure 1).

Figure 1. 10R diagram of the Circular Economy[2]

CE is an industrial economy that is restorative or regenerative by design and value. Although both economic and environmental values are included in the definition; CE tends to focus on the reduction of environmental impact. To underpin this outcome, we must calculate ecological footprints. The methods require data on inputs (natural resources) then we calculate the outputs—such as GHGs. The most extensive form of a footprint is Life Cycle Assessment (LCA). However, LCA is complicated, time-consuming, and expensive, and therefore simplified methods are often applied. Currently, most ecological footprint methods seem to focus on GHG emissions or merely on resource inputs such as water, energy, and materials.

1 https://www.apple.com/environment/pdf/products/iphone/iPhone_8_PER_sept2017.pdf

2 Jacqueline Cramer (2017)

Irrespective of environmental concerns, to have a viable business case and for industry *buy-in* we also need to look at economics. Surplus Asset Management (SAM) is a potentially profitable activity to redeploy products, goods, or items owned by an entity that are not core to its operations and that no longer support the business.

Surplus Assets will typically include property (premises), obsolete assets, used items or devices, and working capital (inventory). SAM maximizes the *end-of-life* value of systems and products no longer useful to the owner. SAM is traditionally quantitatively underpinned by return on investment (ROI) or economic value added (EVA) calculations. It can also be quantified by the life extension of a product considering its residual value at every reuse loop or ultimately at recycling.

Combining CE and SAM leads to Circular Economic Surplus Asset Management (CE-SAM). Table 1 maps the CE-SAM playing field. CE-SAM is a circular practice creating value by extending the life cycles of discarded—but still useful products and systems—in a closed-loop supply chain. It incorporates concepts like closed-loop supply chains, life cycle management, new business models, and product stewardship.

Closed-loop supply chains drive multiple values creation as discussed later. Life cycle management focuses on product eco-design, product stewardship, or extended producer responsibility across a product's life cycle often imposed by legislation. CE business models aim for *servitization*, which refers to industries using their products to sell *outcome as a service* rather than a one-off sale. CE-SAM is a profitable business proposition that may reduce environmental impact, limit GHG emissions, and increase social impact by enabling access to technology and products at a lower cost—thus creating multiple values.

	Product focus	*Process focus*
Relationship / network focus	***Product Stewardship: Extended Producer Responsibility (EPR)***	***New Business Models (NBM): servitization***
Technical / operations focus	***Life Cycle Management (LCM): eco-design***	***Closed-loop Supply Chains (CLSC): value creation***

Table 1. Circular Economic Surplus Asset Management playing field (adapted from Krikke, 2020)

So why do we need CE-SAM? The World Economic Forum[3] (WEF) found that the global circularity index is getting worse. The number of goods and packages being reused and recycled is less than 6.5% of the total produced and consumed. Staggering GHG emissions continue with acceleration in global warming. The latest climate change conference COP26 in Glasgow showed a general acceptance that there is a need to act—yet a sense of urgency was not universally shared. Finally, we increasingly witness illegal exports of waste from rich countries to developing economies. We now show how businesses can contribute to sustainable development goals in a profitable way by introducing CE-SAM—making the business case and providing a sustainable business model.

2. Value creation through Circular Economic Surplus Asset Management

Until recently, reuse and recycling were viewed as a cost or as activities with no added value—and not near the core business. As a result of this perspective, *damage control* solutions were adopted. However, redeploying, reusing, and recycling are becoming core business activities. These activities add value thanks to changes in business models, operational processes, and customer behavior.
Products must be designed for reuse and recycling, business models must be geared for circularity, operations must run a closed-loop supply chain, and processes and their enablers—such as information technology (IT) systems—must be adapted. **Four values** can be created and are crucial; these include sourcing, environmental, customer, and informational values. We present a holistic view of

[3] WEF 2021

how to realize these values by reverse chain processes and how they can reinforce each other.

Sourcing value refers to the direct financial gains that come from less expensive sourcing, avoiding the use of new resources, and avoiding disposal fees and environmental fines. The price of remanufactured products, for instance, is known to be about 40% lower than newly built products. About 100 years ago labor cost represented more than half the total cost of car production. Through reuse, all added value embedded in the product is reused, hence the full cost does not need to be added again. For example, if building a new product requires 1000 hours, a remanufactured one only 500 hours, and reconditioning one only 50 hours, the cost benefits can be enormous. No wonder Henry Ford disliked scrapping.

In CE-SAM, there are two main types of redeployment of assets: (1) redeployment with costs; and (2) redeployment without costs, defined as direct redeployment. Redeployment with costs occurs because the asset must be retrieved, reconditioned, and redistributed. Redeployment without costs occurs when an asset is redeployed within the same location. A CE-SAM platform provides an opportunity for users to identify assets in a facility before planned disposition and redeploys the assets internally within a department, building, campus, or industrial complex.

Footprint reduction, pro-active compliance, and environmental leadership through reuse and recycling contribute to **environmental value**. Europe has been leading in formulating directives for producer responsibility—such as in consumer electronics, automotive, and hazardous materials. Asia, including China, Japan, and Korea, and several North American states or provinces have followed. Lowering ecological footprints turn into value once you communicate this possibility to stakeholders.

Customer value refers to activities that enhance customer satisfaction and loyalty through the offering of well-organized product return channels or installed base contracts instead of seeing returns as a cost item. This situation is especially pertinent to electronic retailing—e-tailing—where consumer return rates are relatively high.

Perhaps the least known value is **informational** (or learning) **value** derived from analyzing returns data on common production or supply disruptions, product failures, useful lifetime, consumer usage patterns, and complaints. This information is extremely valuable for improving business processes.
Table 2 provides examples of each of the four value types, their triggers, and recapture.

Trigger	Value Type	Example
Resource scarcity	**Sourcing value**	The company secures supply and lowers the cost of scarce materials by reusing
Climate change	**Environmental value**	The company positions itself as an environmental leader by reducing GHG emissions and trading emission rights
High return rates	**Information value**	Learning from customer complaints or product failures to upgrade products and improve customer satisfaction
Availability	**Customer value**	Extended product life cycles through harvested spare parts

Table 2: Different types of value in practice (source: own research)

Figure 2 visualizes where the four value types are captured in the reverse value chain used for CE-SAM loop closure. Each major activity or business in the reverse value chain creates some type of value.

The literature distinguishes three key processes in the reverse value chain. **Product Acquisition** concerns retrieving the product from the market—sometimes by active buy-back—as well as physically collecting it. **Re-processing** is the process of retrieving, reconditioning, and regaining products, components, and materials. In principle, all recovery options may be applied either in the original supply chain or in some alternative supply chain. **Re-marketing and Sales** lead to re-entry into a forward chain.

In Figure 2, each process represents a portion of the pie. The coloured arcs identify which business process (re)captures which value(s). For example, customer value appears in acquisition (through returns services) and remarketing (by offering reconditioned products). These customers may differ from the original customers.

Sourcing value is captured by acquisition and reprocessing, as is environmental value. The grey areas indicate that—perhaps surprisingly—where no immediate value is captured, at least not according to current academic research. However, this may be due to the perception of value. Information value goes the full circle.

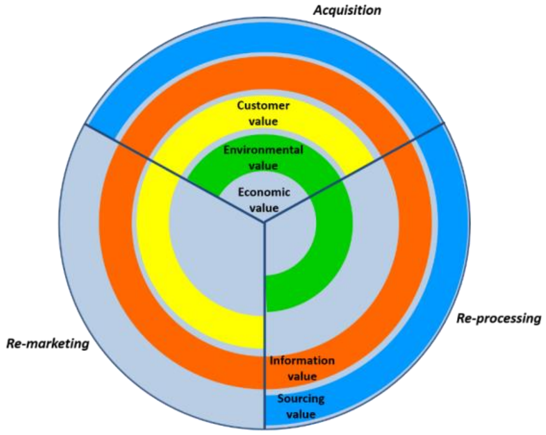

Figure 2: CE-SAM value re-capture in the reverse value chain (source: own research)

Companies should aim for synergy. For instance, integrating used parts and products in production provides sourcing value, which may be the firm's primary concern, but it also lowers the footprint, hence providing environmental value. It is important to emphasize that in CE-SAM, all values eventually are monetized, i.e. generate economic value directly or indirectly. Value is **(**re-)captured in the reverse value chain and monetized (released) in the forward value chain. Before we continue with more concepts, we present two case examples.

3. Two Illustrative Cases at REUZEit

REUZEit is offering services to life science and pharmaceutical companies to optimize the use of their resources, assets, and equipment, to reduce obsolescence, waste, and increase profit at the same time. REUZEit is building the world's largest B2B circular economic platform, introducing CE-SAM in the Life Sciences industry, with a mission to enable organizations to reach their sustainability goals, profitably. The company captures value by product management during disposition and redeployment workflows, offering pickups, reconditioning, refurbishing, and remarketing via distributors and its own platform https://www.REUZEit.com

Based on studies in copiers, electric motors, routers, and switches we constructed a model to calculate the delta—carbon footprint reduction—for two case products a mass spectrometer and an ultra-low temperature freezer. Limited data, required us to make some assumptions, but we consider both cases as representative of the potential to reduce the carbon footprint of the (closed-loop) supply through reconditioning equipment or—if this is not possible—recycling the materials.

The *use* phase is not included in this analysis since we focus on end-of-life CE-SAM. This is a fair assumption since only relatively new equipment is reconditioned. Recycled materials are used to make new products similar to the ones produced out of virgin materials. Tables 3 and 4 present the results. Input data were obtained from Berchowitz, & Kwon (2012), actual recycling data of a mass spectrometer and ultra-low freezer from e-Recycling of California, and our own research.

Ultra-low temp (ULT) freezers store material below -40℃ to as low as -150℃. The pharmaceutical industry uses them to preserve drug compounds and biological samples. The biological samples play a vital role in the research and development of therapeutics for rare and chronic diseases. ULT freezers are also used to store vaccines, where temperature uniformity is critical. These types of freezers are available in various types and sizes to accommodate individual lab needs. The refrigeration system may have different power compressors and can use different types of refrigerant fluids.

CLSC process ULT freezer	New built with virgin material **CO^2 kg eq/prod**	Redeploy only **CO^2 kg eq/prod**	Reconditi on **CO^2 kg eq/prod**	New built with recycled material **CO^2 kg eq/prod**
virgin material supply	104.5			
compone nt manufact ure	41.8			41.8
assembly	31.3			31.3
testing and configura tion	20.9		20.9	20.9
sales and distributi on	10.4		10.4	10.4
reverse chain			6.3	20.8
digital platform		0.5		
total CO2 kg eq/produ ct	209	0.5	37.6	125.2
delta, in CO2 kg eq. per product	NA	-208.5	-171.3	-83.8

Table 3: Carbon footprint reduction through reconditioning and recycling of ULT freezers

Depending on the manufacturer, capacity, and features, new freezers can range in price from USD 15,000 to 35,000 each. Assuming an average price of USD 25,000 means that approximately 31,320 newly manufactured freezers are expected to be purchased in 2027 globally. On average, a used, late-model—less than 5 years old—freezer costs USD 8,000 – 25,000. These models can be redeployed with or without reconditioning while still maintaining manufacturer specifications.

By providing a discount of 20–70% customers who cannot afford a new ULT freezer can now be served. Also, an increasing number of customers target buying circular products instead of purchasing new ones. Customer value, environmental value, and economic value are created concurrently. Although future markets are hard to forecast, the potential is clear. If 50% of new purchased products are replaced by redeployed products—a percentage that is in line with European Union targets—and assuming an average of a USD 10,000discount per product, buyers will globally realize irect annual economic benefits of more than USD 16 million by 2027. Moreover, new segments in the arket can be developed. There is a risk of cannibalization between new and redeployment market segments and should be considered in long-term plans.

The second case concerns mass spectrometers. Mass spectrometry is an analytical tool useful for measuring the mass-to-charge ratio of one or more molecules present in a sample. These measurements can often be used to calculate the exact molecular weight of sample components. Typically, mass spectrometers are used to identify unknown compounds via molecular weight determination, quantify known compounds, and determine the structure and chemical properties of molecules.

Medical labs employ mass spectrometry to diagnose metabolism deficiencies, determine whether biomarkers or enzymes are present, and for toxicology testing. To operate a mass spectrometer, it often must be coupled with a separation instrument like a gas chromatography (GC) or high-performance liquid chromatography (HPLC) system. This adds complexity and cost, which may be a stimulus to buying reconditioned and refurbished equipment.

CLSC process Mass Spectrom eter	New built with virgin materials **CO2 kg eq/prod**	Redeploy only **CO2 kg eq/prod**	Recondit ion **CO2 kg eq/prod**	New built with recycled materials **CO2 kg eq/prod**
virgin material supply	38.4			
compone nt manufact ure	15.5			15.5
assembly	11.7			11.7
testing and configura tion	7.8		7.8	7.8

sales and distribution	3.9		3.9	3.9
reverse chain			2.3	20.9
digital platform		0.5		
total CO2 kg eq/product	77.7	0.5	14	59.8
delta	NA	-77.2	-63.7	-17.9

Table 4: Carbon footprint reduction through reconditioning and recycling of mass spectrometers

The global mass spectrometer market size was USD 5.89 billion in 2020 and is projected to reach USD 12.7 billion by 2030[4]. Depending on the manufacturer, capacity, and features, new mass spectrometers can range in price from USD 200.000 to one million each. Assuming an average price of USD 400,000 means that 31,750 newly manufactured mass spectrometers are expected to be globally purchased in 2030. An average used, late-model spectrometer (less than 5 years old) can also be redeployed to meet manufacturer specifications. These models range in price from USD 75,000 to 220,000. Similar to the ULT freezer, redeployment provides a value to customers by offering cost avoidance ranging between USD 125,000 and 780,000 per product.

New green segments can be developed for customers who prefer to buy circular instead of new. If 50% of new mass spectrometer purchases are replaced by redeployed alternatives and assuming a USD 150,000 discount per unit, could save global buyers almost USD 2.4 billion annually in direct economic benefits by 2030. New circular segments can increase total market sales for the vendors, providing new business models are in place.

Please note that our calculations consider three recovery options: direct redeployment, redeployment after reconditioning, and material recycling. We argue that most equipment can go through all three loops sequentially, as explained in Krikke (2010). Clearly, direct redeployment creates the most economic value of direct savings. But like economic value, from a footprint point of view, the preference is also first to directly redeploy, then redeploy and recondition, then new products from recycled materials, and last new products from virgin materials.

In the case of reuse, the forward chain processes are substituted; meaning that these processes are less needed or skipped. In material recycling, only (virgin) material supply is replaced and hence the *delta* is less. Moreover, reconditioned equipment can still be recycled at a later stage, the opposite is not usually possible. Recovery process emissions need to be considered in the calculations. Recycling is more energy-intensive than reconditioning or direct reuse, which leads to higher emissions.

When using an emissions calculator provided by the EPA[5] to consider potential GHG reduction for desktop computers without reconditioning costs, just costs to move a computer from desk to desk within the same building, the reuse of this equipment can result in a 23 times reduction relative to recycling. It is important to note that a functioning product exists for reconditioning—for recycling only materials are recovered.

Still, all recovery options for closing the loop can significantly contribute to reducing GHG emissions. A ballpark estimate is that annual reductions of 1.3 million kg CO2 (recycling-based) up to 3.2 million CO2 kg eq. (direct redeployment) are realistic for ULT freezers by 2027. Similarly, for mass spectrometers reductions would equal 285,000 kg CO2 eq (recycling-based) up to 1.2 million kg CO2 eq (direct redeployment) annually by 2030.

In addition to reducing GHG emissions, scarce materials are saved lessening resource depletion. Together these results can make CE-SAM a *game-changer*. In both cases, multiple values are created. An increasing number of customers of life sciences equipment seek re-used products. The procurement of circular products creates environmental value. Environmental value has been turned into economic value via carbon fees[6]. Based on projected volumes of ULT freezers and mass spectrometers, and assuming that all three recovery options will be

[4] https://www.alliedmarketresearch.com/mass-spectrometry-market

[5] https://www2.epa.gov/sites/production/files/2013-06/eebc_v3_1.xlsm

[6] OECD 2021

applied, by 2030 a total of 580 million USD could be saved on carbon fees worldwide.

Sourcing value leads to direct economic benefits in terms of reduced prices. Customer value is increased because now the equipment is more affordable for certain customers who cannot afford to buy new products. Information value has not been mentioned in the examples, but it is relevant for product development and customer service.

4. A closed-loop supply chain as a value creator

The closed-loop supply chain (CLSC) (see Figure 3) is an important value creation driver of CE-SAM. CSLC management has defined as "the design, control, and operation of a system to maximize value creation over the entire life-cycle of a product with a dynamic recovery of value from different types and volumes of returns over time"[7].

In CLSC, value creation occurs in the (re-)capture of value through reuse and recycling. The value recaptured lies in preserving embedded materials, energy, water, and labor value from forward chain activities—value that is embedded in surplus equipment. Some of these resources are also invested in the reverse chain, as processes acquisition, re-processing, and remarketing need to be completed.

The value of these reverse chain resources needs to be subtracted from the regained value. **The gain is in the delta, meaning the difference between resources invested in the 'forward chain' (value to be re-captured and leveraged) and 'reverse chain value' of resources invested in acquisition, re-processing, and re-marketing.** For example, since recycling steel requires less energy than new production it reduces cost and emissions.

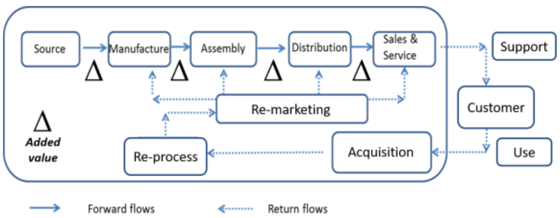

Figure 3: Value creation by CE-SAM in the closed-loop value chain, the importance of the delta (adapted from Krikke et al., 2003)

Six out of 10 Rs recapture value from discarded surplus equipment in the reverse value chain as shown in Figure 3. The others deal with prevention or low-level recovery. The literature on closed-loop supply chains describes 6 similar options, presented in Table 5. As a rule of thumb, reuse/reconditioning and harvesting create the most value since only a few operational processes are needed.

The closer the products are looped back into the customer or end-user the higher the value to be captured. However, quality or functional requirements may require an upgrade, refurbishing, or remanufacturing. Recycling only recaptures the materials and hence will create less value. However, if discarded products and parts are obsolete, too worn out, or otherwise no longer re-usable, recycling may be the only option left. Ultimately, there is no value created unless the product—or its parts and materials—is reused.

Value is (re-)captured in the reverse value chain but released in a forward chain, serving either the original market or an alternative segment! Please note this applies to all four types of value.

Recovery option	Operations	Output	Re-deployment
Repair	To fix or mend a device to good working order	Original product	Same users
Reconditioning	To restore to good working condition	Original product	New users in a similar market
Refurbishing	Disassembly and selective replacement of critical parts	Upgraded product	Other segments in the market
Harvesting (Retrieval)	Selective dismantling of parts for repair	Spare parts	Maintenance
Remanufacturing	Full disassembly and integration with new production	Equal-to-new product	Original markets
Recycling	Shred, separate, and recover of materials	Secondary materials	Commodity markets

[7] Guide and Van Wassenhove (2003)

Table 5: Recovery options that regain value (adapted from various literature)

5. The role of third party service providers in value creation

A third-party service provider (3PSPs) is an independent company that performs services for other companies. In the context of CE-SAM, we distinguish physical services, administrative and financial services, IT services, and trading services.

- 3PSPs providing physical services include waste collectors, logistics service providers, recyclers, contract (re-) manufacturers, maintenance - and repair, refurbish, and recondition firms.
- Administrative and financial services include leasing—new business models—and compliance auditing, collective EPR schemes in Europe and Asia, or related to carbon quotas.
- Specialized IT companies offer IT systems geared for product acquisition, reprocessing, and remarketing/sales. Also, ERP systems must be adapted. Returns data help to streamline the returns process itself but also to learn from returns to improve the product or forward value chain processes.
- Trading services involve internet platforms, trading desks, and brokers.

Many 3PSPs combine some of these services into one package. Other important actors are the brand or asset owners, sales agents, suppliers, and the final customer or user. In the CE-SAM market, it is usually the brand and/or asset owner who decides which activities to carry out themselves and which to outsource. In this context, brand and asset owner may be used interchangeably. However, independent parties may act on their own and decide, for example, to actively buy back surplus equipment from the market, reprocess and resell them. Ideally, actors in the CLSC perform those activities where they add the most value, which can be sourcing -, environmental -, customer - or informational value. How to cope with challenges is best analyzed by looking at the strategic enablers in CE-SAM and the business processes of closed-loop supply chains. Table 6 illustrates how Circular Economy generally and CE-SAM in specific have very distinct characteristics compared to a linear system. First, we deal with multi-value systems. Although the ultimate goal remains to create economic value, four underlying values need to be managed and integrated. Failure to comprehensively manage these values can cause conflict where synergy is needed. Because we have more actors, more business processes, and more objectives, all four solutions are crucial.

	Challenge	**Eco-design**	**New buzz models**	**IT systems**	**CLSC**
Product acquisition	Products not traceable for collection			x	
	Customers do not return (properly)		x	x	
	Uncertainty in (forecasting) volume, quality, and composition of returns		x		x
	Returns not properly valued		x		
Re-processing	Low yield for reuse	x			x
	Recycled materials of low quality	x			x
	Hard to test and disassemble	x			
	Upgrades not possible	x			
	Hazmat not detectable	x			
	disassembly BOM needed			x	
	(backward) compatibility issues/ no standardisation	x			x
	Integration MF and re-MF				x
Re-marketing / Sales	Customers not willing to pay for circular products		x		
	Market cannibalization effects		x		
General	(carbon) footprint too high	x			x
	Natural resource depletion	x			x
	Compliance issues	x		x	x
	Waste				x
	Staff not trained for CE	x	x	x	x

Table 6: Main challenges versus enablers (own research)

Managing one success factor is already difficult, managing all four is a mission. Second, **managing the enablers and circular business processes takes time**. For example, when re-designing your product for recycling as a brand owner, it may take years before you reap the benefits, namely when the product is returned from the market. The longer time horizon in CE-SAM is at odds with the current short-term, profit maximization approach of many companies. Third, the reverse chain is—due to multiple "R" options--**more fragmented** than the forward chain.

The reverse value chain involves many segments with specific processes and relatively small volumes. Also, it often takes very specific knowledge for example how to disassemble and recondition equipment, how to resell it, and how to deal with compatibility issues. Consequently, many specialized 3PSPs, often small-medium enterprises (SMEs), are active in the various market segments.

Circularity will most certainly change the rules of business. CE-SAM is intended to be the **game changer!**

6. What are the steps to make Circular Economic Surplus Asset Management work?

In the case study research, we have observed that many circular value chains go through three phases as presented in Table 7.

	Phase 1: control	Phase 2: streamline	Phase 3: integrate
Product Stewardship	x		
New Business Models		x	
Life Cycle Management			x
CLSCs	x	x	x

Table 7: Three phases in developing a circular value chain (based on Schenkel et al., 2015)

Phase 1 involves controlling the (four) negative externalities which are basically the same as the four values but with negative values. For example, many hard disks must be disassembled from computers and all data wiped for security or privacy reasons. Also, environmental regulations based on producer responsibility impose mandatory collection and recycling. To this end, many European countries have set up collective closed-loop systems where the reverse value chain is disconnected from the forward value chain. In most cases, the reverse chain is fully outsourced. Economic value is also often negative, but bigger damage is avoided.

It is best to quickly complete phase 1. In **phase 2** asset owners or 3PSPs start working together on the (final) customer side. One example offering harvested spare parts or reconditioned equipment is nearly as good as a new state, although in other market segments than the new products to prevent cannibalization. New business models may involve extended service programs, flat fee maintenance, and trading platforms. The closed-loop supply chain becomes more responsive by actively buying back from the market and selling via a platform to match supply and demand effectively. Good IT systems are crucial. Also, higher "Rs" options are applied, mostly reconditioning, refurbishing, and (parts) reuse with a possible upgrade. Usually, three of the four values (sourcing, environmental, and customer) are optimized, and the resulting economic value is positive. Still, forward and reverse value chains are not fully connected.

Ideally, but not always, **phase 3** integration is reached. Due to the new business models, the value chain is based on servitization. By applying remanufacturing, but also refurbishing and reconditioning for relatively new equipment, the reverse value chain feeds the forward chain with materials, parts, modules, and products. The distinction between new and recovered equipment becomes invisible (and irrelevant) to the final customer as availability, cost and footprints are part of a service offering. However, the products must now be designed according to the 10Rs.

A CLSC perspective means involving suppliers in the development of circular products, and brand owners must select suppliers on different criteria. What might arise is the *supplier paradox*: where the first and second-tier suppliers that cooperate in making reusable products may lose business in new-built equipment. So, there is an issue of "what's in it for us" when we participate in CE-SAM.

Finally, more data on processes and systems are needed to learn from returns—information value. Also, enterprise resource planning (ERP) systems must be fundamentally adapted. ERP systems, for example, must now have a triple bill of materials (BOM). This triple BOM combines a disassembly BOM and a replacement BOM for reconditioning, refurbishing, and remanufacturing with the new product BOM. Few software vendors offer this type of information.

7. Summary and Concluding Statements

This paper presents CE-SAM, which is a business-wise approach to the circular economy. After defining the field and its four sub-areas we focus on multiple value creation, with CLSC playing a key role. The two cases illustrated the possible monetary savings as well as the reduction of footprints. Also, we presented challenges and how to manage enablers that create value. Finally, we described the role of 3PSPs in value creation and steps to make CE-SAM work.

Our findings can be summarized with a circular value chain based on the well-known Porter value chain, adapted for CE-SAM—see Figure 4. The enablers exist as support activities, indicating which actors play a role where the primary activities are executed with three key business processes: acquisition, re-processing, and remarketing. All four values are represented (capture and leverage) which eventually leads to economic value. Also, we can observe which actor adds value to particular stages of the value chain. The process can be managed with strategic tools. For example, visit https://www.REUZEit.com, a platform offering CE-SAM services.

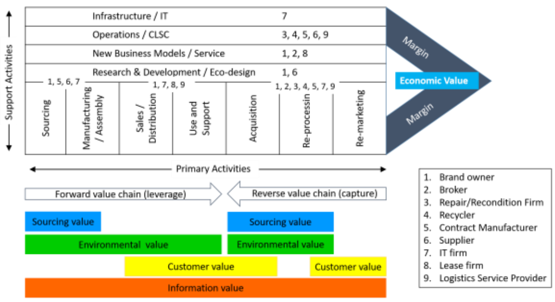

Figure 4: CE-SAM value chain with actors, based on Porter's value chain (source: own research)

We summarize for the reader a few takeaways. These takeaways include:

- The circular economy is an important instrument to tackle the current crises on climate change, waste, and natural resources depletion.
- CE-SAM ensures that CE is implemented business-wise a game-changer.
- The key value creator within CE-SAM is the closed-loop supply chain. We distinguish sourcing value, customer value, information value, and environmental value. In the end, they all create economic value.
- Value is captured by the reverse chain, value is leveraged (released) in a forward chain, either in the original market or an alternative segment.
- In principle, reuse is favoured over recycling and recycling over new products provided there is demand for circular products/materials. All values benefit from this.
- Value creation is maximized by managing all four enablers in a coordinated manner.
- Challenges in closing the loop can be best tackled by different actors, depending on their capabilities. Specialized 3PSPs can add more value and are better equipped for CE-SAM than forwarding chain actors.

Overall, many complexities exist in a CE-SAM system, there are strategic and operational considerations. Managing these activities is not a trivial matter and significant resources may be necessary for organizations to build up these capabilities. But, as the world's resource limits are reached there may be no other feasible alternatives.

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