White Paper

Information Systems for Sustainable Consumption Practices

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1 Introduction

Considering the increasing waste volumes of electronic goods and other manufactured products that get downcycled or disposed via landfilling or incineration[1], human mankind must challenge and question existing consumption patterns. The paradigm of a Circular Economy (CE) might become a key vehicle to achieve Sustainable Consumption (SC). The CE paradigm comprises a collection of short-term objectives, principles, and enablers that facilitate the transition from a linear 'cradle-to-grave' economy towards a circular 'cradle-to-cradle' economy, an economic model that proffers increased chances of economic and environmental sustainability for organizations and society at large.

However, the development of a CE is presently hampered by several recurring challenges of financial (e.g., economic profitability), structural (e.g., inter-organizational information flow and cooperation), technological (e.g., manufacturing complexity), and sociological (e.g., customer awareness and acceptance) origin. At face value, these challenges all point to information systems (IS) solutions as a way to mitigate these barriers, as IS-enabled solutions have over the past fifty years addressed similar challenges in classical economical models.

We believe the timing is opportune to examine the solution potential of IS for the establishment of SC practices in our society, by aiding the establishment of a CE. Our motivation is grounded, first, in the observation that many of the challenges of establishing a CE are, in their essence, problems of information flow[2]. For instance, pro-longing a product's life through repairing requires knowledge about its condition, location, and reparability. Second, recent advances in information technology, especially sensor-based technologies, provide means to integrate information with material flows, which hold great transformative power if leveraged appropriately. We ask, therefore:

> *How can information systems contribute to sustainable consumption practices in our society?*

To offer a first answer, we develop a framework of IS-enabled SC, inspired by the existing 'energy informatics framework' (EIF) by Watson and colleagues[3]. Like Watson and colleagues, we assume a buffering effect of information on overall consumption; yet unlike them we do not refer to the consumption of energy but of materials and resources. Therefore, our aim in developing our framework is to examine an equation similar to Watson and colleagues:

$$\text{Is} \quad \textit{Primary Consumption} + \textit{Information} < \textit{Primary Consumption} \quad ?$$

[1] Eurostat. 2017. "Waste Statistics," Statistics Explained, European Commission, Brussels.

[2] European Commission. 2014. "Scoping Study to Identify Potential Circular Economy Actions, Priority Sectors, Material Flows & Value Chains: Final Report," European Union.

[3] Watson, R. T., Boudreau, M.-C., and Chen, A. J. 2010. "Information Systems and Environmentally Sustainable Development: Energy Informatics and New Directions for the IS Community," MIS Quarterly (34:1), pp. 23–38.

2 Principles of a Circular Economy

Figure 1 visualizes the main idea of a CE incorporating SC practices. It illustrates how different feedback flows (e.g., recycle) help transform the traditional linear product flow from design to use (i.e., cradle-to-grave) into a circulating product flow (i.e., cradle-to-cradle).

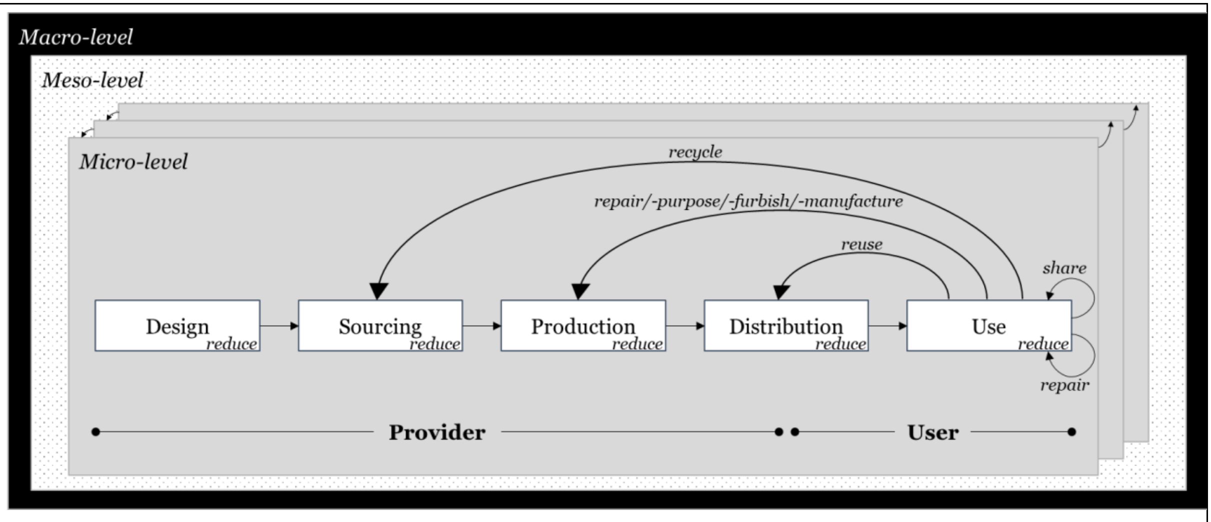


Figure 1. Conceptual model of a circular economy

The CE is an economic model with the goal of minimizing resource input as well as waste, emission, and energy leakage by slowing, closing, and narrowing material and energy loops. This is purportedly realized through the **useful application of materials** (i.e., *recovering* and *recycling*), an **extended lifespan of products and their components** (i.e., *repurposing*, *remanufacturing*, *refurbishing*, *repairing*, and *reusing*), and a **smarter product use and production** (i.e., *reduce*, *rethink*, and *refuse*). Table 1 summarizes these principles using Potting et al.'s 9-R-framework.

Table 1. 9-R-framework[4]

CE Objective	CE Principle	Explanation
Smarter product use and production	R0 Refuse	Make current product redundant by abandoning its function or by offering the same function with a radically different product
	R1 Rethink	Make product use more intensive (e.g., through sharing products, or by putting multi-functional products on market)
	R2 Reduce	Increase efficiency in product manufacture or use by consuming fewer natural resources and materials
Extended lifespan of products and their components	R3 Reuse	Re-use by another consumer of discarded product which is still in good condition and fulfils its original function
	R4 Repair	Repair and maintenance of defective product so it can be used with its original function
	R5 Refurbish	Restore an old product and bring it up to date
	R6 Remanufacture	Use parts of discarded product in a new product with the same function
	R7 Repurpose	Use discarded product or its parts in a new product with a different function
Useful application of materials	R8 Recycle	Process materials to obtain the same or lower quality
	R9 Recover	Incineration of materials with energy recovery

[4] Potting, J., Hekkert, M., Worrell, E., and Hanemaaijer, A. 2016. Circular Economy: Measuring Innovation in Product Chains, The Hague: PBL Netherlands Environmental Assessment Agency.

3 The 'Sustainable Consumption Informatics Framework' (SCIF)

We believe IS solutions will be a key element to the establishment of a CE; many identified CE barriers relate to a lack of the right information at the right time to the right stakeholder, for instance:

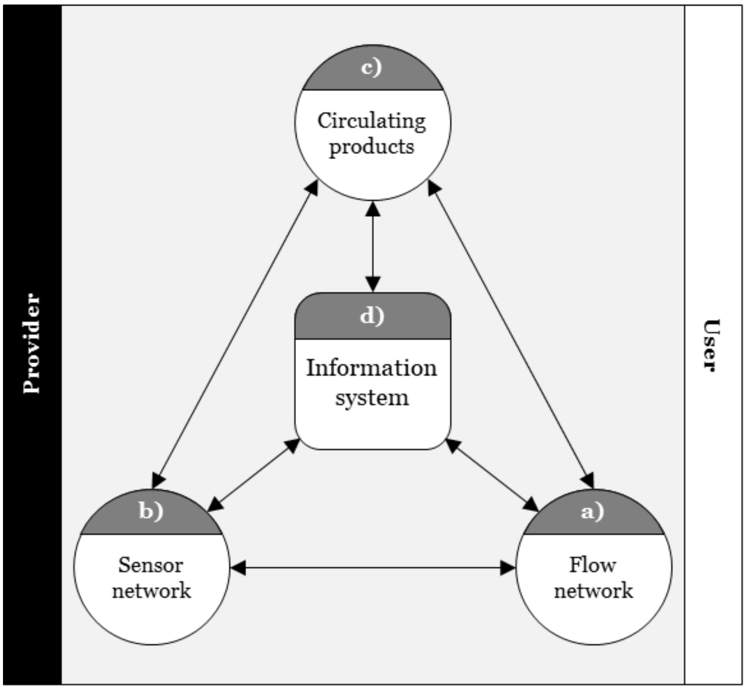
- Servicized business models come with longer warranties extending the ownership responsibility beyond the traditional point of sale. Real time or near-real time information about the product condition and utilization could potentially prevent mishandling of products by consumers and reduce information asymmetries.
- Circular flows of manufactured products require complex return logistics and remanufacturing processes. Product data (e.g., condition or scheduled utilization) could potentially improve planning, forecasting, and management of closed-loop, inter-organizational supply chains.
- Consumers lack awareness about and acceptance of circular offers (e.g., refurbishment of product or service plan for product use instead of product acquisition). Provisioning of appropriate information in pre-sale (i.e., marketing) and post-sale (i.e., product utilization phase) could potentially increase consumer awareness and acceptance respectively.
- Consumers lack knowledge about reparability of products and repair guidelines. Accessible information about reparability and repair guidelines can potentially empower do-it-yourself (DIY) abilities of consumers.

Our framework explains how IS can enable SC through the support of CE principles. We, thus, call it the 'Sustainable Consumption Informatics Framework' (SCIF). Figure 2 shows our view of this framework. It describes a dualistic consumption system of providers and users who collaboratively make use of sensor networks of distributed devices and an orchestrating central IS to enable and optimize the flow networks of circulating products and materials. As such, the SCIF is a blueprint for an intelligent product consumption system. In accordance to SC of manufactured products, its goal is to minimize "the use of natural resources, toxic materials and emissions of waste and pollutants over the [product] life cycle"[5].

Effectively, the SC goal can be achieved through the application of CE principles, which try to extend the lifespan and intensify the use of products. Without the assumption of linear consumption patterns, the provider loses its dominating position in the economic system. Instead, providers and users become equally important integral parts essential for the circulating movement of the product. This means, the SCIF does not assume a linear supply/demand relationship. Instead, it promotes the circulation of products within one integrated consumption system. We, thus, remove the supply/demand structure of the original EIF and instead refer to 'providers' and 'users'.[6]

[5] Norwegian Ministry for the Environment. 1994. "Symposium on Sustainable Consumption," Norwegian Ministry for the Environment, Oslo.

[6] Users can be both consumers of a product and suppliers of product to other users.



Explanation:

a) A **flow network** can be:
- provider-bound (i.e., operated and controlled by a provider); or
- user-bound (i.e., operated and controlled by users).

b) A **sensor network** can be:
- automatic (i.e., distributed devices automatically create data); or
- manual (i.e., distributed devices require manual data entry).

c) **Circulating products** can be:
- sensitized (i.e., part of the sensor network); or
- non-sensitized.

d) The **information system** can be:
- provider-bound (i.e., operated and controlled by a provider); or
- independent (i.e., operated and controlled by users or a third-party provider).

Figure 2. Sustainable consumption informatics framework (SCIF)

3.1 Main Components of the SCIF

Flow Network

A flow network is a composite set of connected transport components and individuals that supports the movement of discrete objects (e.g., circulating products, spare parts). We deliberately distinguish between networks operated and controlled by the provider (i.e., provider-bound) and provider-independent user flow networks (i.e., user-bound). The **provider-bound flow network** in the SCIF usually represents a physical distribution system (e.g., delivery vehicles). The independent **user-bound flow network**, instead, is oftentimes characterized by individuals as the essential transportation component. Therefore, the SCIF comprises two very different problems: (1) enable circulating provider and user-bound flow networks by changing user consumption patterns (i.e., eco-effectiveness) and (2) optimize the arising provider and user-bound flow networks to reduce their energy consumption (i.e., eco-efficiency).

Sensor Network

A sensor network is a set of spatially distributed devices that automatically or manually reports the status of a physical item, an individual, or the environment. Sensor networks are socio-technical constructors, i.e., we distinguish between **sensor networks with automatic and/or manual data collection**. Thereby, we reflect the manual user interaction with the central IS in our framework. Automatically collected data can originate from sensors as part of (a) circulating products (cf., ‘Sensitized Objects and Circulating Products’), (b) smartphones, wearables, or other devices capable of tracking behavioral routines and habits (e.g., individual’s commute), or (c) production and distribution-related business processes. Manually collected data originate from any end-user device (e.g., laptop, smartphone) that supports user interaction in form of manual data entries (e.g., posts on social media platform, user-generated content, or similar). Consequently, the data can take many forms and functions, ranging, for instance, from actual and forecasted product condition, availability, or location to user preferences, ideas, or needs.

Sensitized Objects and Circulating Products

A **circulating product** is a physical good owned by providers or users, whose life and use is extended and intensified, respectively, through the application of CE principles. It is an essential part of the flow network defined before (cf., 'Flow Network'). Circulating products in SC scenarios might be equipped with sensors. **Sensitized products** have the capability to sense and report data about its condition, availability, and location. With integrated sensors, circulating products become part of sensor networks and enrich the data to further enable the circularity (i.e., eco-effectiveness) of products and to optimize corresponding flows (i.e., eco-efficiency) in the system (cf., 'Sensor Network'). We deliberately refer to both providers and users as owners of circulating products, as in CE business models, the ownership of the manufactured product might remain with the provider over the complete life cycle.

Information Systems

The SCIF distinguishes **two types of IS** based on their ownership. One is owned by the provider (i.e., provider-bound IS) and the other one is independent of the provider and can be owned by a third-party, government, or a group of users (i.e., independent IS). Effectively, the circulating flow network of products in our system can run without the involvement of the provider (e.g., second-hand sales). The IS in the SCIF, thereby, also differ in their objectives. While the **provider-bound IS** mainly supports the objective of eco-efficient flow networks, the **independent IS** must do both (a) enabling SC flow networks (i.e., eco-effectiveness) and (b) optimizing the resulting flow networks, in terms of their energy consumption (i.e., eco-efficiency). To achieve both, the independent IS must integrate the socio-technical sensor networks (cf., 'Sensor Network') and circulating products (cf., 'Sensitized Objects and Circulating Products') by directing the right information at the right time to the right recipient.

3.2 How the SCIF can be applied

One key advantage of the SCIF lies in its ability to serve as an **analytical framework** for the sustainability of consumption patterns. To illustrate, Table 2 provides a summary of the analysis of six selected SC practices with their underlying CE principles and example cases. It details the case analyses through the lens of our framework. The summarized analysis immediately demonstrates that at present, IS solutions are only featured sparingly and conservatory in existent SC solutions (e.g., only few automated sensor networks), a finding especially prevalent in scenarios with independent IS.

These exemplary case discussions illustrate how the SCIF can identify current coverage, and voids thereof, of IS-enablement for the establishment of CE principles leading to SC. Beyond, a second advantage of the SCIF lies in its ability to provide **testable propositions** that can guide researchers in the application of the SCIF to instantiations, present or future. The propositions are general statements about possible instantiations of the SCIF constructs (e.g., non-sensitized products vs. sensitized products) conditional to features of the employed CE principle in the SC practice. We distinguish these features into (1) flow network and (2) circulating product features.

Table 2. Overview of SC practices analyzed through the SCIF

SC Practice		Circulating products		Flow network		Sensor network		Information System	
CE Principle	**Case**	**Sensitized**	**Non-sensitized**	**Provider-bound**	**User-bound**	**Automatic**	**Manual**	**Provider-bound**	**Independent**
Rethink	*Shared mobility services:* • DriveNow	• shared vehicles	• n/a	• collective fleet management of shared vehicles (e.g., relocation of vehicles to locations with uncovered demand)	• individual user trips with shared vehicles (i.e., mobility demand)	• location sensors (e.g., GPS) in vehicles • location sensors (e.g., GPS) in smartphones	• manual app-based data entry by user (e.g., search for available car or entry of planned destination)	*Frontend app:* • provides info. on availability, location, condition of vehicles *Backend software:* • calculates optimal number and location of vehicles to cover demand	• n/a
Rethink	*Neighborhood sharing platform:* • Nextdoor • Neighbourly • Nebenan	• n/a	• shared household appliances • shared garden tools • shared sports equipment	• n/a	• redistribution flows of circ. products in neighborhood (self-collection by user)	• n/a	• manual web or app-based data entry by user (e.g., platform post offering circ. product)	• n/a	*Social network platform:* • provides info. on availability, location, condition of circ. products
Reuse	*Online marketplace for discarded building materials:* • Restado	• n/a	• re-used discarded building materials	• n/a	• redistribution flows of discarded materials (self-collection by users)	• n/a	• manual web-based data entry by user (e.g., marketplace post offering circ. product)	• n/a	*Online marketplace:* • provides info. on availability, location, condition of circ. products
Repair	*Do-it-yourself (DIY) smartphone and coffee machine repair:* • kaputt.de	• n/a	• spare parts for broken product • repair tools • broken product to repair café / repair shop	• n/a	• parcel delivery of ordered spare parts and repair tools • user trips to repair shops	• n/a	• manual web-based data entry by user or provider (e.g., repair instructions)	• n/a	*Repair platform:* • provides repair instructions for broken product • provides info. on location of repair shops
Repair/ -furbish/ -manufacture	*White goods leasing:* • Gorenje	• washing machines • dishwashers • refrigerators	• n/a	• repair logistics • reverse logistics • redistribution logistics	• n/a	• piezoelectrical vibration sensors in leased white goods	• n/a	*E-maintenance platform:* • provides info. on condition of leased white goods • optimizes repair, re-verse, redistribution flow logistics	• n/a
Recycle	*Workwear from recycled polyester:* • Dutch Awearness	• raw materials • products (e.g., work-wear)	• n/a	• recycling flows • production flows • distribution flows • reverse logistics	• n/a	• sensitized production machines • QR codes attached to circ. products	• n/a	*Circular Content Mgmt. System:* • provides info. on location & condition of materials and products	• n/a

SC-Relevant Flow Network Features

The higher the **flow network frequency**, the more pressing coordination efficiency becomes. Knowledge about the availability and location of the circulating product is crucial. Consequently, sensitized products, automated sensor networks, as well as a flow-optimizing IS gain importance in SC practices with high-frequency flow networks (e.g., vehicles). In comparison, low-frequency flow networks (e.g., garden tools) rely little on current data reducing the necessity for sensitized products and automated sensor networks.

The larger the **flow network size**, the more relevant effective monitoring of the product becomes. Knowledge about the product's location is important. Sensitized products and automated sensor networks have an increased benefit in SC practices with large flow networks. To illustrate, flow networks of car sharing providers (i.e., operating area) are remarkable in size. GPS trackers inform about the location of the car fleet in real-time. The flow network of *Nextdoor* (i.e., neighborhood) is physically limited to a specific district. Sensitized objects and automated sensor networks are less important.

The higher the **flow network complexity** (i.e., number and heterogeneity of involved stakeholders), the more relevant efficient coordination among the involved stakeholders becomes. Knowledge about location, availability, and condition of the circulating product is important. Sensitized products and automated sensor networks reduce coordination costs and are important elements in SC practices with complex flow networks. A homogeneous or small group of involved stakeholders attenuates the coordination problem and sophisticated sensor-technology and automation is of less relevance.

SC-Relevant Circulating Product Features

The higher the **product value**, the more relevant product monitoring effectiveness becomes. Information on location and condition of the product is crucial as the involved financial risk is high. For instance, the financial risk for car sharing providers is indisputably higher than for neighbors lending a lawn mower to next-door. Sensitized products and automated sensor networks enable this monitoring.

The higher the **product use complexity**, the more relevant information on the condition of the product becomes. Compare, for instance, the sharing of gas vehicles and electric vehicles: Electric vehicles exhibit an increased use complexity due to the limited operating range and increased refill time. This complexity comes with an increase need for information. Car sharing providers have responded to this information problem by collecting data on the condition of the battery charge (i.e., they sensitized the circulating product). This data can be used for both enabling the flow network through informing the user and optimizing the flow network in terms of number of provided charging stations. Products with a low complexity of use (e.g., lawn mower) are self-explanatory and require less IS support.

The higher the **product homogeneity**, the easier the development of standardized sensor technologies and automated sensor networks. Provider-bound flow networks oftentimes exhibit a higher level of product homogeneity as CE principles apply to a selected set of products only. In contrast, independent social network platforms for sharing exhibit a high level of product heterogeneity as different kinds of products are shared.

4 Conclusion

The purpose of our whitepaper was to advance a new framework that explains the role of IS for the establishment of SC practices through the enablement of CE principles. Our framework, the SCIF, is situated at a general, abstract level to facilitate wide applicability, broad theorizing, and design. It allows to (a) better analyze the problem space of SC, (b) better design suitable and impactful solution-oriented artifacts, as well as (c) evaluate novel technology-based artefacts with solution potential.

One contribution of our work is the introduction of concepts of SC and CE into the academic conversation of the IS research community. Both are timely and intensely debated ideas in other fields that have not yet really entered our own discourse yet. We believe, and expanded on this belief, that IS theory and artefacts can play a focal role in both areas, which in turn allows solution-oriented IS research to become a referent discipline to the emerging discourse in other academic fields.

One major practical implication of our work is **technological design advice for companies** that already have integrated or plan to integrate SC practices in their business models. We see two prime application areas:

1. Companies already operating in the SC space can draw on the framework to evaluate existing and direct future technology development for their operations. We suggest analyzing existing SC practices applying the core concepts of our SCIF. Corresponding guiding questions address (a) the applicability of so-far ignored CE principles, (b) the financial and technical feasibility of sensitized products, (c) the adequate automation level of the underlying sensor network, and (d) the type of central IS (i.e., provider-bound vs. dual-side vs. provider-independent).

2. Companies that consider the new development of SC practices might refer to the SCIF to evaluate scenarios of potential business models. Such companies can represent established ventures in need of developing their business (e.g., *Gorenje*) or start-up ventures looking for a piece of the cake in the value chain (e.g., *kaputt.de*). Within our framework, we removed traditional stakeholder structures, as known from linear economic systems, to explicitly consider the development of producer-independent sustainable solutions aiming at the empowerment of users through third-party platform providers (e.g., *Neighborhood*).

The second major practical implication of our work is **regulatory design advice for policy makers**. The SCIF core concepts provide structural guidance for reflecting on possible regulatory levers. For instance, the guidance aids city planners in analyzing how they might support the development of SC practices within their districts. In this case, regulators can facilitate (a) automated sensor networks by providing technological infrastructure (e.g., city-wide Wi-Fi) and (b) flow networks by providing technical infrastructure (e.g., city-owned IS repair platform listing all repair cafés in the city) or urban infrastructure (e.g., designated areas for the establishment of neighborhood sharing points).

About the Authors

Roman Zeiß is a research scholar at the Cologne Graduate School (CGS). He joined the Chair for Information Systems and Systems Development of Prof. Jan Recker, Ph.D. in October 2017. His current research interests are on sustainable information systems (Green IS) and the related business models. Roman Zeiß studied General Management with a focus on Information Systems in the Bachelor program at the EBS Universität für Wirtschaft und Recht. In September, he completed his Master's in Information Systems at the University of Münster. Within his studies he spent terms abroad at the Stellenbosch University in South Africa as well as at the Queensland University of Technology in Brisbane, Australia. He has worked for four years as an IT Management Consultant for Horváth & Partners GmbH. As of January 2018, he is Managing Editor of the Communications of the Association for Information Systems (CAIS) Journal.

Jan Recker is Alexander-von-Humboldt Fellow, Chaired Professor for Information Systems and Systems Development at the University of Cologne, and Adjunct Professor at the QUT Business School at Queensland University of Technology, Brisbane. He is Germany’s leading Information Systems scholar, measured by publications in the field’s top journals. His research focuses on digital innovation, systems analysis and design, and environmental sustainability. He is one of the world’s leading scholars on the role of IT in environmental sustainability. Amongst others, he was one of the first to study green IT transformations, the role of green strategies for CIOs and the design of green IS artefacts. He also co-edited a book on Green BPM – Creating the Sustainable Enterprise.