SOCIAL SUSTAINABILITY OF A HOME APPLIANCE PRODUCT-AS-A-SERVICE FOR A CIRCULAR ECONOMY

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Abstract

Generally speaking, modern business practice emphasizes the social dimension as equal to the environmental (Sutherland, Richter et al. 2016). According to the European Commission's vision for a clean planet, social sustainability interplays with much-needed transitions to a circular economy (CE). However, research on social sustainability is underdeveloped compared to environmental sustainability for manufacturing and in the context of a CE (Alvarez and Ligthart 2021, Bhatnagar, Härri et al. 2024). Additionally, the viability of socially conscious circular business models involving environmental and economic aspects has yet to be researched substantially.

This conference contribution aims to fill this research void by highlighting the social sustainability of a product-as-a-service (PaaS) as a category of circular business models. The paper aims to answer two research questions: i) how could a socially conscious PaaS business model be viable, and ii) what could the relevance of a PaaS business model be to social sustainability? It presents a preliminary case study of the social sustainability assessment of a PaaS offering with household goods for a CE and discusses its potential impacts on social sustainability. The assessment method used is social LCA (UNEP 2020, UNEP 2021). The information was collected from the organizations providing this PaaS, namely a social enterprise (SAAMO West-Vlaanderen) and the product manufacturer (BSH Home Appliance), as well as relevant websites and scientific literature on PaaS.

The paper shows the potential impacts on the social sustainability of this PaaS offering. For instance, consumers benefit from poverty allegation thanks to the PaaS offering; however, possible concerns exist regarding workers' working hours. Discussions will be presented for key aspects to be addressed in designing such a circular business model, including a double systems perspective proposed by (Sakao, Bocken et al. 2024) regarding the product lifecycle and value network perspectives.

1. INTRODUCTION AND MOTIVATION

The EU Circular Economy Action Plan (EC 2020) informs that transitions to a circular economy (CE) can be significantly accelerated by employing product-as-a-service (PaaS) business models, where a provider retains ownership of the product, and the end user pays for the access and service provided. A PaaS is a special type of product/service system (PSS) where related services are provided to a product in ways not limited to a PaaS' ownership and payment terms (Brissaud, Sakao et al. 2022). The central PaaS in this paper allows an individual contractor to use the product for a certain period and excludes sharing business models such as car sharing. The focal PaaS has been less researched than the sharing models with regard to assessment (Pauliuk, Heeren et al. 2021, Metic, Guzzo et al. 2024). However, it creates an inherent economic incentive for the provider to extend the product's lifespan (Kaddoura, Kambanou et al. 2019) and thus contributes to reducing natural resource use. It also allows the provider to better control the product's material flows, facilitating improved resource efficiency through remanufacturing, refurbishment, and recycling. Regarding traditional manufacturing organizations, exploiting the concept of a PaaS or PSS is complex and challenging (Tukker 2015), and recommendations such as installing a facilitator to coordinate integration activities have been given (Matschewsky, Kambanou et al. 2018).

A CE is expected "to promote value maintenance and sustainable development, creating environmental quality, economic development, and social equity, to the benefit of current and future generations" (Kirchherr, Yang et al. 2023). This is in line with the fact that sustainability is often discussed from three perspectives, that is, environmental, social, and economic. The performance of the three perspectives and the relations (such as trade-offs) between the three perspectives need to be considered. Shifts to a CE at the level of business offerings (e.g., products and services) motivated by the environmental or economic perspectives, or both, influence social sustainability, or both, which is important in the sustainability of a product lifecycle: shifts to a PaaS are not an exception. Despite a CE aiming for overall sustainability, the social impact of transitioning to a CE remains hidden (Schroeder, Anggraeni et al. 2019): little knowledge is available for the social sustainability aspects of a

PaaS in the CE context. Only a handful of concrete PaaS business cases have been reported, and key enablers for enhanced social sustainability of PaaS cases have been rarely discussed.

Therefore, the objective of this paper is to exploratively discuss a PaaS business case from the social sustainability perspective. The intention of using a case study (Yin 2006) as a research method is to contribute to theory building from cases in a research phase of emerging theories (Eisenhardt and Graebner 2007). The PaaS business case is selected from a European consumer market, and the social aspect is qualitatively assessed. In the assessment, the UNEP/SETAC guideline (UNEP 2020, UNEP 2021) will be employed, and some preliminary results will be presented in this paper. The leading questions were: i) how could a socially conscious PaaS business model be viable, and ii) what could the relevance of a PaaS business model be to social sustainability?

2. REVIEW OF RELATED WORK

This section is structured by the three perspectives of sustainability, respectively, by prioritizing the readability of this brief review, although the three aspects are entangled. The environmental aspects of a PaaS or PSS at large have been documented in the literature. A significant contribution to the increase in resource efficiency has been indicated after a review of previous assessment works on PSSs (Blüher, Riedelsheimer et al. 2020). The engineering activities contributing to the advantages were reported recycling, remanufacturing, reuse, maintenance, and holistic planning and operation, and the enablers were found to be the provider's higher flexibility and closer relationships with relevant actors (Lindahl, Sundin et al. 2014). On the other hand, a primary factor for diminishing potential environmental benefits regarding the sharing business models is reported as less careful use of the products (Ackermann and Tunn 2024).

In terms of economic potential, extending the lifetime of passive products by providing services under PaaS has high potential to save economic costs (Kaddoura, Kambanou et al. 2019). Specifically looking into the leasing and remanufacturing of washing machines, business offerings with multiple lifecycles struggle to earn a profit mainly due to the administrative and transportation costs also incurred (van Loon, Delagarde et al. 2020). Such newly added cost types are corroborated by another quantitative assessment (Vogt Duberg and Sakao 2024); however, systemic changes could offer a solution to make a PaaS outperform by prolonging the PaaS contract cycle length and keeping the maintenance within certain intervals (ibid).

Unlike the environmental and economic aspects, the social aspect of the PaaS or PSS has been sparsely researched. A few scientific publications overviewed the social sustainability for manufacturing in general; for instance, Sutherland, Richter et al. (2016) showed relevant national-level indicators as well as stakeholders and indicators for manufacturers. For the enterprise level, relevant indicators are further developed; see, for example, (Hutchins, Richter et al. 2019). Recent developments in theories and applications provide opportunities to expand social sustainability assessment case studies to various business offerings. A literature review by Alvarez and Ligthart (2021) informs that the UNEP/SETAC guideline (UNEP 2020, UNEP 2021) seems to be the most promising methodology due to its reception in the scientific community. Compared with the UNEP/SETAC guideline in terms of applicability, another method called Product Social Metrics (PSIA) (Goedkoop, de Beer et al. 2020) is a more industry-oriented approach (Alvarez and Ligthart 2021). For the impact assessment, PSIA offers a five-point-scale method (from − 2 to + 2) to assess the performance indicators, while the UNEP/SETAC guideline proposes no impact assessment methods and models nor interpretation approaches. According to Pollok, Spierling et al. (2021), among the social impact categories discussed, the most commonly employed are health and safety for workers, local employment within the local community, and contribution to economic development within societies. A systematic literature review on social life cycle assessment (S-LCA) for a CE (Bhatnagar, Härri et al. 2024) concluded that most research focused on circular activities like energy recovery and material recycling as well as on categories such as unfair wages and working hours, and not on product life extension by, for example, reuse, remanufacturing, and repair. State of the art in the literature shows the gap with social sustainability of PaaS offerings for a CE. Only a few works focusing on PSS or PaaS can be found in literature. For instance, a concrete case of car-sharing services in the use phase was analyzed (Gompf and Hetterich 2022): the findings included that within the worker stakeholder group, worker safety exhibited negative impacts due to increased involvement in repair work. In contrast, the society stakeholder group demonstrated positive performance in contributing to societal development.

3. TECHNOLOGY APPROACH

3.1 Methodology used

The guideline for S-LCA provided by UNEP/SETAC was used. It is a methodology to evaluate the social impact of a product or service throughout its lifecycle. It consists of two documents: (1) guidelines for the S-LCA of products and organizations (UNEP 2020) and (2) methodological sheets for subcategories in S-LCA (UNEP 2021). This guideline helps examine the positive and negative impacts of products or services on stakeholders. According to the guideline, the stakeholders are divided into six categories: workers, the local community, consumers, value chain actors, society, and children. Subcategories are prepared for each stakeholder, such as health and safety, forced labor, child labor, local employment, and contribution to economic development. Each subcategory is assessed using an inventory indicator with the help of the methodological sheets (UNEP 2021). In this study, the authors propose to use qualitative indicators, utilizing the following options to categorize the directions of their influence compared to traditional businesses by an original equipment manufacturer (OEM). The reference is set as the traditional product one-off sales businesses as an OEM for the identical product. This proposal is motivated by the lack of data and the significantly large resources needed for decisive assessment results.

- **No influence:** no influence observed
- **Unknown:** the effect is currently not known
- **Net beneficial:** an influence of a beneficial direction observed
- **Possibly net beneficial:** a possible influence of a beneficial direction observed
- **Net detrimental:** an influence of a detrimental direction observed
- **Possibly net detrimental:** a possible influence of a detrimental direction observed

This paper shows the results from the authors' application of the guideline to the case (explained in the next section).

3.2 Material used

In this work, the information used for the assessment is collected from interaction with the two organizations providing the case, public websites regarding the PaaS, and, for more general purposes, scientific literature on PaaS. The example offering analyzed is a PaaS for home appliances such as washing machines provided by collaboration between an OEM in Europe, BSH (Bosch and Siemens home appliance), and a social enterprise in Belgium called SAAMO West-Vlaanderen (SAAMO, hereafter). This variant of the PaaS model has been implemented in Belgium since 2018 under the name Papillon, targeting impoverished families who cannot afford to buy energy-efficient household appliances (Dworak and Longmuss 2019). SAAMO's mission is to help socially vulnerable people, which is concretized in this PaaS offering. The OEM is the PaaS provider, taking advantage of its knowledge of the products and services. The three actors with flows of products/services and money involved in the case PaaS offering are visualized in Fig. 1.

The data collection interaction included an online interview with SAAMO as well as in-person and online meetings with BSH. The authors first drafted the assessment result, which was then explained to SAAMO. Thereafter, SAAMO pointed out information to be added or adjusted to the assessment result, which was then incorporated by the authors. The latest interaction occurred in March, 2025 to document the actual status.

The business idea stemmed from the energy poverty at SAAMO in approximately 2014: it grew with CE concepts. While the idea was discussed with Bosch, the intention was maintained to develop this business as one economically sustainable (and not as a one-time activity, e.g., donating appliances). The fact that the share capital of Robert Bosch GmbH is held by Robert Bosch Stiftung GmbH, a charitable foundation, is considered by SAAMO as a positive factor for this business development. Note that BSH is a trademark licensee of Robert Bosch GmbH for the Bosch brand and Siemens AG for the Siemens brand. More information about Papillon is available at https://papillon.saamo.be/nl/.

Papillon is a result of envisioning the value cocreation between SAAMO and BSH, meaning the two organizations share the goal but keep their own role. BSH's role is providing quality products and services. SAAMO focuses on setting up partnerships while thinking with and from the standpoint of people in poverty. On the other hand, SAAMO doesn't have the financial means to buy so many appliances. The two organizations that collaborate with each other are essential for Papillon.

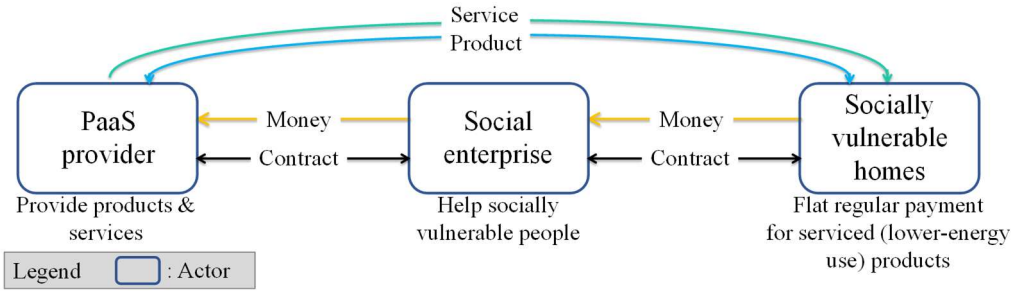

FIG. 1: Three actors with flows of products/services and money involved in the case PaaS offering (Source: BSH home appliance).

3.3 Case study result

The assessment result is shown in Table 1, focusing on key aspects from all the six stakeholder categories. Among the 41 subcategories, many were assessed as having "no influence" or "unknown," and none were assessed as "net detrimental"

Table 1. Key aspects of the PaaS case from social sustainability assessment

Stakeholder category	Subcategories	Inventory Indicator	Assessment	Reasoning behind
Workers	Working hours	Number of hours effectively worked by employees and Number of holidays effectively used by employees	Possibly net detrimental	When providing 24*7 service to the end users in the PaaS, the hours and the holidays may be increased and decreased, respectively, compared with the product sales businesses.
Local Community	Community engagement	Diversity of community stakeholder groups that engage with the organization	Net beneficial	In the PaaS, the local social enterprise contributes to the business viability and bridging with local municipalities. This diversifies the community stakeholder groups engaged.
	Local employment	Percentage of spending on locally based suppliers	Unknown	In the PaaS, local dealers are not needed, but repair work generates local jobs, leading to detrimental and beneficial direction, respectively.
Value chain actors	Promoting social responsibility	Integration of ethical, social, environmental, and regarding gender equality criteria in purchasing policy, distribution policy, and contract signatures	Net beneficial	The PaaS is judged to have integrated ethical, social, and environmental aspects in the business.
Consumer	End-of-life responsibility	Do internal management systems ensure that clear information is provided to consumers on end-of-life options (if applicable)?	Net beneficial	The PaaS includes end-of-life treatment and maintenance support (prolonging product lifetimes) so that end users are informed and significantly supported.
Society	Poverty alleviation	The organization carries out a poverty alleviation program	Possibly net beneficial	The PaaS helps socially vulnerable people in energy poverty in terms of, primarily, energy bills (from using washing machines for cleaned clothes and refrigerators for fresh food) and, secondly, living comfort.
Children	Health issues for children as consumers	The organization carries out programs to promote health impact on children	Possibly net beneficial	The PaaS provides home appliances that contribute to the physical, mental, and social well-being of children (and adults).

The reasoning for some of the subcategories is complemented here:

Regarding “working hours,” the PaaS inherently necessitates the OEM be engaged more in providing services, possibly affecting the working hours.

Regarding “end-of-life responsibility,” the PaaS contract also includes the delivery, installation, instruction, return of an old unit, 10 years of “full service,” and collection of the unit at the end of the contract.

Regarding “poverty alleviation,” it is assumed that poor people cannot (afford to) pay for a more expensive product that is more energy efficient. Therefore, they tend to choose a less expensive product of lower energy efficiency, which requires a higher energy bill. This PaaS constellation enables end users to use energy-efficient, high-quality home appliances, leading to lower energy bills and more comfortable living conditions through rental contracts with affordable monthly flat payments. For some appliances, the contracts run for 10 years with a monthly rent of around €11 per unit: subsidies from the Flemish Minister of Energy (also Environment) contribute to reducing end-customers’ payments down to €9 per month (according to SAAMO). It depends largely on how frequently the washing machine is used as to whether the total cost is lower for a given period than buying a cheaper and less energy-efficient machine.

Regarding the health impact on children, the PaaS, compared with buying a cheaper and less energy-efficient machine, is considered to provide access to higher quality washing machines and contribute to i) better sanitary conditions from the clothes cleaned more frequently and ii) better mental conditions and better social well-being because of the cleaner clothes.

4. DISCUSSION

4.1 Impacts on social sustainability

The result explained in the previous section sheds light on multiple (possibly) net beneficial aspects, an unknown aspect, and a possibly net detrimental one. The factors that caused the positive assessment can be boiled down to the PaaS business model and the constellation (visualized in Fig. 1), including the social enterprise whose missions include support of socially vulnerable people (see the community engagement subcategory), making this business viable.

Several PaaS cases of this kind can be found in the literature on social aspects. A PaaS example in the renewable energy sector uses solar panels in rural areas of the emerging economy (Müller, Kebir et al. 2009, Marzal López, Musonda et al. 2017). Here, the adoption of the flat-rate payment scheme by the contribution of micro-finance institutions is considered a key factor to eliminate the issue of consumer affordability. This case is assessed as positive with regard to poverty alleviation in a similar manner to the home appliance case explained in the previous section. Payment schemes allowing a lower fee have the potential to ease poverty; see discussions about the so-called sachet economy in the Philippines (Lu, Mateo-Babiano et al. 2019). Payment is a critical issue for any business in emerging economies. Research and innovation opportunities building upon the flat-rate payment scheme are found considering a global circular economy (Sakao, Kanda et al. 2023).

One common factor for the enhanced social sustainability between the home appliance and solar panel cases explained above is the effective introduction of a special organization that fits the purpose. The actor constellation has been under-researched in earlier studies on PSSs, which may explain Yang and Evans (2019) conclusion that a PSS alone does not have significant social sustainability effects. Recent research on the CE highlights the importance of the actor constellation building a value co-creation ecosystem (Sakao, Bocken et al. 2024); see the visualization in Fig. 2. A new concept named “manufacturer’s double-system perspective for a CE” was proposed to fill the knowledge gaps in state of the art on a CE for manufacturing. A double system perspective is needed for a manufacturer’s CE implementation: one is the product lifecycle perspective, and the other is the value co-creation ecosystem. This need is based on the knowledge that the two systems and their interaction influence environmental sustainability. The key processes in the two systems are depicted in Fig. 2, together with the area of a company’s control. This new perspective encompasses the value co-creation ecosystem and recommends manufacturers go beyond the product lifecycle perspective.

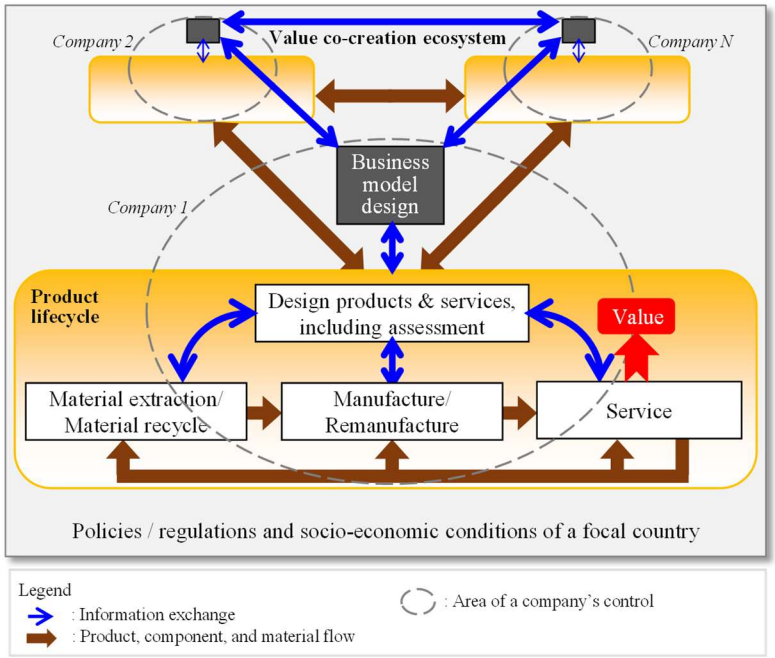

FIG. 2: Manufacturer's double-system perspective for a CE: adjusted from (Sakao, Bocken et al. 2024).

Note: This figure aims to visualize a network of N companies, each of which designs its own business model and controls a part of a product lifecycle. The product users and the financers for Company 1 are examples of N companies. The area of a company's control (shown by the dashed oval) depends on the company's business model. The number of companies in the network can be more than three. Value is co-created with one or more other companies.

4.2 Environmental sustainability

Quantitative assessment from the environmental perspective of washing machines in PaaS is addressed here for further discussion. Washing machines in PaaS have been researched, for instance, specifically with a pay-per-use contract (Bocken, Mugge et al. 2018) and a sharing model (Moon, Amasawa et al. 2020). Although a quantitative environmental assessment of this specific PaaS offering is not presented in this paper, that of various PaaS concepts was published (Sakao, Wasserbaur et al. 2019) and thus built upon in this section. Sakao, Wasserbaur et al. (2019) presented a static material flow analysis (MFA) to show basic resource efficiency indicators. The functional unit was a one-washing-cycle usage of a washing machine. The BoM (bill of materials) of a washing machine model was used, and the MFA with several critical raw materials was shown. The total outflow of the materials from the system is superior to the product's one-off sales by a gap of 27% to 38%. The MFA showed that service-based models with closed loops substantially improve product one-off sales in terms of resource efficiency, mainly through longer use length and increased product collection ratios. The latter essentially enables OEMs to better control the product lives and, thus, (critical) raw materials. It is unknown whether the PaaS addressed in this paper yields a longer use length. Note that the length of use in the case of product one-off sales is estimated at 11.7 years using Dutch data (Wang, Huisman et al. 2013). Also, no data on the number of washing-cycles per washing machine in the PaaS case during the 10-year contract has been reported thus far. Therefore, it's impossible to compare the sales and the PaaS with an identical functional unit. However, the latter factor is valid with the PaaS addressed, contributing to improving the MFA result: the Dutch collection ratio for compliant recycle of large electrical and electronic equipment in the product one-off sales was recently reported as 53% (Baldé, van den Brink et al. 2020), while that in PaaS is 100%.

4.3 Economic sustainability

Quantitative assessment from the economic perspective of washing machines in PaaS is addressed here for further discussion. Although a full quantitative economic assessment of this specific PaaS offering is not shown, a basic, preliminary assessment from the end user's standpoint is presented here. Two scenarios are set up; the PaaS scenario and a product one-off sales scenario with a washing machine that the target end users could have bought. For the PaaS scenario, an earlier work organized by SETAC (Ciroth, Gensch et al. 2008) is built upon: Electrolux-AEG and BSH models were used to make a baseline, where the energy demand per washing cycle is 6.64 MJ. The resulting lifecycle cost was divided by the acquisition (43%), the electricity in the use phase (22%), and the water in the use phase (35%).

The economic costs are analyzed with the two scenarios as shown in Table 2. Key data used for the calculation is the following: 250 washing cycles per year were assumed. The energy labels for the two washing machines were A and D for the PaaS and the product sales, respectively. A washing machine of energy label D consumes more energy by 55% than that of energy label A according to the energy efficiency index (Label2020), which was applied to the electricity used in the use phase. The market price of the less efficient machine is set as 300 Euros at present. The electricity price in Belgum in the first half of 2024 was 0.34 Euros/kWh according to the eurostat data (eurostat 2024), which was applied with the annual interest rate as 3% for the upcoming 10 years. The interest rate was not applied to the monthly PaaS fee, because the monthly fee for the PaaS contracts that began in 2018 is maintained even in 2025 for the contracts. Therefore, it's assumed here the PaaS monthly fee remains for 10 years.

Table 2. Key parameter values for the two scenarios

	Purchase cost	**Total fee for PaaS**	**Energy label**	**Electricity cost**
Product one-off sales	300 Euros	0	D	2,819 Euros
PaaS	0	1,080 Euros	A	1,819 Euros

Note that several costs are not included in this basic calculation, e.g., the maintenance cost and the water cost, which are likely to make the PaaS alternative preferred (the maintenance is included in the PaaS fee and the water use is likely to be more efficient with the PaaS machine). Note that the water cost was higher than the electricity in the assessment result by (Ciroth, Gensch et al. 2008) as stated above.

The preliminary assessment result shows that a significant magnitude of the electricity cost compared to the purchase cost in the case of product one-off sales, i.e., 9+ times. This is partly caused by the recent increase of the electricity price in Europe; it increased by 31% compared with three years before (eurostat 2024). This analysis indicates that using a product with higher energy efficiency is critical on the economic performance. The PaaS offering contributes to the economic performance through using an energy-efficient washing machine.

4.4 Designing for a CE

In helping industries enhance social aspects in the CE context by adapting their decision-making processes, design for a CE plays a central role in the conceptualization of a CE by Webster (2015). Sections 3.3, 4.2, and 4.3 have shown some preliminary results of assessing the PaaS offering from the three respective perspectives. It is sensible to assume trade-offs exist between the three dimensions. Addressing trade-offs and even finding a possible solution that breaks the trade-off relation is expected in designing; this is future work. However, regarding the results, the social sustainability aspect is determined largely by the business model concept perhaps because the assessment method is qualitative. Therefore, iterative quantitative assessment of environmental and economic aspects, when such quantitative data gets available, in design is important. PSS design has a high potential to contribute to helping industries in this regard. For PaaS design, several principles were proposed, including the application of a flat-rate payment scheme, which is relevant to the case analyzed in this paper (Sakao, Wasserbaur et al. 2019). However, the discussion above shows that an even broader perspective will be necessary to exploit the full potential of PaaS for a CE. This exploitation will require new knowledge and thus require further research.

4.5 Assessment methods

The result explained in Section 3.3 also shows a challenge for data collection referring to the subcategories that were assessed as unknown; such instances include local employment in the local community (stakeholder category), wealth distribution and respect for intellectual property rights among the value chain actors, consumer privacy for the consumer, and contribution to economic development in society.

5. CONCLUSIONS

Transitions to a CE will influence the social sustainability of our society. It is paramount for manufacturing organizations to design business offerings through assessment from the sustainability perspective. Thus far, little research was conducted on the social aspects of PaaS, a much-needed business model to accelerate transitions to a CE. This paper investigated a unique PaaS case focusing on the energy poverty from the social aspects using the UNEP/SETAC guideline and, based on the preliminary assessment result, discussed key elements, such as the involvement of special purpose actors and payment schemes. Answering the two leading questions, the results show that a socially conscious PaaS business model can be viable in Europe through addressing special target end users and incorporating adequate enablers in designing the offering. Also, the relevance of the PaaS business case to social sustainability were found working hours, community engagement, local employment, promoting social responsibility, end-of-life responsibility, poverty alleviation, and health issues for children as

consumers. Regarding the environmental and economic aspects of the PaaS case, positive factors for each aspect were found; for instance, better management of end-of-use products and materials and lower electricity cost in the use phase. The results mean that this specific PaaS case offers a high potential to improve the social, environmental, and economic aspects at the same time. This paper contributed to narrowing the knowledge gap on social sustainability of PaaS, also advancing knowledge on simultaneous assessment of an offering from the three aspects.

Quantitative assessment methods for impacts on the social dimension need to be further investigated. In doing so, compatibility with the environmental life cycle assessment (LCA) should be investigated; things to investigate include the functional unit, system boundary, and lifecycle phases. This is in line with a recommendation from a systematic literature review by (Huang, Sun et al. 2024) on the S-LCA that collecting more experiences of industrial applications is crucial to advance the area. Also, this research may provide opportunities in the context of a globalizing CE, as suggested by Chabowski, Gabrielsson et al. (2023).

6. ACKNOWLEDGEMENTS

SAAMO West-Vlaanderen and BSH Home Appliance are much appreciated for their invaluable support in providing relevant information and data about the PaaS case. This research was supported by the SCANDERE (Scaling up a circular economy business model by new design, leaner remanufacturing, and automated material recycling technologies) project granted from the EU co-funded ERA-MIN3 program under grant number 101003575 and funded by VINNOVA, Sweden's Innovation Agency (No. 2022-00070) as well as by the RE:think (Rethink and improve product design and service cost for circular economy business models) project funded by Swedish Energy Agency (No. P2022-00342). Three anonymous reviewers are appreciated for their constructive comments, which improved the quality of the paper.

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