IMPLICATIONS OF EU INSTRUMENTS ON COMPANY CAPABILITIES TO DESIGN MORE SUSTAINABLE

Citation for the original published paper (version of record):
Lövdahl, J., Isaksson Hallstedt, S., Schulte, J. (2023). IMPLICATIONS OF EU INSTRUMENTS ON COMPANY CAPABILITIES TO DESIGN MORE SUSTAINABLE SOLUTIONS-PRODUCT ENVIRONMENTAL FOOTPRINT AND DIGITAL PRODUCT PASSPORT. Proceedings of the Design Society, 3: 2245-2254.
http://dx.doi.org/10.1017/pds.2023.225

IMPLICATIONS OF EU INSTRUMENTS ON COMPANY CAPABILITIES TO DESIGN MORE SUSTAINABLE SOLUTIONS–PRODUCT ENVIRONMENTAL FOOTPRINT AND DIGITAL PRODUCT PASSPORT

Lövdahl, Josefin (1);
Hallstedt, Sophie I. (1,2);
Schulte, Jesko (1)

1: Blekinge Institute of Technology, Sweden;
2: Chalmers University of Technology

ABSTRACT

In the EU, initiatives with concrete instruments for measuring and storing sustainability-related product data are now introduced in legislation. Based on literature review and semi-structured interviews, this study investigates two EU instruments, the Product Environmental Footprint method and Digital Product Passports, and their potential implications for company capabilities to design and select more sustainable solutions in a strategic way. The results show that these instruments can lead to increased transparency and traceability in the design and comparison of solutions, allowing for more effective collaboration across the value chain. By applying a strategic sustainability perspective, it was found that these EU instruments have major limitations as they lack a systems perspective, do not include a full socio-ecological sustainability perspective, and do not support strategic decision-making. This results in risks for suboptimization and the design of solutions that turn out to be costly dead-ends on the way towards a sustainable society. Research is therefore recommended to investigate how these instruments can facilitate a strategic development of sustainable solutions.

Keywords: Ecodesign, Circular economy, Sustainability, Sustainable Product Development, Digital Product Passport

Contact:
Lövdahl, Josefin
Blekinge Institute of Technology
Sweden
josefin.lovdahl@bth.se

Cite this article: Lövdahl, J., Hallstedt, S. I., Schulte, J. (2023) 'Implications of EU Instruments on Company Capabilities to Design More Sustainable Solutions–Product Environmental Footprint and Digital Product Passport', in *Proceedings of the International Conference on Engineering Design (ICED23),* Bordeaux, France, 24-28 July 2023. DOI:10.1017/pds.2023.225

1 INTRODUCTION

The time window to tackle environmental challenges such as climate change is narrowing, and actions need to be taken to turn society's path towards a more sustainable direction (Steffen et al., 2015). Therefore, both market expectations and the European Union (EU) focus their attention increasingly on sustainability aspects. The speed of change is accelerating, and this "Decade of Action" will be decisive for transitioning society towards sustainability. Correspondingly, companies are required to change quickly across their value chains, and systems thinking is a key to not suboptimize and replace one problem with another (Broman et al., 2000). While speed is important, it is crucial that actions are taken in a strategic way to make sure that they lead in the right direction towards full sustainability (Broman and Robèrt, 2017). Even though companies have realised the challenges and understand that sustainability is critical for business success, they are struggling with the integration and implementation of sustainable design methods and tools in the product innovation process (Faludi et al., 2020). Clearer incentives from authorities can facilitate change to make this shift happen sooner rather than later (Eckert et al., 2019). One promising initiative is the European Green Deal, which provides a strategy and roadmap for tackling the threats of climate change, enhance circular economy, and work towards fulfilling the Sustainable Development Goals (SDGs) and Paris Agreement in the EU (EU Technical Expert Group on Sustainable Finance, 2020; European Commission, 2019). The European Green Deal includes several concrete instruments that will affect decisions made early in the innovation process, i.e., when strategies are formed, ideas are generated, and concepts are selected. These decisions have a major impact on the product lifecycle, which calls for sustainability aspects to be integrated early in the innovation process (McAloone and Tan, 2005).

This study investigates two specific EU instruments, i.e., the Product Environmental Footprint (PEF) and Digital Product Passport (DPP) in relation to the following research question: *What are the potential implications of the EU Product Environmental Footprint method and Digital Product Passport on company capabilities to design and select more sustainable solutions in a strategic way?*

2 BACKGROUND

An important target in the EU Green Deal is to decouple economic growth from resource use which was done by updating the Circular Economy Action Plan from 2015, to the New Circular Economy Action Plan (NCEAP) in 2020. One of the actions in the NCEAP is to launch legislative initiatives to incentivise product designs that are more resource-efficient, climate neutral and can improve circularity by being durable, repairable, and reusable. A review and update of the EcoDesign Directive (2009/125/EC) was described as a key element in this initiative, where learnings and criteria from the current directive and other instruments such as the EU PEF method should be incorporated. Further, DPPs to store product information are to be investigated within the same initiative (European Commission, 2020a). The first EU regulation to use some type of DPPs was proposed in 2020 with the update of the EU Battery Regulation (European Commission, 2020b). In March 2022, a proposal for a new regulation, the "EcoDesign for Sustainable Products Regulation" (ESPR), replacing the EcoDesign Directive (2009/125/EC), was communicated (European Commission, 2022a). Both the EU PEF and DPPs have been implemented in the ESPR. However, specifications on their use and related requirements will be addressed through delegated acts in line with Article 4 in the proposal (Directorate-General for Environment, 2022). As illustrated in Figure 1, the EU PEF Method and DPPs are two instruments mentioned in the NCEAP, while the NCEAP in turn can be seen as an action plan within the EU Green Deal.

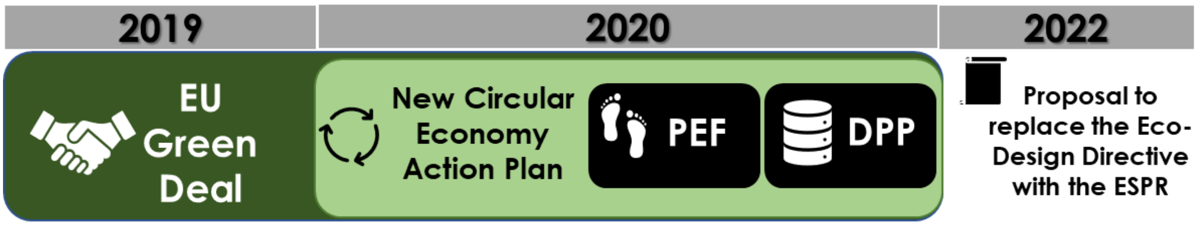

Figure 1. Relationship between some EU strategies, plans, regulations, and instruments.

https://doi.org/10.1017/pds.2023.225 Published online by Cambridge University Press

2.1 Eu product environmental footprint

The work with developing the EU PEF method is based on a need for harmonizing environmental footprint methods to avoid false green claims and to make it easier for consumers to understand eco-labels (European Commission, 2022b). The PEF is based on Life-Cycle Assessment, but prescribes a standard procedure with predefined rules for different product types to define the scope, the relevant environmental impact categories, life cycle stages, models and approaches to be used in the assessment. A first recommendation on the use of the EU PEF method was established in 2013 by the European Commission, followed by the so called "Pilot Phase", which included more stakeholders to test the applicability of the methods and guidelines for a selected number of product types. One of the main outcomes from the Pilot Phase was the establishment of a final set of Product Environmental Footprint Category Rules (PEFCR) for 19 different product types and in December 2021, the European Commission adopted a new version of the "Recommendation on the use of Environmental Footprint methods" (Directorate-General for Environment, 2021). Work is now ongoing to both monitor the use of the already existing PEFCRs and to develop new ones for more product categories (European Commission, 2022c). The PEF method has now also been introduced in legislation through the proposed ESPR where it is to be used for determining the eco-design requirement "Environmental footprint" found in Article 1 and Article 5 (Directorate-General for Environment, 2022).

2.2 Digital product passports

The intention of the Digital Product Passports (DPP) is to be used for tracing and storing data related to a product throughout its entire life cycle and value chain. The DPP aims at increasing transparency and reliability on green claims, and boosting circular material flows by providing consumers and other stakeholders with information on how to repair, re-use or recycle the product (European Commission, 2020a, 2019). In Article 1 and Article 5 of the ESPR, possible product eco-design requirements that could be stored in a DPP are described and cover the following aspects: a) product durability and reliability, b) product reusability, c) product upgradeability, reparability, maintenance and refurbishment, d) the presence of substances of concern in products, e) product energy and resource efficiency, f) recycled content in products, g) product remanufacturing and recycling, h) products' carbon and environmental footprints, i) products' expected generation of waste material. The exact product information requirements for the DPP are yet to be specified and remain uncertain. For example, in the proposed ESPR, the requirements are to be established per product group in delegated acts pursuant to Article 4, which can only be done after the proposed regulation is accepted by the European Parliament. However, some indication on the information to be stored in the DPP can be found in Articles 7-10 and Annex III and is illustrated in Figure 2 (Directorate-General for Environment, 2022).

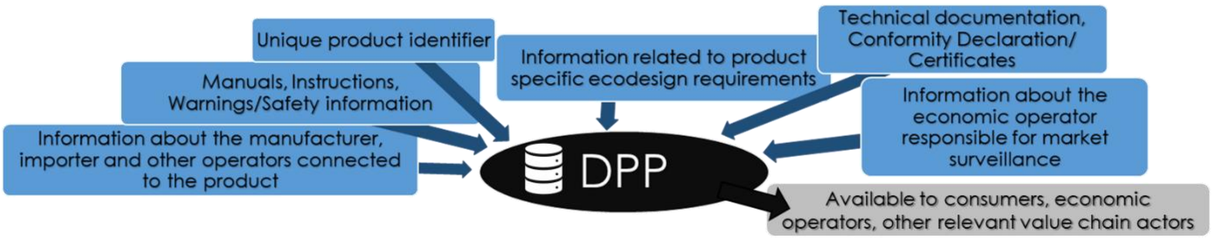

Figure 2. Some requirements on Digital Product Passports (DPP), inspired from the proposed ESPR (Directorate-General for Environment, 2022).

2.3 Strategic sustainable development

Given the complexity and wickedness of the sustainability challenge, a systems perspective and understanding of the direction of change necessary to reach a sustainable society is crucial both for society's transition and for business success within this transition. The framework for strategic sustainable development (FSSD) (Broman and Robèrt, 2017) was designed to understand the current declining trends of our socio-ecological system, plan for change in complex systems, and guide strategic decision-making within the transition towards a sustainable society. This framework has been used to clarify how tools, methods, and concepts, each focusing on certain aspects of the sustainability challenge, relate to each other and when each should be used when planning for sustainability (Robèrt, 2000). Several tools and concepts, such as Environmental Management Systems (EMSs), Life Cycle

https://doi.org/10.1017/pds.2023.225 Published online by Cambridge University Press

Assessments (LCAs), ecological footprinting and Factor 10 are based on traditional forecasting planning, that extrapolates current trends to arrive at a likely future (Hallstedt et al., 2010). However, in order to be strategic, a backcasting approach is necessary, which means starting from the vision of success and then looking back to see what actions that are needed to move towards that vision in a step-by-step way. The FSSD proposes basic principles for socio-ecological sustainability to be used as boundary conditions for the vision of success. By using backcasting from a vision framed by basic sustainability principles, the potential of concepts, legislations, technologies, etc. to contribute to strategic sustainable development can be assessed.

3 METHOD

A literature review was conducted and complemented with semi-structured interviews, which had a particular focus on DPP. In the following two sections, the methods are described in further detail.

3.1 Literature review

A literature review, following a structured and replicable process (Thomas and Hodges, 2013), was conducted to explore the state of the art of research about the EU PEF method and the DPP. The Scopus database was chosen, and two different search strings were created, see Table 1. The title, abstract and keywords of the found publications were analysed and their relevance for continued analysis was assessed based on sets of inclusion criteria for each search string. Only journal articles and conference papers written in English were included. As the EU PEF method has been available for use in different versions since 2013, the analysis focused on studies where the method was tested and evaluated. As the EU DPP is to be used for storing product data, publications where a product passport is evaluated, conceptualized, or developed in line with this intended use were included. The analysis of these publications focused on aspects for designing the requirements on the DPPs to be used in legislation, as well as identification of opportunities and challenges. The findings were then scrutinized from a strategic sustainability perspective by using the FSSD as a lens.

Table 1. Search strings used in Scopus, number of publications found, and the used inclusion criteria for each search string.

Search string		No. hits	Inclusion criteria	No. full text review
# 1	TITLE-ABS-KEY (("Product Environmental Footprint") AND (eu) AND (method))	17	The EU PEF method itself is either being evaluated or the EU PEF method is being applied/tested in the study.	9
# 2	TITLE-ABS-KEY ("digital product passport")	8	The study is investigating or developing a product passport that could be used for storing product related data and information i.e., in line with the intended use of DPPs as EU instrument.	5

3.2 Semi-structured interviews

A focus study on DPP was initiated as industry increasingly pays attention to DPP. This is partly due to the uncertainty of its consequences, and partly due to its clear indication of a stronger demand on producer-responsibility and traceability of sustainability data during the product life cycle. To get insights on how product development companies think they will be affected by the introduction of DPPs, two questions were asked as part of a larger research study with 21 semi-structured interviews. The interviewees were from 11 companies located in Sweden and had roles such as product developers and engineers, sustainability managers, and project leaders. The companies represented in the study are either developing and manufacturing products themselves, consultancy firms, or service providers for manufacturing industry, and vary in size from SME to large and multinational. The interview questions were: “Are you aware about upcoming digital product passport legislation?” and “How do you think this will impact your business?”. The questions were sent to the interviewees

https://doi.org/10.1017/pds.2023.225 Published online by Cambridge University Press

beforehand to allow for preparation. If the interviewee had not heard about this type of legislation, a brief introduction to the EU Green Deal and DPPs was given during the interview. All interviews were recorded, transcribed, and sent to the respective interviewee for confirmation and validation. The answers to the questions concerning DPPs from each transcript were collected in one common document to facilitate the analysis. An inductive coding process took place as one of the researchers read through the document with all answers and discussed findings and thoughts with the other researchers. A final set of codes was established and used to categorize the answers and noted in an excel document. To generate meaning from the data, strategies such as noting patterns and looking for diverging views were deployed (Miles and Huberman, 1994).

4 RESULT

Results from the literature review and the interviews are presented in the following two sections.

4.1 EU product environmental footprint

The search in Scopus with string #1 in Table 1 resulted in 17 publications, published between 2014 and 2022, out of which 9 fulfilled the inclusion criteria. Most of the included publications are based on studies conducted during the Pilot Phase. Four of the reviewed studies (Allacker et al., 2014; Del Borghi et al., 2020; Ojala et al., 2016; Passer et al., 2015) focused on comparing and evaluating the EU PEF method with other environmental impact assessment approaches such as different types of LCA and Environmental Product Declarations (EPD). In the study by Allacker et al. (2014), the EU PEF method and four other LCA approaches were evaluated for their suitability to be used as support for product policy initiatives in the EU. Focus was on the production and end-of-life phases and eight criteria, inspired from a study by Pelletier et al. (2013), were used to check whether the approaches consider all relevant activities across the value chain, provide support for reproducibility and comparability, offer flexibility, and ensure realistic modelling. The early version of the EU PEF method investigated that study was the only approach fulfilling all eight criteria, thus showing better suitability for use in product policy initiatives than the other analysed approaches. Passer et al. (2015) compared the EN15804 EPD standard with the PEF method for construction products and found differences in most phases of the assessment. Therefore, they advise to take the EN15804 EPD standard and other existing EPD programs into consideration when developing the PEFCRs to create better harmonization. Similarly, Del Borghi et al. (2020) compared the EU PEF method with the International EPD® Systems scheme and found that the comparability between the two methods was limited, and that the resulting environmental performance of the same product differs significantly due to diverse requirements in, for example, modelling, allocation method, and on data quality. Ojala et al. (2016) performed a comparison between the PEF method and three other methods, ISO 14044, ISO/TS14067 and the GHG Protocol Product Standard, to identify differences in how the environmental performance of products is calculated to assess the cost-efficiency, reliability, and comparability of the EU PEF method. They found that following the predefined PEFCRs could support and streamline the LCA process and improve the cost-efficiency. However, the EU PEF method also comes with extensive requirements on quality assessment of the data and requires use of several impact categories which could make it more cumbersome and costly to apply. The reliability as well as comparability may be improved by following the standard set by the PEFCRs for a product, though this depends on the ability of the PEFCRs to accurately represent the product group with e.g., choices for data and datasets, and mathematical models to be used in the impact assessment (Ojala et al., 2016). Walker and Rothman (2020) reviewed comparative LCA studies of bio-based and fossil-based polymers, and how well the studies comply with the requirements in the EU PEF method. At the time of the study, there were no PEFCRs available for bio-based polymers. In their review, they found that none of the comparative LCA studies fully complied with the requirements of the EU PEF method, resulting in low levels of comparability across the LCA studies. This is associated with risks when decisions are based on studies where the actual comparability between products is limited. Therefore, Walker and Rothman (2020) highlight the value of the PEF method for increasing comparability and suggest that the PEF method and its requirements should be more widely adopted when performing LCAs. Ojala et al. (2016) conducted interviews to identify challenges with the PEF method development under the Pilot Phase. Firstly, they found that the time schedule for the development of the PEFCR was limited, which could lead to inappropriate requirements and rules being developed for different product categories causing higher costs and lower reliability for studies following the PEF method. Secondly, they identified that products that have a similar scope of use could belong to different product categories, thus limiting comparability since there would be a discrepancy of requirements to be used in the PEF studies. Also, Lehmann et al. (2016) raised a concern that the comparability between products could be limited due to the difficulty of properly representing real world variability in the developed PEFCR from the Pilot Phase. Poolsawad et al. (2017) used the PEF method to evaluate how ready the Thai national life cycle inventory database is to support companies in their use of the PEF method to assess the environmental performance of products and services that are to be exported from Thailand to the EU market. Though they found that there were challenges and gaps in the database, the data quality requirements and assessment set up by the PEF method present an opportunity to further develop life cycle inventory databases by clarifying what data and what data quality that is needed for performing environmental impact assessments.

4.2 Digital product passport

The result from the search done in Scopus with string #2 showed that few academic studies have been published about digital product passports. Out of the eight documents found, all published in the years 2021 or 2022, five fulfilled the inclusion criteria. To successfully implement DPPs, they should be designed to be attractive and easy to use for the product stakeholders, so that they are seen as a benefit rather than a burden (Walden et al., 2021). Adisorn et al. (2021), studied how the DPP could be designed by looking at legal and voluntary information requirements. They identified manufacturers and suppliers to be the main stakeholders to provide product information to the passport, while the necessary level of detail varies among stakeholder groups in later product life cycle phases (Adisorn et al., 2021). The studies by Berger et al. (2022), and Plociennik et al. (2022) present conceptual models for how a DPP could be designed. Berger et al. (2022) developed a Digital Battery Passport (DBP) for an electric vehicle battery based on a stakeholder mapping and literature review. The proposed DBP is built up by four main information categories: “Battery”, “Sustainability and circularity”, “Value chain actors”, and “Diagnostics, maintenance, and performance”, which each contain sub-categories and indicators. Looking deeper into the category “Sustainability and circularity”, the two sub-categories are “Sustainability properties”, in which environmental (e.g. CO2 footprint, energy consumption, water use, toxicity) and social impacts (e.g. indicators for child labour, pay levels, safety) are collected, and “Circularity properties” where information on circularity performance and product design-related properties are found (Berger et al., 2022). In the work by Plociennik et al. (2022), a Digital Life Cycle Passport (DLCP) is presented where the data is stored in a hybrid cloud app and is adapted for both machine and human reading. The type of information stored in the DLCP is related to environmental impacts and resource use, and it is suggested to use a standard to guide the collection of information, such as the EU PEF method. Keeping the information updated and relevant in the DPP during the different lifecycle stages of products has been identified as a major challenge (Adisorn et al., 2021; Walden et al., 2021). This is especially true as the information also must be available for a long time in order to support circular processes (van Engelenburg et al., 2022). The main contributors to the information being stored in the DPPs are the suppliers and manufacturers of the products, but how to collect, handle, and update the DPPs with the data from the later lifecycle stages when the product is being used, maintained, repaired etc., is especially difficult. Further, for the DPPs to really contribute to a more sustainable and circular economy in practice, Adisorn et al. (2021) stress that it must be easy for consumers to interpret and understand the DPP when making their purchasing decision. The access to information that is stored in the DPP is connected to both challenges and opportunities. Different industries and stakeholders in the value chain will likely require access to different types of information. On the one hand, companies might be concerned that confidential or sensitive product information will be available in the passports and want to protect their intellectual property from their competitors, which could have a negative impact on collaboration in the product value chain. On the other hand, access to product information can have a positive impact on traceability by facilitating collaboration among stakeholders, increase recycling rates, and improve market surveillance for authorities (van Engelenburg et al., 2022; Walden et al., 2021).

In the semi-structured interviews, it was found that 12 out of the 21 interviewees were aware of digital product passports in legislation. The level of awareness varied from having heard about it briefly to being involved in company internal investigations on how proposed legislation could affect them. Eleven interviewees expressed that they thought that the passports will have a positive impact on their business and sustainability work. Some reasons for this were that sustainability-related work would be more prioritized by management to fulfil legislative requirements and lead to more resources being assigned to work with sustainability in product development, which in turn can increase the implementation of design strategies for sustainability. The legislation would also push the companies to develop capabilities, skills and knowledge about sustainability and approaches to work towards more sustainable solutions. Also, the possibility to compare products to one another through the information stored in the DPP was seen as positive. Eleven of the interviewees, regardless of whether they were aware about DPPs being introduced in legislation or not, said that they were unsure whether their company, products and solutions would be covered by such legislation, and, if so, to what extent. This made it difficult for some interviewees to say how big the impact would be on the business. Among the interviewees that had answered yes to the first question, it was recognized that a lot of work would be needed to adapt their operations to delivering DPPs, specifically concerning IT- and data management systems. How the data for the DPP will be stored, e.g., whether there will be a central EU database or a requirement for each company to have an open database with their product information was another question that was raised. It was also perceived as unclear, if, how, and when the companies will be required to have DPPs.

5 CONCLUDING DISCUSSION

In the last five years, new policy instruments have been introduced by the EU with the aim of steering towards a more sustainable and circular society. Increased responsibility and introduction of new policy instruments by authorities and politicians have been requested by proactive companies that systematically and strategically plan to fit into a more sustainable society (Hallstedt et al., 2020; Robèrt and Broman, 2017). The updated and new policy instruments can therefore be an advantage for proactive companies, but also a signal for other companies that it can be risky not to keep up with the change towards a more sustainable and circular market (Schulte and Hallstedt, 2018)

This study showed that the EU PEF method has the potential to support a comparison, from an environmental point of view, between products that can be classified into the same product group. However, the method has three limitations. Firstly, the method does not include a full socio-ecological sustainability perspective and does not provide support for how to connect such sustainability aspects to economic implications for the company. Instead, it only focuses on the environmental impact of a product, guided by predefined rules and guidelines for performing LCAs. The pre-defined category rules, PEFCRs, can be useful for companies when comparing different product concepts to one another and selecting a solution to move forward with. However, PEFCRs are so far only available for 19 product groups, creating a potential barrier for the PEF method. This results in the second limitation, i.e., the challenge to achieve a wide adoption by companies developing products outside of these categories. Thirdly, like with other types of LCA, the PEF method requires detailed information and quantitative data that is usually not available in the early phases of the product innovation process. Consequently, the data quality assessment requirements in the PEF method are not likely to be fulfilled. Still, the PEFCR could guide companies in what data they need to collect and consider for evaluating and comparing their product designs. Regardless of their geographical location, companies developing and producing products to be placed on the EU market must comply with EU legislation, and the implementation of the EU PEF method in regulations will therefore have an impact on aligning requirements on product-related data from all value chain actors. This can lead to improvements in transparency and traceability of environmental data, which will demand new processes and approaches in product development to meet this requirement. In general, the PEF risks becoming another instrument that is developed but disappears in the multitude of other standards and tools. Alternatively, it may end up not adding much value to product development companies as there are already established tools, such as EPD, that cover the need to report a product's environmental impact. However, the difference is that the PEF may be part of a legislation and therefore may have a larger impact.

Digital Product Passports may have a significant impact on manufactures and their suppliers in relation to understanding and implementing design support for sustainable and circular solutions that enable proactive decision-making and innovation for stakeholders across the value chain. The research findings point towards the following gaps with DPP: i) unclear what sustainability criteria are needed to meet the DPP requirements, and how these can be represented, (ii) insufficient technology and

https://doi.org/10.1017/pds.2023.225 Published online by Cambridge University Press

methods in place to transparently trace such data, (iii) inability to quantitatively assess sustainability impact of alternatives in early design stages, and (iv) design methodology not sufficiently addressing factors that are decisive for circular solutions, such as how to benefit and integrate supplier solutions for circularity. To realise DPP, an integration of digitalization in the product innovation process, also stated in previous research, has become increasingly important for companies as e.g., the requirements on analysing, handling, and tracing product-related data are raised (Hallstedt et al., 2020). To store and trace sustainability and circularity-related product data in digital product passports that are both human and machine readable could facilitate the handling of the data necessary for evaluating the sustainability performance of a product. This requires companies to adapt their data handling and management systems for smooth integration with the DPP which could be challenging before the actual requirements of the DPPs are set. Even if the DPP is not fully developed, it could be an advantage for companies to prepare their organization for the implementation of the DPP. Future research should investigate if DPP can contribute to a faster transition by being able to identify possible sustainability challenges in the value chain and product design early on. In addition, it may be easier to place clear sustainability requirements on suppliers and other actors in the value chain.

Using the FSSD as a lens on the findings of this study reveals major shortcomings and risks of the studied EU instruments. Firstly, PEF and DPP lack a systems perspective and a full socio-ecological sustainability perspective. Also, the sustainability-related criteria that are proposed to be included in these instruments were identified based on either fragmented approaches like circular economy, or some symptoms of unsustainability, down-streams in cause-and-effect chains, e.g. climate change. This results in reductionism and poses risks for suboptimization. Instead, these instruments should be designed starting from the root-causes of unsustainability, up-streams in cause-and-effect chains, to facilitate systems thinking. Secondly, PEF and DPP lack a strategic perspective. They do not include any guidance on the direction of change that has to be taken to move towards full sustainability over time. A product being designed to be circular does not necessarily mean that it is sustainable, since design for circularity rather should be considered as a strategy for sustainable development, but it should not be seen as the end goal. The lack of a strategic perspective results in the risk of misleading decision-makers to design products that might be better from a sustainability point of view than the status quo, but that are blind alleys on the way towards full sustainability. Instead, these EU instruments should be designed based on backcasting from basic principles for sustainability, which would allow company decision-makers to assess whether a solution is a smart steppingstone and a flexible platform on the way towards a future society that is compliant with the sustainability principles.

Further research is needed to better understand the impact of PEF and DPP, and how a strategic sustainability perspective can be integrated into these instruments. Ongoing research will include larger scale descriptive studies, such as questionnaires, to cover more roles in companies. Also, in-depth interview studies within a specific sector are needed to get a deeper understanding of the impact of these EU instruments on product development.

ACKNOWLEDGMENTS

Financial support from Sweden’s Innovation Agency – Vinnova, is gratefully acknowledged. Sincere thanks to the study participants at the industrial companies.

REFERENCES

Adisorn, T., Tholen, L., Götz, T. (2021), "Towards a Digital Product Passport Fit for Contributing to a Circular Economy" *Energies*, Vol. 14 No. 8, pp. 2289. https://doi.org/10.3390/en14082289

Allacker, K., Mathieux, F., Manfredi, S., Pelletier, N., De Camillis, C., Ardente, F., Pant, R. (2014), "Allocation solutions for secondary material production and end of life recovery: Proposals for product policy initiatives", *Resources, Conservation and Recycling*, Vol. 88, pp. 1–12. https://doi.org/10.1016/j.resconrec.2014.03.016

Berger, K., Schöggl, J.-P., Baumgartner, R.J. (2022), "Digital battery passports to enable circular and sustainable value chains: Conceptualization and use cases", *Journal of Cleaner Production*, Vol. 353 No. 131492. https://doi.org/10.1016/j.jclepro.2022.131492

Broman, G., Holmberg, J., Robèrt, K.-H. (2000), "Simplicity without reduction: Thinking upstream towards the sustainable society", *Interfaces*, Vol. 30, pp. 13–25. https://doi.org/10.1287/inte.30.3.13.11662

Broman, G.I., Robèrt, K.-H. (2017), "A framework for strategic sustainable development", *Journal of Cleaner Production*, Vol. 140, pp. 17–31. https://doi.org/10.1016/j.jclepro.2015.10.121

Del Borghi, A., Moreschi, L., Gallo, M. (2020), "Communication through ecolabels: how discrepancies between the EU PEF and EPD schemes could affect outcome consistency", *International Journal of Life Cycle Assessment*, Vol. 25, pp. 905–920. https://doi.org/10.1007/s11367-019-01609-7

Directorate-General for Environment (2022), *Proposal for a regulation of the European parliament and of the council establishing a framework for setting ecodesign requirements for sustainable products and repealing Directive 2009/125/EC (No. COM(2022) 142 final)*. European Commission.

Directorate-General for Environment (2021), *Commission Recommendation of 16.12.2021 on the use of the Environmental Footprint methods to measure and communicate the life cycle environmental performance of products and organisations. (No. COM(2021) 9332 final)*. European Commission.

Eckert, C., Isaksson, O., Hallstedt, S., Malmqvist, J., Öhrwall Rönnbäck, A., Panarotto, M. (2019), "Industry Trends to 2040", *22nd International Conference on Engineering Design (ICED19)*, Delft, Netherlands, 5-8 August, pp. 2121–2128. https://doi.org/10.1017/dsi.2019.218

EU Technical Expert Group on Sustainable Finance (2020), *Taxonomy: Final report of the Technical Expert Group on Sustainable Finance*. [online] European Commission. Available at: https://finance.ec.europa.eu/system/files/2020-03/200309-sustainable-finance-teg-final-report-taxonomy_en.pdf (accessed 2022-03-23).

European Commission (2022a), *Communication from the Commission of the European parliament, the council, the European economic and social committee and the committee of the regions on making sustainable products the norm (No. COM(2022) 140 final)*, European Commission.

European Commission (2022b), *Single Market for Green Products - Environment - European Commission*. [online] European Commission. Available at: https://ec.europa.eu/environment/eussd/smgp/policy_footprint.htm (accessed 2022-03-23).

European Commission (2022c), *The Environmental Footprint transition phase - Environment - European Commission*. [online] European Commission. Available at: https://ec.europa.eu/environment/eussd/smgp/ef_transition.htm (accessed 2022-03-23).

European Commission (2020a). *Communication from the commission of the European parliament, the council, the European economic and social committee and the committee of the regions on a new Circular Economy Action Plan For a cleaner and more competitive Europe (No. COM(2020) 98 final)*, European Commission.

European Commission (2020b), *Proposal for a regulation of the European parliament and the council concerning batteries and waste batteries, repealing Directive 2006/66/EC and amending Regulation (EU) No 2019/1020 (No. COM(2020) 798 final)*, European Commission.

European Commission (2019), *Communication from the commission of the European parliament, the council, the European economic and social committee and the committee of the regions on the European Green Deal (No. COM(2019) 640 final)*, European Commission.

Faludi, J., Hoffenson, S., Kwok, S.Y., Saidani, M., Hallstedt, S.I., Telenko, C., Martinez, V. (2020), "A Research Roadmap for Sustainable Design Methods and Tools", *Sustainability*, Vol. 12 No. 8174. https://doi.org/10.3390/su12198174

Hallstedt, S., Isaksson, O., Öhrwall Rönnbäck, A. (2020), "The Need for New Product Development Capabilities from Digitalization, Sustainability, and Servitization Trends", *Sustainability*, Vol. 12 No. 10222. https://doi.org/10.3390/su122310222

Hallstedt, S., Ny, H., Robèrt, K.-H., Broman, G., (2010), "An approach to assessing sustainability integration in strategic decision systems", *Journal of Cleaner Production*, Vol. 18, pp. 703–712. https://doi.org/10.1016/j.jclepro.2009.12.017

Lehmann, A., Bach, V., Finkbeiner, M., (2016), "EU Product Environmental Footprint—Mid-Term Review of the Pilot Phase", *Sustainability*, Vol. 8, pp. 1-13. https://doi.org/10.3390/su8010092

McAloone, T.C., Tan, A.R., (2005), "Sustainable product development through a life-cycle approach to product and service creation: An exploration of the extended responsibilities and possibilities for product developers", *Eco-X Conference: Ecology and Economy in Electronix*, *KERP*, Vienna, Austria, 2005, pp. 1–12.

Miles, M.B., Huberman, A.M. (1994), *Qualitative Data Analysis: An Expanded Sourcebook*. SAGE. Thousand Oaks, CA.

Ojala, E., Uusitalo, V., Virkki-Hatakka, T., Niskanen, A., Soukka, R. (2016), "Assessing product environmental performance with PEF methodology: reliability, comparability, and cost concerns", *International Journal of Life Cycle Assessment*, Vol. 21 No.8, pp. 1092–1105. https://doi.org/10.1007/s11367-016-1090-0

Passer, A., Lasvaux, S., Allacker, K., De Lathauwer, D., Spirinckx, C., Wittstock, B., Kellenberger, D., Gschösser, F., Wall, J., Wallbaum, H. (2015), "Environmental product declarations entering the building sector: critical reflections based on 5 to 10 years experience in different European countries", *International Journal of Life Cycle Assessment*, Vol. 20 No. 9, pp. 1199–1212. https://doi.org/10.1007/s11367-015-0926-3

Pelletier, N., Allacker, K., Pant, R., Manfredi, S. (2013). "European Commission Organisation Environmental Footprint method: comparison with other methods, and rationales for key requirements", *International Journal of Life Cycle Assessment*, Vol. 19 No. 2, pp. 387–404. https://doi.org/10.1007/s11367-013-0609-x

Plociennik, C., Pourjafarian, M., Nazeri, A., Windholz, W., Knetsch, S., Rickert, J., Ciroth, A., Precci Lopes, A. do C., Hagedorn, T., Vogelgesang, M., Benner, W., Gassmann, A., Bergweiler, S., Ruskowski, M., Schebek, L., Weidenkaff, A. (2022), "Towards a Digital Lifecycle Passport for the Circular Economy", *29th CIRP Conference on Life Cycle Engineering*, Leuven, Belgium, 4-6 April 2022, Procedia CIRP, Vol. 105, pp. 122–127. https://doi.org/10.1016/j.procir.2022.02.021

Poolsawad, N., Thanungkano, W., Mungkalasiri, J., Wisansuwannakorn, R., Suksatit, P., Jirajariyavech, A., Datchaneekul, K. (2017), "Thai national life cycle inventory readiness for product environmental footprint", *International Journal of Life Cycle Assessment*, Vol. 22, pp. 1731–1743. https://doi.org/10.1007/s11367-016-1257-8

Robèrt, K.-H. (2000), "Tools and concepts for sustainable development, how do they relate to a general framework for sustainable development, and to each other?", *Journal of Cleaner Production*, Vol. 8, pp. 243–254. https://doi.org/10.1016/S0959-6526(00)00011-1

Robèrt, K.-H., Broman, G. (2017), "Prisoners' dilemma misleads business and policy making", *Journal of Cleaner Production*, Vol. 140, pp. 10–16. https://doi.org/10.1016/j.jclepro.2016.08.069

Schulte, J., Hallstedt, S. (2018), "Company Risk Management in Light of the Sustainability Transition", *Sustainability*, Vol. 10 No. 11, 4137. https://doi.org/ 10.3390/su10114137

Steffen, W., Richardson, K., Rockström, J., Cornell, S.E., Fetzer, I., Bennet, E.M., Biggs, R., Carpenter, S.R., De Vries, W., De Wit, C.A., Folke, C., Gerten, D., Mace, G.M., Persson, L.M., Ramanathan, V., Reyers, B., Sörlin, S. (2015), "Planetary boundaries: Guiding human development on a changing planet", *Science*, Vol. 347 No. 6223, pp. 736. https://doi.org/10.1126/science.1259855

Thomas, D.R., Hodges, I.D. (2013), "Doing a Literature Review", In: *Designing and Managing Your Research Project: Core Skills for Social and Health Research*. Sage Publications Ltd., London. https://dx.doi.org/10.4135/9781446289044

van Engelenburg, S., Rukanova, B., Ubacht, J., Tan, S.L., Tan, Y.-H., Janssen, M. (2022), "From requirements to a research agenda for governments governing reuse of critical raw materials in the circular economy", *DG.O 2022: The 23rd Annual International Conference on Digital Government Research*, Virtual Event Republic of Korea, 15-17 June 2022, Association for Computing Machinery pp. 62–67. https://doi.org/10.1145/3543434.3543645

Walden, J., Steinbrecher, A., Marinkovic, M., (2021), "Digital Product Passports as Enabler of the Circular Economy", *Chemie Ingenieur Technik*, Vol. 93, pp. 1717–1727. https://doi.org/10.1002/cite.202100121

Walker, S., Rothman, R., (2020), "Life cycle assessment of bio-based and fossil-based plastic: A review", *Journal of Cleaner Production*, Vol. 261, 121158. https://doi.org/10.1016/j.jclepro.2020.121158