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Sustainability risk and portfolio management—A strategic scenario method for sustainable product development

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Abstract

Companies need to strategically develop their portfolio and find the balance between being proactive and passive in relation to sustainability. In this study, a strategic perspective based on backcasting from overarching socio-ecological sustainability principles was used as a lens to understand how companies might adapt their product portfolios to avoid threats and exploit opportunities on increasingly sustainability-driven markets. The study shows that sustainability performance, market success, and time are key areas to be considered in the product portfolio process to ensure short-term profitability and long-term competitiveness. A novel method was developed and tested in one academic group and two companies to explore how such a strategic sustainability perspective can support the product portfolio process in practice. The results indicate that the strategic layered double-flow scenario method, including different time horizons, was supportive in identifying opportunities and avoid risks in the sustainable development process at the company.

KEYWORDS
backcasting, forecasting, market success, product portfolio, scenario modeling, strategic sustainable development

1 | INTRODUCTION

Human activities require a vast number of products and services. While being the engine of the economic system and contributing to human welfare, products, and the socio-technical systems they are part of, currently cause a systematic degradation of the ecological and social systems. For example, there is an increasing use of natural resources, emissions of harmful substances, and physical encroachment, all of which putting the well-being of human society at risk (Steffen et al., 2011). Humanity is overpassing several of the nine planetary boundaries, which represent the safe operating space (Clift et al., 2017; Steffen et al., 2015), for example, the anthropogenic perturbation of the nitrogen and phosphorus cycles (Steffen et al., 2015). However, there are not only challenges related to the functioning of the Earth system, but also related to the social foundations of society, such as the just distribution of resources, access

Abbreviations: AM, additive manufacturing; B2B, business to business; DRM, design research methodology; EVs, electric vehicles; FSSD, Framework for Strategic Sustainable Development; ICE, internal combustion engine; LCA, life cycle assessment; MS, Market Success; PDP, product development process; PSA, Portfolio Sustainability Assessments; RQs, research questions; SCI, sustainability compliance index; SLCA, sustainability life cycle assessment; SLCA 2.0, sustainability life cycle assessment version 2.0 (improved version); SPs, sustainability principles; STARDUST, strategic layered double-flow scenario modeling for sustainability risk and portfolio management; TBL, triple bottom line.

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to education and healthcare, and so forth (Raworth, 2012). Industry plays a key role in moving society towards a sustainable state, not only because this sector is causing many of the current problems, but also because this is where new innovations can be conceived, which can contribute to new production and consumption systems and new societal norms (Gaziulusoy et al., 2013). However, radical change of the whole system is required to avoid reaching critical tipping points in the ecological and social systems (Steffen et al., 2011). This change entails significant risks, that is, threats and opportunities, for companies in the form of legislative change, shifting customer preferences, increasing raw material and waste costs, and so forth (Schulte & Hallstedt, 2018). Therefore, it is crucial for product development and manufacturing companies to integrate a sustainability perspective in their decision-making processes to ensure competitiveness in light of this radical change and to contribute to society's transition. But how fast should a company shift to offering more products with a higher sustainability performance? A company might have products with low sustainability performance that generate high revenue in the short term, but in the long term, these products can be rejected due to environmental legislation or changing customer requirements (Zartha Sossa et al., 2020). At the same time, the company may develop products with a higher sustainability performance that are not profitable in the short term, but in the future, these products might have a higher revenue, complying with new environmental regulations and being ahead in the market (Schulte et al., 2020).

Previous studies found that it is difficult to balance the product portfolio in light of the trends and changes that society's transition towards sustainability entails (Villamil & Hallstedt, 2021). Furthermore, the methodologies, tools, and portfolio selection criteria used by companies for the product portfolio process are lacking a strategic sustainability perspective, that is, applying backcasting from a future vision of success, framed by principles for socio-ecological sustainability, which is essential for guiding the product portfolio in the right direction (Villamil & Hallstedt, 2018, 2021).

Based on these challenges, two research questions (RQs) are addressed in this study:

> **RQ1.** In which way can a strategic sustainable development lens be included in the product portfolio process?
>
> **RQ2.** How can decision-makers at product development companies be supported in strategically balancing the product portfolio process in relation to market success and sustainability aspects over time?

By addressing these questions, the contribution of this study is (i) to enrich the understanding of sustainability product portfolio by applying a strategic sustainable development lens on the product portfolio process and (ii) to provide a novel method for strategic sustainability product portfolio process that can be used as decision support to balance the portfolio in relation to sustainability risks and business opportunities.

2 | CONCEPTUAL BACKGROUND

To answer the RQs, this study builds on concepts from three main areas: (1) design for sustainability transitions; (2) strategic sustainability perspective in product development; and (3) sustainability product portfolio.

2.1 | Design for sustainability transitions

The sustainability transition entails radical transformations of today's socio-technical systems (Chen et al., 2020; Gaziulusoy & Ryan, 2017; Loorbach et al., 2009). The development of products has evolved from a technical systems perspective to a socio-technical systems perspective, which is a more complex, dynamic, and wider approach. In this case, the stakeholder collaboration has a crucial role in the development of sustainable solutions (Gaziulusoy & Erdoğan Öztekin, 2019; Gaziulusoy & Ryan, 2017), requiring a cultural shift and a systemic perspective (Valderrama & Jørgensen, 2018). These transformations pose significant risks for product development and manufacturing companies, where practices and activities that enforce unsustainable development face increasing threats, for example, tougher legislation, reputational damage, and decreasing demand among others (Kiefer et al., 2019; Schulte & Hallstedt, 2018). Meanwhile, companies that contribute to strategic sustainable development can benefit from business opportunities, such as meeting new customer demands, attracting talented and motivated employees, and saving cost, resilience, and so forth (Gomez-Valencia et al., 2021; Korhonen & Seager, 2008). To do so, companies need to adapt and change their activities on both strategic, tactical, and operational organizational levels (Gaziulusoy et al., 2013). Gaziulusoy et al. (2013) proposed a workshop method to address the societal transition towards sustainability from a product development company perspective. The method is based on systemic double-flow scenario modeling to analyze and connect possible events in the present and in the future, resulting in transition pathways. It allows companies to explore different scenarios from a forecasting and backcasting perspective. The forecasting scenarios help to identify events that are likely to happen in line with existing trends (Fotiadis & Polemis, 2018). The backcasting scenarios start from a future vision and explore what is necessary to happen to reach the vision over time.

2.2 | Strategic sustainability perspective in product development

The ability to apply strategic thinking requires knowing the desired outcome, that is, having a vision of success (Broman & Robèrt, 2017). Only then, backcasting, as described in the previous section, can be applied to identify which steps that are stepping stones towards that vision (Robèrt & Broman, 2017). Without a strategic perspective, there is a risk that solutions, which might be better from a sustainability perspective than the status quo, later turn out to be blind alleys on

the way towards full sustainability (Schulte et al., 2020). For a product development company, this can mean that resources are spent on developing products or technologies that have no future. On the other hand, applying a strategic perspective can help anticipating changes on increasingly sustainability-driven markets and support identifying products and technologies that are flexible platforms on the way towards a sustainable future (Robèrt & Broman, 2017). However, there are challenges related to creating a vision that is neither too detailed, making it quickly become obsolete when technology break-throughs hit the market and also difficult for people to agree upon, nor too general, resulting in a lack of guidance and applicability in practice. To overcome this challenge, the Framework for Strategic Sustainable Development (FSSD) uses a definition of sustainability that is built on the following first-order principles: "in a sustainable society, nature is not subject to systematically increasing (1) … concentrations of substances extracted from the Earth's crust, (2) … concentrations of substances produced by society, (3) … degradation by physical means, and, people are not subject to structural obstacles to (4) health, (5) influence, (6) competence, (7) impartiality, and, (8) meaning-making" (Broman & Robèrt, 2017). The sustainability principles (SPs), which represent the root causes of unsustainability, can be used as boundary conditions for re-design. Thereby, they can guide the development of products without limiting the solution space more than necessary.

In the product development process (PDP), it is necessary to implement a strategic sustainability perspective in the early stages, where the majority of a product's life cycle sustainability impact and function within the larger socio-technical system is determined (Hallstedt, 2017). At the same time, knowledge about the impact of a concept or solution is limited at this stage and detailed quantitative data are usually scarce. This comes with challenges for how to assess sustainability performance in these early phases. In product development, life cycle assessment (LCA) is a common tool to identify the environmental impacts across the whole product life cycle (Stewart et al., 2018). However, LCA lacks a strategic perspective, omits social aspects, requires detailed quantitative data that are only available in later stages of the PDP (Finkbeiner et al., 2010), and seldom considers changes over time (Moshrefi et al., 2020). To include a strategic long-term perspective using a backcasting approach, an alternative LCA tool, the sustainability life cycle assessment (SLCA), can be used, also called strategic life cycle management (Ny et al., 2006). The SLCA adds a strategic perspective to LCA by using the SPs as a lens to identify hotspots of sustainability impact across the life cycle in a qualitative way (Hallstedt et al., 2013). This can be done already in the early phases of product development, and the identified hotspots can later be quantified when more data become available. In practice, the improved version SLCA 2.0 can be applied by using templates and guiding questions to support companies to identify sustainability hotspots with limited time and data (Villamil & Hallstedt, 2018). The sustainable design space (Hallstedt, 2017) is another approach that is based on backcasting from SPs to get guidance in the early phases of the PDP. In this approach, a qualitative scale for assessing the compliance level for different sustainability criteria is defined, called sustainability compliance index (SCI) (see Table 1).

2.3 | Sustainability product portfolio

A product portfolio is a selection of products and services that a company offers, following their strategic plan (Cooper et al., 2000). In portfolio management, companies assess programs and projects, where a program is a group of several projects and a project focuses on the development of products and services (Cooper et al., 2000). The selection of the portfolio products is determined by criteria such as profit, quality, legislation, innovation, and competitiveness, besides other criteria (Cooper et al., 2000). These criteria differ depending on the industry sector, company strategy, and other factors (Kohl, 2016; Ölundh & Ritzén, 2004). Balancing the product portfolio is challenging due to the complexity of the diverse and constantly changing market, which makes it necessary to consider many variables, for example, legislation and customer requirements, in order to have a profitable and successful product portfolio over time (Jugend & Figueiredo, 2017; Villamil & Hallstedt, 2021). In the product planning phase, that is, early in the PDP, companies align the company strategy with the offers that will be part of the portfolio (Ulrich & Eppinger, 2012). Cooper et al. (1999) proposed to cover the following areas in the product portfolio process: (1) strategic fit, (2) value maximization, and (3) balanced and right size of the portfolio. A successful product portfolio requires having a clear picture of the different events that might affect it over time (Kock et al., 2016; Zvezdov & Hack, 2016). Therefore, Jugend and Figueiredo (2017) suggested to complement the areas proposed by Cooper et al. (1999) with a fourth area, "preparation for the future." It adds a long-term perspective to the product portfolio, although it is missing a strategic sustainability perspective. The product portfolio must be constantly updated according with external trends and new requirements of the market, legislation, and technology advances, among other aspects (Jugend et al., 2017; Ma et al., 2020).

TABLE 1 Sustainability compliance index (SCI) scale (Hallstedt, 2017)

Sustainability compliance index (SCI) scale	
SCI 9	The strategic sustainability criterion is fulfilled. Reached excellent level.
SCI 6	Have implemented a strategy with concrete actions for how to move step-wise towards more sustainable solutions. Moving strategically towards the excellent level (SCI 9).
SCI 3	Compliance with socio-ecological regulations. A low but acceptable level
SCI 1	Lowest level of sustainability compliance. Not acceptable level.
0	No information to score a SCI value. Need more research and investigation.

In a previous study, based on a systematic literature review, workshops, and semi-structured interviews with high-level positions in product development companies, the sustainability product portfolio was defined as: "A process to set a company platform of solutions, i.e., a cluster of products, services, technologies, and/or customized options, based on the company strategic plan and assessed by a strategic sustainability perspective" (Villamil & Hallstedt, 2021). To assess the sustainability performance of the portfolio, companies use several tools and methods such as LCA (Ma et al., 2020), eco-design tools (Cluzel et al., 2016), and checklists. Those tools are usually adapted to fit company needs (Villamil & Hallstedt, 2021). Some companies have developed their own methodologies, for example, the World Business Council for Sustainable Development (WBCSD, 2018), and several industries developed the Framework for Portfolio Sustainability Assessments (PSA) to follow up the portfolio process, where sustainability plays an important role. To select and balance the portfolio components, the sustainable strategic project selection methodology (Ma et al., 2020), the Sustainability Balanced Scorecard (Figge et al., 2002), and the Sustainable Solution Steering (BASF, 2020) are based on the triple bottom line (TBL), that is, economic, environmental, and social dimensions of sustainability. In the Total Environmental Impact–Total Profit matrix, the portfolio products are assessed by using the Boston Consulting Group matrix and LCA (Moshrefi et al., 2020), where products can be classified as (1) "Stars," with high environmental and profit performance; (2) "Cash Cows," with a good profit in the present but with the tendency to be low in the future; (3) "Question mark," low environmental and profit; and (4) "Dogs," with a low profit but high environmental performance. Three-dimensional visualizations are proposed to analyze the portfolio process; for example, Schmidt et al. (2004) compared portfolio alternatives in three axes with cost, environmental impact, and social impact. However, these existing tools are missing a strategic sustainability perspective, which ensures that solutions are profitable stepping stones towards sustainability (Villamil & Hallstedt, 2021). Implementing sustainability in the product portfolio requires the active participation of internal and external stakeholders (Goodman et al., 2017; Massaro et al., 2021; Sánchez, 2015; Silvius & Schipper, 2014; Tang et al., 2018). It is therefore crucial to raise sustainability awareness in the high-level positions of the company (Nilsson-Lindén et al., 2019), where the final product portfolio is determined (Vliex, 2013).

In practice, sustainability implementation in the product portfolio comes with challenges, for example, in relation to lack of a strategic planning perspective (Villamil & Hallstedt, 2021), deficient knowledge for the implementation of eco-design and life cycle thinking (Favi et al., 2019), and incomplete assessment of social sustainability aspects (Ma et al., 2020; Ma & Kremer, 2015; Martens & Carvalho, 2016).

3 | RESEARCH APPROACH

This study presents the prescriptive part of research, which is inspired by the design research methodology (DRM) (Blessing & Chakrabarti, 2009). The research clarification and the descriptive study phases of the DRM were developed in previous research studies by the authors performed since 2016 (Schulte & Hallstedt, 2018; Schulte et al., 2020; Villamil & Hallstedt, 2018, 2021; Villamil et al., 2018). The previous research investigated the implementation of a strategic sustainability perspective in product portfolio and risk management, using multiple methods, such as literature review, interviews, and workshops, and other approaches. This included a mapping of existing research, the creation of definitions, and the identification of preconditions in relation to processes, tools, and methods for sustainability risk and portfolio management. The main fields of the research were related to the implementation of sustainability in the product portfolio, tools used for the assessment and support of the portfolio process, portfolio selection criteria and interdependencies, strategic sustainability assessment, sustainability risk management, and design for sustainability transitions. Thereby, an understanding of key concepts from an academic and industrial perspective was established and a foundation for the development of prescriptive support was established. The utilization of the previous findings for the development of the prescriptive support is further described in Section 4. One of the challenges identified in these previous studies was that companies are lacking practical support to implement a strategic sustainability perspective in their product portfolio and risk management processes. Therefore, some promising tools can be used to address this challenge, for example, the FSSD (Broman & Robèrt, 2017), the systemic double-flow scenario modeling (Gaziulusoy et al., 2013), the SLCA (Ny et al., 2006), and the SCI (Hallstedt, 2017).

To provide an answer to RQ1, a strategic sustainable development lens was used to increase the conceptual understanding of what a strategic sustainability product portfolio is. To that end, existing research on product portfolio and sustainability was viewed from a lens of FSSD, that is, a lens of SPs from a backcasting perspective. Then, based on an understanding of strategic sustainability product portfolio, a method was developed and tested for how to apply this in practice, providing an answer to RQ2. This resulted in the development of a method called strategic layered double-flow scenario modeling for sustainability risk and portfolio management (STARDUST), which is based on a strategic sustainability perspective and the synergies between portfolio and risk management. The purpose of the method is (i) to get an awareness of the implications and risks of the macro-level societal transformation towards sustainability from a company and product or technology perspective; (ii) to get an overview and balance the portfolio over time, considering market success and sustainability; (iii) to identify improvements for products or technologies in the portfolio; and (iv) to initiate critical thinking about how requirements must be changed and weighted over time. This method is described in more detail in Section 4.2.

The STARDUST method was tested in three on-line workshops in September and October of 2020. The method aims to encourage active participation, discussions, and critical thinking related to the sustainability product portfolio process in multidisciplinary groups, by using specific templates and guiding questions. The different steps

and stages of the workshop are described in detail in Section 4.2. The first workshop was a pilot test performed with four academic researchers in the area of sustainable product development, where the results helped to improve the next workshops. The second round of workshops was performed with industrial practitioners at two large multinational companies with presence in Sweden. Company A is a large business to business (B2B) company in the aerospace industry with approximately 2000 employees. Company B is a medium-sized B2B company in the industry construction, and vehicle and machinery equipment sector with approximately 250 employees. These companies were selected as they are between stage 3, beyond compliance, and stage 4, integrated strategy, on the sustainability integration ladder described by Willard (2005). As such, they are companies that have recognized the importance of building capabilities for sustainable product development without being companies that have sustainability as their core purpose. This makes them representative for a wide spectrum of product development and manufacturing companies. Further work is planned to test the method with companies from other sectors. In company A, the method was tested using a comparison between metal additive manufacturing technology (AM) and a traditional process like milling and forging as a case. The case at company B focused on the comparison between a current solution and a new alternative that is based on material recovery and recycling. A total of 13 participants with diverse roles from these two companies were part of the workshops. These participants were selected for their expertise related to sustainability, portfolio, or risk management (see Table 2).

Prior the workshop, participants were provided with a video that explained the method and the industry case. At the end of the workshops, feedback sessions were performed to know about the participants opinions about the STARDUST method and its applicability, usability, and usefulness. In addition, an evaluation questionnaire, Appendix A, was used to gather individual and anonymous feedback about the method. A total of five participants replied the questionary. The STARDUST workshops and feedback sessions were recorded for analysis. The data were coded and restructured into three main themes: (1) benefits of the method; (2) challenges and improvement possibilities; and (3) actions for further implementation of the method in companies. Within-case analysis was performed before doing cross-case analysis by creating a matrix with the two companies and the coded results for each of them. This matrix helped to compare the results and identify similarities and differences between the two companies. Finally, the findings were listed and reported back to the companies to validate the results. Figure 1 presents an overview of the research stages.

4 | RESULTS AND DISCUSSION

By using the FSSD as a lens, it is explored how a strategic sustainability perspective can be added to the concept of product portfolio. A method is then presented for which steps a company would need to perform to apply such a strategic sustainability perspective in the product portfolio process in practice. The method was tested and evaluated based on the application in real industrial cases.

4.1 | Product portfolio from a strategic sustainability perspective

Within the FSSD, a funnel metaphor is used to illustrate how the ecological and social systems' potential to support the fulfillment of human needs is systematically degraded by violating the SPs (Robèrt & Broman, 2017). As this unsustainable development goes on and the systems are moving closer towards a collapse, there is an increasing urgency and need for solutions that can turn the path of development towards the vision of a sustainable society, framed by the SPs (Broman & Robèrt, 2017). This dynamic has far reaching consequences from a company perspective. It entails significant threats for companies that contribute relatively much to unsustainable development, since it becomes more and more likely that they will be targeted by stricter regulation, experience brand damage, have difficulties attracting talented employees, and so forth (Schulte & Hallstedt, 2018). At the same time, there is an increasing demand for

TABLE 2 Information about the companies that participated in the STARDUST workshops

	Company A	Company B
Role of the workshop participants	- Manufacturing lead	
	- Method specialist	- Global product manager
	- Design engineer	- Technical product manager
	- Material engineer	- Product development and engineering
	- Technology lead	- Technical product engineer
	- Design team lead	- Global environmental manager and sustainability coordinator
	- Process engineer	
	- Method development	
Total number of participants	8	5
Duration	2 h	4 h

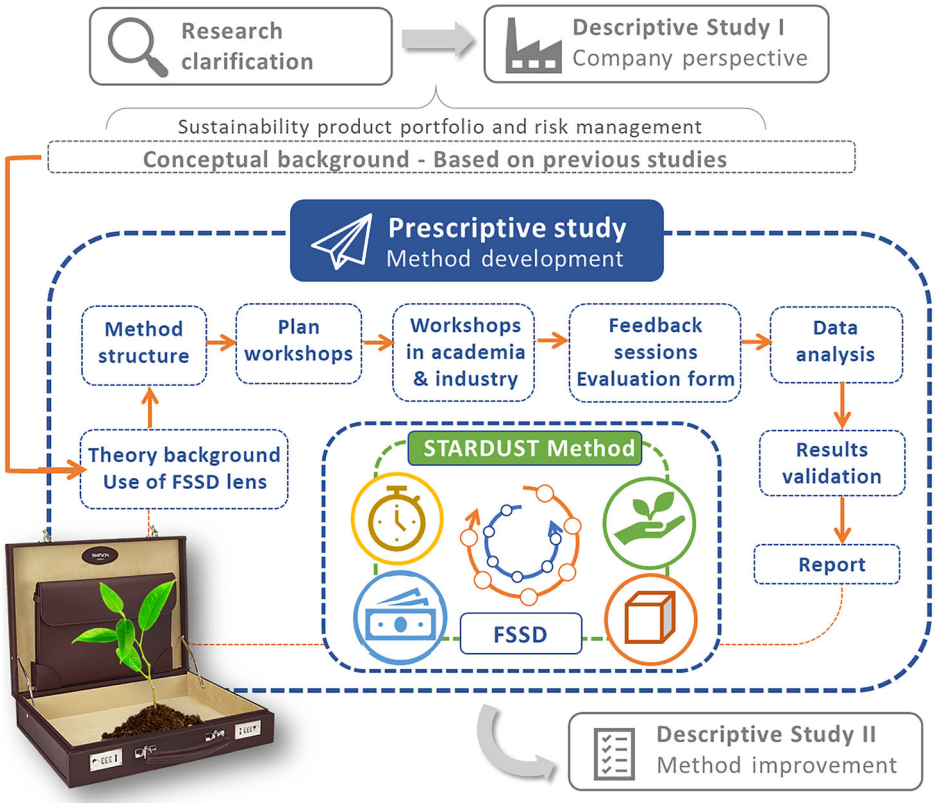

FIGURE 1 Research approach of this study. Based on the theoretical background regarding product portfolio through the FSSD lens, the method was structured to plan the workshops and conduct the STARDUST method at the company cases [Colour figure can be viewed at wileyonlinelibrary.com]

solutions that lead towards sustainability, presenting opportunities for companies that provide those solutions. To ensure society's well-being in the long term, markets will inevitably become more and more sustainability driven. Hence, there is a company self-benefit of proactivity for sustainability by understanding the dynamics of this major system change better than competitors (Robèrt & Broman, 2017). However, companies must find a smart zone: being too passive in relation to sustainability results in risking falling behind competitors, seeing the demand for company offerings drop, and other beforementioned threats (Schulte et al., 2020). Meanwhile, being too proactive can result in not getting sufficiently high or timely return on investment, for example, by developing solutions that are very sustainable, but currently far too costly because technologies and markets are not mature enough yet (Robèrt & Broman, 2017).

Looking through the lens of the FSSD, the product portfolio process plays a central role for placing the company in the smart zone, because its main purpose is to plan what offerings the company should have now and in the future (Robèrt & Broman, 2017). It thereby also largely determines how much resources that should be spend on research and development of future solutions compared to existing ones. Current approaches for integrating sustainability in the product portfolio process commonly apply a TBL perspective (BASF, 2020), where the product portfolio is assessed in relation to environmental, social, and economic performance with the purpose of making it more sustainable (Villamil & Hallstedt, 2018). However, these approaches lack a strategic perspective and do not capture the dynamics of the system change (Villamil & Hallstedt, 2021). Instead, based on a strategic sustainability lens and previous studies, where the industry perspective was analyzed (Schulte et al., 2020; Villamil & Hallstedt, 2021), the following three key areas are proposed to be used in the product portfolio process: (i) sustainability; (ii) market success; and (iii) time. Firstly, it is necessary to assess the sustainability performance of the offerings in the portfolio. This provides an understanding of how the offering might be affected by market changes within the sustainability transition (Gaziulusoy et al., 2013). Besides the actual (positive or negative) social and environmental impact of the solution, it should also be considered whether it can work as a flexible platform to be further developed to reach full sustainability in the future (Robèrt & Broman, 2017). Secondly, market success of the solution must be assessed because a company cannot survive in the longer term if its products or services are not profitable. Thirdly, time plays a key role, because a transition is a process, which means that it takes time, which in turn entails change and uncertainty (Schulte et al., 2020). For example, customers' needs and expectations as well as market conditions like legislation or raw material prices and availability are changing. These changes represent the risks both in terms of threats and opportunities (Schulte & Hallstedt, 2018; Schulte et al., 2020).

Based on this reasoning, it is proposed that these three key areas capture the dynamics of the sustainability transition in the product portfolio process (Schulte et al., 2020; Villamil & Hallstedt, 2021). Additional evaluation criteria, for example, quality, cost, customer requirements, legislation, climate change impact, and so forth, might be used to investigate details within these three key areas (Villamil &

Hallstedt, 2018, 2021). When assessing the product portfolio along these three areas, it is key to apply a strategic perspective by backcasting from a vision, framed by the SPs (Broman & Robèrt, 2017). By doing so, the direction of change can be foreseen, and the portfolio can be formed to place the company in a strong market position. As the direction of change in relation to, for example, legislation or customer preferences can be anticipated, the portfolio can be guided towards the smart zone between being too passive and too proactive (Schulte et al., 2020). It is important to highlight that this implies that the purpose of the sustainability product portfolio process is not to make all parts of the portfolio more sustainable. Instead, the portfolio as a whole shall make sure that the company is in the smart zone. A company may consciously choose to have offerings in the portfolio that have a low sustainability performance if they generate high profit in the short term. In the same way, offerings with high sustainability performance and low economic performance may be included to make sure that solutions are developed that can be expected to see an increase in demand and a stronger competitiveness in the longer term. In this context, strategic sustainability risk management plays a key role, because it is the threats and opportunities that come with the transition towards sustainability, that affect the market success of a solution dependent on its sustainability performance over time (Schulte et al., 2020).

A simplified example from the automotive industry is that companies that only had internal combustion engine (ICE) vehicles in their portfolio started developing and selling electric vehicles (EVs). Even though EVs were not profitable, they had a better sustainability performance. Over time, it can be expected that the revenue from ICE vehicles decreases, while the revenue from EVs increases, given market changes such as stricter legislation and shifting customer demands. The challenge for companies is to find the optimal pace of shifting focus and investment from ICE vehicles to EVs to avoid threats and exploit opportunities on changing markets.

Based on this understanding of the product portfolio process from a strategic sustainability perspective, a method was developed and tested for how a company can strategically assess parts of the portfolio with the three key areas in order to find the smart zone and ensure short-term profitability and long-term competitiveness (see Figure 2).

4.2 | STARDUST method

The strategic layered double-flow scenario modeling for sustainability risk and portfolio management (STARDUST) method was developed to guide companies in integrating a strategic sustainability perspective into the product portfolio process. It was designed to provide practical support for how a portfolio can be assessed considering sustainability, market success, and changes over time. Building on previous studies related to the implementation of sustainability in product portfolio and risk management, it was found that essential aspects need to be considered (see Table 3).

More specifically, the purpose of the STARDUST method is to support companies in (i) helping to determine sustainability hotspots across all life cycle stages and their connection with current and future events; (ii) connecting potential future events with implications on products' market success based on their sustainability performance; (iii) including short-, medium-, and long-term time perspectives, where strategies can be identified for how to adapt the portfolio and change products in response to the scenarios to exploit opportunities and avoid threats; (iv) helping to determine the portfolio selection criteria, which are useful to assess the sustainability performance and market success of the product portfolio; and (v) creating strategies to balance the portfolio in the medium and long term from a sustainability and market success perspective.

To address this purpose, the STARDUST method is composed of four steps that are linked to each other: (1) strategic, layered, double-flow scenario modeling allows to identify the events that pose risks in the short, medium, and long term that might affect the portfolio, (2) sustainability assessment enables the evaluation of the sustainability performance of the portfolio components over time, (3) market success guides the assessment of the market success over time, and

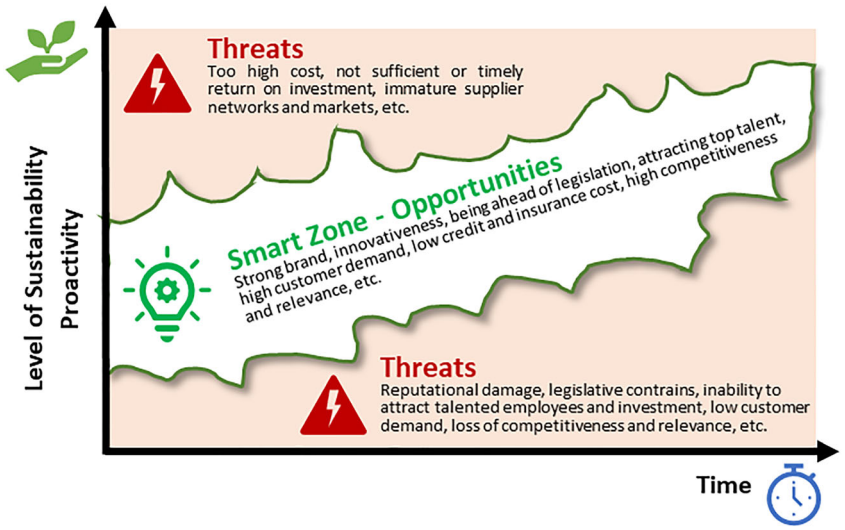

FIGURE 2 The smart zone between being too passive and too proactive in relation to sustainability (inspired by Johansson, 2012) [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 3 Aspects identified in previous studies performed by the authors

Aspects identified in previous studies	STARDUST design	Reference
Include a long-term time perspective.	The method explicitly includes three different time perspectives, including a long-term view.	Schulte et al., 2020
Be applicable in the earliest phases of the product innovation process, that is, product planning.	The method was particularly designed to be used in the product and technology planning.	Schulte & Hallstedt, 2018; Schulte et al., 2020; Villamil & Hallstedt, 2018, 2021; Villamil et al., 2018
Determine and prioritize clear portfolio selection criteria, including sustainability as part of the criteria.	Portfolio selection criteria identified by the interviewed companies were used to guide the market success assessment.	Villamil & Hallstedt, 2018, 2021
Balance the portfolio content over time, considering changes in the market, legislation, technology, and so forth that affect the performance of the product in the present and in the future.	The portfolio balance cube combines the market success, sustainability, and time dimensions and visualizes changes over time.	Schulte et al., 2020; Villamil & Hallstedt, 2021
Include a system perspective in the product portfolio selection process.	The complete product life cycle and its performance in the social, economic, and environmental sustainability is assessed.	Schulte et al., 2020; Villamil & Hallstedt, 2018, 2021
Include a holistic socio-ecological and strategic sustainability perspective and make sustainability risks tangible for company practitioners.	Utilizing backcasting from basic principles for social and ecological sustainability. Linking potential events to tangible business implications can make sustainability-related risks tangible.	Schulte & Hallstedt, 2018; Schulte et al., 2020
Establish the connection between a product's contribution or counteraction to strategic sustainable development of society and its potential implications for the company from a business perspective.	The sustainability performance of products is assessed. Business implications are investigated by linking this to scenarios.	Schulte & Hallstedt, 2018; Schulte et al., 2020
Provide guidance for how to mitigate sustainability-related threats and exploit opportunities.	Understanding the connections between the sustainability performance of products in the portfolio and the implications of different scenarios allows the identification and strategic management of related threats and opportunities.	Schulte & Hallstedt, 2018; Schulte et al., 2020; Villamil et al., 2018

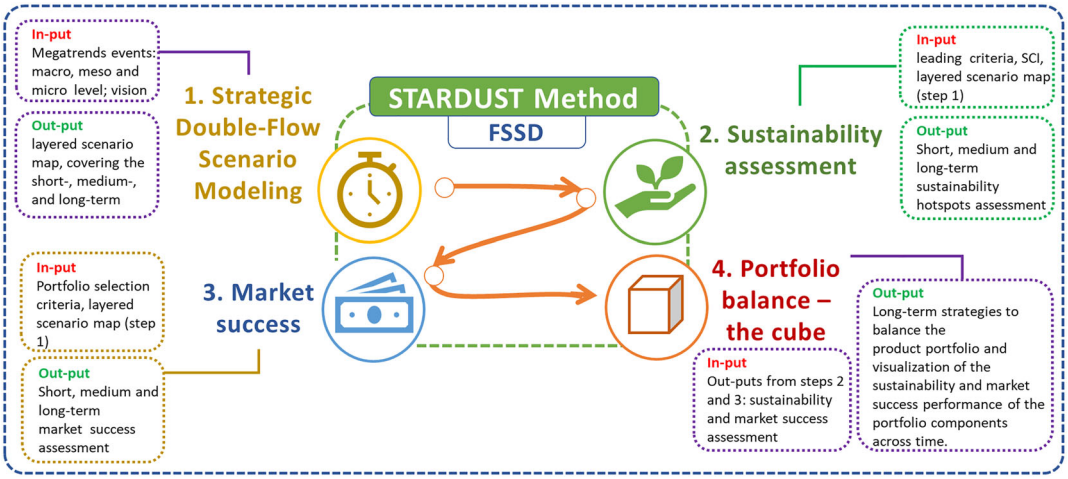

FIGURE 3 The steps of the STARDUST method and related inputs and outputs [Colour figure can be viewed at wileyonlinelibrary.com]

(4) portfolio balance—cube allows to visualize the sustainability and market success performance in the short, medium, and long term for the identification of strategies to balance the product portfolio. Figure 3 presents the STARDUST method steps with its respective inputs and outputs. The outcome of each step is needed to perform the following step; for example, the events related to forecasting and backcasting scenarios are the outcome of step 1, which are needed to assess the sustainability performance in step 2 and determine the market success in step 3. The outcome from steps 2 and 3 are the inputs for step 4, the so-called portfolio balance—cube.

4.2.1 | Step 1—Time: Strategic, layered, double-flow scenario modeling

To capture the time dimensions and to encourage the development of a long-term and strategic perspective, this step focuses on the analysis of the events and risks that might occur in the future by modeling the forecasting and backcasting scenarios. It follows the conceptual approach for strategic risk management within the sustainability transition developed by Schulte et al. (2020), which in turn is based on the FSSD and the double-flow scenario modeling method proposed by Gaziulusoy et al. (2013). The double-flow scenario modeling method allows companies to identify different events that occur over time and might pose risks to the company or particular products. In line with this, the STARDUST method combines backcasting from a vision that is framed by the SPs with forecasting from current trends to identify events that pose risks to the company and its portfolio (Schulte et al., 2020). The analysis in step 1 follows this process: (1) the backcasting modeling provides a strategic perspective and supports in identifying which events that are necessary to happen in order to reach a sustainable society in the long term; (2) the forecasting modeling helps identifying which events that are likely in the short term based on today's situation, for example, ongoing trends in relation to demographic changes, urbanization, technological innovation, power shifts, resource scarcity, and climate change (Retief et al., 2016); and (3) a bridging stage is conducted to connect the backcasting and the forecasting scenarios through events in the mid-term that are plausible given the current starting point and sufficient to reach sustainability in the end (Schulte et al., 2020). Building on transition theory, this method uses a layered approach to connect the events that will occur on the (i) macro-level: society in general; (ii) meso-level: the company within its industry; and (iii) micro-level: the product portfolio components and their life cycles (Rovanto & Bask, 2021). Thereby, implications of macro-level societal change towards sustainability on the product portfolio on the micro-level can be explored. For example, new sustainability-related legislation that is created on a macro-level can directly affect the meso-level and the micro-level, where the industry sector as well as individual companies need to adapt their manufacturing processes, product design, logistics, or management to ensure compliance in a competitive way. In the workshops, a template with the following stages was used to facilitate this step: (1) backcasting, (2) forecasting, and (3) bridging (see Figure 4).

4.2.2 | Step 2—Sustainability assessment

The purpose of the second step is to assess the sustainability dimension in the product portfolio in light of the scenarios created in step 1. To that end, the SLCA 2.0 (Ny et al., 2006; Villamil et al., 2018) and the SCI scale (Hallstedt, 2017) are used to analyze each stage of the product life cycle by using guiding questions based on the SPs. The

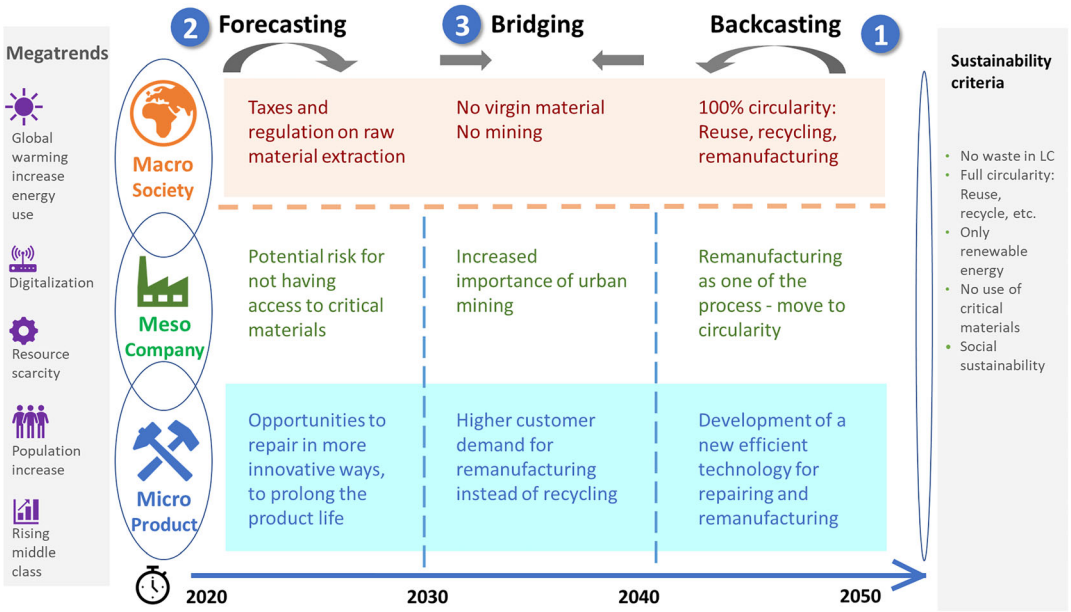

FIGURE 4 The strategic double-flow scenario modeling template. The user follows the process (1) backcasting, (2) forecasting, and (3) bridging [Colour figure can be viewed at wileyonlinelibrary.com]

sustainability performance is ranked from SCI 0 to SCI 9 for the three-time perspectives (short, medium, and long term) based on the events identified in step 1. For example, in the raw material extraction stage, it is possible to consider the backcasting event that requires total circularity by 2050, implying to use only recycled material.

The averages of each stage are aggregated into a single sustainability performance value for the short, medium, and long term. In the workshops, a template was used for step 2 with the following process: (1) link the SP guiding questions with the outcomes from step 1, (2) 2020 assessment, (3) 2035 assessment, (4) 2050 assessment, (5) repeat the process for all life cycle stages, and (6) calculate total values (see Figure 5).

4.2.3 | Step 3—Market success assessment

In this step, the market success of the product portfolio is assessed over time. Firstly, the product portfolio evaluation criteria identified by Villamil and Hallstedt (2021) are prioritized by the workshop participants based on the industry and market context. It is also possible to add more criteria to the assessment. The criteria prioritization might vary according to the industry field, market niche, portfolio requirements, and future trends, among other aspects related to market success (Villamil & Hallstedt, 2021). Secondly, the product portfolio selection criteria are measured by the Market Success (MS) scale for the short, medium, and long term, where specific guiding questions were used to assess each criterion. The ranking of the MS scale determines the market success performance in a similar way as the SCI scale does for sustainability (Hallstedt, 2017). The outcome from the previous steps is used to support critical thinking and inform how the market success could change over time, considering the product's sustainability impact and the identified scenarios and the risks they entail. A product with high profitability in the present might face drops in demand, legislative constrains, or reputational issues in the future, because of a low sustainability performance, resulting in decreasing market success. In the same way, a product with high sustainability performance but low profitability can become competitive and reach market success in the future by exploiting opportunities when, for example, customer preferences are changing. The portfolio evaluation criteria are linked to future scenarios; for example, the profit criterion is related to the backcasting event (identified in step 1) which requires 100% circularity by 2050, demanding investment in new technologies to repair, remanufacture and use recycled material in a sustainable way. In the workshops, a template was used for step 2 with the following process: (1) prioritization of the portfolio evaluation criteria, (2) linking of the guiding questions with the outcomes of steps 1 and 2, (3) 2020 assessment, (4) 2035 assessment, (5) 2050 assessment, (6) repeat the process for the other criteria, and (7) calculate total values (see Figure 6).

4.2.4 | Step 4—Portfolio balance—cube

In this step, the sustainability and market success assessments are summarized graphically, by using the outcome from the previous steps, to understand the performance of the portfolio in the short, medium, and long term. Therefore, the data are visualized in a cube with three axes: (i) sustainability; (ii) market success; and (iii) time (see Figure 7). The purpose of the cube is to help identifying actions to balance the product portfolio from a strategic sustainability perspective. It makes it possible to compare, improve, and select alternatives to ensure short-term profitability and long-term

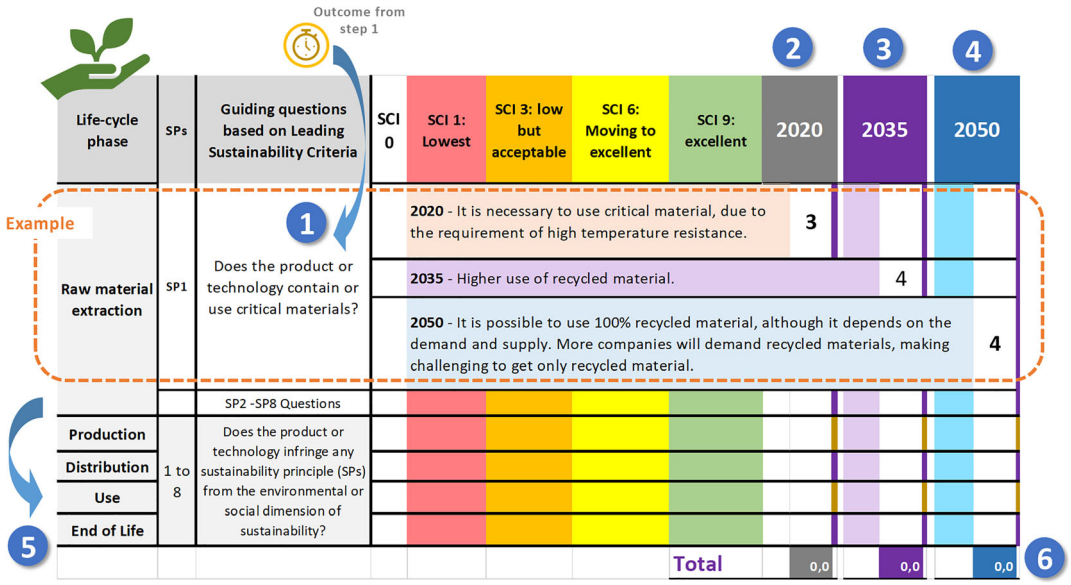

FIGURE 5 Template used for the sustainability assessment. The raw material stage and the SP1 guiding question was used as example. The user follows the process (1) link the SP guiding questions with the outcomes from step 1, (2) 2020 assessment, (3) 2035 assessment, (4) 2050 assessment, (5) repeat the process for all life cycle stages, and (6) calculate total values [Colour figure can be viewed at wileyonlinelibrary.com]

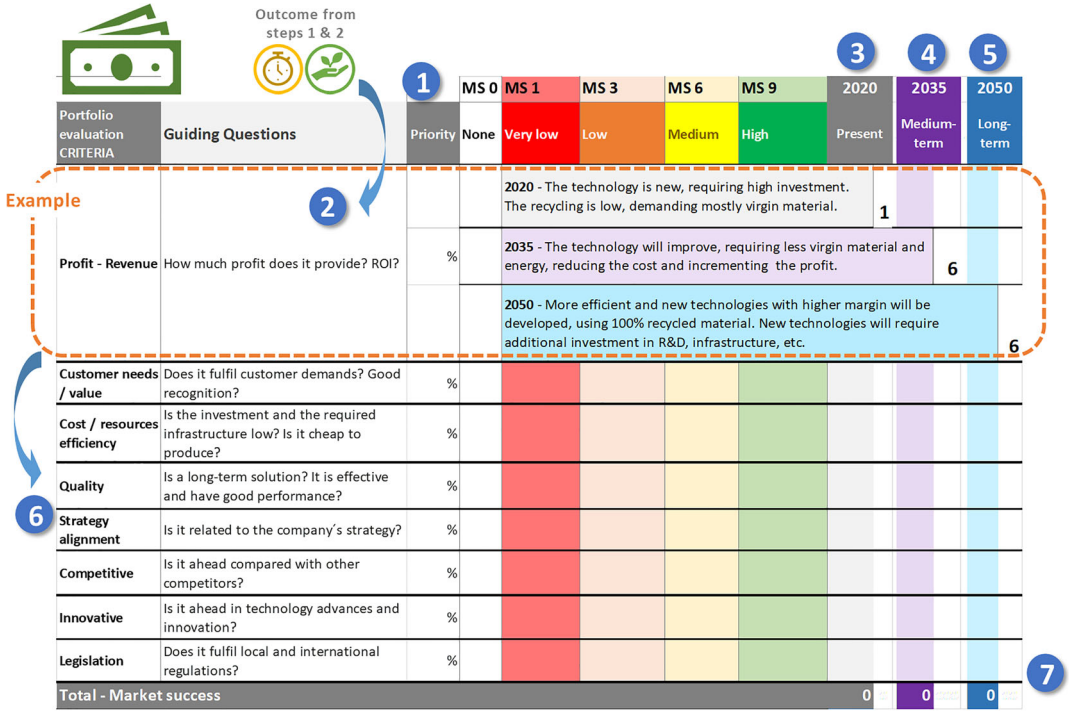

FIGURE 6 Template used for the market success assessment. The profit criterion was used as example. The user follows the process (1) prioritization of the portfolio evaluation criteria, (2) linking of the guiding questions with the outcomes of steps 1 and 2, (3) 2020 assessment, (4) 2035 assessment, (5) 2050 assessment, (6) repeat the process for the other criteria, and (7) calculate total values [Colour figure can be viewed at wileyonlinelibrary.com]

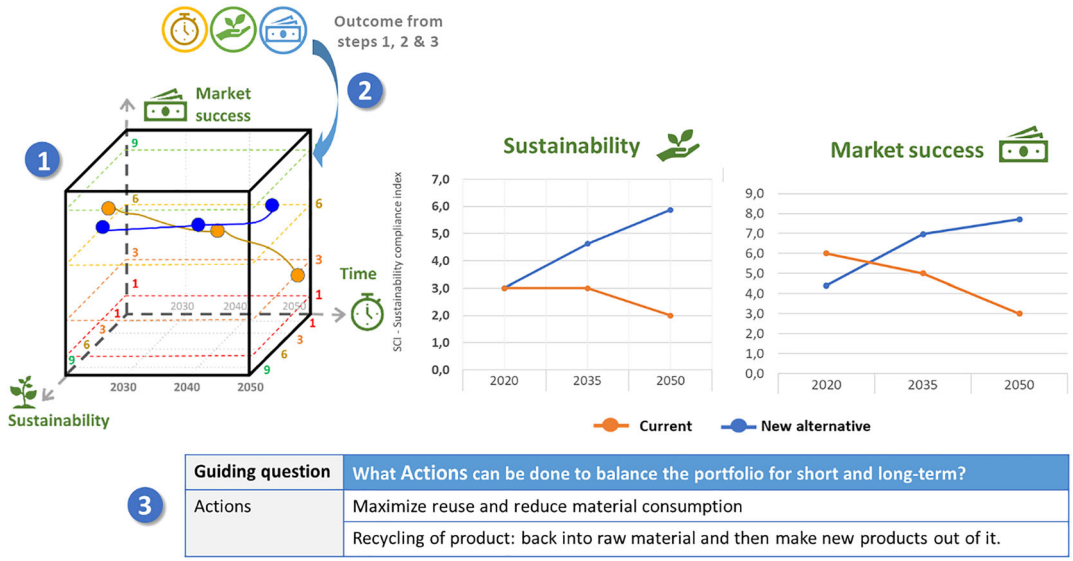

FIGURE 7 The cube—portfolio balance: Visualization of the sustainability and market success over time. The three-dimensional (left) and bi-dimensional (right) graphics. The user follows the process (1) visualization of final values, (2) reflection on the values and findings from steps 1 to 3, and (3) identification of actions to balance the product portfolio over time [Colour figure can be viewed at wileyonlinelibrary.com]

competitiveness (Nwoba et al., 2021; Peiró-Signes & Segarra-Oña, 2018), that is, to determine the smart zone, where the portfolio as a whole is neither too passive nor too proactive. Besides selecting which offerings might be included in the portfolio, the cube can also support exploring how particular parts could be improved, for example, how a currently profitable product can be made more sustainable to ensure its profitability for a longer time or how a product with high sustainability performance can be more profitable to scale it up on the market earlier. Finally, this step encourages a critical thinking about the actions and future planning that the company

needs to improve their sustainability product portfolio over time. The company might find that some of its offerings have no long-term future in the light of the identified scenarios. This is why it is crucial to think strategically about products and services' potential to work as flexible platforms that can be improved and used as stepping stones within the sustainability transition. In the workshops, a template was used with the following process: (1) visualization of final values, (2) reflection on the values and findings from steps 1 to 3, and (3) identification of actions to balance the product portfolio over time (see Figure 7).

4.3 | Evaluation of the STARDUST method

Workshops with one academic group and two manufacturing companies were conducted to get feedback on the STARDUST method performance and to guide its further development. This section presents the evaluation obtained from the feedback sessions and the questionnaire. Each of the four steps of the STARDUST method was evaluated to identify their strengths and weaknesses. In the step 1—strategic double-flow scenario modeling, the workshop participants explored the events that might affect the product portfolio over time. In the feedback session, it was mentioned "it helped to put us in the right mindset for the following steps and reminded us of what can affect us" (workshop participant from company A), "I really liked the bridging between the forecasting and backcasting" (workshop participant from company B). It was noticed that a previous definition of the scope is necessary to delineate the analysis. For both companies, the analysis of the long term was challenging, where the time perspective from 2020 to 2050 was longer compared to their current plan, "it is easier to assess the short-term … it is uncertain to know what will happen in 20 or 30 years" (workshop participant from company A). Company B noticed that the used template can be overwhelming due to the amount of information and it requires time to be comprehended completely.

In the step 2—sustainability assessment, workshop participants identified sustainability hotspots in the product life cycle stages over time. Both companies determined that the analyzed solution has a low sustainability performance today, but it will increase in the future, "I hope we are getting access to better technology to be more sustainable in the future" (workshop participant from company A), "we are expecting to be fully circular by 2050" (workshop participant from company B). In the analysis, participants linked their reflection with discussions from step 1, "If the industry is growing there is an increase of raw materials demand" (workshop participant from company A). Moreover, they noticed their lack of sustainability knowledge related to some product life cycle stages, for example, unsustainability practices of raw material suppliers. In some occasions, facilitators supported with extra questions to clarify the process and help to use the SCI scale.

In the step 3—market success, workshop participants assessed the market success of the alternatives over time by using portfolio evaluation criteria such as cost, revenue, and quality, among others, by triggering the reflection about the portfolio performance in the future, the interdependencies between evaluation criteria, and the link between previous discussions from steps 1 and 2, "as customers will expect more sustainable solutions, we need to invest in better technology, to fulfill the demand and increase the profit over time" (workshop participant from company B). Participants identified that the portfolio evaluation criteria prioritization needs to be reflected on individually first and then collectively to determine the interconnection between criteria and the correct weighting to fulfill the product portfolio expectations. Moreover, company B highlighted that participants have different perspectives in mind, and it is necessary to "provide clearer instructions, so everyone interprets and assesses the task in the same way" (workshop participants from company B).

In the step 4—the cube, workshop participants visualized the market success and sustainability performance over time, to propose actions to balance the product portfolio, they reflected that it is unfeasible to solve the long-term demands with current solutions. It was mentioned that "It is a good idea to visualize the data in the cube" (workshop participant from company B). Although, workshop participants noticed that it was difficult to understand the 3D visualization and preferred to use 2D graphics. In addition, it was mentioned that the cube "lacks the measurement of current actions. We would like to see the relation with actual data, e.g., what will the cost be" (workshop participant from company B).

4.3.1 | Benefits of the STARDUST method

Existing tools and frameworks to implement sustainability in the product portfolio, mentioned in Section 2.2, are missing the strategic sustainability perspective (Villamil & Hallstedt, 2021). In contrast, the STARDUST method was planned to support and guide companies to implement strategic sustainability in their product portfolio. With the workshops, it was identified that the method motivates critical thinking, provides a better understanding of scenarios that might affect the sustainability product portfolio over time, and supports the prioritization of the product portfolio selection criteria and the identification of short-, medium-, and long-term actions to balance the portfolio in a strategic way. It was mentioned in the questionnaire, "we lack the strategic perspective, and we need a method to evaluate the whole portfolio … we need a more visionary view of our strategy and technology planning" (workshop participant from company A), "it is positive to talk and reflect about sustainability" (workshop participant from company B). Workshop participants mentioned in the feedback session that "tools like this are good to drive change, visualize things and make it easier to take the right decision and drive change" (workshop participant from company A), "It was good to work with the next generation demands in parallel with the existent product portfolio" (workshop participant from company B). Participants noticed that the method might guide the early phases of product development, mainly the product planning phase. Furthermore, the method encouraged the active participation of stakeholders in the product portfolio process,

as suggested by Jugend and Figueiredo (2017). Company A highlighted the importance of making this process as a group discussion, similar to Jonas et al. (2013).

4.3.2 | Limitations and suggestions to improve the STARDUST method

Several limitations of the STARDUST method were identified, such as (1) high involvement of the facilitators, a limitation previously identified by Villamil et al. (2018); (2) lack of connection between the different steps of the method; (3) bias in the portfolio assessment, where participants have different knowledge, experience, and expectations that might affect the results; (4) high amount of data necessary for the analysis; (5) complexity of the used templates; and (6) minor influence of the method in decision-making. The STARDUST method fostered a dynamic discussion about the sustainability and market success performance over time. In line with this, BASF (2020) claimed that a deeper conversation with several departments is necessary to set the sustainability product portfolio; in the questionnaire, it was suggested that the STARDUST method "needs input from several people, which can be hard, but it creates good and valuable discussions" (workshop participant from company A). Moreover, Silvius and Schipper (2014) and Martens and Carvalho (2016) highlighted the need of a trained team for the sustainability implementation in the portfolio. Similarly, it was noticed that the STARDUST method requires to "have the right discipline in place, some of the questions are more related to sourcing, managing, or product portfolio … important to clarify who should be part of the different topics" (workshop participant from company A). It was suggested to include a prior discussion, to determine the aim and the scope of the assessment. The STARDUST method requires to be performed several times to assess, compare, and identify actions to balance the product portfolio components, it was mentioned "it is difficult to go through the complete tool" (workshop participant from company A). Moreover, it requires further testing with several industry cases to improve its effectiveness in different fields.

4.3.3 | Further implementation of the STARDUST method in industry

Workshop participants identified the potential to implement the STARDUST method in their company. Although the method is still in the testing stage, it provides the strategic sustainability perspective needed for the product portfolio process. Both companies agreed to test an improved version of the method with different industry cases. Moreover, it was noticed that it would be beneficial to implement this method in their regular processes: "take this kind of tool and make it every day's work, otherwise tomorrow we will continue in the same way doing things" (workshop participant from company A). Furthermore, it was highlighted to include the right roles and disciplines in the process for developing of an accurate assessment, requiring an additional training on sustainability transition (Gaziulusoy & Ryan, 2017). With a single method, it is not possible to make a radical change. Instead, the STARDUST method is a stepping stone to support companies to implement sustainability in their product portfolio.

5 | CONCLUSIONS

This study presents the rationality as well as a novel method for implementing a strategic sustainability perspective in the product portfolio process. To answer RQ1, this study used a strategic sustainable development lens to investigate the implications of society's transition towards sustainability for the company product portfolio process. By bringing together the FSSD with existing research in the field of risk and product portfolio management, it was found that the main purpose of a strategic sustainability product portfolio process is to develop a selection of products and services that places the company in the smart zone between being too passive and too proactive in relation to sustainability, ensuring short-term profitability and long-term competitiveness. To explore how such a strategic sustainability perspective can be included in the product portfolio process in practice, providing an answer to RQ2, the strategic layered double-flow scenario modeling for sustainability risk and portfolio management (STARDUST) method was developed and tested.

Based on the research presented in this study, the following recommendations for decision-makers in a business strategy context can be made: (i) bring in sustainability in the early phases of the product innovation process. This is necessary because this is where most of a products trajectory and sustainability impact are determined. (ii) Ensure a long-term strategic perspective in the product portfolio process by applying backcasting from a vision of success that is framed by basic principles for sustainability. This is necessary in order to identify which solutions that present smart stepping stones rather than potentially costly dead-ends within the sustainability transition. (iii) Use a risk management approach to understand and manage the dynamic interplay between sustainability aspects and business implications. This is necessary to go beyond TBL thinking and to view ecological and social performance as a necessity and driving force for economic performance. (iv) Recognize that uncertainty is neither good nor bad. This is necessary to not only view society's transition towards sustainability as a threat, but also as a major opportunity. (v) Aim for the smart zone. This is necessary to ensure that the company neither is too passive nor too proactive in relation to sustainability, resulting in low threats and high opportunities. (vi) Adjust portfolio selection criteria accordingly.

The method was tested with only two companies and a limited number of participants. Additional application of the method in different industrial cases is necessary to validate its generalizability and applicability in diverse industry fields and contexts and to explore its effects on decision-making and improving the portfolio from a sustainability perspective. Also, future work will investigate how digitalization and gamification approaches can be used to catalyze and ease application and integration with the aim to make companies excel in their strategic sustainability endeavors.

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APPENDIX A: This section presents the evaluation questionnaire of the STARDUST method (see Table A1).

TABLE A1 Evaluation questionnaire of the strategic layered double-flow sustainability portfolio and risk management (STARDUST) method

1. To what degree do you think the method could … Scale: 1 (*not at all*) to 5 (*to a high degree*)[a]	**1**	**2**	**3**	**4**	**5**
a. … connect macro to micro level and show related threats and opportunities?					
b. … help to balance the portfolio in a strategic way?					
c. … improve solutions in the portfolio?					
d. … support the prioritization of portfolio selection criteria?					
e. … guide the reflection and the planning for future scenarios?					
2. What parts or aspects of the tool do you like? Scale: 1 (*not at all*) 3 (*to some degree*) 5 (*very much*)[a]	1	2	3	4	5
• Scenario modeling—identifying events and risks in the short, medium, and long term					
• SLCA—sustainability assessment					
• Market success assessment—using portfolio evaluation criteria					
• Cube—balancing the portfolio and finding strategies to improve solutions					
3. To what degree do you perceive the following aspects to be barriers for use and implementation of this method? Scale: 1 (*low barrier*) to 5 (*high barrier*)[a]	1	2	3	4	5
• Time intensiveness					
• It requires data we do not have					
• It requires expert knowledge we do not have					
• Too little influence of the method's outcomes on decision-making					
• Not possible to integrate the method into existing decision-making processes					
4. Do you perceive any other barriers? Which?					
5. To what degree would you be interested to implement this method in your organization? Scale: 1 (*not interested at all*) to 5 (*highly interested*)[a]	1	2	3	4	5
• Interest in implementation of the method in your organization					
6. Why are you (not) interested in implementing the method?					
7. In your organization, which roles do you think should be involved in the use of this method (please state specific roles)?[a]					
8. Optional—What kind of knowledge do you think is necessary but missing to do the assessment proposed in the method?					
9. Is there anything else you would like to add or comment?					

[a]Mandatory.