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REVIEW ARTICLE

Defining the "Positive Impact" of socio-technical systems for absolute sustainability: a literature review based on the identification of system design principles and management functions

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Abstract

Socio-technical systems represent complex interactions of humans with ecological, social and economic systems. A system's design and its operations determine whether its impact is "negative", "neutral/zero" or "positive" over the system life cycle with regard to its contribution to sustainable development. But coping with exceeded planetary boundaries and social challenges requires more than "net-zero" approaches to achieve biosphere resilience and healthy societies. While negative and zero impacts are widely studied, the term "**positive impact**" has just recently gained importance to describe the outcome of design, planning, operational, organizational or engineering processes. Various case studies, reviews and conceptual proposals exist—mostly applied in a specific context—but a clear definition is not yet detectable. Based on a review of existing literature, this paper: (i) analyzes current perceptions of negative, zero and positive impacts of socio-technical systems on absolute sustainability, (ii) summarizes the current state of knowledge on positive impact concepts for sustainable development, (iii) identifies relevant socio-technical system design principles for positive impacts on biosphere, society and economy, (iv) derives management functions and organizational prerequisites within socio-technical systems to enable positive impacts, (v) proposes a guiding framework and a definition for "positive impact of socio-technical systems for absolute sustainability", and (vi) discusses briefly potential applications and further research demand. This review intends to synthesize existing knowledge from an industrial and engineering design perspective, and delivers an overview on the subject from a global sustainability level to the operational level. The derived insights provide a basis for method development, system design processes and new business models.

Keywords Positive impact · Absolute sustainability · Socio-technical systems

Introduction

Problem statement

Current conceptualizations of absolute sustainability (Hauschild et al. 2020) refer to the ecological limitations of the planet and the measurable interference of human activities with the planetary boundaries (Steffen et al. 2015). The "Sustainable Development Paradigm for the Anthropocene" (Rockström 2015) describes a reconnection process of human development with the biosphere. According to this novel approach, sustainability implies a hierarchical structure between economies, human societies and the biosphere, which provides life-supporting functions for humankind (Rockström 2015). Furthermore, the trespassing of currently five out of nine planetary boundaries (Persson et al. 2022) requires consideration (Randers et al. 2018).

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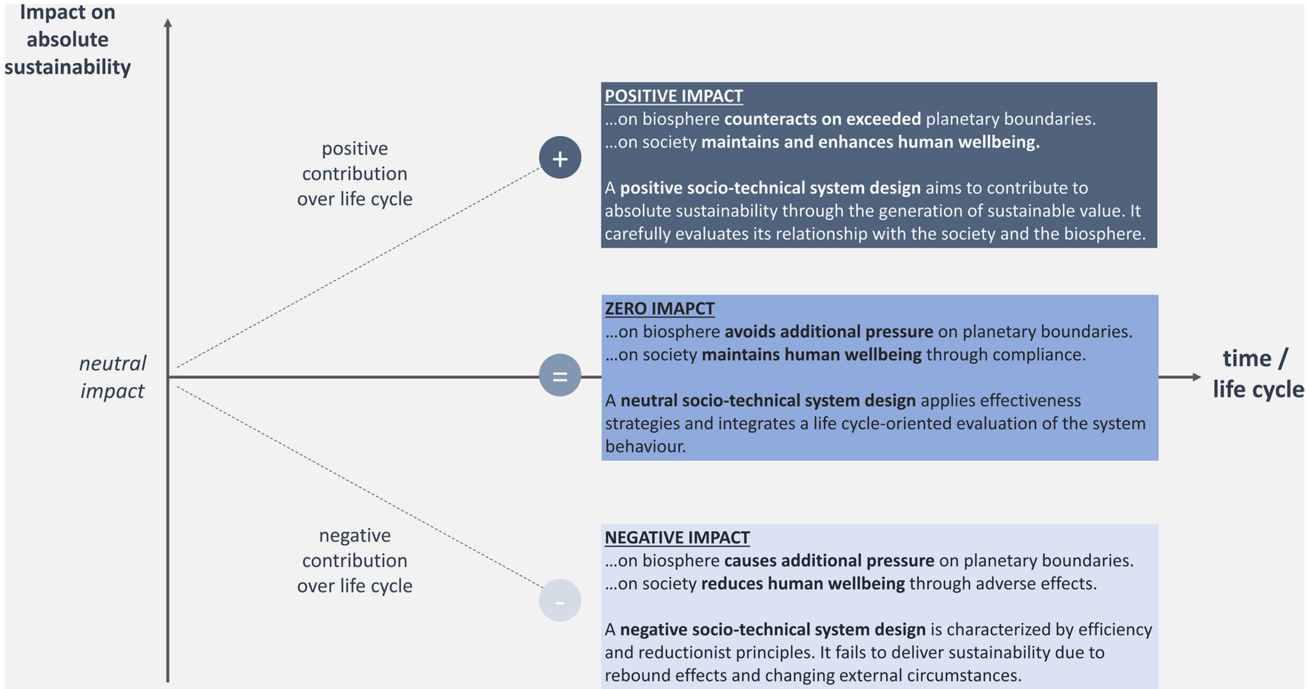

Fig. 1 Negative, zero and positive impacts of socio-technical systems on absolute sustainability

Sustainable development describes a transformative process of human societies to achieve a sustainable and resilient state on this planet. To enter a sustainable development pathway in accordance with the United Nations Sustainable Development Goals (UN SDGs, UN 2015), vast societal changes are required, which are, e.g., outlined by Sachs et al. (2019) as the "Six Transformations".[1] These societal transformations can be understood as transformations of socio-technical systems or as "reconfiguration processes" (Geels 2002) of technologies, which are embedded in societies on systemic (or global), sub-systemic (or regional) and elementary (or local) levels (Geels 2002).

Socio-technical systems describe and represent complex interactions of humans with technologies and influence the development of societies (Geels et al. 2017). These systems can be differentiated based on their purpose (Siddiqi and Collins 2017) or their spatial expansion (Coenen et al. 2012). However, similarities can be identified when assessing the impact on sustainability, as socio-technical systems are connected with natural resource systems and deeply rooted in societies for generating services and providing for the needs of humanity (Savaget et al. 2019). Therefore, transformative processes or new conceptualizations of socio-technical systems demand a life cycle perspective (Kara et al. 2018) to enable "connected lifecycle systems" for a symbiotic behavior in a system-of-systems environment (Kobayashi et al. 2020). The consideration of socio-technical systems in the context of exceeded planetary boundaries (Steffen et al. 2015) requires a distinction of systemic impacts on sustainability (Geels 2018). Figure 1 visualizes three types of impacts on sustainability and their characteristics over a system's life cycle.

Negative impact Negative impacts occur through an inappropriate system design and shortcomings of relative sustainability approaches (Hauschild 2015). Based on reductionist principles (WBCSD 2000), relative sustainability conceptualizations failed to deliver due to rebound effects or changing external circumstances. Negative environmental impacts cause additional pressure on the planetary boundaries and generate a further exceeding of ecological limits through socio-economic processes (Bjørn and Hauschild 2013). Negative social impacts reduce human wellbeing by generating adverse effects on, e.g., health, safety, access to resources, local capacity building, employment or wages (Goedkoop et al. 2018).

Zero impact Neutral environmental impacts represent the effect of appropriate effectiveness strategies such as substitution and/or regeneration (Hauschild et al. 2020). Neutral social impacts maintain human wellbeing through

[1] (1) education, gender and inequality; (2) health, wellbeing and demography; (3) energy, decarbonization and sustainable industry; (4) sustainable food, land, water and oceans; (5) sustainable cities and communities; as well as (6) digital revolution for sustainable development.

compliance with international standards and local laws as well as meeting basic requirements of affected stakeholders (Goedkoop et al. 2018). An effective system design requires the integration of solutions, which avoid generating additional pressure on planetary boundaries (Bjørn et al. 2016) and human wellbeing. This implies a life cycle-oriented evaluation of the system behavior in an ecological and social context.

Positive impact Positive impacts aim at supporting sustainable development in a connected ecological and/or social system to achieve a state of absolute sustainability. Positive ecological impacts aim at enabling ecological resilience (Chapin III et al. 2011) through an active counteracting on exceeded planetary boundaries and—if necessary—a compensation of historical emissions (Stoknes and Rockström 2018). Positive social impacts can be understood as socio-economic activities to maintain and enhance human wellbeing (Dyllick and Rost 2017). Corresponding system design strategies apply an integrative perspective (Ceschin and Gaziulusoy 2016), in which the relationship between the biosphere, society and the socio-technical system is carefully evaluated.

From a system perspective, the conceptualization of "positive impact for absolute sustainability" faces various challenges concerning its definition and assessment of impacts. As Bjørn et al. (2020) conclude, "*it is necessary to explore what actions policy makers, the private sectors and citizens can take to drive the innovations in production and consumption that are needed to reduce impacts sufficiently [for absolute sustainability]*". The authors claim that the earth's carrying capacity has to be taken into consideration for absolute environmental sustainability. This leads to an "emission/impact budget" which has to be allocated to an anthropogenic system or process (Bjørn et al. 2020). In the case of already exceeded planetary boundaries, the emissions budget of an anthropogenic (or socio-technical) system needs to be negative, which implies the need or justification of positive impacts for ecological resilience. This requires a careful definition of the multi-system boundary between anthropogenic and natural systems (Hauschild et al. 2020). For the definition of a positive impact, it is crucial to understand its direction (i.e., what is the "sending" and the "receiving" system?). Furthermore, the quality of a potential positive impact depends upon the specific circumstances within the receiving system (Bull and Brownlie 2017). The occurrence of various and somewhat fragmented approaches regarding socio-technical system characteristics, system design principles and system management functions shows the need to derive a holistic and more general understanding of this subject.

Structure of the paper

The paper is structured in accordance with the *Integrated Framework for Life Cycle Engineering* (Hauschild et al. 2017), which provides a multi-layered understanding of socio-technical systems in an absolute sustainability context. The framework is applied in a top-down manner, so that absolute sustainability defines the overall goal on a global level, and positive impact concepts for sustainable development represent the link to the socio-technical system. On the socio-technical system level, relevant system design principles and management functions are analyzed to bring together the existing knowledge in the field. This leads to the following structure of the paper: A section on the "State of knowledge: positive impact concepts for sustainable development" provides a brief development of sustainability concepts and presents conceptual dimensions of related sustainability approaches. This is necessary to define general characteristics of positive impact concepts, which are used as the literature selection criteria to identify relevant publications for the subsequent literature analysis. The next section "Socio-technical system design principles and management functions for positive impacts" provides a structured overview of current publications on positive impacts and identifies system design principles for positive impacts on biodiversity, society and economy. The literature samples are furthermore evaluated concerning management functions to operate socio-technical systems in a positive manner. A section on "Synthesis" synthesizes the identified aspects in a guiding framework on positive impacts of socio-technical systems for absolute sustainability, and provides a proposal for a general definition, and points out further research in the field. The final section "Outlook: potential implications and research demand" discusses potential applications and further research demands.

State of knowledge: positive impact concepts for sustainable development

Positive impact concepts build on the insight that absolute sustainability requires additional efforts to reduce pressure on exceeded planetary boundaries and to enhance human wellbeing in accordance with the UN SDGs. Therefore, sustainable development should focus on "human prosperity and equity within a safe biosphere" (Randers et al. 2018) to provide a transformational pathway for socio-economic processes. The evolution of the perception of sustainable development in the context of the earth's carrying capacity has emerged in the early 1990s through population growth, changing lifestyles and environmental impacts to the living conditions of future generations (Daily and Ehrlich 1992). The growing concern about unsustainable resource consumption and increasing deterioration of natural ecosystems has led to the question of what level of impact is acceptable to ensure a necessary viability of ecological life support functions (Daily and Ehrlich 1992). Eco-effectiveness approaches aim at integrating "impact thinking" to the conceptualization of socio-technical approaches or socio-ecologic systems (Figge and Hahn 2004) beyond eco-efficiency (WBCSD 2000) and have gained popularity for instance with the presentation of the "Cradle-to-Cradle" concept in 1998 (Braungart et al. 2007). In terms of sustainability, the cross-influences of social and ecologic systems require a "resilience thinking", which demands a re-adjustment of socio-technical systems to ecologic limits (Folke et al. 2010). This should be reflected as the recognition of planetary boundaries in global politics (Dryzek and Stevenson 2011) and business concepts (Whiteman et al. 2013) to ensure a sufficient and equitable life on a global scale (O'Neill et al. 2014). Within the past decade, the concept of "Planetary Boundaries" (Rockström et al. 2009), which defines nine ecological boundaries as crucial for the life support system for humankind, has strongly influenced the debate on sustainable development. Therefore, the protection of earth's life support system is ultimately a concept of "guiding human behavior and protecting human interests" (Biermann 2012). Various studies have detailed the general concept of the earth's carrying capacity with investigations on human health questions (Whitmee et al. 2015), agricultural practices (Reganold and Wachter 2016), nitrogen management (Zhang et al. 2015), decision-making processes (Guerry et al. 2015), global vulnerability due to forest die-back and tree-mortality (Allen et al. 2015) or sustainable business models (Adams et al. 2016). However, social and economic aspects need to be considered to achieve sustainable development (Giovannoni and Fabietti 2013). This can cause challenges in an actual socio-technical system analysis due to trade-offs between global and local sustainability issues and uncertainties due to differences in the indicator definition (Thies et al. 2019). The concept of "Doughnut Economics" (Raworth 2017) aims at integrating the nine planetary boundaries with 12 dimensions of social standards (based on the United Nations Sustainable Development Goals). It describes a blueprint for a "safe and just space for humanity", which can be considered a socio-economic approach for absolute sustainability. This concept claims a regenerative, circular and integrative design of socio-technical systems to mitigate ecological overshoots and social shortfalls. Within the past years, the concept has gained much attention and it can be interpreted as an attempt for a positive impact on a global scale *"to enable humanity to thrive in the safe and just space"* (Raworth 2012).

The term "positive impact" is common to various disciplines without yet being specified and defined. Cole and Kashkooli (2013) provide a definition for *Net Energy Positive Building* of a building that "*generates more energy than it uses over time*". McEvoy (2004) presents a definition for *Positive Impact Forestry* based on "*forest management within the context of a long-term plan of objectives that are [at] once economically expedient but conserving of resources, and socially, environmentally and ecologically responsible*". Rainey et al. (2015) describe *Net Positive Impact* (NPI) on biodiversity as "*where the gain exceeds the loss*". Rahimifard et al. (2018) define *Net Positive Manufacturing* as "*to put back more into society and environment than what they take out*". In many cases, an ongoing debate concerning a clear definition is recognizable. Dyllick and Rost (2017) highlight a constant adjustment of definitions for corporate sustainability in the changing context of contemporary perception of sustainability and sustainable development. Di Cesare et al. (2018) argue that—for positive impacts in social assessments—aspects such as value judgements, ethical beliefs or chosen analytical perspectives interfere with the development of a clear definition. Joustra and Yeh (2014) provide a simplified definition for *Net-Positive Building Water Cycle* and discuss subsequently its limitations in the context of system boundaries and life cycle considerations. The Association of Chartered Certified Accountants' (ACCA) Global Forum for Sustainability notes that "*a generally accepted definition does not exist at present, and the topics and timeframes addressed by the various corporate initiatives tend to vary"* (ACCA 2014). This is as well noted by Di Cesare et al. (2018) who state that "*positive impacts are barely covered in literature. There is a clear need of streamlining [a] definition and indicators, especially if they should be applied in a policy context"*. The occurrence of various approaches and definitions for positive conceptualizations of socio-technical systems (and related business models) shows the need to identify relevant and determining characteristics of positive impacts.

To cluster various concepts, approaches and strategies for sustainability, we build on the distinction by Lankoski (2016) and propose a structure as visualized in Table 1. It consists of three conceptual dimensions (scope, hierarchy and impact), providing an indication about the underlying characteristics of sustainable business models. Scope comprehends the question whether a concept is based on a *narrow* (only ecological) or *broad* (ecological, social and economic) understanding of sustainability. Hierarchy describes whether a concept recognizes the planet's carrying capacity as a foundation for a conceptual structure. Impact describes the type of effect that the concept aims at: *negative* (reduction or improvement), *neutral* (consistency or zero impact) or *positive* (safe and just space for humanity).

In essence, a conceptualization for absolute sustainability expresses the most ambitious combination of the three dimensions. It requires a broad scope for an integration of

Table 1 Conceptual dimensions of sustainability approaches

Conceptual dimensions	Scope		Hierarchy		Impact		
	Narrow	Wide	Unclear	Clear	Negative	Neutral	Positive
Characteristic	Focus only on environment	Focus on environment, society and economy	Equal notion of dimensions	Hierarchy between dimensions	Efficiency-oriented system design and management	Effectiveness-oriented system design and management	Sustainable value-oriented system design and management
Description	Focus on one dimension	Integration of all dimensions	Inter-connection	Carrying capacity orientation	Reduction or improvement	Consistency or zero impact	Contribution to absolute sustainability
Exemplary concepts	Industrial ecology	Sustainable development	Triple Bottom line	Sustainability paradigm for the Anthropocene	Eco- efficiency	Cradle-to-Cradle	Doughnut Economics
Source	Ayres (2002)	Brundtland Commission (1987)	Elkington (2013)	Rockström (2015)	WBCSD (2000)	Braungart et al. (2007)	Raworth (2012)

all sustainability dimensions, a clear hierarchy to reflect the carrying capacity orientation and positive impacts. A positive socio-technical system configuration integrates the generation of sustainable values as a principle of its system design and behavior. It can be understood as the interplay of a distinctive **system design** and effective **system management** as described, e.g., by Aiama et al. (2015) in the context of mining operations and nature conservation.

Socio-technical system design principles and management functions for positive impacts

Motivations to design socio-technical systems for positive impact

The motivation and goals of developing positive impact concepts for socio-technical systems are manifold and often rooted in a critical reflection of a human-nature relationship. Dyllick and Rost (2017) describe the necessity to generate overcompensation for ecological restoration and sustainability. Birkeland (2018) emphasizes that *"development must instead reverse the global rates of degradation and inequity […] by increasing the 'natural' environment"*. Cole and Kashkooli (2013) refer to a partnered relation between human society and natural systems, which builds social and natural capital instead of diminishing it. Alshehhi et al. (2018) discuss a balance between cooperative financial, environmental and social performance in the context of fulfilling expectations of societal and ecological stakeholders. In finance, Wendt (2018) postulates the necessity for humankind to live within the ecological carrying constraints and to re-conceptualize all major systems through an internalization of all externalities. This is supported by Scheel (2016) who claims that solutions "*must be able to recover environmental resilience and, at the same time, create economic returns, as well as shared social benefits for the communities*". The Forum of the Future (2014) proposes that "*Net Positive approaches can ensure results across the value chain and have real positive impacts on communities and the biosphere*". Birkeland and Knight-Lenihan (2016) consider urban infrastructure as an enabler for positive sustainability solutions, as eco-positive design can effectively create restorative synergies between human and natural systems. Rahimifard et al. (2018) urge businesses to implement a "*restoring, self-healing, and regenerative*" approach to generate a "*Net-Positive Manufacturing*" impact. They claim that reductionism is "*too small and too slow to tackle the needs of tomorrow*".

Selected literature

For assessing the relevance of and raising attention to the research subject of "positive impact", an analysis of publications was conducted with the database *Scopus*. Title, abstract and keywords of records published in the time between 1980 until 2018 were searched for the phrase "positive impact". The results show a steady rise in scientific publications relating to the concept of positive impact accelerating from the early 2000s. The growth of records per year from less than 30 in the year 1980 to more than 5000 in 2018 illustrates the attention positive impact received in the recent decades. Subsequently, based on several keyword searches ("positive impact", "net gain", "net-positive") in various scientific databases (Scopus, ScienceDirect, Google Scholar), more than 20,000 publications were identified and supplemented by publications from a further research of internet sources.

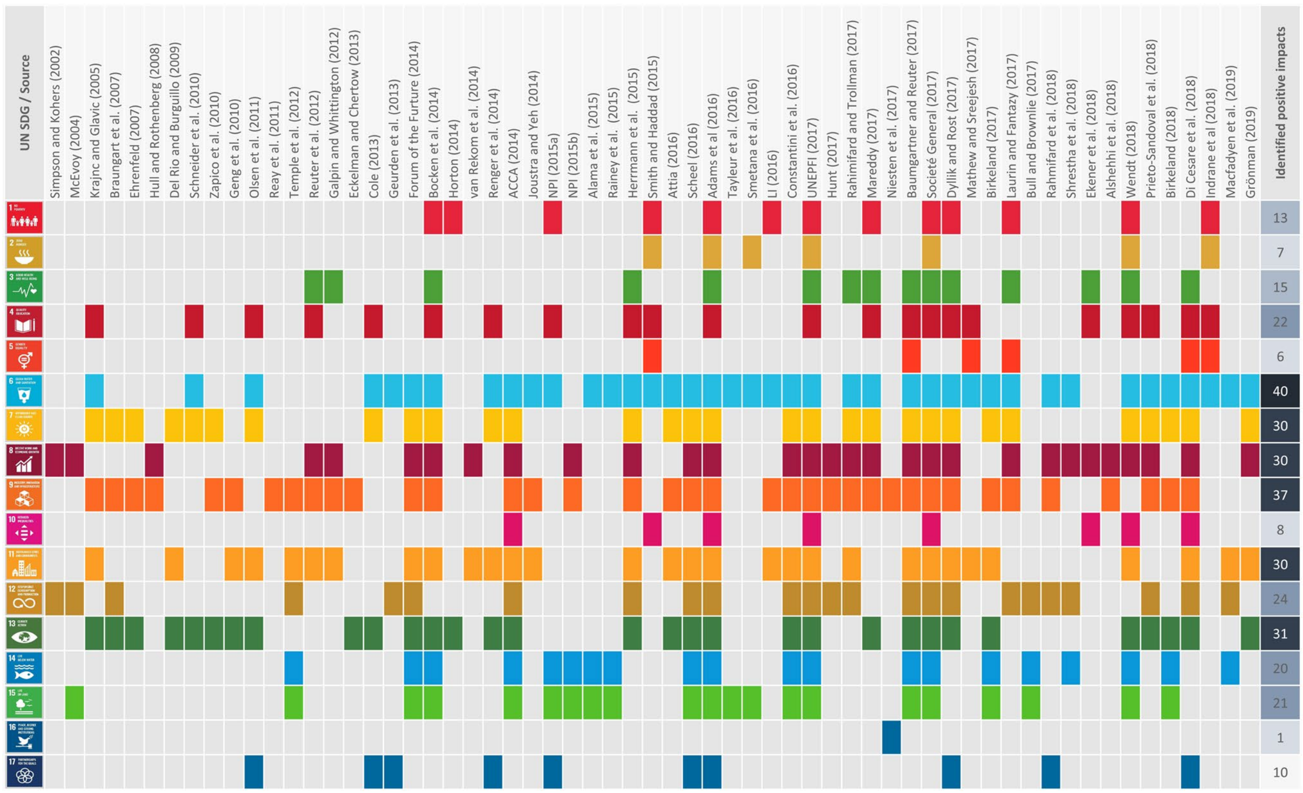

Fig. 2 Literature analysis on positive impact and mapping to the UN SDGs ($n = 62$)

In a multi-step analysis, the literature was skimmed and sorted by an abstract and title analysis. This led to a sample of 524 publications from scientific databases and 129 publications from grey and Internet sources. Hence, the total of 653 publications were critically assessed concerning the description and presentation of a positive impact. In this step, publications that showed either a relative or neutral impact or an impact outside of the scope of the United Nations Sustainable Development Goals were excluded. This full-text analysis was conducted in a critical manner, which explains that roughly about 10% of the previously selected literature was chosen for an in-depth analysis. 62 records were finally selected for the detailed evaluation and a mapping to the UN SDGs, as shown in Fig. 2.

A significant number of publications in the context of absolute sustainability can be related to SDG 6 (clean water and sanitation), SDG 7 (affordable and clean energy), SDG 8 (decent work and economic growth), SDG 9 (industry, innovation and infrastructure), SDG 11 (sustainable cities and communities) and UN SDG 15 (life on land). The remaining SDGs show fewer relationships with the assessed literature. This shows that current descriptions of positive impacts are resource-focused (e.g., water or energy), relate to innovation of industrial systems, target the improvement of human livelihoods, or aim at increasing the quality of ecosystems.

Identification of socio-technical system design principles for positive impact

The following in-depth analysis of the final literature sample was focused on extracting **system design principles** for positive impact and identifying prerequisites for a desired **system management** for positive impacts, ultimately leading to an overview of current descriptions on positive impacts. The identified positive impacts are structured according to the 17 UN SDGs and are explained in more detail in the section "Biosphere-related system design principles for positive impact" (biosphere-related), in the section "Society-related system design principles for positive impact" (society-related) and in the section "Economy-related system design principles for positive impact" (economy-related).

Biosphere-related system design principles for positive impact

Biosphere-related positive impacts show a clear orientation towards water (UN SDG 6), climate change (UN SDG 13) or biodiversity (UN SDG 14 & 15). Table 2 summarizes the identified biosphere-related design principles that were presented in the literature sample.

Table 2 Identified biosphere-related system design principles for positive impact

System design principle	Positive impact (example)	Impact on planetary boundaries	Sources
Biodiversity integration (in industrial processes)	Net-positive impact on ecological value	Net gain in biodiversity	Aiama et al. (2015), Bull and Brownlie (2017)
Circular water resources	Provision of harvested rainwater and recycling water	Reduced and avoided freshwater use	Joustra and Yeh (2014)
Renewable energy generation and supply	Substitution of fossil with regenerative energy	Avoidance of greenhouse gas emissions	Rahimifard et al. (2018)
Circular material use and supply (in industrial resource systems)	Avoidance of new and abiotic resource use through circular material use	Avoidance of greenhouse gas emissions and toxic emissions	Attia (2016), Braungart et al. (2007)

Biodiversity integration focuses on the inclusion of ecological impacts in the overall impact assessment of industrial activities (Aiama et al. 2015) to support ecological development and create a net gain in biodiversity. Positive impacts on biodiversity are presented in various business cases, in which biodiversity-related activities are integrated into project development plans or corporate strategies in the mining, chemical, energy and manufacturing industry (Rainey et al. 2015). The International Union on Conservation and Nature (IUCN) defines a net-positive impact on biodiversity (see Temple et al. 2012; Aiama et al. 2015) must be beyond offsetting, equivalent in the ecological value and permanent to ensure a net gain (Bull and Brownlie 2017), and could be supported by ecosystem valuation (NPI 2015a, b). Biodiversity-related positive impacts often show a connection to local communities (Rainey et al. 2015). Macfadyen et al. (2019) and Shrestha et al. (2018) describe positive ecological impacts of the fishing industry and aquaculture through changes in operational practices and community integration.

Circular water resources describe the use and supply of harvested rainwater and recycling water for an internal purpose and an external system (Joustra and Yeh 2014) with the aim of reducing the overall freshwater use. Positive impacts are generated through various approaches, as for instance water treatment of mining operations with the aim of strengthening biodiversity through environmentally-integrated industrial activities (Olsen 2011), water positive buildings that enable a positive water balance through rainwater harvesting (Joustra and Yeh 2014), or water conservation as a requirement in agriculture sustainability standards (Tayleur et al. 2017). Li (2016) describes a water management concept as part of a social design policy for reasonable water consumption and the prevention of flooding on courtyard level in Beijing. The ACCA (2014) presents a corporate water management strategy with the aim of providing equal sharing of resources between industry and communities. The integration of water use in product life cycles can generate positive impacts on sustainability, if closed loop approaches are realized (Adams et al. 2016), if symbiotic resource flows among industries and municipalities are established (Geng et al. 2010), or if water footprints are integrated in product performance indicators (Grönman et al. 2019).

Renewable energy generation and supply encompasses the generation and supply of solar energy for internal and external demand to avoid the use of fossil fuels in a greater systemic context (Herrmann et al. 2015). Positive impacts for climate change mitigation can be found in the formulation of sustainable business models [see Krajnc and Glavič (2005), Bocken et al. (2014), Forum of the Future (2014), Adams et al. (2016), Costantini et al. (2017), Baumgartner and Rauter (2017)], in which carbon neutrality is defined as a pre-condition for sustainable entrepreneurship. Birkeland (2018) describes architectural and building design approaches, which integrate the exclusive use of renewable energy as a design requirement. Herrmann et al. (2015) present a concept of a positive impact factory that produces more renewable energy than needed with a surplus supply for the local community. The carbon handprinting perspective assesses the positive climate impacts of products and business approaches (Grönman et al. 2019), while the Societe General (2017) focuses on the assessment of positive climate impacts in present sustainable finance schemes.

Circular material use and supply claims a circular and symbiotic resource utilization and provision within the industrial sector (Rahimifard et al. 2018) to avoid demands of "virgin" materials and minimize related greenhouse gas emissions (and toxic materials). Attia (2016) presents a concept of regenerative architecture with circular building materials. The same principle is applied in the Cradle-to-Cradle (C2C) eco-design concept of Braungart et al. (2007), which aims at the extensive utilization of solar energy. Zapico et al. (2010) present an approach to measure "accurate real-time metabolism accounting" through information technology to support industrial ecology.

Society-related system design principles for positive impact

Positive impacts for social sustainability often target the various society-related SDGs (UN SDGs 1–5, 7, 11, 16,

Table 3 Identified society-related system design principles for positive impact

System design principle	Positive impact (example)	Impact on society	Sources
Social integration (of stakeholder needs in business processes)	Income distribution, participation in decision-making	Public value generation	Aiama et al. (2015)
Stakeholder networks	Net-positive effect on a community through integration and social impact evaluation	Addition and provision of value to stakeholders	Forum of the Future (2014)
Provision of access (to socio-economic processes)	Access to economic revenues and jobs, access to education and health, access to physical resources	Income growth of households	Societe General (2017)
Provision of financial resources	Directed monetary resource allocation	Reductions in poverty, community development	Wendt (2018)

17). Table 3 summarizes the identified society-related design principles for socio-technical systems.

Social integration refers to the integration of stakeholder needs in business processes (Aiama et al. 2015). The incorporation of community support through social business approaches is explained by the International Union for Conservation of Nature in the context of biodiversity integration in project planning and development policies (Aiama et al. 2015). Positive impacts for social sustainability are often described as an integrative element of an economic activity of an organization [see Krajnc and Glavič (2005), Bocken et al. (2014), Adams et al. (2016), Dyllick and Rost (2017)]. Laurin and Fantazy (2017) describe the case of IKEA, which aims at integrating stakeholders along the supply chain and at defining a global standard of working and living conditions for employees. Galpin and Lee Whittington (2012) describe the integration of social sustainability aspects and social values as a competitive market advantage for companies and lay out examples of how organizations measure their social performance.

Stakeholder networks describe the formalized organization of a social integration to systematically identify needs of and evaluate impacts on stakeholders (Laurin and Fantazy 2017). Forum of the Future (2014) outlines net-positive principles for businesses which include the integration of affected communities, public engagement, wider partnerships, networks, and supply chains. Baumgartner and Rauter (2017) propose life cycle thinking and the evaluation of first- and second-level impacts for the development of a sustainable organization. Indrane et al. (2018) summarize the existing definitions for positive social impacts, which are characterized through a *"net positive effect of an activity on a community"*, *"add/provide value to stakeholders"* and *"tailored interventions that have resulted in positive outcomes"*. Positive social impacts occur through stakeholder integration in decision-making processes and access to economic revenues. This can be facilitated by, e.g., income distribution in local energy deployment (del Río and Burguillo 2009), public value generation of sustainable products (Dyllick and Rost 2017) or income growth of households through appropriate policies (Smith and Haddad 2015). From a methodological perspective, the evaluation of positive social impacts is crucial and could be measured through different approaches: the application of Social-LCA indicators (Indrane et al. 2018), applying a stakeholder perspective (Ekener 2018) or by evaluating Social Impact Assessment (SIA) indicators for project appraisal (Mareddy 2017).

Access to socio-economic processes encompasses the enabled accessibility to economic, social and physical resources to improve living conditions and the income of households (Societe General 2017). The Société General aims at generating access to water, energy, education, health and job creation (Société General 2017). Bocken et al. (2014) describe employee welfare and living wages, community development through education, health and provision of livelihoods and sustainable agricultural practices with minimal water consumption and chemical utilization as elements of programs for sustainable business models. Mareddy (2017) discusses direct poverty alleviation through better access to employment and business opportunities, increased accessibility to and from a community and funding of social infrastructure. Herrmann et al. (2015) describe the vision of implementing positive health effects for workers ("factory as a fitness studio"), capacity sharing for learning and knowledge provision for residents and customers as well as provision of recreational spaces as positive social impacts of factories. Li (2016) provides an example of how integrative water management can strengthen cultural identity and reinforce communities (and their wellbeing) in the case of Beijing. Mathew and Sreejesh (2017) provide evidence that responsible tourism in India can generate community sustainability and wellbeing through increasing incomes (and linked poverty reduction), improved access to information and market opportunities.

Provision of financial resources represents the directed supply of financial resources (Wendt 2018) to reduce poverty

Table 4 Identified economy-related system design principles for positive impact

System design principle	Positive impact (example)	Impact on economy	Sources
Sustainable value generation	Sustainable value proposition	Long-term economic revenues and performance	McEvoy (2004), Bocken et al. (2014)
Sustainable business models	Contribution to ecological development, social services and economic value	New types of products, services and operational practices	Bocken et al. (2014)
Synergetic networks	Symbiotic mutualism of organizations	Waste valuing, material cascading, sharing of infrastructure, joint venture creation or circular value ecosystems	Hunt (2017)
Innovation for absolute sustainability	Contribution to sustainable value	New (and sustainable) product and service systems	Adams et al. (2016), Dyllick and Rost (2017)

or stimulate development. Wendt (2018) describes investment approaches (microfinance, lending and crowdfunding) for a directed monetary resource allocation to support poor and developing populations. The United Nations Environment Programme Finance Initiative (UNEPFI) has published principles to finance the 17 SDGs. The overall aim of the initiative is to provide a framework that ensures transparency and measurability of a sustainability impact (UNEPFI 2017). The framework is applied by financial institutions, such as Société General, within their UN SDG-related project assessments (Societe General 2017).

Economy-related system design principles for positive impact

Positive impacts on economy-related UN SDGs (UN SDG 8–10, 12) often originate from business approaches or concepts that are linked with environmental and social aspects. Table 4 summarizes the identified economy-related design principles for socio-technical systems.

Sustainable value generation refers to the generation of long-term value through linking economic activities to absolute social and environmental goals (Bocken et al. 2014). McEvoy (2004) describes long-term economic revenues besides environmental gains and community wellbeing through responsible forestry or stewardship. Hunt (2017) proclaims an enhancement of a firm's financial performance through improved corporate social performance. This is supported by Simpson and Kohers (2002), who provide a positive example from the banking sector. Van Rekom et al. (2014) depict that the communication of social activities leads to customer loyalty and stakeholder satisfaction. Costantini et al. (2017) show that eco-innovations and sustainable supply chains both contribute to sectoral ecological sustainability and economic performance.

Sustainable business models describe the organizational mission that connect sustainable value generation with innovative product design for absolute sustainability. Bocken et al. (2014) identify and discuss various types of sustainable business archetypes for sustainable value proposition. A sustainability-oriented organization can generate new types of products, operational practices and activities, and contribute to social and ecological services or value (Adams et al. 2016). Rahimifard and Trollman (2017) describe this business attitude as *"to put back more into society and the environment than what they take out"*.

Synergetic networks describe economic structures that generate a mutual benefit for all partners (Hunt 2017). Synergetic networks for the exchange of resources are considered to generate positive economic impacts in many cases [see Geng et al. (2010), Eckelman and Chertow (2013), Forum of the Future (2014), Adams et al. (2016), Wendt (2018)]. Hunt (2017) describes economic opportunities through symbiotic mutualism of organizations. Symbiotic structures and circular economy implementation can generate new forms of material utilizations through waste valuing, material cascading, sharing of infrastructure, joint venture creation (Prieto-Sandoval et al. 2018) or circular value ecosystems (Scheel 2016).

Innovation for absolute sustainability encompasses the inventive development of new products and service systems that aim at generating sustainable value (Adams et al. 2016). Adams et al. (2016), who propose new forms of innovation and define this approach as "Systems Builder", in which a business organization fosters the creation of sustainable systems, provide solutions for a greater societal purpose (e.g., shared value) and mobilize partners for a transformative change. Dyllick and Rost (2017), who refer to a shift from "inside-out" towards "outside-in" thinking, integrate socio-ecological needs at the basis of business innovation and operations. This implies that absolute sustainability targets represent premises for product development processes.

Table 5 Identified management functions for positive impact of socio-technical systems

Management level	Management function	Sources
Normative management	Collaborative management (in a wider system boundary) Establishment of a corporate culture, ethical principles and code of conduct for sustainability Implementation of a sustainable business model	Niesten et al. (2017), Baumgartner and Rauter (2017), Reuter et al. (2012), Bocken et al. (2014)
Strategic management	Strategic management for sustainability Formulation of strategic principles Implementation of innovation and learning processes	Baumgartner and Rauter (2017), Forum of the Future (2014), Adams et al. (2016), Dyllick and Rost (2017)
Operative management	Sustainability evaluation of supply chains Adaptation management (internal) Intersection management (internal and external) Life cycle-oriented coordination of activities	Laurin and Fantazy (2017), Adams et al. (2016), Baumgartner and Rauter (2017), Herrmann (2010)

Identification of socio-technical system management functions for positive impact

The socio-technical system design defines the architecture of a system, its structural alignment in environmental, social, and economic networks, as well as the type and amount of processed resources. A continuous steering of the system behavior is required to fulfil the purpose of generating positive impacts. The integrated management model by Bleicher (1999) ("St. Galler management model") provides a holistic and integrative management approach for this purpose by integrating information of its complex external environment into internal decision-making processes. Integrated management in general aims at identifying relevant internal as well as external information and knowledge to enable a long-term viability of the socio-technical system in accordance with its overall purpose (Herrmann 2010). Therefore, the integrated management model is considered an important analytical framework to identify relevant management functions to enable positive impacts of socio-technical systems (in a greater systemic context). An integrated management requires the definition of normative, strategic and operative management functions (see Section "Normative, strategic and operative management of socio-technical systems for positive impact") as well as required structures, behavior and activities (see Section "Structures, behavior and activities of socio-technical systems for positive impact").

Normative, strategic and operative management of socio-technical systems for positive impact

Three management layers of Bleicher's (1999) integrated management model distinguish between normative, strategic and operative management functions. Various concepts and approaches are identified in the literature review, summarized in Table 5, and documented in Online Appendix 1.

Normative management encompasses general norms, values and guiding procedures. Only a few studies so far discuss normative models for positive impacts. Normative management for positive impact is explained by Niesten et al. (2017) with a hybrid governance model and by Costantini et al. (2017) with collaborative governance mechanisms that enable a wider system boundary including the supply chain. The corporate culture should be related to values (Laurin and Fantazy 2017), ethical principles (Baumgartner and Rauter 2017), and a code of conduct for sustainability (Reuter et al. 2012). The definition of policies or business models and a mission for positive impact complements the normative functions. Bocken et al. (2014) propose several conceptualizations of technology-, society-, and organization-oriented models as well as related approaches for value proposition, creation, delivery and capture.

Strategic management functions for positive impact are addressed by various studies. Baumgartner and Rauter (2017) highlight a strategic management system for identifying relevant strategic sustainable issues. Forum of the Future (2014) defines strategic principles to align an organization with net-positive overall targets. Sustainability-oriented innovation (Adams et al. 2016) and learning processes [see Adams et al. (2016), Scheel (2016), Dyllick and Rost (2017) and Niesten et al. (2017)] define strategic behavior. The connection of normative principles with operative processes represents the key task for the strategic management. Baumgartner and Rauter (2017) explain in detail how strategic sustainability programs can fulfil this complex task for sustainability outcomes. Forum of the Future (2014) furthermore lays out how strategic sustainability targets for positive impact can be formulated.

Operative management functions comprehend operations and executions to enable positive impacts. Notions to managing and evaluating the supply chain sustainably are manifold [see Bocken et al. (2014), Scheel (2016) and Laurin and Fantazy (2017)] as the supply chain needs to

Table 6 Identified structures, behavior and activities for the management of socio-technical systems for positive impact

Organizational aspect	Content	Sources
Structures	Mutual economic networks Social networks Resource networks	Hunt (2017), Simpson and Kohers (2002), Scheel (2016)
Behavior	Normative behavior concepts (ethics, values and code of conduct) Innovation and learning behavior for sustainability Adaptation behavior and impact thinking	Horton (2014), Reuter et al. (2012), Baumgartner and Rauter (2017), Adams et al. (2016), Rahimifard et al. (2018)
Activities	Establishing of a sustainable business model Facilitation of the sustainable strategic program Execution of life cycle-oriented activities	Bocken et al. (2014), Baumgartner and Rauter (2017), Herrmann et al. (2015)

be integrated into the system boundary to enable positive impacts. Adaptation management (Adams et al. 2016) and intersectional management (Baumgartner and Rauter 2017) are identified as important functions to react to changing circumstances and to integrate stakeholder knowledge in decision-making processes. To execute operations towards positive impacts, a life cycle-oriented coordination of activities is needed (Herrmann 2010).

Structures, behavior and activities of socio-technical systems for positive impact

Structures, behavior and activities are organizational requirements or preconditions that support the integrated management of a socio-technical system. In the context of systems that generate positive impacts, the literature review provides concepts and approaches, which are summarized in Table 6 and documented in Online Appendix 1.

Structures enable organizational behavior and activities and, therefore, represent a necessary pre-condition for a desired socio-technical system performance (Herrmann 2010). Collaborative structures are described by Hunt (2017) as a pre-condition to enable symbiotic and mutual relationships with external systems. Niesten et al. (2017) identify inter-firm collaboration as a necessary governance structure for positive impacts. This leads to three different network types: resource networks (see Geng et al. 2010, Eckelman and Chertow 2013), social networks (see Simpson and Kohers 2002, Adams et al. 2016, Baumgartner and Rauter 2017, Laurin and Fantazy 2017) and economic networks (Bocken et al. 2014). Scheel (2016) adds that a systemic perspective on macro-level is required. The socio-technical performance needs to be evaluated, whereas different evaluation systems represent identified operative structures. These evaluation systems and their processes should focus on the environment [see Eckelman and Chertow (2013), Attia (2016), Dyllick and Rost (2017), Grönman et al. (2019)], stakeholder [see Rainey et al. (2015), Laurin and Fantazy (2017), Mareddy (2017), Di Cesare et al. (2018)] and supply chain (Laurin and Fantazy 2017).

Behavior-related aspects are identified to support the three management layers for an intended behavior of people within the socio-technical system. Normative behavior concepts comprehend globally accepted and unified ethics (Horton 2014), values for corporate sustainable management (Baumgartner and Rauter 2017), as well as a code of conduct for sustainability (Reuter et al. 2012). Strategic behavior is characterized through various types of innovation [see Adams et al. (2016), Forum of the Future (2014), Laurin and Fantazy (2017), Scheel (2016), Bocken et al. (2014)] and learning behavior (Adams et al. 2016) to develop sustainability knowledge and solutions. Operative behavior is characterized though adaptation (Rahimifard and Trollman 2017) to apply sustainability knowledge and impact thinking.

Activities describe required systemic actions that are necessary to pursue positive impacts. On a normative level, Bocken et al. (2014) highlight the functioning of sustainable business models through detailed technological, social and organizational principles. Galpin and Lee Whittington (2012) add the approach of a citizenship model that could serve as a blueprint for a positive organizational performance. The integration of environment and society in strategic actions lead to the definition of sustainability goals. The facilitation of the strategic program connects the strategic goals with the operative activities (Baumgartner and Rauter 2017) to contribute to the organizational mission as stated in the business model (Bocken et al. 2014). On an operative level, positive impacts result from the execution of life cycle-oriented activities (Herrmann et al. 2015), whereas a sustainable value is generated in a greater ecological and/or societal context.

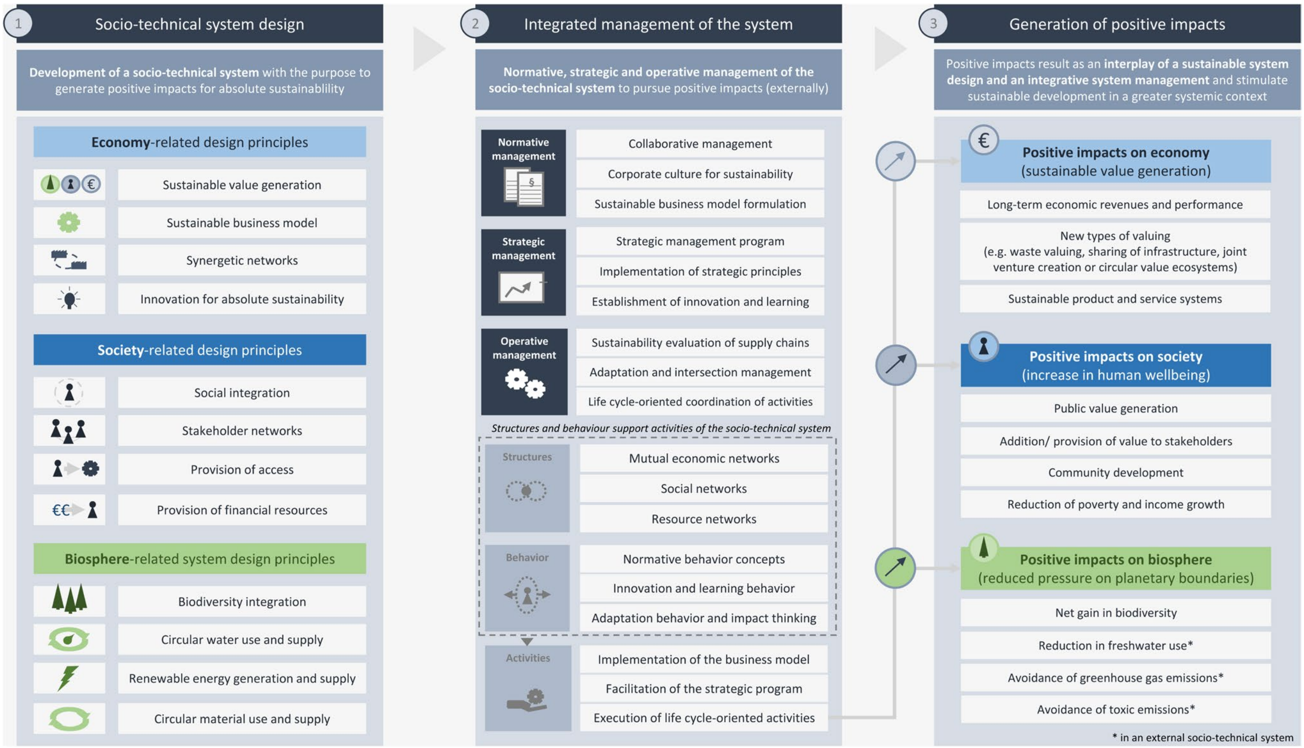

Fig. 3 Guiding framework for positive impacts of socio-technical systems

Synthesis

The analysis of publications on positive impacts for sustainable development detected several system design principles (Section "Identification of socio-technical system design principles for positive impact") and management functions (Section "Identification of socio-technical system management functions for positive impact"). These were utilized for the development of a guiding framework to explain the generation of positive impacts from a socio-technical system perspective and the derivation of a definition for "positive impact of socio-technical systems". The following **definition** is proposed:

> *A positive impact reduces pressure on planetary boundaries, increases human wellbeing and/or generates sustainable value. In socio-technical systems, positive impacts result from combining sustainability-related system design principles with an integrated system management and support sustainable development for absolute sustainability in a wider system boundary. This requires a structural alignment in resource-, stakeholder- and circular value-networks and a continuous development through innovation, learning and adaptation.*

This definition is based on a cooperative understanding of positive and net-positive concepts and it explains industrial preconditions. It can be applied in business, planning, design or engineering contexts to support projects or developments with an absolute sustainability target. The **guiding framework** shown in Fig. 3 consists of three steps and should be considered as a first proposal for consolidation of the fragmented and specific knowledge on positive impacts. It summarizes the identified knowledge, and provides an overview about systemic preconditions and organizational processes to generate positive impacts.

First, the **socio-technical system design** should be based on the identified principles, which can be considered as general premises for system planning and development stages. Biosphere-related system design principles claim a regenerative and circular energy, water and material use as well as supply of external systems. Society-related design principles focus on the social integration of stakeholders and their needs into the system design. This can be facilitated via stakeholder networks, the provision of access to employment, health and education services or financial resources. Economy-related system design principles encompass the generation of sustainable values in synergetic networks. This requires a sustainable business model as well as a continuous innovation of the socio-technical system to create products and services (as a system output) that fit to the goal of absolute sustainability and a changing external environment. Five general system design principles can be derived: (1)

networks, (2) regeneration, (3) circularity, (4) integration, and (5) sustainable value generation.

Second, an **integrated system management** is required to steer the socio-technical system purposely towards the generation of positive impacts. On a normative level, organizational prerequisites are defined. This includes a sustainable business model, the corporate culture for sustainability as well as a governance mechanism for sustainability. Governance should be facilitated collaboratively in a wider system boundary. This enables a life cycle-oriented system management, which integrates economic partners, and stakeholders as well as the pre- and post-supply chain. Strategic management connects the normative management with operative processes through establishing a strategic management program for sustainability, strategic principles and innovation and learning processes. Being evaluated against strategic goals for sustainability, the strategic management develops socio-technical solutions to fulfil the organizational mission in a continuously changing external environment. The operative management coordinates life cycle-oriented activities of the system including supply chain evaluation as well as adaptation and intersection management. The integrated management is supported by structures (resource, social and mutual economic networks), which should be considered as the outcome of the system planning processes. The system behavior is determined by the stakeholders that organize, control and steer the system. Therefore, the normative behavior concepts for absolute sustainability (values, ethics and a code of conduct) determine also innovation potential, learning and adaptation processes. Activities result from an interplay of existing socio-technical structures and intended behavior of people (within the system) and—ultimately—to the execution of life cycle-oriented activities for the desired system output.

Third, the **generation of positive impacts** represents consequently a result of socio-technical planning and integrated system management. Positive impacts on the biosphere reduce pressure on the planetary boundaries through a net gain in biodiversity, reduced freshwater uses and avoided greenhouse gas or toxic emissions in external systems. Therefore, positive ecological impacts are either based on the principles of (1) conservation and restoration (of ecosystems and natural habitats) or (2) substitution and avoidance (of resource uses or harmful emissions in external systems). Positive social impacts increase human wellbeing by public value generation, addition of value to stakeholders, community development and the reduction of poverty. Two principles are detected: (1) the integration of stakeholder needs and (2) the provision of access to social services and economic processes. Positive economic impacts increase economic growth and offer long-term economic revenues and performances through the establishment of sustainable product and service systems.

Outlook: potential implications and research demand

"Positive impact" is a contemporary concept with a growing significance. Various specific descriptions or visionary guiding principles exist, although a comprehensive definition and guidelines for incorporating positive impact thinking in organizations is yet missing. Therefore, an overview about the current topic was established to condense the fragmented knowledge and derive a more general understanding. This has been achieved by establishing a guiding framework that contains identified system design principles and management functions to steer socio-technical systems to positive impacts. The identified system design principles can support, e.g., system designers and engineers in planning processes as premises for the development of absolute sustainable systems. The principles enable the evaluation of the effectiveness of development processes. Thus, they could function as conceptual targets or general requirements in systems engineering (INCOSE 2006), socio-technical system innovation (Gaziulusoy 2015), system transformation (Geels 2018) or system collaboration (Adams et al. 2016) processes. The identified management functions can support an effective system management and serve as a blueprint for a cohesive and holistic system control and steering. The application of the framework could support socio-economic organizations that aim at generating sustainable value over their life cycle (Bocken et al. 2014). If the integrated management functions are applied in organizations to establish an "internalization of externalities" (Wendt 2018), they would allow and facilitate necessary management processes in a structured and systematic manner to achieve sustainable outcomes. Therefore, the synthesis of the results from Section "Identification of socio-technical system design principles for positive impact" (system design principles) and Sect. Identification of socio-technical system management functions for positive impact (integrated management functions) from the literature into the guiding framework is considered a novel insight for the development of absolute sustainable systems.

However, methodological challenges arise from the multi-systemic nature of the subject. The integration of a safe and just space for humanity into the socio-technical system design raises questions on allocation of remaining "impact budgets" (see Bjørn et al. 2020). This requires a careful calculation of a sustainable natural resource use and a thorough understanding of social wellbeing along the supply chain. Here, the definition of a sufficiently wide scope is crucial. Therefore, a clear and conscious definition of a multi-system boundary is essential and requires more research. This might as well have an influence on the formulation of sustainable design strategies for system innovation (see Ceschin and Gaziulusoy 2016). It is important to note that socio-technical systems with positive impacts will in reality co-exist with neutral or negative impacting systems. The resulting interaction needs to be considered in design and operation stages, but can provide a motivation and/or justification for generating a positive impact. Therefore, sustainable design strategies need to reflect the above-mentioned methodological challenges, develop solutions to integrate "positive impact thinking" systematically and provide guidance concerning system boundary definitions. New business models (see Bocken et al. 2014) could provide incentives for positive system transformations and raise the question on measuring sustainable values from an economic perspective. This might be a crucial question within strategic and organizational decision-making processes. In summary, future research should focus on method development to evaluate positive impacts, design strategies (e.g., "design for positive impact") and positive business models for sustainable value generation.

Conclusion

This study has analyzed the term "positive impact" in the context of absolute sustainability of socio-technical systems and evaluated in detail 62 selected publications concerning their descriptions of positive impacts. More than half of the assessed studies were published within the past 5 years, which shows the rising relevance of the subject. The in-depth literature analysis identified (general) socio-technical system design principles as well as normative, strategic and operative management functions leading to a definition of "positive impact". Several characteristics of positive impacts on biosphere, society and economy were detected. The developed guiding framework explains systemic preconditions and required organizational processes to reduce pressure on planetary boundaries, increase human wellbeing and generate sustainable value.

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References

ACCA (2014) Net positive natural capital ambitions. The Association of Chartered Certified Accountants, London, Großbrittanien. https://www.accaglobal.com/content/dam/acca/global/PDF-technical/sustainability-reporting/tech-tp-npnca.pdf, checked on 5/28/2020. Accessed 13 June 2022

Adams R, Jeanrenaud S, Bessant J, Denyer D, Overy P (2016) Sustainability-oriented innovation. A systematic review. Int J Manag Rev 18(2):180–205. https://doi.org/10.1111/ijmr.12068

Aiama D, Edwards S, Bos G, Ekstrom J, Krueger L, Quétier F et al. (2015) No Net Loss and Net Positive Impact Approaches for Biodiversity. Exploring the potential application of these approaches in the commercial agriculture and forestry sectors. International Union for Conservation of Nature (IUCN), Switzerland. https://portals.iucn.org/library/sites/library/files/documents/2015-003.pdf, checked on 5/28/2020. Accessed 13 June 2022

Allen CD, Breshears DD, McDowell NG (2015) On underestimation of global vulnerability to tree mortality and forest die-off from hotter drought in the Anthropocene. Ecosphere 6(8):art129. https://doi.org/10.1890/ES15-00203.1

Alshehhi A, Nobanee H, Khare N (2018) The impact of sustainability practices on corporate financial performance literature trends and future research potential. Sustainability 10(2):494. https://doi.org/10.3390/su10020494

Attia S (2016) Towards regenerative and positive impact architecture: a comparison of two net zero energy buildings. Sustain Cities Soc 26:393–406. https://doi.org/10.1016/j.scs.2016.04.017

Ayres RU (ed) (2002) A handbook of industrial ecology. Elgar, Cheltenham

Baumgartner RJ, Rauter R (2017) Strategic perspectives of corporate sustainability management to develop a sustainable organization. J Clean Prod 140:81–92. https://doi.org/10.1016/j.jclepro.2016.04.146

Biermann F (2012) Planetary boundaries and earth system governance: Exploring the links. Spec Sct Planet Bound Glob Environ Gov 81:4–9. https://doi.org/10.1016/j.ecolecon.2012.02.016

Birkeland J (2018) Eco-positive design: moving beyond ecological restoration. In: Research Futures. https://researchfeatures.com/2018/08/22/eco-positive-design-moving-beyond-ecological-restoration/. Accessed 13 June 2022

Birkeland J, Knight-Lenihan S (2016) Biodiversity offsetting and net positive design. J Urban Des 21(1):50–66. https://doi.org/10.1080/13574809.2015.1129891

Bjørn A, Hauschild MZ (2013) Absolute versus relative environmental sustainability. J Ind Ecol 17(2):321–332. https://doi.org/10.1111/j.1530-9290.2012.00520.x

Bjørn A, Margni M, Roy P-O, Bulle C, Hauschild MZ (2016) A proposal to measure absolute environmental sustainability in life cycle assessment. Ecol Indic 63:1–13. https://doi.org/10.1016/j.ecolind.2015.11.046

Bjørn A, Chandrakumar C, Boulay A-M, Doka G, Fang K, Gondran N et al (2020) Review of life-cycle based methods for absolute environmental sustainability assessment and their applications. Environ Res Lett 15(8):83001. https://doi.org/10.1088/1748-9326/AB89D7

Bleicher K (1999) Das Konzept Integriertes Management. Campus Verlag, Frankfurt am Main

Bocken NMP, Short SW, Rana P, Evans S (2014) A literature and practice review to develop sustainable business model archetypes. J Clean Prod 65:42–56. https://doi.org/10.1016/j.jclepro.2013.11.039

Braungart M, McDonough W, Bollinger A (2007) Cradle-to-cradle design. Creating healthy emissions—a strategy for eco-effective

product and system design. J Clean Prod 15(13–14):1337–1348. https://doi.org/10.1016/j.jclepro.2006.08.003
Bull JW, Brownlie S (2017) The transition from No Net Loss to a Net Gain of biodiversity is far from trivial. Oryx 51(1):53–59. https://doi.org/10.1017/S0030605315000861
Ceschin F, Gaziulusoy I (2016) Evolution of design for sustainability. From product design to design for system innovations and transitions. Des Stud 47:118–163. https://doi.org/10.1016/j.destud.2016.09.002
Chapin FS III, Power ME, Pickett STA, Freitag A, Reynolds JA, Jackson RB et al (2011) Earth Stewardship: science for action to sustain the human-earth system. In Ecosphere 2(8):art89. https://doi.org/10.1890/ES11-00166.1
Coenen L, Benneworth P, Truffer B (2012) Toward a spatial perspective on sustainability transitions. Res Policy 41(6):968–979. https://doi.org/10.1016/j.respol.2012.02.014
Cole RJ, Kashkooli AMS (2013) Clarifying Net Positive Energy Design. In: CaGBC National Conference and Expo., Conference: Stream 5 – Pushing the Boundaries: Net Positive Buildings (SB13), At Vancouver, BC, Canada.
Costantini V, Crespi F, Marin G, Paglialunga E (2017) Eco-innovation, sustainable supply chains and environmental performance in European industries11 We gratefully acknowledge the support by the European Union's Horizon 2020 research and innovation programme under grant agreement No. 649186—ISIGrowth. The comments and suggestions by three anonymous referees are also acknowledged. The usual disclaimers apply. Imaking Buy Collab More Sustain Prod Consum 155:141–154. https://doi.org/10.1016/j.jclepro.2016.09.038
Daily GC, Ehrlich PR (1992) Population, sustainability, and earth's carrying capacity. Bioscience 42(10):761–771. https://doi.org/10.2307/1311995
del Río P, Burguillo M (2009) An empirical analysis of the impact of renewable energy deployment on local sustainability. Renew Sustain Energy Rev 13(6–7):1314–1325. https://doi.org/10.1016/j.rser.2008.08.001
Di Cesare S, Silveri F, Sala S, Petti L (2018) Positive impacts in social life cycle assessment. State of the art and the way forward. Int J Life Cycle Assess 23(3):406–421. https://doi.org/10.1007/s11367-016-1169-7
Dryzek JS, Stevenson H (2011) Global democracy and earth system governance. Spec Sect Earth Syst Gov Account Legit 70(11):1865–1874. https://doi.org/10.1016/j.ecolecon.2011.01.021
Dyllick T, Rost Z (2017) Towards true product sustainability. J Clean Prod 162:346–360. https://doi.org/10.1016/j.jclepro.2017.05.189
Eckelman MJ, Chertow MR (2013) Life cycle energy and environmental benefits of a US industrial symbiosis. Int J Life Cycle Assess 18(8):1524–1532. https://doi.org/10.1007/s11367-013-0601-5
Ekener E (2018) To assess use phase impacts in S-LCA. Social LCA. In: 6th SocSem, People and Places for Partnership, Pescara, Italy, 10–12 September, 2018
Elkington J (2013) Enter the Triple Bottom Line. In: Henrieques A, Richardson J (eds) The Triple Bottom Line - does it all add up? Taylor & Francis Group, United Kingdom, pp 1–16
Figge F, Hahn T (2004) Sustainable value added—measuring corporate contributions to sustainability beyond eco-efficiency. Ecol Econ 48(2):173–187. https://doi.org/10.1016/j.ecolecon.2003.08.005
Folke C, Carpenter SR, Walker B, Scheffer M, Chapin T, Rockström J (2010) Resilience thinking: integrating resilience, adaptability and transformability. Ecol Soc 15:4. https://doi.org/10.5751/ES-03610-150420
Forum of the Future (2014) Net Positive—a new way of doing business. https://www.theclimategroup.org/sites/default/files/archive/files/Net-Positive.pdf, checked on 5/28/2020. Accessed 28 May 2020
Galpin T, Lee Whittington J (2012) Sustainability leadership. From strategy to results. J Bus Strateg 33(4):40–48. https://doi.org/10.1108/02756661211242690
Gaziulusoy AI (2015) A critical review of approaches available for design and innovation teams through the perspective of sustainability science and system innovation theories. J Clean Prod 107:366–377. https://doi.org/10.1016/j.jclepro.2015.01.012
Geels FW (2002) Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. Res Policy 31:1257–1274 (**checked on 12/7/2019**)
Geels FW (2018) Disruption and low-carbon system transformation. Progress and new challenges in socio-technical transitions research and the Multi-Level Perspective. Energy Res Soc Sci 37:224–231. https://doi.org/10.1016/j.erss.2017.10.010
Geels FW, Sovacool BK, Schwanen T, Sorrell S (2017) The socio-technical dynamics of low-carbon transitions. Joule 1(3):463–479. https://doi.org/10.1016/j.joule.2017.09.018
Geng Y, Tsuyoshi F, Chen X (2010) Evaluation of innovative municipal solid waste management through urban symbiosis. A case study of Kawasaki. J Clean Prod 18(10–11):993–1000. https://doi.org/10.1016/j.jclepro.2010.03.003
Giovannoni E, Fabietti G (2013) What is sustainability? A review of the concept and its applications. In: Busco C, Frigo ML, Riccaboni A, Quattrone P (eds) Integrated reporting: concepts and cases that redefine corporate accountability. Springer International Publishing, Cham, pp 21–40
Goedkoop M, de Beer I, Indrane D (2018) Product Social impact assessment: handbook 2018. Amersfort
Grönman K, Pajula T, Sillman J, Leino M, Vatanen S, Kasurinen H et al (2019) Carbon handprint—an approach to assess the positive climate impacts of products demonstrated via renewable diesel case. J Clean Prod 206:1059–1072. https://doi.org/10.1016/j.jclepro.2018.09.233
Guerry AD, Polasky S, Lubchenco J, Chaplin-Kramer R, Daily GC, Griffin R et al (2015) Natural capital and ecosystem services informing decisions: from promise to practice. Proc Natl Acad Sci USA 112(24):7348–7355. https://doi.org/10.1073/pnas.1503751112
Hauschild MZ (2015) Better—but is it good enough? On the need to consider both eco-efficiency and eco-effectiveness to gauge industrial sustainability. Proc CIRP 29:1–7. https://doi.org/10.1016/j.procir.2015.02.126
Hauschild MZ, Herrmann C, Kara S (2017) An integrated framework for life cycle engineering. Proc CIRP 26:2–9
Hauschild MZ, Kara S, Røpke I (2020) Absolute sustainability: challenges to life cycle engineering. CIRP Ann 69(2):533–553. https://doi.org/10.1016/j.cirp.2020.05.004
Herrmann C (2010) Ganzheitliches life cycle management. In: Herrmann C (ed) Nachhaltigkeit und Lebenszyklusorientierung inUnternehmen. Springer Nature (VDI-Buch), Berlin
Herrmann C, Blume S, Kurle D, Schmidt C, Thiede S (2015) The positive impact factory-transition from eco-efficiency to eco–effectiveness strategies in manufacturing. Proc CIRP 29:19–27. https://doi.org/10.1016/j.procir.2015.02.066
Horton K (2014) Global ethics: increasing our positive impact. J Glob Ethics 10(3):304–311. https://doi.org/10.1080/17449626.2014.971384
Hunt RA (2017) The Oxpecker and the Rhino: the Positive Effects of Symbiotic Mutualism on Organizational Survival. Working Papers 2017-03, Colorado School of Mines, Division of Economics and Business
INCOSE (2006) Systems engineering handbook—a guide for system engineering life cycle processes and activities. International

Council on Systems Engineering. http://www.las.inpe.br/~perondi/21.06.2010/SEHandbookv3.pdf, checked on 9/30/2019. Accessed 13 June 2022

Indrane D, Goedkoop M, Beer de i (2018) Consistent assessment of positive impacts. In: Social LCA, 6th SocSem, People and Places for Partnership, Pescara, Italy, 10–12 September, 2018

Joustra CM, Yeh DH (2014) Framework for net-zero and net-positive building water cycle management. Build Res Inf 43(1):121–132. https://doi.org/10.1080/09613218.2015.961002

Kara S, Hauschild MZ, Herrmann C (2018) Target-driven Life Cycle Engineering: staying within the Planetary Boundaries. In: 25th CIRP Life Cycle Engineering (LCE) Conference, 30 April–2 May 2018, Copenhagen, Denmark 69, pp. 3–10. https://doi.org/10.1016/j.procir.2017.11.142

Kobayashi H, Murata H, Fukushige S (2020) Connected lifecycle systems: a new perspective on industrial symbiosis. In 27th CIRP Life Cycle Engineering Conference (LCE2020) Advancing Life Cycle Engineering : from technological eco-efficiency to technology that supports a world that meets the development goals and the absolute sustainability 90, pp. 388–392. https://doi.org/10.1016/j.procir.2020.01.107

Kommission B (1987) Our common future: the report of the world commission on environment and development. Oxford University Press, Oxford

Krajnc D, Glavič P (2005) How to compare companies on relevant dimensions of sustainability. Ecol Econ 55(4):551–563. https://doi.org/10.1016/j.ecolecon.2004.12.011

Lankoski L (2016) Alternative conceptions of sustainability in a business context. J Clean Prod 139:847–857. https://doi.org/10.1016/j.jclepro.2016.08.087

Laurin F, Fantazy K (2017) Sustainable supply chain management A case study at IKEA. Transnatl Corpor Rev 9(4):309–318. https://doi.org/10.1080/19186444.2017.1401208

Li M (2016) No net negative water + culture. Peoples´s countryard in downtown Beijing. http://cardinalscholar.bsu.edu/handle/123456789/200348, checked on 4/15/2020. Accessed 13 June 2022

Macfadyen G, Huntington T, Cappell R (2019) Maximising the chances for positive impacts of fisheries and aquaculture Official Development Assistance. Mar Policy 107:103218. https://doi.org/10.1016/j.marpol.2018.08.002

Mareddy AR (2017) Impacts on the socioeconomic environment. In: Mareddy AR (ed) Environmental impact assessment. Butterworth-Heinemann, Oxford

Mathew PV, Sreejesh S (2017) Impact of responsible tourism on destination sustainability and quality of life of community in tourism destinations. J Hosp Tour Manag 31:83–89. https://doi.org/10.1016/j.jhtm.2016.10.001

McEvoy TJ (2004) Positive impact forestry. Achieving sustainability on family-owned woodlands. Island Press,Washington, 268 p

Niesten E, Jolink A, de Sousa Jabbour L, Ana Beatriz C, Maryse LR (2017) Sustainable collaboration. The impact of governance and institutions on sustainable performance. J Clean Prod 155:1–6. https://doi.org/10.1016/j.jclepro.2016.12.085

NPI (2015a) Net Positive Impact on biodiversity—the business case. Net Positive Alliance, International Union for the Conservation of Nature (IUCN)

NPI (2015b) Net Positive Impact on biodiversity—The conservation case. Net Positive Alliance, International Union for the Conservation of Nature (IUCN)

O'Neill BC, Kriegler E, Riahi K, Ebi KL, Hallegatte S, Carter TR et al (2014) A new scenario framework for climate change research: the concept of shared socioeconomic pathways. Clim Change 122(3):387–400. https://doi.org/10.1007/s10584-013-0905-2

Olsen N (2011) Exploring ecosystem valuation to move towards net positive impact on biodiversity in the mining sector. IUCN, International Union on Conservation of Nature

Persson L, Almroth C, Bethanie M, Collins CD, Cornell S, de Wit CA, Diamond ML et al (2022) Outside the safe operating space of the planetary boundary for novel entities. Environ Sci Technol 56(3):1510–1521. https://doi.org/10.1021/acs.est.1c04158

Prieto-Sandoval V, Ormazabal M, Jaca C, Viles E (2018) Key elements in assessing circular economy implementation in small and medium-sized enterprises. Bus Strateg Environ 27(8):1525–1534. https://doi.org/10.1002/bse.2210

Rahimifard S, Trollman H (2017) Surpassing sustainability. Making a 'net-positive' impact. Int J Sustain Eng 10(6):299–301. https://doi.org/10.1080/19397038.2017.1401037

Rahimifard S, Stone J, Lumsakul P, Trollman H (2018) Net positive manufacturing. A restoring, self-healing and regenerative approach to future industrial development. Proc Manuf 21:2–9. https://doi.org/10.1016/j.promfg.2018.02.088

Rainey HJ, Pollard EHB, Dutson G, Ekstrom JMM, Livingstone SR, Temple HJ, Pilgrim JD (2015) A review of corporate goals of No Net Loss and Net Positive Impact on biodiversity. Oryx 49(2):232–238. https://doi.org/10.1017/S0030605313001476

Randers J, Rockström J, Stoknes PE, Golüke U, Collste D, Cornell SE (2018) Transformation is feasible. How to achieve the Sustainable Development Goals within Planetary Boundaries. Stockholm Resilience Centre. https://www.stockholmresilience.org/download/18.51d83659166367a9a16353/1539675518425/Report_Achieving%20the%20Sustainable%20Development%20Goals_WEB.pdf, checked on 9/6/2019. Accessed 13 June 2022

Raworth K (2012) A safe and just space for humanity—can we live within the doughnut? Oxfam Discussion Paper. https://www-cdn.oxfam.org/s3fs-public/file_attachments/dp-a-safe-and-just-space-for-humanity-130212-en_5.pdf, checked on 8/4/2021. Accessed 13 June 2022

Raworth K (2017) Doughnut economics. In: Raworth K (ed) Seven ways to think like a 21st-century economist. Random House Business Books, London

Reganold JP, Wachter JM (2016) Organic agriculture in the twenty-first century. Nat Plants 2:15221. https://doi.org/10.1038/nplants.2015.221

Reuter C, Goebel P, Foerstl K (2012) The impact of stakeholder orientation on sustainability and cost prevalence in supplier selection decisions. J Purch Supply Manag 18(4):270–281. https://doi.org/10.1016/j.pursup.2012.06.004

Rockström J (2015) Bounding the planetary future: Why we need a great transition'. The Great Transition Initiative. http://www.greattransition.org/publication/bounding-the-planetary-future-why-we-need-a-great-transition., checked on 5/28/2020. Accessed 13 June 2022

Rockström J, Steffen W, Noone K, Persson Å, Chapin FS III, Lambin EF et al (2009) A safe operating space for humanity. Nature 461:472 EP

Sachs JD, Schmidt-Traub G, Mazzucato M, Messner D, Nakicenovic N, Rockström J (2019) Six transformations to achieve the sustainable development goals. Nat Sustain. https://doi.org/10.1038/s41893-019-0352-9

Savaget P, Geissdoerfer M, Kharrazi A, Evans S (2019) The theoretical foundations of sociotechnical systems change for sustainability. A systematic literature review. J Clean Prod 206:878–892. https://doi.org/10.1016/j.jclepro.2018.09.208

Scheel C (2016) Beyond sustainability. Transforming industrial zero-valued residues into increasing economic returns. J Clean Prod 131:376–386. https://doi.org/10.1016/j.jclepro.2016.05.018

Shrestha MK, Bhandari MP, Diana JS, Jaiswal R, Mishra RN, Pandit NP (2018) Positive impacts of Nile tilapia and predatory Sahar on carp polyculture production and profits. Aquac Fish 3(5):204–208. https://doi.org/10.1016/j.aaf.2018.06.002

Siddiqi A, Collins RD (2017) Sociotechnical systems and sustainability. Current and future perspectives for inclusive development. Curr Opin Environ Sustain 24:7–13. https://doi.org/10.1016/j.cosust.2017.01.006

Simpson WG, Kohers T (2002) The link between corporate social and financial performance: evidence from the banking industry. J Bus Ethics 35(2):97–109. https://doi.org/10.1023/A:1013082525900

Smith LC, Haddad L (2015) Reducing child undernutrition. Past drivers and priorities for the post-MDG era. World Dev 68:180–204. https://doi.org/10.1016/j.worlddev.2014.11.014

Societe General (2017) Positive Impact Assessment Framework. Societe General Group. https://www.societegenerale.com/sites/default/files/documents/positive-impact-bond/SG_Positive_Impact_Assessment_Framework.pdf. Accessed 13 June 2022

Steffen W, Richardson K, Rockström J, Cornell SE, Fetzer I, Bennett EM et al (2015) Planetary boundaries: guiding human development on a changing planet. Science 347(6223):1259855. https://doi.org/10.1126/science.1259855

Stoknes PE, Rockström J (2018) Redefining green growth within planetary boundaries. Energy Res Soc Sci 44:41–49. https://doi.org/10.1016/j.erss.2018.04.030

Tayleur C, Balmford A, Buchanan GM, Butchart SHM, Ducharme H, Green RE et al (2017) Global coverage of agricultural sustainability standards, and their role in conserving biodiversity. Conserv Lett 10(5):610–618. https://doi.org/10.1111/conl.12314

Temple HJ, Anstee S, Ekstrom J, Pilgrim JD, Rabenantoandro J, Ramanamanjato J-B et al. (2012) Forecasting the path towards a Net Positive Impact on biodiversity for Rio Tinto QMM. International Union for the Conservation of Nature (IUCN), Switzerland. https://www.iucn.org/es/node/20876. Accessed 13 June 2022

Thies C, Kieckhäfer K, Spengler TS, Sodhi MS (2019) Operations research for sustainability assessment of products: a review. Eur J Oper Res 274(1):1–21. https://doi.org/10.1016/j.ejor.2018.04.039

UN (2015) Transforming our world: the 2030 Agenda for Sustainable Development. United Nations. https://sustainabledevelopment.un.org/post2015/transformingourworld, checked on 5/6/2020. Accessed 13 June 2022

UNEPFI (2017) The principles for positive impact finance: United Nations Environmnet Programme - Finance Initiative. https://www.unepfi.org/positiveimpact/principles-for-positive-impact-finance/. Accessed 12 Oct 2021

van Rekom J, Go FM, Calter DM (2014) Communicating a company's positive impact on society—can plausible explanations secure authenticity? J Bus Res 67(9):1831–1838. https://doi.org/10.1016/j.jbusres.2013.12.006

WBCSD (ed) (2000) Eco-efficiency—creating more value with less impact. World Business Council for Sustainable Development, Genf

Wendt K (2018) Positive impact investing: a new paradigm for future oriented leadership and innovative corporate culture. In: Wendt K (ed) Positive impact investing: a sustainable bridge between strategy, innovation, change and learning. Springer International Publishing, Cham, pp 1–26

Whiteman G, Walker B, Perego P (2013) Planetary boundaries: ecological foundations for corporate sustainability. J Manag Stud 50(2):307–336. https://doi.org/10.1111/j.1467-6486.2012.01073.x

Whitmee S, Haines A, Beyrer C, Boltz F, Capon AG, Souza D, de Braulio F et al (2015) Safeguarding human health in the Anthropocene epoch. Report of The Rockefeller Foundation-Lancet Commission on planetary health. The Lancet 386(10007):1973–2028. https://doi.org/10.1016/S0140-6736(15)60901-1

Zapico JL, Brandt N, Turpeinen M (2010) Environmental metrics. J Ind Ecol 14(5):703–706. https://doi.org/10.1111/j.1530-9290.2010.00272.x

Zhang X, Davidson EA, Mauzerall DL, Searchinger TD, Dumas P, Shen Ye (2015) Managing nitrogen for sustainable development. Nature 528(7580):51–59. https://doi.org/10.1038/nature15743