Sustainability Management in Industrial Companies

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Industrial companies have numerous avenues for implementing sustainability innovations, which can significantly reduce the negative ecological impact of their activities. In this context, a variety of options for action and types of innovation are available to companies at different system levels. These range from innovations in the material and energy flows used for processing, procedural and product innovations, through to comprehensive organisational and functional innovations at the consumer and user level. There are numerous interdependencies between the different levels and types of innovation.

Keywords: production & product ecology, function orientation, system levels, types of innovation

INTRODUCTION

There is a substantial agreement among scientists and politicians that the current ecological challenges, such as climate change, are of a global scale and are approaching planetary boundaries (Rockström et al. 2009). Furthermore, these challenges are posing significant obstacles for the economy and businesses. Industrial companies are especially affected by this phenomenon, as they contribute significantly to ecologically problematic material and energy flows and are therefore particularly affected by ecologically motivated political and social demands and government regulations. In this regard, addressing the ecologically sustainable value creation issue represents a significant future challenge for these companies. Concurrently, a multitude of innovations exist that can facilitate ecological improvements at the organizational level. When implemented appropriately, these innovations have the potential to enhance the long-term viability of industrial companies.

SUSTAINABILITY AS A TASK FOR CORPORATE MANAGEMENT

The perception of sustainability issues within society exhibits a cyclical pattern, characterized by periods of both ascension and decline. However, an overall upward trajectory is discernible. It is, therefore, of existential importance for companies to address the issue of sustainability. Otherwise, they risk finding themselves in a situation that threatens their existence in the long term.

Therefore, dealing with the issue of sustainability represents a general challenge for corporate management and requires qualified sustainability management. The following definition is used as a basis for the following explanations:

Sustainability management is defined as the comprehensive design, steering, and development of a company that considers economic, ecological, social, and socio-cultural aspects. Consequently, the objective is to establish a multidimensional target reference, or "sustainability polytelia", within the context *of a dynamic equilibrium between competing target dimensions. This entails a comprehensive* assessment of economic, ecological, social, and socio-cultural opportunities and constraints, intending to shape corporate policy in a *manner that optimizes the realization of these diverse objectives. As a cross-sectional function, sustainability management is cross-functional, encompassing all company functional areas and involving all employees. Furthermore, it is cross-company and also takes into account cooperating companies in upstream and downstream stages. Finally, it is characterized by a proactive behavioral and transformative innovation orientation.*

CURRENT CHALLENGES FOR SUSTAINABILITY MANAGEMENT

Contemporary sustainability management is based on an equal footing on both the social-human and ecological dimensions. It can be defined as value- and responsibility-oriented management (corporate social responsibility, CSR) (Pfister 2020) on the one hand and as environmental and resource-oriented management on the other. These two issues are considered part of an integrated management system. This form of management is innovation-oriented and therefore highly relevant for the future viability of companies. (Seidel (Ed.) 1999, Göllinger 2022).

Companies are not only directly confronted with current problems such as the environmental and climate crisis, supply bottlenecks, and geopolitical developments, but also with many demands from society and politics regarding sustainability. These demands have already led to market-relevant consequences. Consequently, companies are facing an increasing number of demands in this area.

Additional specific objectives include: The concept of a circular economy, defined as a system in which materials are kept in circulation for as long as possible, has gained significant traction in recent years. This approach, also known as "cradle to cradle", is designed to reduce the amount of waste generated by avoiding unnecessary consumption and promoting recycling. (Migliore/Talamo/Paganin (Ed.) 2020). In light of the mounting challenges posed by waste accumulation over the past few decades, governments and corporations have been pursuing a range of measures to reduce waste and increase recycling. The principles of a comprehensive circular economy are increasingly guiding these efforts. A key concept is the notion of a fully residue- and waste-free (zero waste) production and economic system. In a narrow sense, this concept is related to the specific operational production processes, which makes its implementation challenging. This is because a multitude of industrial production processes yield a range of undesirable by-products and secondary products that cannot be directly utilized in the production or operation process and therefore accumulate as residues. However, suppose the guiding principle is interpreted broadly, in the sense of recycling residues in the value creation network of the entire economy. In that case, it can be expected that a zero-waste strategy can increasingly be realized. The cradle-to-cradle approach should be seen in this context (McDonough/Braungart, 2009). This relies on consistent recycling by either continuously keeping material flows in technical cycles or returning them to natural cycles.

The considerable number of regulatory measures in place give rise to many requirements, which presents a significant challenge for companies in terms of developing efficient concepts and integrating them into their established corporate routines. The question of reconciling economic, social, and ecological objectives has been a topic of social and political debate for some time. In recent times, disputes between disparate ecological objectives have also emerged. One illustrative example of an internal ecological conflict is the ongoing debate about the relative priority of climate protection over nature conservation. The conflicts mentioned above of objectives and values give rise to a more complex situation about the social evaluation and interpretation of information concerning the actual or only supposed social and ecological benefits of certain materials, products, and production processes. This is due to the various interactions and the difficulties in adequately recording them. As a result, the demands on companies' social and ecological communication are increasing.

Concurrently, the escalating costs associated with environmental and resource consumption (e.g., CO_2 pricing) necessitate a thorough examination within the context of a company's profitability calculations. In favorable circumstances, these augmented endeavors may culminate in augmented resource and cost savings for companies. (Fernández/Zubelzu/Rodrigo (Ed.) 2017).

TOPICS AND TASKS OF SUSTAINABILITY MANAGEMENT IN INDUSTRIAL COMPANIES

In the traditional economic perspective, a company's material value creation process is conceptualized as the transformation of raw materials and supplies (input) into goods and services (output). In contrast, the ecological perspective posits that the corporate performance creation process is a transformation of resource input (energy, materials) into desirable products and undesirable emissions, residues, and ecological risks. From this perspective, value creation processes are inextricably linked to harmful creation processes, which are referred to as external effects in environmental economics. While the traditional economic perspective abstracts from the material-energy processes in the value creation process, the ecological perspective explicitly addresses these material-energy aspects. (Costanza 1991, Daly/Farley 2004, Weizsäcker/Hargroves/Smith 2009).

In the future, the emphasis will be on developing products (goods and services) that do not present any risks to human health or the environment throughout their entire life cycle, from manufacture and use to consumption, recycling and disposal. Furthermore, these products will consume few resources. (Seliger/Khraisheh/Jawahir 2011, Benetto/Gericke/Guiton (Ed.) 2018).

Greening of Industrial Production - Production Ecology

Traditional Environmental Protection in Industrial Companies

In the context of operational production within industrial companies, sustainability is closely associated with traditional operational environmental management and its orientation towards the environmental protection function. The operational processes of the production area and the associated neighboring areas constitute the primary focus of tasks and activities. Environmental and organizational issues are of particular importance, particularly concerning operational and production-related environmental protection measures. This dominance is a consequence of the environmental protection legislation that has developed over decades, which has been and continues to be strongly oriented towards environmental media, substances, and plants.

Similarly, aftercare environmental protection has been a dominant area of focus for an extended period. It is important to distinguish between remedial environmental protection, which employs cleaning and repair technologies, and additive environmental protection, which utilises filter and retention technologies. Remedial environmental protection is only applicable when pollutant emissions have already occurred, that is to say, when an environmental medium has already been polluted. A case in point is removing contaminated sites, for example, cleaning contaminated soil or leaking landfills. It is inevitable that remedial environmental protection will be required in the future, given that numerous contaminated sites still need to be removed to prevent more serious harmful effects. The implementation of filter and retention technologies represents an initial step in the process of additive environmental protection. These technologies are designed to address emissions, which, despite not being eliminated, can be contained and prevented from spreading. In this regard, the concept of additive environmental protection is concerned with avoiding emissions. (Haasis (Ed.) 2007).

Production-Integrated Environmental Protection (PIEP)

Production-integrated environmental protection (PIEP) represents a proactive and innovative avoidance strategy (Göllinger 2012). It entails the implementation of integrated environmental protection technologies and a corresponding organizational orientation of operational environmental protection, intending to prevent emissions and residues from occurring in the first place. The fundamental premise is that environmental protection measures must be initiated at the earliest stage of the production process, which is why industrial production represents the central starting point. This is what is meant by the term "production-integrated environmental protection," or PIEP. This objective entails an ecological modernization of the entire production process, entailing a structural change in the production processes themselves. Consequently, environmental protection becomes an intrinsic aspect of production, accompanied by reduced resource utilization. The following sequence of steps can be regarded as programmatic for PIEP: avoid, then reduce, then recycle, then dispose.

Recycling as an Integral Part of a Circular Economy

The integration of recycling as a fundamental component of a circular economy is a necessity, despite the advent of revolutionary advancements in production and manufacturing techniques. The aspiration of achieving an entirely residue-free production process remains unattainable. It is of paramount importance that unavoidable residues resulting from production processes be reused. In this regard, all potential avenues for recycling must be pursued. The term "recycling" is typically understood to signify the reintroduction of residual materials into the economic cycle. (Göllinger/Harrer-Puchner 2022).

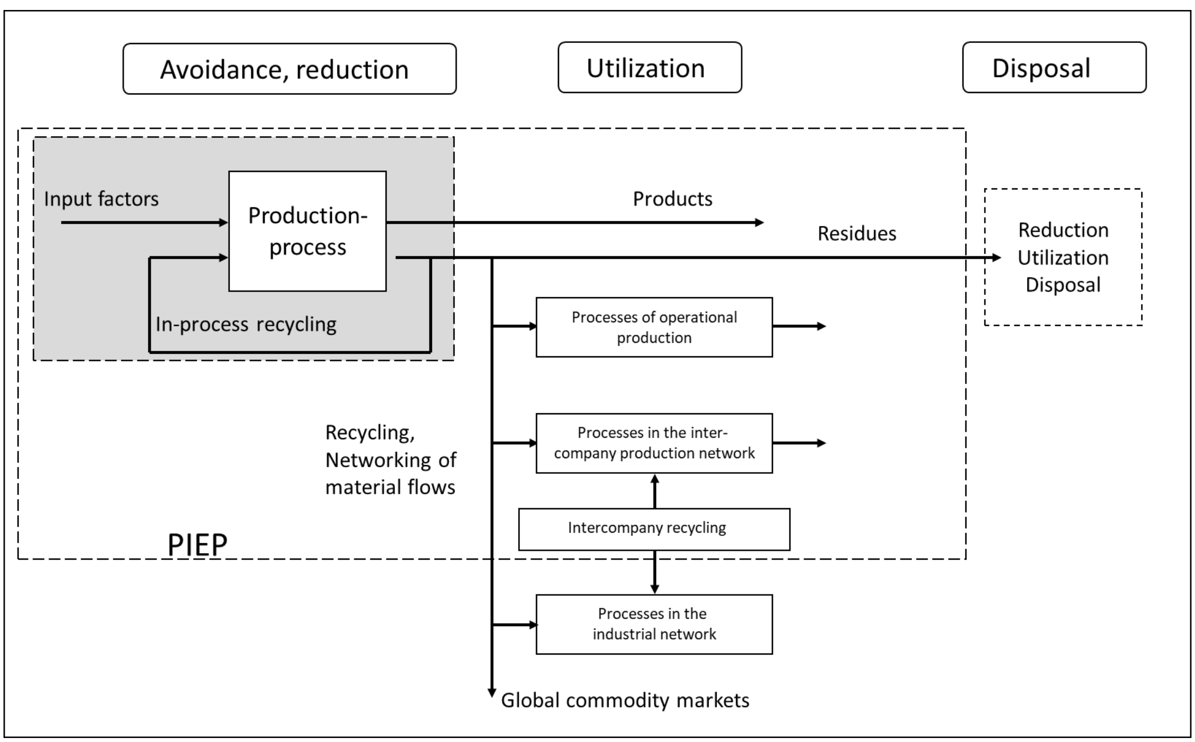
This may occur within the company's own production (internal recycling) or by extending the recycling possibilities beyond the company itself (external recycling). Typical measures include the implementation of use and recycling cascades, such as establishing closed water cycles or recovering materials from electroplating and etching processes. (Veit/Bernardes (Ed.) 2015).

A further differentiation can be made based on the spatial or institutional scope of the material flows. A company can have several production facilities at one location that are networked with each other in terms of their material flows. One example of this is chemical Verbund sites. In such constellations, the recycling basis for residues extends to all processes within the inter-company production network (inter-company recycling).

A number of industrial recycling networks have already been established based on inter-company cooperation. These networks are formed with the aim of recycling residues and are therefore referred to as recycling networks (industrial ecology) (Isenmann/Hauff (Ed.) 2007). Figure 1 illutrates the areas of responsibility of PIEP and recycling.

Residue recovery tasks can be subsumed under the term "operational reduction management". The coordination between operational production and operational reduction leads to an integrated production and reduction economy.

FIGURE 1
PIEP AND THE POSSIBILITIES FOR NETWORKING MATERIAL FLOW



Product-Related Environmental Management - Product Ecology

Product-related Environmental Management represents an extension of production ecology to encompass product ecology. The environmental impact of products is not limited to the production phase; it also extends to the use phase. From a product-related environmental management perspective, products themselves can be a source of emissions. For instance, adhesives may release solvents into the environment. Conversely, utilizing a multitude of products necessitates utilizing supplementary resources in the form of operational materials, such as electricity for the refrigerator. The additional consumption of resources and the associated emissions and environmental impact have the potential to exceed the environmental impact of producing a consumer good over its lifetime. In light of the legal requirements and customer preferences, companies must prioritize the development of environmentally conscious and resource-efficient products. (Göllinger 2012, 2022).

Upon reaching the end of their useful life, products are ultimately destined for the waste management system as consumer waste. Up until this point, the prevailing practice has been to dispose of these materials in landfill sites or incineration plants. This approach is not aligned with the tenets of a circular economy, as the products in question may contain valuable raw materials that should be returned to the economic cycle. Subsequent to the production and consumption phase, the objective of the reduction phase is to conclude the material cycle. (Charter/Tischner (Ed.) 2001).

Product ecology can be summarized as follows: The use of hazardous substances to the environment and health should be avoided.

Products should be designed to allow for resource conservation and minimal emissions, possess an extended service life, and be straightforward to repair and recycle. These objectives may be subject to some degree of overlap, but they may also be in competition with one another. In individual cases, it is important to utilise appropriate instruments, such as product life cycle assessments, in order to optimise the entire product life cycle. If all areas of a company that are affected by the product issue (e.g. R&D, materials management, marketing) are included in this optimisation, the result is an ecological product policy.

Function- and Needs-Oriented Corporate Policy

Both production ecology and product ecology concentrate on technological innovations. Nevertheless, these approaches are inadequate for fully exploiting the existing potential for efficiency. The functional orientation approach incorporates an additional dimension: benefit or functionality. The objective is to ascertain the benefits that a product offers the user and determine how this useful service can be provided ecologically efficiently. The objective is to provide services that meet consumer demand, focusing on the use of fewer ecologically compatible products. The functional orientation approach involves the integration of product and process innovations, as well as organisational innovations. In essence, the aim is to satisfy the service demanded by consumers with fewer but ecologically compatible products. A number of service concepts already exist that increase the ecological efficiency of goods through professional product usage management. (Göllinger 2012, Vester 2007).

The goods and services offered by companies represent specific solutions to problems encountered by customers or users. The user typically combines multiple goods and services to derive specific benefits. Such offerings may be designated as a "utility service" or "product as a service." One illustrative example is that of chemical companies, which offer application consulting services in addition to their chemical products. In many instances, this is the very factor that enables the effective and efficient utilisation of chemicals, as exemplified by the case of agrochemicals in agriculture. From the user's perspective, it is paramount to provide the desired chemical usage service through an optimal combination of chemical use and application advice.

The emphasis in usage-oriented services is no longer on the tangible benefit, but rather on the customer benefit that is effectively generated. The services are designed in such a way that the utilization potential of a carrier medium is used as intensively as possible. The service consumers can be either individual customers who borrow a carrier medium or several people who use a carrier medium together (e.g., car, washing machine, etc.). Rental of products is also included in these usage-oriented services, as are concepts of joint use of products (pooling and sharing).

The rental of products is by the manufacturer's product responsibility. In the event that the manufacturer rents out products, the products are returned after use. The manufacturer is then responsible for the recycling or disposal of the products. The manufacturer's economic interest is already geared towards recycling-oriented product design during the product development stage. If the products are made available to users via a pool, the manufacturer is interested in the longest possible and most intensive use. This is achieved by having several users in a pool, while a long service life is attained by a product design oriented towards the product's service life.

Expansion to Include Further Properties and Functions

An expansion to include further properties and functions is achieved by extending the ecologically compatible design of all infrastructures and processes to the buildings and land used, thereby creating factory and site ecology. In this context, the objective is to identify and assess the direct ecological impact of operational activities at the local site. The effects are particularly felt by local stakeholders, including residents, environmental groups, local government, and local service providers.

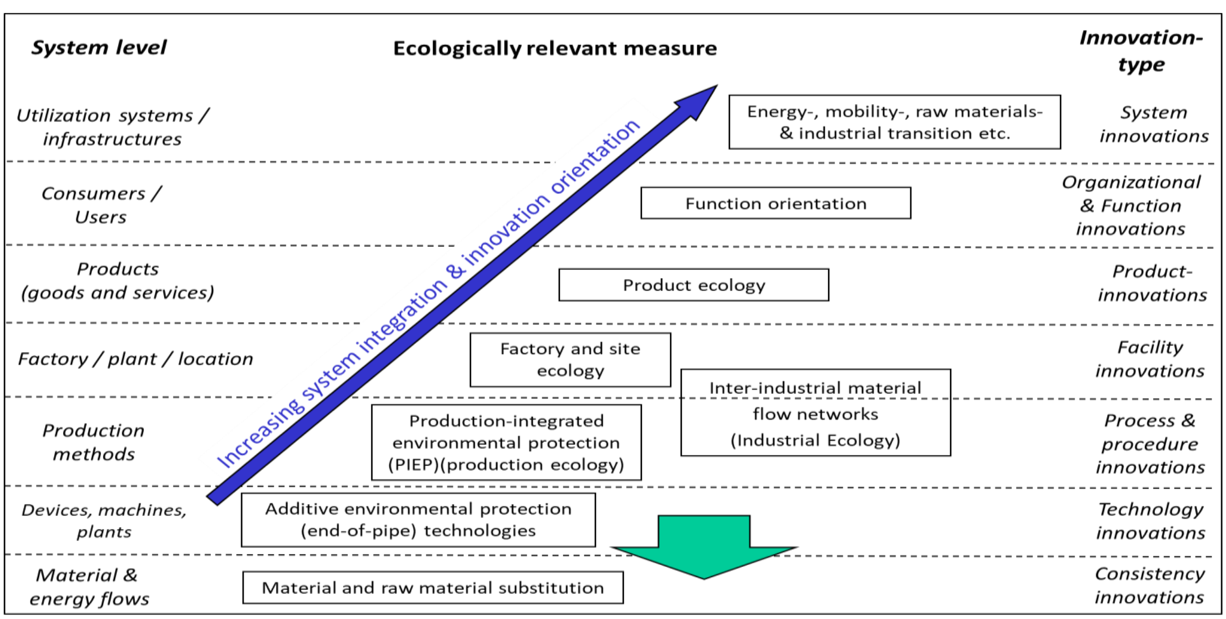
Socio-ecologically oriented processes are also integrated into the procurement of raw materials, consumables, and supplies and the distribution of goods. This corresponds to a functional, holistic approach in which the aforementioned processes of procurement, distribution, production, and product ecology are linked together. (Vester 1980, 1988, 2007).

INTERDEPENDENCIES OF THE SYSTEM LEVELS AND INNOVATIONS

In previous literature, analogous integration-oriented attributes have been identified as characteristics of environmental management, which can be considered a precursor to sustainability management (Göllinger 2012). To gain a more comprehensive understanding of sustainability that encompasses the social, socio-cultural, and societal dimensions, it is essential to integrate the aspects above.

There are numerous avenues for an ecological orientation of companies, occurring at disparate system or action levels and associated with diverse types of innovation. Figure 2 illustrates these system levels, measures, and innovation types in tabular form.

FIGURE 2
SYSTEM LEVELS, OPTIONS FOR ACTION AND TYPES OF INNOVATION IN THE GREENING OF INDUSTRY



The scheme presented gives the impression of a clear and linear layering of the individual levels and options for action or measures. However, an analysis of the interrelationships reveals that the scheme is, in fact, more complex and can be viewed in two fundamental aspects:

1. Interconnections between the levels: The levels are interwoven in a variety of ways, rendering it generally infeasible to view them in isolation. In particular, a substantial number of foundational repercussions on lower levels can be observed, as the following examples will illustrate.
   - For instance, process and procedural innovations that result in a reduction and/or alteration of the quality of operational emissions frequently necessitate the substitution of raw, auxiliary, and operating materials to ensure the optimal functioning of these novel processes.
   - This is particularly relevant in the context of the inter-company exchange of material flows within the framework of inter-industrial material flow networks.
   - In addition, product innovations within the context of product ecology may necessitate the implementation of alternative production processes. A central tenet of product ecology is the utilisation of alternative raw materials for products with a reduced environmental impact.
   - System innovations, such as the energy or mobility transition, typically necessitate the coordinated development of a multitude of innovations at the underlying levels. This is particularly relevant in the context of organizational and functional innovations that more closely align with the needs and expectations of consumers and infrastructure users.
2. The fundamental level of analysis is that of material and energy flows: The initial or fundamental system level (material and energy flows) serves as the foundation for all subsequent levels, as it possesses a dual and therefore optimal function within this comprehensive system.
   - From the perspective of operational material and energy flows, there is a clear opportunity for innovation in greening corporate activities. In this context, the substitution of problematic Raw, auxiliary, and operating materials is of particular relevance, as it represents a crucial avenue for advancing material and raw material innovations. In this context, the development of consistency innovations is of particular significance.
   - Conversely, the material and energy conversion processes that result from operational value creation are responsible for the material and energy flows exchanged with the natural environment. This implies that all innovations and measures at the other levels ultimately exert an influence on the first level (as evidenced by the large downward arrow in Fig. 4.6). This is because the various measures at these levels each serve the purpose of quantitatively and qualitatively modifying the material and energy flows induced by companies. In this respect, this level differs fundamentally from all other levels.

CONCLUSION AND OUTLOOK

There are numerous opportunities for industrial companies to implement innovations at different system and operational levels thereby reducing the environmental impact of operational value creation processes. The innovations mentioned initially extend to the level of material and energy flows, then cover the level of production processes and extend to the products. Additionally, consumer usage systems are encompassed. In addition to technological innovations, organizational and functional innovations are also necessary. With regard to this, there is an observable increase in system integration and innovation orientation can be observed with the ascending levels, which results in numerous repercussions and interdependencies between the levels and innovation arenas.

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