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Principles of Management Systems for Positive Impact Factories

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Abstract: The sustainable design of production systems is essential for the industry's future viability. In this context, the concept of positive impact factories has recently evolved, striving for a completely loss-free factory benefiting positively its surroundings. To establish a holistic view of this approach in everyday corporate life, it is necessary to develop a management policy with defined process flows in the sense of a dedicated management system. This paper thus reviews the scientific literature on (sustainable) management systems and develops a tailored management system for the example of the ultra-efficiency factory. In doing so, we specifically combine and complement established management systems such as environmental, energy and quality management, as well as compliance, maintenance, and lean management. In order to define an applicable framework, the basic considerations presented here were developed in cooperation with and reviewed by a large German automotive supplier. Thereupon, the results are discussed with regard to the future implementation of the system, and starting points for future research are derived.

Keywords: sustainable production; sustainable management; ultra-efficiency; positive impact factory

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1. Introduction

The transformation of traditional industrial value creation towards a sustainable way of production is essential for the future well-being of humanity. The challenges individuals and companies are facing in this context are manifold. Due to demographic change, individualization, urbanization, and digitalization, ensuring the continuous availability of resources and a drastic reduction in environmental pollution is indispensable [1–5]. In addition, there are general requirements concerning constantly stricter regulations and climate targets [6]. Only through enormous cross-sectoral efforts and by rethinking the production and consumption patterns can the satisfaction of the human needs of future generations be ensured within planetary boundaries [7,8]. This forces companies to internalize new ways of thinking. A sustainable, effective, and efficient design of production systems, both inside and outside the company boundaries, is necessary. In this context, the concept of a positive impact factory has recently evolved in the scientific literature. Instead of sticking to the efficiency paradigm, it is based on a metamorphosis towards eco-effectiveness. Figure 1 illustrates the concept, including an adaptive building shell, a flexible manufacturing system, modular and scalable technical building services, cyber-physical systems, a production cloud, and training environments, according to Herrmann et al. [9].

Another concept that aims at a holistic improvement of manufacturing systems is the ultra-efficient factory. It differentiates between five performance areas: energy and material efficiency, emission reduction, organization, and human resources [10,11]. Joint consideration of both approaches to realize a waste-free factory that contributes positively to its immediate environment and is embedded symbiotically in its urban surroundings. To establish a holistic view of these concepts in a company's daily operations on all levels, a management policy with defined process flows and iterative procedures in a holistic management system (MS) is needed. However, since the introduction of both the positive impact and the ultra-efficient factory, no tailored MS has been presented. Current MS and approaches, such as quality [12], energy [13], and environmental management systems [14], only partially fulfill the requirements of holistic management. Therefore, a new approach is necessary that internalizes the holistic way of thinking and acting, uses synergy effects with the environment, and considers conflicting goals at an early stage. This also includes internalizing the resulting ecological effects in the costs [15]. Thus, the objective of this paper is to outline the principles of management systems for positive impact factories. By using the example of the ultra-efficient factory, we compare the recent literature on management systems with the requirements of the holistic view needed here. Finally, we outline the definition and principles of a tailored management system and discuss implementation issues. The paper is structured as follows:

Section 2 briefly describes the methodology for defining the principles of management systems for positive impact factories, as well as the definition of the concept of the ultra-efficient factory and relevant management systems and concepts. Section 3 describes the results of the basic considerations on the structure of the UEMS. The discussion in Section 4 introduces existing gaps that need to be filled in order to move from basic considerations to a clear definition. Furthermore, a first evaluation of the implementation of the UEMS in a large German automotive supplier is described.

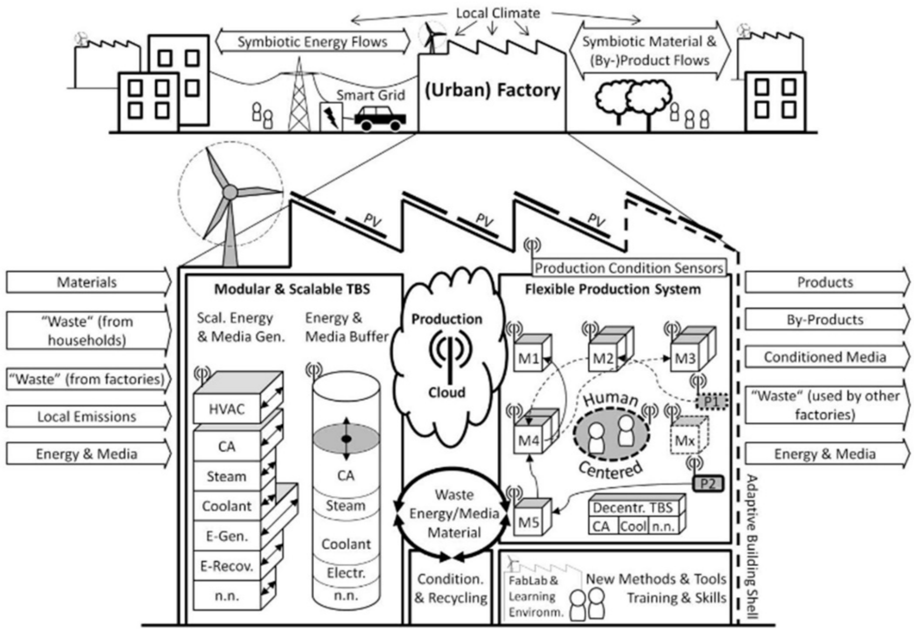

Figure 1. Enablers for a positive impact factory according to Herrmann et al. [9].

2. Methodology and State of the Art

2.1. Methodology

To meet the requirements of a positive impact factory, the scientific literature on (sustainable) management systems (MS) was reviewed using the example of the ultra-efficient factory. The basis of most management systems and approaches is DIN SPEC 36601. According to DIN SPEC 36601 [16], a management system consists of interconnected and mutually influencing elements of an organization to define policies, objectives, and processes in a way that the objectives of an organization can be achieved. A management system can be multidisciplinary, and its scope of application can cover the whole organization as well as its specific functions. The use of management systems results in stable processes that deliver the required output as well as a structured approach to the development, implementation, and continuous improvement of an organization's management [17–19]. To ensure consistency and conformity with ISO management system standards, a high-level structure (HLS) was introduced. The harmonized structure (i.e., identical clause numbers, clause titles, text, and common terms and key definitions) for use in management system standards is described in DIN SPEC 36601, which, therefore, provides a basis for the development of the UEMS [16,20].

To outline a definition for a so-called ultra-efficient management system (UEMS), it was necessary to consider content overlaps and synergy effects between the five fields of action in ultra-efficiency when selecting suitable management approaches. Therefore, already established management systems such as environmental, energy, and quality management were used to define the basics (Section 2.3). The literature on (sustainable) management systems was investigated using the example of the ultra-efficient factory with the requirements of positive impact factories.

In addition, developing an MS for positive impact factories also requires the establishment of a methodological basis. For this purpose, a comprehensive analysis of suitable methods from different fields in the literature, such as Life Cycle Sustainability Assessment [21], Lean Management [22], or decision-making, was also conducted. The method selection was based on two selection criteria. First, the output of the method had to contribute to the goals of the ultra-efficiency or positive impact factory, and second, the method could not represent a management system alone. The detailed classification of the methods is described in Section 3.9.

The basic considerations and principles for the management system and the methodological toolbox presented here were developed together with a large automotive supplier from Germany. For this purpose, five structured and moderated workshops were conducted with participants from the top management level as well as management system representatives (lean management officer, environmental management system officer). In the first workshop, the general conditions of the management system to be developed were discussed. The aim was to create a common understanding of ultra-efficiency and to discuss an initial rudimentary concept for the UEMS. In the second workshop, the basic structure of the management system was defined, and the first components of the methodological toolbox were discussed. The basis for defining the basic structure was provided by the existing management systems of the automotive supplier. In this context, the guidelines, methods, and processes of the automotive supplier were also checked for their integration into the MS described here. In the third and fourth workshops, the initial definition and principles of the UEMS summarized here were presented to members of the top management of the site of the automotive supplier, discussed, and minimal adjustments were made. In addition, current obstacles and gaps to implementation into the existing management systems were defined. In the concluding fifth workshop, the implementation at the process level and the further development of the system were addressed. In particular, the aim was to make the results from the application of the UEMS measurable and assessable. To this end, an initial, simple system of key performance indicators (KPI) was developed, and the information required for this and the interfaces to existing management systems were defined. However, this is not part of this publication.

In addition to the workshops, regular exchanges took place between the stakeholders to discuss progress on the initial definition and methodological toolbox of the UEMS, as well as difficulties/challenges. In conclusion, starting points for further research were derived from this (Section 4).

2.2. Defining Ultra-Efficiency

The main goal of ultra-efficiency is to achieve completely lossless and load-free value creation while making a positive contribution to the urban environment through symbioses [11]. The scope for consideration ranges from processes in the factory to the production level from the urban environment to the global level. This guarantees a holistic approach [23]. Material, energy, human resources, and capital should be used in such a way that emissions and waste are avoided. By improving not only the efficiency of the production output but also the consumption of resources, the ultra-efficiency enables a simultaneous increase in eco-efficiency while realizing eco-effectiveness [24–26]. Influenced by the emerging potentials of digital and biological transformation [27,28], new methods and opportunities are enabling the future development of the ultra-efficiency factory. Contrary to other approaches, the ultra-efficiency factory reveals existing and emerging conflicting goals in an early stage with the help of its holistic consideration [25]. This is achieved, among other things, by explicitly considering defined target states in the five fields of action. Thus, it is ensured that the three dimensions of sustainability--ecology, economy, and social issues--are taken into account. Extending the consideration to a global level is particularly important when it comes to the integrated implementation of sustainability. Figure 2 illustrates the concept.

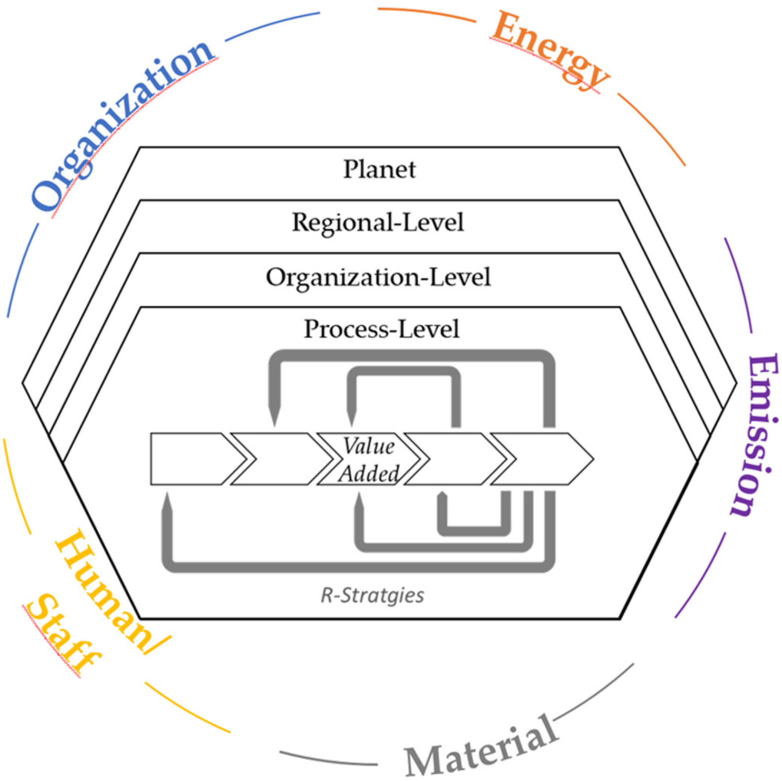

Figure 2. System model with ultra-efficient added value on different levels, including the five fields of action, based on Miehe et al. [11].

2.3. Underlying Management Systems for an Ultra-Efficient Management System

The existing literature mainly studies the opportunities and possibilities of integrated management systems (IMS) concerning the sustainable management of companies [29–36]. Jorgensen and Herreborg, as well as Souza et al., choose a different approach since they discuss the combination of different management systems towards a sustainable system in their analysis [37,38]. The basic considerations for the UEMS presented here differ from existing approaches in that the UEMS can neither replace an IMS nor represent a combination of different management systems. Instead, it is to be understood as an independent management system that takes into account synergies and interactions between the five fields of action covered by ultra-efficiency. These fields of action can be directly linked to the management systems of quality (ISO 9001) [39], environment (ISO 14001) [14], energy (ISO 50001), compliance (ISO 37301) [40], maintenance (DIN EN 13306, DIN 31051) [41,42], and lean (VDI 2870) [22] which is why they are taken into account for the basic considerations of the UEMS. These links are shortly described in Table 1.

Table 1. Links between the considered management systems for UEMS and fields of action of ultra-efficiency.

Management System/Concept	Refs.	Related Field of Action	Common Purpose
Energy	[13,23]	Energy	Improving energy-related performance, energy efficiency, energy use, and energy consumption
Environment	[14,23]	Energy Emission Material	Improving environmental performance, meeting binding commitments, reducing negative impacts on the environment, achieving environmental goals, and raising environmental awareness throughout the product life cycle
Compliance	[23,40]	Material Human/Staff Organization	Fulfilling material compliance Contributing to the socially responsible behavior of organizations, compliance with ethical principles and social expectations Introducing and shaping an organizational culture
Quality	[39]	Material Human/Staff Organization	Ensuring dependence of quality on the performance of employees and on the materials used Consistently high-quality products through a resilient organization with stable processes
Maintenance	[41]	Energy Organization	Enabling energy-efficient production methods and ensuring them long term Ensuring the resilience of an organization by eliminating certain risks
Lean	[22]	Material Human/Staff Organization	Avoiding raw material-related waste Using methodical approaches to support employees; waste has human causes Improving the organization by creating transparency, flexibility, and adaptability

3. Basic Considerations for a Management System for Positive Impact Factories

To run positive impact factories, processes have to be flexible, robust, and resilient. The same applies to the basic considerations of its management system. In the following, the fundamental pillars and principles of a management system are discussed using the example of an ultra-efficient factory. To define and describe the latter, a definition of ultra-efficient management is necessary. Therefore, the definition of the term management by Schreyögg and Koch [43] is expanded.

Ultra-efficient management includes all activities of planning, execution, monitoring, and control measures through an integrative, systematic consideration of the five fields of action, energy, emissions, material, organization, and human/staff, for the well-being of the company and all stakeholders involved. Synergies and interdependencies across all fields of action have to be taken into account. Therefore, a systemic process approach is fundamental.

The UEMS thus encompasses the integrated activities by which an organization systematically identifies necessary processes and resources in and across the action areas of energy, emissions, materials, organization, and human/staff that are required to achieve ultra-efficiency or to realize ultra-efficient actions. The components of the system include organizational context, leadership, planning, support, and operations, as well as performance evaluation and improvement. By drawing on methods, tools, and design principles from the disciplines mentioned in Section 2.3, the UEM system has comprehensive resources to identify actions to address the intended and unintended consequences of processes throughout the organization and its functional areas.

The UEMS differs from existing management systems in its holistic approach to economic, ecological, and social challenges by building on the contents of existing management systems and extending them towards ultra-efficiency. In other words, the UEMS leverages the processes, standards, and methodologies of these existing MS links to resolve conflicting goals and uses positive interaction between them to achieve ultimate efficiency.

The basic considerations of the UEMS consider all fields of action of ultra-efficiency, which marks another unique selling point of this management system. According to the HLS of DIN SPEC 36601, the Plan-Do-Check-Act cycle is the basis of the UEMS [16]. The cyclical approach enables the implementation of the process-based approach of the UEMS, according to which the output of an activity, in turn, represents the input for the next activity.

Only by taking into account the four phases of the PDCA cycle do the interrelationships and interactions of the individual processes and underlying MS become transparent. The structure of the UEMS is shown in Figure 3.

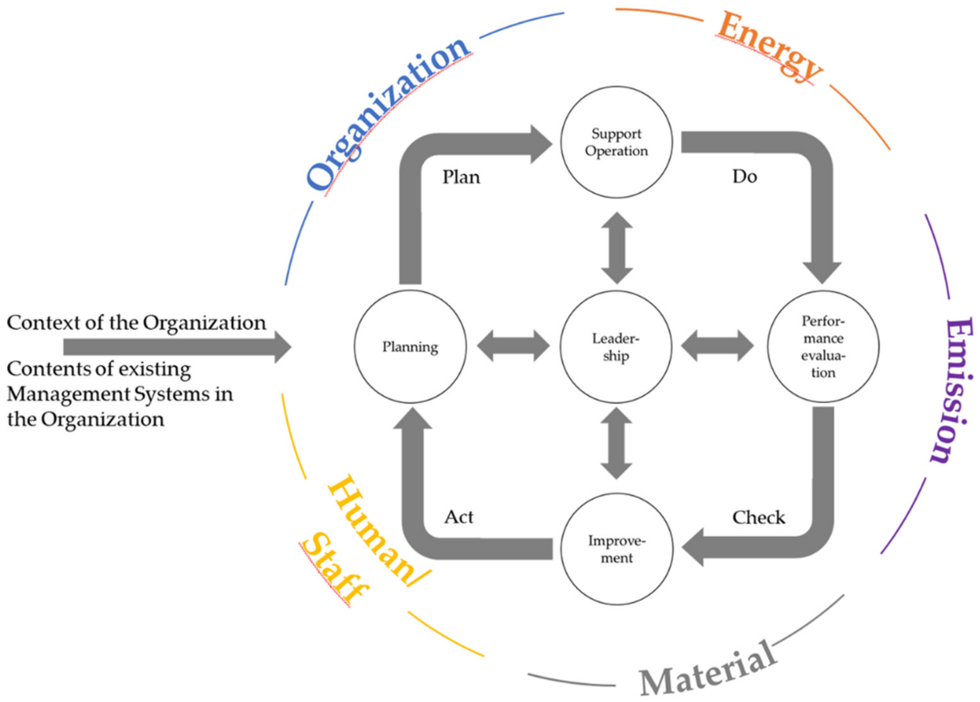

Figure 3. Structure of the UEMS.

The organization's context influences the entire management system and brings in external factors. These include all issues from the "legal, technological, competitive, market, cultural, social, and economic environment" [39]. In the center of the illustration is the leadership component, which has a reciprocal relationship with the five operational components of planning, support, operations, performance evaluation, and improvement. These can be assigned to the individual phases of the PDCA cycle in terms of content. In the following, the basic considerations per element, the methods, and the design principles are examined in more detail.

3.1. Scope

The UEMS, as currently defined, provides a first orientation framework that supports organizations to achieve the ultra-efficiency goals described in Section 2. The result of the UEMS should be the standardized and holistic control, organization, and planning of operational performance with regard to the ultra-efficiency aspects represented by the five fields of action. The UEMS is not defined for a specific industry, type, or size of the organization and can be used regardless of geographic, cultural, and social conditions [39,44]. This enables the increased use of the system in practice, which is essential for the overall objective of ultra-efficiency. After all, it is the symbiotic exchange with the environment and the sharing of resources among organizations that create sustainable ways of conducting business and enables successful incorporation into urban spaces [24].

3.2. Context of the Organization

To address the purpose and strategic direction of the organization, internal (values, culture, knowledge, and performance of the organization) and external (legal, technical, competitive, market, cultural, social, or economic environment) factors influencing the achievement of objectives must be identified. For this purpose, the internal and external factors already identified by other management systems used in the organization can be used. The same applies to the analysis of all interested parties in areas of the environment, customers, competitors, trade unions, regulatory authorities, owners, and individuals. However, for the implementation of the UEMS, it is crucial to understand their requirements and expectations in terms of ultra-efficiency and to investigate their influence on the UEMS. The requirements and expectations of interested parties can be determined with the help of the various methods in the methodological toolbox (Section 3.9). In addition, the defined design principle (Section 3.10), "Participation orientation and stakeholder dialog", pick up content to monitor and review stakeholder requirements and expectations over time so that the corresponding content of the UEMS can be adjusted as necessary.

Finally, the area of application is specified. Physical or organizational system boundaries must be defined for this purpose. For the implementation of the UEMS, it is possible to set physical boundaries, i.e., the consideration of a single site, but a product line is also possible. Due to the holistic nature of the UEMS, it is not expedient to set organizational boundaries since this would result in increased individual optimizations, which contradicts the idea of ultra-efficiency. In addition, the aim is to overcome divisional thinking, which could not be achieved by setting organizational boundaries. Porter [45] describes the value activities within the value chain that must be fully considered in the physical scope delineation to cover all functional areas within the organization. In addition to primary value activities such as inbound and outbound logistics, operations, marketing and sales, and customer service, secondary value activities (business infrastructure, human resources, technology development, and procurement) must also be considered. However, it is imperative to consider the entire supply infrastructure and factory building and how it fits into the urban and global environment, regardless of the defined boundaries.

3.3. Planning

Since the UEMS takes a holistic view of the organization and its urban environment and does not focus on any specific area, it is also imperative to take a holistic view of all the possible opportunities and risks and the measures to avoid them. The methods listed in the method toolbox (Section 3.9) to identify the opportunities and risks cover all five fields of action. The measures of the organization's actions can then be derived based on the defined opportunities and risks. If the opportunities and risks of other implemented MS are already available, these should also be included in the investigation. In managing opportunities and risks, the measures defined are intended to ensure that the UEMS can achieve the desired results [16].

In addition, ultra-efficiency targets can be defined in management, describing a result of a strategic, tactical, or operational nature. These goals may relate to different disciplines and apply to different levels of ultra-efficiency (Figure 2). They must meet the following requirements:

1. Ultra-efficiency goals are precisely described and understandable for all stakeholders.
2. Ultra-efficiency goals are consistent with the design principles and corporate policy in general, as well as the ultra-efficiency policy.
3. Ultra-efficiency goals contribute to the implementation of identified opportunities.
4. Ultra-efficiency goals are measurable.
5. Ultra-efficiency goals have defined responsible parties.
6. Ultra-efficiency goals can be implemented and adjusted if necessary.
7. Ultra-efficiency goals must be communicated, monitored, and documented within the organization.

In addition, both the scope of the goals and a plan to achieve them must be defined. Strategic goals are checked using an individual UEM-Audit; tactical and operational goals are evaluated through a company-specific key performance indicator system based on the benchmark defined by Waltersmann and Kiemel et al. [10]. If changes to the UEMS are necessary, it must be ensured that they are still compatible. In addition, the consequences of the changes must be fully identified and evaluated in advance.

3.4. Support

The support component summarizes the basic requirements for resources, competencies, awareness, communication, and documentation that help implement the management system.

To enable the establishment, realization, maintenance, and improvement of the UEMS, all necessary resources must be determined and their availability ensured [16]. In the sense of ultra-efficiency, the organization's environment must also be considered, in particular, to implement cooperation strategies regarding necessary resources if necessary. In UEMS, resources include materials, personnel, energy, infrastructure, collected production data, a suitable process environment, and knowledge. The process environment plays an important role, especially in the field of action human/staff. It includes social, physical, and psychological factors and thus influences the organization's environment. It also considers the influences of the environment during implementation.

To provide all the necessary competencies and qualifications for the UEMS, the required competencies must be defined. For this purpose, the people responsible for the respective management system (e.g., energy management officer for the field of action energy) must be involved to facilitate a holistic analysis. It is essential to create awareness within the organization regarding ultra-efficiency and the content of the UEMS, and also in achieving the ultra-efficiency goals. Employees are made aware of their contribution to the system's effectiveness, and the benefits of improved performance can be communicated. Awareness can be created with the help of regulated communication.

The communication strategy of the organization and the UEMS build on each other. The communication processes must ensure that the information communicated is consistent with the information generated and that it is reliable. In addition, the communication strategy must consider and respond to relevant questions, concerns, and other communicated input from interested parties. An established communications strategy provides the foundation for implementing continuous improvements to the UEMS and its performance.

Finally, the support component includes the documentation of all the information necessary for the effectiveness of the UEMS following the organization's requirements. The amount of documented information may vary due to several factors, such as the organization's size, activities, number, and complexity of the production processes. Those made be available to the interested parties.

3.5. Operation

The operational planning and control of UEMS processes are carried out in accordance with defined design principles (Section 3.10) and considering the defined measures (Section 3.2). To address ultra-efficiency, it is important that design production processes are symbiotically loss-free and emission-free, which is why an analysis of the required inputs and the expected results of the process is particularly important. To uncover possible synergies, it is also vital to identify and analyze the interactions between the processes. Processes need to be constantly monitored and reviewed for their efficiency and effectiveness with respect to ultra-efficiency. Where necessary, a timely adjustment should be made in line with the activities described in Section 3.7 to ensure that the intended objectives are met at all times. Regarding the process design, responsibilities for the processes must be assigned, and the availability of the required resources must be ensured. The release of products and services must be integrated into the processes so that the requirements for the product meet the UEMS. In addition, processes for controlling non-compliant results need to be defined and initiated to ensure high quality and to identify deviations from the target state on time [16]. For example, the processes of the quality management system can be built upon.

The holistic elaboration of the product life cycle has a high priority for ultra-efficiency. Among other things, it considers the recycling-friendly design of products to enable the reusability of raw materials. Considering the entire product life cycle, this includes all post-sales processes that the customer receives in the sense of services. This means that after-sales activities, such as service and maintenance, must meet ultra-efficiency requirements. To close (material) loops, raw material tolerant processes are essential. To ensure this, an analysis of the resource criticality of the materials and raw materials used in the production process and the consideration of material compliance requirements are necessary [46,47].

All these requirements are defined in the company's product development process. In particular, upstream and downstream processes must also be considered. To this end, the aforementioned product requirements must be integrated into the company's existing supplier strategy, and new external suppliers must be selected according to the defined criteria to ensure that they are compatible with the ultra-efficiency goals. The UEMS, therefore, also serves as a control authority to verify the product requirements defined in the product development process.

3.6. Performance Evaluation

Monitoring, measuring, analyzing, and evaluating performance provides information on the implementation of the planning, performance, and effectiveness of the UEMS. It reports any need for improvement back to the management system. Organizations must define what needs to be monitored and measured, what methods to use when to perform monitoring and measurement, and when to analyze and evaluate the monitoring and measurement results [16]. The benchmark developed by Waltersmann and Kiemel [25] is used to evaluate operational and tactical targets. The benchmark application requires company-specific data, which implements the design principle of fact-based decision-making (Section 3.10). Strategic goals are evaluated by a UEM audit that is yet to be defined. By conducting both internal and external audits at regular intervals, the suitability of the activities to meet the requirements of the UEMS can be reviewed, adjusted, and improved. The outcome of ultra-efficiency audits in the ultra-efficiency action areas is the assessment of all individual actions that support the validation of ultra-efficiency in the overall context. It must be taken into account at this point that interfaces to audits of the other management systems must be defined. In addition to the performance evaluation, the management system must also be evaluated by the company's management to analyze decisions and actions on opportunities for continuous improvement, the use of new technologies, future collaborations to exploit synergies, and the need for change in the UEMS.

3.7. Improvement

With the help of the performance evaluation, areas with activities, tasks, and processes that have the potential for improvement can be identified. If non-compliant UEMS requirements are identified, corrective actions must be defined, and the immediate consequences of the non-compliance must be addressed. Subsequently, the root cause of the nonconformity must be identified and eliminated to ensure ultra-efficient operations in the long term. It must also be investigated whether similar nonconformities may occur in the future. The corrective actions that are taken must be verified for effectiveness using monitoring, measurement, analysis, and evaluation methods and be consistent with the requirements of the UEMS. To continuously improve the suitability, adequacy, and effectiveness of the UEMS, the previously defined weaknesses of the system must be taken into account so that further development of the UEMS is possible.

3.8. Leadership

The centrally located strategic component leadership in Figure 3 influences all operational components. The leadership goal is to implement the requirements of the UEMS, achieve the intended ultra-efficiency goals, and perform feedback of the generated information to leadership and other relevant people. In addition, these must be aligned with the strategic direction of the organization. The same also applies when making strategic decisions.

In addition, top management must verify that the requirements of the UEMS are integrated into the business processes and that the necessary resources (Section 3.4) are available. Furthermore, the importance of an effective UEMS must be communicated by the management, as its introduction will involve a change in thinking. It may overturn or advance familiar approaches and thinking principles, depending on the maturity of the organization. The successful implementation of the UEMS requires that individuals at all levels of the organization actively participate and identify with the design principles and ultra-efficiency policy.

Another management task is to introduce a policy that meets the UEMS and enables its realization. The principles of action of the ultra-efficiency policy are reflected by the design principles (Section 3.10). The defined policy provides a framework for setting ultra-efficiency targets and includes a commitment to meet the corresponding requirements and to improve the UEMS continuously. The goal of the successfully implemented ultra-efficiency policy is to provide the organization with a framework for action to act in the interests of ultra-efficiency and, thereby, achieve the goals of the UEMS. The ultra-efficiency policy must be compatible with the corporate policy, as well as the strategic direction, and be extended according to the criteria of ultra-efficiency.

Further, it is the responsibility of the leadership to define the necessary responsibilities and authorities of the corresponding roles within the UEMS. This ensures that the requirements of the UEMS are implemented, the intended ultra-efficiency goals are achieved, and the generated information is fed back.

3.9. The Methodological Toolbox for the UEMS

In addition to the fundamental considerations of defining an ultra-efficient management system, both performance evaluation and the methodological foundations of the management system (esp. the context of the organization, support, improvement, leadership, and evaluation of performance) are essential. By addressing methods and tools from the disciplines of lean, environmental, compliance, quality, energy, and maintenance management, the UEMS has comprehensive means to identify actions to address the intended and unintended consequences of processes throughout the organization and its functional areas.

The methodology toolbox was developed through a comparative analysis of existing management systems (Table 1) and their methods, as well as an analysis of the literature regarding the fields of action. Likewise, the methodology toolbox was evaluated by a German automotive supplier and supplemented by additional methods. It includes numerous methods from a wide range of areas assigned to the management systems under consideration. The management system standards that were compared in terms of content for the initial definition of the UEMS mainly contained general formulations and statements about the respective management system without a methodological basis for implementation. Therefore, the methodological toolbox facilitates the introduction, implementation, maintenance, and improvement of UEMS in an organization. At the same time, the methods are not designed for a specific industry, type, or size of the organization and can be used regardless of the geographic, cultural, and social conditions of the organization, thus ensuring broad applicability. Certain methods of the methodological toolbox are assigned to several components, emphasizing the interoperability of the selected methods with the content of the management system. Concerning the degree of maturity of the methodological toolbox, it must not be regarded as complete. The methods of it have not yet been validated for their effectiveness for ultra-efficiency. Therefore, an extension of the methodological toolbox according to the needs and requirements of the respective organization is conceivable at any time, taking into account the goals of ultra-efficiency. Table 2 depicts the methodological toolbox's structure as well as the classification of its selected methods.

Table 2. Overview of the methodological toolbox.

	1. Level	2. Level	3. Level	4. Level	5. Level	6. Level	Field(s) of Action				
	Phase of the PDCA-Cycle	**Component of the Management System**	**Content of the Component**	**Method**	**Sub method**	**Further Detailing**	(orange)	(purple)	(grey)	(yellow)	(blue)
Examples	Plan	Planning	Determine risks and measures to deal with risks	Criticality Assessment	Plant Criticality Assessment		x				x
					Raw Material Criticality Assessment						x
				Failure Mode and Effects Analysis			x	x	x	x	x
			Determine opportunities and measures to deal with opportunities	Early Warning System			x				x
				Cardboard Engineering						x	
	Do	Support	Determine and provide required resources	Visual Management	5 S					x	x
					Andon-Board				x	x	x
				Chaku Chaku						x	x
			Ensure competence of personnel and development	Kata Coaching						x	x
				360 degree Feedback						x	
		Operation	Operational planning and control	Process Simulation			x		x	x	x
				Kanban							x
			Requirements for products, services, and processes	Environmental Design of Industrial Products					x		x
				Visual Management	Critical to Quality Tree						x
	Check	Performance Evaluation	Monitoring, measurement, analysis, and evaluation	Sustainability Balanced Scorecard			x	x	x	x	
				Ecological Evaluation	Impact assessment	Life Cycle Assessment	x	x	x		
					Continuous Energy Monitoring System		x	x			
				Economic Evaluation	Cost–benefit Analysis	Cost-effectiveness Analysis	x	x	x	x	x
						Damage Cost Approach	x	x	x		
			Internal Audit	EMAS			x	x	x		
	Act	Improvement	Determine and select opportunities for improvement	8D- Report							x
				Visual Management	Problem Solving Board					x	x
				Maturity Model						x	x
			Nonconformity and corrective action	Environmental Impact Assessment			x	x	x		
				Integrated Hazardous Material Management					x		

Each color in the outer right-hand columns of the table represents a field of action for ultra-efficiency: orange stands for Energy, purple represents Emissions, grey relates to Material, yellow covers Human/Staff and blue refers to Organization.

The methodological toolbox is divided into six levels. The degree of detail increases with the number of levels. The sixth level is followed by an assignment of the method to the five fields of action. For clarity, the illustration uses the color coding of the fields of action from Figure 3. The four phases of the PDCA cycle are located on the first level. The components of the management system are, if possible, assigned to the four PDCA phases on the second level. The third level describes the content of the respective component. It differentiates the various tasks to be performed within the component so that the methods can be specifically assigned on the three further levels 4–6.

3.10. UEMS Design Principles

The design principles (DP) define the principles or mental maxims that must be internalized and applied by all operators for the successful introduction and establishment of the UEMS. In addition, the DP listed here contributes to the implementation and maintenance of an ultra-efficiency policy and, thus, defines the organization's principles of action. The definitions of the DP are based on the definitions of ISO 9000, Eco Lean Management [12,48], and Pfeiffer and Weiß [49]. A total of seven overarching design principles and another seven subordinate DPs have been defined as contributing to the fulfillment of the overarching DP. However, the content of each GP is to be understood independently. They are presented in Table 3. Some are examined in more detail below.

Table 3. Overview of the design principles of the UEMS.

Overarching Design Principle	Subordinate Design Principle
Holistic thinking and acting	Avoiding divisional thinking Systemic thinking and acting Process-oriented thinking and acting Life Cycle Thinking
Conformity/Compliance	-
Transparency	-
Corporate social responsibility (CSR)	Participatory orientation and stakeholder dialogue
Risk-based thinking	
Fact-based decision making	
Continuous improvement process	Standardization Consistency and consequence in thinking and acting

Holistic thinking and acting means evaluating problems and improvements in the system context (organization, material resources, technology, personnel, natural environment, etc.). The goal is the identification and elimination of problem causes, not problem symptoms. The DP transparency serves to uncover existing obstacles and weaknesses as well as to highlight potentials within the company and inspire confidence among the stakeholders. Transparency can be created concerning every substance, material, and assembly used, material flows, energy consumption, and emission generation, about corporate goals or diverse activities, tasks, and processes.

Risk-based thinking describes the planning and implementation of actions to address risks and opportunities so that intended objectives can be met and undesirable outcomes are avoided. It forms the basis for increasing a management system's effectiveness as it takes into account the handling of incomplete information, unpredictability, and lack of understanding [16,17]. Decision-making is a complex process, as a large number of imponderables occur, involving various aspects that must be taken into account. Decisions based on facts and data or information evaluations reduce the degree of uncertainty and are more likely to lead to the desired results (fact-based decision-making) [12]. This reflects the benefits arising from digitization.

4. Discussion

The descriptions in Section 3 contain basic and general considerations for defining a UEMS or principle for a management system with positive impact factories. These were finalized in the fourth workshop together with a large automotive supplier in Germany. In this context, the integration of the UEMS into the existing management systems was also analyzed. This can be summarized as follows for the five fields of action:

A comprehensive energy management system has already been implemented for the field of action energy. Here, it is particularly important to define the relevant KPIs and threshold values for complete ultra-efficient performance evaluation. If possible, this should be undertaken at the process level (e.g., energy requirements at the plant level) but also at the site level (primary energy generation at the site). This also applies to the material field of action. Here too, key figures such as material consumption and scrap per plant must be calculated at the process level or the use of secondary materials at the site level. In organizational terms, there is already extensive internal documentation of the management systems currently in use. This can be used ideally to integrate the system into the existing management systems, first at the process level and then, in the long term, to roll it out at all company levels following the PDCA cycle to identify and analyze all responsibilities and processes of the UEM system, and to transfer the UEMS to the existing documentation form. This also enables an initial analysis of potentially conflicting goals and positive interactions with the management systems already in place. It is also important to support all employees in the operational introduction and establishment of the UEMS (Section 3.4). For example, the change management of the automotive supplier can provide support here. Particularly for the field of action emissions, profound information is already available for the site under consideration through a detailed environmental management system. However, the goals, for example, of a climate strategy must also be transferred to the management system.

In further cooperation, the definition of the ultra-efficiency management system, in particular, is specified to ensure the implementation of the UEMS. In addition to the step-by-step operational implementation of the system at the process level (e.g., placing the system on the store floor through suitable visualizations), the requirements and potential analysis for operational implementation are conducted with the relevant managers and employees. The goal is to develop a common vision for the UEMS and to identify initial starting points for optimization potential in terms of ultra-efficiency. The UEMS methodological toolbox (Section 3.9) is also tested for effectiveness by applying the collected methods and evaluating their results. Through the collaboration, some advantages and disadvantages in the application of the system were also discussed. These are summarized in Table 4.

From the advantages and disadvantages mentioned above, as well as from the co-operation with the automotive supplier, further research needs can be derived for the development of a generally valid and application-oriented definition of the UEMS.

To ensure that the UEMS takes into account all aspects relevant to the implementation of ultra-efficiency, other relevant management systems must be identified and analyzed with regard to ultra-efficiency and integrated into the UEMS. This leads to a complete description and differentiation of the UEMS from the existing MS. Thereby, the holistic character of the system is ensured. This can be achieved by taking into account all the relevant management systems, existing conflicts of interest, and interrelationships that are identified at an early stage. For the application-oriented implementation, there is still a need for significant research, especially at this point. Initial starting points for this are offered by a company-specific interaction analysis. The goal must be to ensure that an adjustment, for example, in the production process through the intervention of the UEMS, does not lead to the deterioration of other management systems.

Table 4. Advantages and disadvantages of UEMS.

Advantages of UEMS	Disadvantages of UEMS
• Holistic optimization of value creation within the company as well as positive impact on the urban environment (e.g., reduction in emissions, an increase in resource efficiency, reduction in residual, and waste streams)	• The implementation and application of the UEMS are very effort-intensive and company-specific. All existing processes must be checked for integration into the UEMS
• Provision of a wide range of analytical tools and methods for optimizing value creation on all levels	• No uniform performance evaluation of ultra-efficiency management based on KPIs exists to date
• Application of the UEMS is possible at all company levels. From the process level to that of a site and up to the global level	• Requires a very high level of competence, both for the integration of existing management systems and for the implementation of ultra-efficiency.
• Support in the identification and resolution of conflicting objectives within existing management systems	• Strategic goals established by the UEMS cannot yet be evaluated
• Avoidance of multiple works through the expansion of existing management systems	• Centralized data storage and management requires detailed and potentially complex allocation of access rights
• Improvement of internal transparency through the holistic view of the UEMS. All data and information are located in a central entity	• The characteristic of centrality increases vulnerability if security systems are compromised

To achieve the goals of ultra-efficiency or positive impact factories (e.g., holistic action), it is necessary to transfer the associated requirements and considerations to the entire process chain. To consider the further impacts on MS, it is necessary to define how organizations could successfully transfer the requirements and goals of ultra-efficiency to the entire process chain. This also requires differentiating the ultra-efficiency policy from the policies of other MS and defining a set of criteria for the ultra-efficiency policy. At the same time, organizations need to work out the individual interfaces to their existing policies to ensure a targeted deployment. Furthermore, it must be examined how the ultra-efficiency policy can ensure that the defined ultra-efficiency goals are achieved. It must become clear how the policy can reinforce the desired effects.

In order to assure the application of the UEMS, key performance indicators must be defined. The standard DIN EN ISO 14031 [50] defines the implementation of a performance evaluation in environmental management. The transfer of this or a similar standard to ultra-efficiency is necessary to carry out a qualitative and quantitative performance evaluation with the help of key performance indicators. The concept of Waltersmann and Kiemel [25], as well as Jasiński et al. [51], can provide the first basis for this. This can be extended at any time to include company-specific performance indicators. It is central that the KPIs of a UEMS system can be monitored and controlled. In addition, it is necessary to define the threshold values at which measures for improvement must be taken by the UEMS or top management. Furthermore, it must be checked in which type and quality all the necessary information and data are available in the company and whether they are traceable to enable the performance evaluation. As described in Section 2.1, further coordination has already taken place here with a German automotive supplier. Other considerations include using an organization's existing performance metrics to conduct a performance evaluation and monitoring the activities, tasks, and processes relevant to the evaluation of these. In addition, to evaluate strategic ultra-efficiency goals, the content, processes, and criteria for conducting an ultra-efficiency audit must be defined. This should also be taken into account when defining key performance indicators.

5. Conclusions

Sustainability is the inherent challenge for industrial production's future. Therefore, science increasingly focuses on the design of sustainable production systems. In this context, the concept of positive impact factories with ultra-efficiency factories as a prominent representative has emerged, aiming at an altogether loss-free factory that has a positive impact on the urban environment. To enable the consideration of these concepts in a company's daily business, it is necessary to establish a holistic management system, including management policies with defined process flows and iterative procedures. This publication defines the basic considerations and principles for such a management system, using ultra-efficiency as an example. The basis for this was an extensive review of the current scientific literature on existing (sustainable) management systems and close cooperation with a large German automotive supplier. The developed framework was iteratively discussed and refined in several workshops with the industrial partner. The ultra-efficient management system aims to support organizations in introducing and implementing ultra-efficient thinking and acting within the organization. The ultra-efficiency management system differs from existing management systems in its holistic approach by addressing economic, environmental, and social challenges. This is achieved by building on the content of existing management systems and extending them toward the five fields of action for ultra-efficiency. In addition to the basic considerations for the definition, methods, and tools from a variety of management systems, relevant subject areas (e.g., decision-making) were transferred into a multi-level methodology toolbox. This is intended to facilitate the implementation, maintenance, and improvement of the management system in an organization. To extend the holistic view of the system, principles were defined, which are to be internalized and applied by all employees. This made it possible to discuss the integration of the management system into existing structures. In this context, the advantages and disadvantages of the system were identified.

Nevertheless, the UEMS has not yet been applied in practice, as further research is needed to establish a universal definition of the ultra-efficiency management system to make the concept transferable. For example, the performance evaluation and the setting of KPIs represent a major challenge. In addition, it is important to continue to broadly communicate the concept of ultra-efficiency and introduce the UEMS into the industry through accessible activities. In addition, the impact of future developments on the management system for factories with positive effects, as well as the newly created potentials through digital and biological transformation, must be monitored and evaluated. The digital and biological transformation and the resulting developments pave new ways of conducting business and, thus, highly efficient value creation. Prospectively UEMS can support companies in their transformation to sustainable production by postulating the added value of fact-based decisions and promoting developments toward transparent value creation.

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