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The Positive Impact Factory – Transition from Eco-Efficiency to Eco-Effectiveness Strategies in Manufacturing

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Abstract

Manufacturing of products and goods contributes to more than one-third of the global CO_2 emissions caused by humankind mainly due to combustion of fossil fuels. Current measures to reduce the emissions primarily focus on eco-efficiency, seeking mainly for minimized energy demand and to a smaller extent also for minimized resource consumption. However, this strategy of just "making things less bad" will not suffice to overcome the aforementioned challenges. Instead eco-effectiveness strategies need to be aspired, containing manufacturing systems which lead to a positive recoupling between economy and ecology. Contemporary trends and solutions in industry prove that the metamorphosis towards eco-effectiveness has already started and is gaining momentum. This contribution gives an overview about historically related bad impacts of manufacturing to environment and society and derives requirements for future manufacturing, leading to the concept of a Positive Impact Factory. Several industry examples are presented, showing factories on their individual way towards such positive impacts.

Keywords: Positive Impact Factory, Eco-Effectiveness Strategies, Factory Sustainability Evaluation, Sustainable Manufacturing

1. Introduction

Manufacturing is the process of transforming inputs like material, personnel and energy into valuable outputs (products) often together with undesirable outputs like different forms of waste and other emissions [1]. History has shown that manufacturing has been and still is a driving force for the development as well as prosperity and wealth of nations [2, 3]. While starting from handcraft scale, within the last two centuries industrial revolutions lead to manufacturing in factories with higher manufacturing volumes and productivity. With economic aspects being clearly in focus, factories are - certainly not without reason - associated with diverse negative environmental and social impacts. Just within the last decades more and more work has been done in order to minimize these impacts (e.g. [4]). However, most activities focus on the strategy of efficiency ("doing the things right" [5]). With given types of manufacturing inputs and outputs a relative improvement of this ratio practically means "making things less bad" [6]. While being an obvious approach and relatively easy to implement, pursuing efficiency has its natural limits. Less attention is paid on the strategy of effectiveness - "doing the right things" - which typically requires more effort but might result in real absolute improvements by a "change of the story" [7].

Against this background this paper proposes a radical paradigm shift from "bad impact" to the vision of "Positive Impact Factories". Having in mind the strategy of effectiveness, different environmental and social impact categories can also be seen as opportunities which might be proactively turned into positive contributions of the factory. Therefore, the paper firstly describes those impacts from both negative and potentially positive perspective. In the latter part, related social and environmental aspects are put in context of a system definition and current technical developments of factories of the future.

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2. Paradigm change – From Bad towards Positive Impacts of a Factory

2.1. Overview of Dimension Characteristics

The following table provides an overview of opportunities to make production sites a Positive Impact Factory. Both the environmental and the social dimension are considered. Positive impacts are named in an abstract way at this point instead of providing concrete solutions to foster innovative approaches. The way from bad impacts from the given categories to positive impacts is further explained in the following sections.

Table 1. Comparison of bad and positive factory impacts

Dimension	Category	Bad	Positive
Environmental	Energy & resource demand	High demand for natural resources/ materials	Use of secondary materials, renewable energies (energy flexibility)
	Waste	High quantities of residual waste	Reuse, recycling, conversion of industrial or residential waste and sewage water
	Particle Emissions	Air and land pollution, PM emissions peril human health	Emission sink for e.g. air and water pollutants
	Noise Emissions	High noise level	Factory as a noise sink
	Biodiversity	Destruction of bio-diversity	Creation of new habitats for animals and environmental regeneration
	Traffic	Congestion	Development of transport infrastructure, short distances for workers
	Risks	Source of danger	Source of domestic emergency supplies, factory as shelter
Social	Worker Satisfaction	Lack of motiva-tion and development perspectives	Place for life-long learning and personal development
	Work Life Balance	Workers adept to factory rhythm	Factory adapts to the workers' capabilities, place for recreational activity
	Working Conditions	Harmful manual labor and mental stress	Factory as a fitness studio
	Automation	Substitutes human workers	Safeguards human health
	Openness	Factory as a black box	Factory is open for customers and residents
	Individuality of Products	Anonymous mass production	Individualized products
	Architecture	Factory spoils landscape, no acceptance among residents	Factory as architectural attraction, harmonic integration into surrounding

2.2. Environmental Dimension

Due to rising standards of living and population growth, there is an increasing *energy and resource demand* for the enhanced production. This entails a decrease in the availability of primary raw materials, followed by a rise of prices for the materials as well as an increase of emissions to the environment. Politics react with stricter laws relating to environmental issues. People often regard factories as solely resource consumers. Reducing the demand of primary raw materials by increasing the use of secondary materials for instance through more efficient recycling processes seem to be a promising start. Therefore, most of the effort shall be put into finding adequate substitutes for materials and/or processes enabling true change towards eco-effectiveness. To have a positive impact, future factories will be more and more able to produce, store, and use renewable energy. This will facilitate an energy flexible production entailing an additional decrease in primary raw material demand. From a residential perspective, the factory may then work as an energy provider for instance during night time and/or also as an energy purchaser of privately generated renewable energy [8, 9].

Waste from the manufacturing sector amounts to approximately 14% of the total primary waste of the OECD countries [10]. This sheer quantity of waste generation represents a significant loss of resources in terms of materials and energy alike. Main reasons for those excessive quantities are inefficient production processes, a low durability of goods and unfavorable consumption patterns. Above that, further solid waste results from an attempt to tackle other environmental issues for instance water and air pollution entailing again new issues such as sewage sludge and residues from flue gas cleaning [11]. Apart from the waste quantity, hazardous substances in waste streams can also result in a negative environmental impact. These may comprise leaching nutrients, heavy metals, oil or further toxic compounds. As a general perception, factories exhibit enormous amounts of waste. However, since resources such as material and energy are already spent, future trends indicate that cross-sectorial applications of technologies for waste reuse, conversion and recycling are quite promising by forming collaborative value chains e.g. in industrial parks and/or also with residential areas facilitating future industrial symbiosis [12, 13]. The positive impact of this approach is the reduction of industrial as well as household waste by regarding it as a new valuable resource. Today, factories already comprise facilities for the reconditioning of e.g. sewage water [14]. Their employment radius could be extended to the surrounding residential or industrial areas to create a positive impact.

Another perceived bad impact of factories are *particle emissions* causing air and land pollution. Some of these emissions are regarded as a harm to human health such as particulate matter (PM) and ground-level ozone (O_3) followed by benzo(a)pyrene (BaP), and nitrogen dioxide (NO_2). With respect to ecosystems, their main effects are eutrophication, acidification and damage to vegetation coming from exposure to O_3, ammonia (NH_3) and nitrogen oxides (NH_x) [15]. This concern has been regulated in many countries over the past decades and target values have been set in miscellaneous legislations with further recommendations, e.g. the Air Quality Guidelines from the World Health Organization (WHO) [15]. Thus, nowadays factories are required by law to comply with these targets encouraging the use of new cleaning technologies and methods. Thinking this step further, future factories may even represent emission sinks e.g. for air and water cleaning to have a positive impact.

Past and current factories cause *noise emissions* coming from their production and supply processes. This has an effect on both the environment and people. Constant noise exposes people and animals to a higher stress level and prevents them from recreation [16]. Because of that many people refuse to live in close proximity of a factory. In that regard a more positive impact of a factory could be realized by an actively noise-damped factory shell and/or noise reduced production and supply machines and equipment lowering the potential stress level of people living close by.

Another perceived bad impact of factories is the destruction of the local *biodiversity* including organisms in the air, on land and in water as well as parts of the local fauna due to space requirements and accessibility to running water [17]. However, due to updated legislative constrains future factories may accomplish the opposite by creating new habitats by integrating polishing lakes and/or palm-/greenhouses for current living organisms and new species.

With respect to their surroundings, contemporary factories often imply an increased volume of *traffic* coming from commuting of the employees as well as daily supply of materials and distribution of finished products. It also includes more transport with heavy trucks to dispose waste of the factory. In France for instance, the waste quantity amounts for 15% of the overall weight of freight [11]. Because of that, general infrastructure is more burdened and the air is likely to contain more PM. To decrease this effect, the creation of industrial parks should be encouraged, where many factories and/or entire value chains share the same infrastructure, have short ways of transportation and use common media supplies. The same applies to factories and workers moving closer together. Reintegration of production sites into residential areas as "urban factories" is a promising approach [18]. This development would foster that (end-) customers are in closer vicinity to their producers, which could considerably favor a positive perception of factories.

Yet, factory operations may also pose certain *risks*, so that the factory is often regarded as a source of danger. These risks comprise the workers health when working closely to operations within a factory, but also risks for the close surrounding and environment through the aforementioned aspects such as particle and noise emissions as well as potential loss of biodiversity. More importantly, catastrophes like a flooded chemical plant [19], an exploding fireworks factory [20] or a flour dust explosion in mills [21] pose severe dangers. Despite these risks, it must not be neglected that factories may also serve as a source for domestic emergency supplies such as electricity and heat. Factories may then act as a decentralized unit in the smart grid having a positive impact on the surrounding area in a supportive sense [22, 23]. Additionally, robust factory buildings could serve as shelters or emergency accommodations during natural disasters.

2.3. Social Dimension

Factory work is often regarded to be monotonous in nature due to recurrent working steps which have their origins in the division of labor according to Taylorism and the moving assembly line [24]. Support and active demand towards the worker are often missing. This results in a lack of motivation and development perspectives among workers. Together with the job dependency of the employees due to e.g. plant closures these aspects add up to a low *worker satisfaction*. In recent decades concepts have been developed to improve the workers' situation: job enrichment, job enlargement and job rotation can be named, which aim at the magnification of the employees' fields of work [25]. Apart from this less-bad-approach, factories could also have a positive social impact as a place for life-long learning of the employees and also for education of students. Thus, the concept of learning factories [26] should be comprehensively implemented.

In modern society the awareness for a positive *work life balance* is growing [27]. However, workers still have to accommodate themselves to the rhythm of the factory. Shift work or strict assembly line tact times are examples. Future factories should instead support workers. Flexible production systems allow an adaption of the tact time according to the individual worker capabilities. Additionally, factories should offer childcare facilities to relieve parents and to counteract governmental cutbacks in the educational sector. As a place for a get together, factories can support the establishment of social networks. Company-facilitated sports activities need to be a matter of course as they foster health and team spirit of employees. Such programs should be open to local residents and the employees' families.

During the industrial revolution factories featured bad *working conditions* and were considered to cause physical damage to the workers due to hard manual labor [28]. This is still an issue in countries of the emerging markets. Nowadays, this factor is of decreasing importance in highly developed countries but is progressively superseded by mental illnesses due to continuous stress [29]. Factories should counteract by designing manual labor steps in a way that workers execute multifaceted and fair movements. Simulation tools for the ergonomic design of manual assembly processes are already state of the art [30, 31]. Thinking this step further, manual labor steps could be designed in a way that they serve as a fitness program. Factories would then actively contribute to the workers' health whose workforce, as a result, would be longer available (Factory as fitness studio).

Automation is often perceived ambivalently. On the one hand, it relieves workers from hard labor. On the other hand, it substitutes jobs with lower requirements regarding dexterity and education. As the positive aspects of automation cannot be neglected, it will have an increasingly important role in future production. Human-machine-interaction in hybrid work spaces is promising: Robots assist workers by performing unsafe or harming tasks, repetitive work, or jobs in unsafe environment. Wherever necessary, sensomotoric and cognitive capabilities of human workers are employed [32].

The *openness* of factories is generally rather low in various perspectives. Plants are perceived as "black boxes" or "closed shops” from the in- and outside. External people such as neighbors cannot gain insight into the factory processes and might thus assume that the factory embodies risks and threats. Events like open days are first step in the right direction. Factory workers on the contrary are often not able to retrace the reasons for organizational and manufacturing processes being as they are. The reason is that they are not allowed to participate in the decision processes. To overcome these drawbacks and to create a positive impact, the factory could also serve as a FabLab. This way, the production equipment could be used in a synergetic way by customers and local residents. Free capacities would thus feature a higher utilization rate and transparency would be enhanced. This system could be accompanied by market mechanisms, where offers and demands determine the machine utilization while the operators serve as brokers for “their” machines.

In wide parts of society factories are considered as a place for anonymous mass production like it was until the middle of the 20th century [33]. Besides, many enterprises feature a customer order specific production with the associated *individuality of products* at high output rates such as the automotive industry. However, their products base upon product families with shared parts [34]. A true step forward with positive impact for customers would be a lot-size-1-production on demand for completely individualized products. If additional transparency about the relation between product features and environmental impacts was created, the customer awareness could also have a positive environment impact. Only those functions would be integrated in the products (and resources consumed) which the customer really demands and which agree with the customer’s green-consciousness.

The acceptance of factories as neighbors is often not distinct among residents. Instead, factories are considered to mutilate the landscape or urban district with their utility-maximizing *architecture*. As a vision, factory buildings could be architectural monuments which mesh with their surroundings and/or serve as tourist attractions. Moreover, these factories could be integrated into the existing infrastructure and thus prevent additional facilities such as sewage treatment plants or power stations.

3. Enabling a Positive Impact Factory

Today, several organizations such as USGBC with the LEED standard, ENERGY STAR or German DGNB award environmental conscious buildings and factories by evaluating different sustainability criteria [35, 36, 37]. Also in academic research several approaches, methods and tools have been developed for holistic sustainability evaluations of factories or companies [38]. Several examples of already implemented factories prove that eco-efficiency and effectiveness strategies have yet found their way into industry so that more and more Positive Impact Factories will be realized in future. Still, it has to be stated that most efforts towards improved ecological and social factory impacts have been made in the industrial countries (e.g. due to stricter laws and public pressure), while factories in developing countries are often built at lower standards. As raising wages and tightened laws can also be observed here, similar developments can be expected with a distinct delay. However, it will be challenging to achieve positive impacts for whole value chains in developing countries, as also the infrastructure (transportation, water and electricity grid, etc.) has to be suitable to support positive impacts. More autarkic factories might be a solution, if these conditions are not fulfilled.

While a sole reduction of bad factory impacts can be achieved by an efficiency increase in production, positive impacts require fundamental changes towards effective utilization of resources from both production and consumer perspective. Although the following approaches focus on the production perspective, the great influence of consumption patterns on the impacts of production should be kept in mind. Consequently, the idea of less but more durable and eco-friendly products instead of “use-and-throw things” needs to be fostered. Nevertheless, efficiency measures in production are a good starting point for positive factory impacts, but need to be developed towards eco-effectiveness containing closed-loop material and energy flows as well as a strong linkage with the external environment. In an ideal factory every output being produced serves as input for other processes – comparable to biological systems where all waste flows serve as nutrient for other organisms [39]. For many of the discussed factory impact categories, especially for emissions and pollution of the direct environment, a need for action has already been recognised and considerable progress can be stated. Hence, several technical and organisational solutions to at least reduce negative effects are available. However, a Positive Impact Factory mustn’t be confined to few positive impacts, but should address many of the identified areas. A perfect Positive Impact Factory has probably not been built yet, but enablers which are likely to contribute to the positive impacts (through interaction with the environment, technical systems or human beings) can be identified. Several changes in a factory’s physical infrastructure will be necessary, regarding the inner factory elements and structures as well as the linkage to natural and human-made surroundings. Seven important enablers have been identified, which appear to be crucial for generating positive impacts [40]:

- *Urban Integration*
- *Symbiotic Flows*
- *Adaptive Building Shell*
- *Flexible Production System*
- *Modular & Scalable TBS*
- *Production Cloud and CPS*
- *Learning and Training Environments*

Fig. 1 connects these enablers for positive impacts with the identified impact categories, emphasizing the responsible enabler for the generation of each impact. For instance, a positive impact regarding emissions can be reached through adaptive building shells (e.g. by absorbing substances from the air) modular TBS systems (e.g. through water purification, air filtration, etc.). A positive impact regarding the worker satisfaction can be fostered by flexible production systems (e.g. through flexible working times, changing work contents) or adequate learning and training environments (e.g. through development of human abilities). In general, positive impacts on the environment are mainly enabled by factory elements with a direct external interaction. On the contrary, social impacts mainly correlate with anything happening inside the factory. Consequently, a systematic optimization of selected impact dimensions is possible by developing certain enablers. However, on the long term all dimensions of sustainability (economical, environmental, social) have to be addressed. The existing Factory of the Future perspective [40], as presented in Fig. 2, merges the identified enablers and can therefore also be regarded as a Positive Impact Factory perspective. In the following, the enablers will be explained in detail and examples of already implemented solutions will be presented.

3.1. Factory Integration into Surroundings

The Positive Impact Factory is integrated into its surroundings like existing artificial infrastructure, for instance electricity and water supply, roads and public transport. This allows the factory to provide additional services for society due to its physical closeness to other facilities. Beneath the connection to artificial infrastructure, integration also means the embedding into local biota and aims at conservation and regeneration of natural habitats. A proper example for a well integrated plant is the Volkswagen factory for car assembly in Chattanooga, USA. So far it is the only automotive plant worldwide which is certified with platinum as the highest category of LEED, rewarding the broad application of green technology in the factory. The factory was built on a brown field site using existing infrastructure of a former military factory, which once made Chattanooga one of the most polluted US cities. Beneath the usage of recycled building materials, an implementation of renewable energy generation and rainwater recovery, especially huge efforts were made in restoring nearby creeks and forests while habitats for native vegetation were defined directly on-site [41, 42].

The surroundings of a future factory may very likely be urban or suburban areas, as population in rural areas is continuously decreasing. In 2008, for the first time in history, more than half of the world's human population lived in urban areas [43]. So especially an *urban integration* of the factory gains importance. Compared to factories in rural areas, Urban Factories nowadays have several advantages, while the historical negative impacts related to factories will be overcome: Short distances to households make commuting dispensable, leading to a better work life balance of workers.

Closely related to urban integration is the idea of sharing *symbiotic flows* like energy and materials. By connecting the factory directly to other factories, urban infrastructure, and households, partners can benefit: solid waste can be exploited by the factory and used for new products, wastewater can be treated, renewable energies can be produced or stored and local emissions can be neutralized. The factory can adapt its production output to a lack or surplus of renewable energies and materials using its high flexibility. By integrating the factory and other smart energy consumers like electric cars into smart energy grids, it serves as energy buffer and helps to balance energy generation and demand. This is demonstrated in several current research activities like the Sustainable Integrated Grid Initiative [44] or the Mobility2Grid project funded by German BMBF [45]. In Hamburg, Germany, a bunker remaining from World War II has been converted into a huge heat storage, receiving waste heat from the nearby oil factory Nordische Ölwerke and also generating sustainable energy by solar power, biomethane and woodchips [46]. The goal of waste reutilization has already been pursued in practice with the concept of so called eco-industrial parks where a factory uses outputs of close-by factories as inputs, which would otherwise be treated as waste flows. In Kalundborg, Denmark, such a collaboration of companies began in the 1970's, when a gypsum production started using excess gas from a nearby refinery, leading to economical benefits for both companies. In 2010, about 30 media connections between local companies existed, ranging from gas, water, steam and heat exchange over sludge, ashes, straw or lignin to bioethanol and fertilizer [47]. The evolution of the Kalundborg eco-industrial park has become THE prototype of a working industrial symbiosis with the goal to reduce and reuse industrial waste flows. An overview about several other realized projects all over the globe is given by Chertow [12].

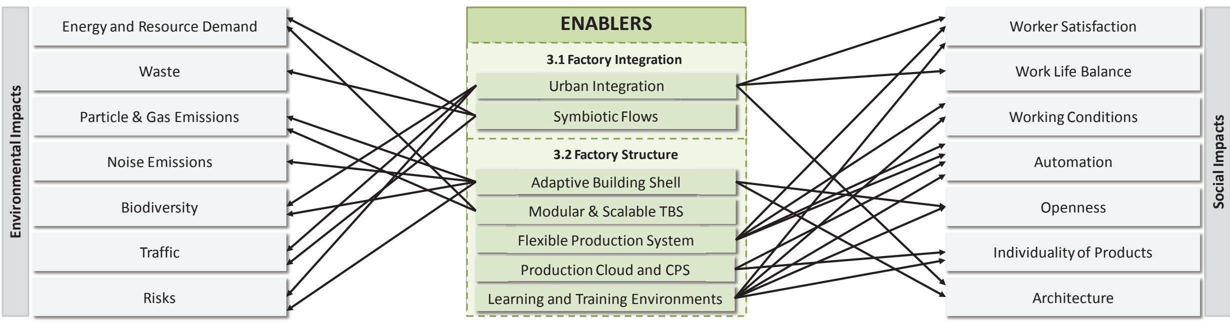

Fig. 1. Enablers for Positive Impacts related to Impact Categories

3.2. Factory Structure

Concerning the inner factory structure, three elements are of particular importance for a Positive Impact Factory [32]: The building shell as insulation from the outer conditions and local climate, the production system comprising machines and logistics for the manufacturing of products as well as the technical building services (TBS) providing the production system with energy and media. All three factory elements need to adapt to rising and volatile requirements regarding economical, ecological, technical and social aspects. While implementing such infrastructure it has to be ensured that positive impacts are not limited to the use phase of the elements but also comprise their production stage, transport and end-of-life to avoid problem shifting to other factory life cycle phases, preventing overall positive impacts.

An *adaptive building shell* as primary structure of the factory needs to react to changing requirements. This is reached by a modular and expandable construction. Approaches for mobile factory modules (e.g. in combinable containers) have already been identified as research fields [48, 49]. Following an eco-effectiveness approach, the factory shell has to be made of recycled and recyclable materials. A good example for an existing realization of such a building shell is the ECOVER factory in Malle, Belgium, which has been built of natural European pine wood as well as brickwork made of clay, wood pulp, and coal dust with a coating of trass lime and straw. Further, a green roof serves as thermal and acoustic insulation [50]. In a Positive Impact Factory, the shell does not only absorb emissions already released to the environment but rather uses them as resource input and hence for value creation [51]. Therefore, new functional building materials are already under development, e.g. surfaces which absorb pollutants or generate electricity like building-integrated photovoltaics [52, 53]. The building also needs to be architecturally integrated into its surroundings. This can be reached for instance by vegetating the shell and plant site or through attracting designs like in the case of an incineration plant in Spittelau, Austria. The eye-catching shell was designed by the famous artist Friedensreich Hundertwasser, evolving a bleak industry building into a tourist attraction [54]. Other examples like the glass building shell of the Volkswagen "Transparent Factory" in Dresden, Germany, contribute to a higher degree of openness, as the factory's inner structure is no longer invisible [55].

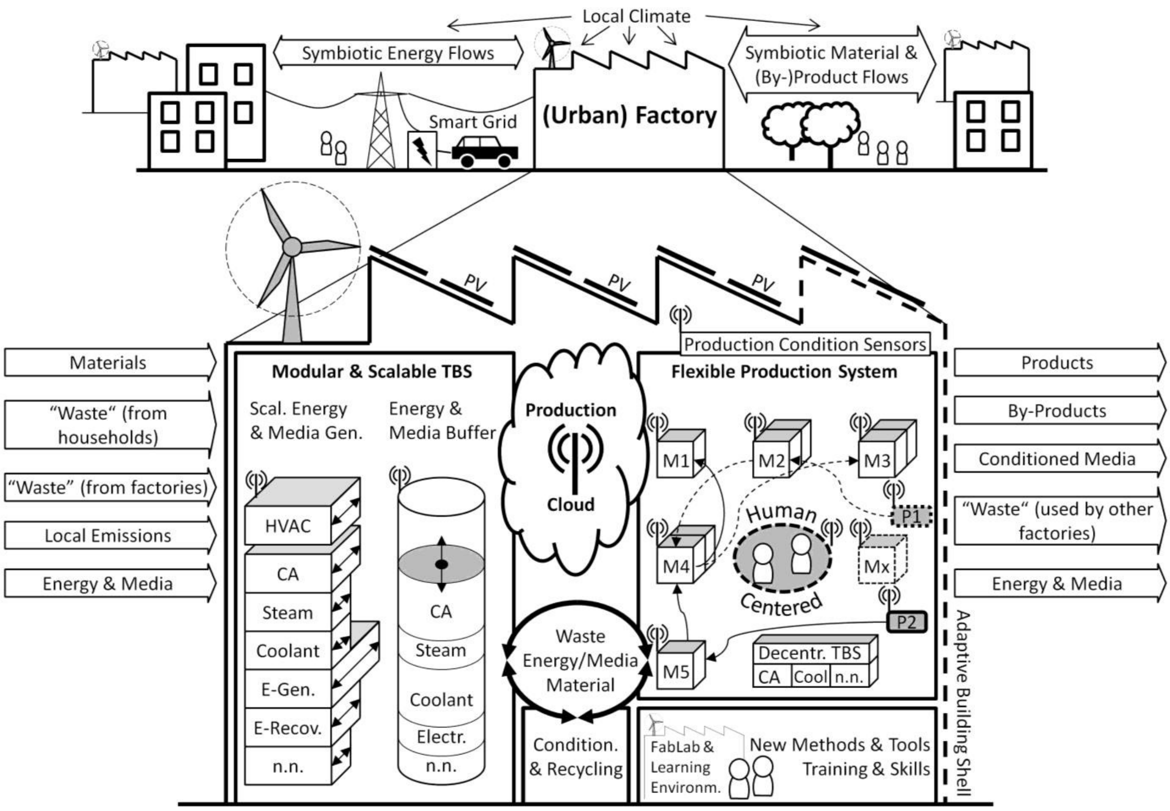

Fig. 2. Enablers for a Positive Impact Factory in the Factories of the Future Perspective [40]

The *flexible production system* with its machinery needs to adapt to an increasing variety and complexity of the products while consuming a minimum of resources and causing minimal environmental impact. This demands for alternative production line layouts with flexible production cells like for instance the matrix production concept [56]. Multi-agent systems (MAS) with decentralized intelligence and decision abilities may be needed to operate such agile systems [57], being also able to perfectly communicate and interact with human workers. Generally, technology does not replace the human, as his cognitive and sensomotor abilities are still needed [58]. Instead, technology fundamentally supports human action and therefore has to be adjusted strictly to human needs. Sensors in the production system allow monitoring and immediate reaction to changing requirements and make all relevant information available at any time in a user-centred way. However, at the same time more and more factories operate following the paradigm of the slow movement producing products with long life time and/or high standards of quality [59].

The *modular and scalable TBS* structure bases upon renewable energy generation capacities, which may be solar, wind, water and geothermal power or renewable fuels. In this context the factory of J. Schmalz in Glatten, Germany, constitutes a good example for a surplus energy plant, generating more electricity (by wind, solar and water power) as well as heat (by combustion of woodchips) than utilized within the company's premises [60]. In the Positive Impact Factory, there are physical but also virtual links from the TBS to the flexible production system, allowing quick and automatic reactions to altering conditions. Due to the plug-and-produce philosophy [61], additional elements and devices can simply be plugged in or off the TBS elements to instantly enlarge or reduce the capacities. Beneath supplying the production, the TBS also balances fluctuating energy and media inputs and demands, serving as stabilization for energy and media grids [23]. Storages like battery systems or media buffers therefore are elementary parts of the system. A good example for the realisation of a factory with renewable energy demand and buffer functions is Solvis GmbH, manufacturer of solar heating systems, situated in Braunschweig, Germany. The factory of Solvis received several awards and is designated as Europe's largest zero-emissions plant. The wooden building structure has a minimized building volume and renewable energy generation capabilities like PV-collectors and a rapeseed oil fired block-type thermal power station, accounting for a CO_2 neutral energy and heat supply. Excess heat from the collector system and the thermal power station is stored in buffers, balancing fluctuations in generation and demand [62].

The huge amount of data collected from the production system and TBS requires the setup of a decentralized data pool, referred to as *production cloud*, collecting and processing all information. By a broad physical network of sensors, actuators and processors, the idea of an Internet of Things becomes reality in the Positive Impact Factory [63, 64]. This allows an analysis and optimization of current and future states of all factory elements and the factory system as a whole. The storage and processing of all data in a cloud entails several advantages like a high degree of transparency through embedded monitoring and control functions, constituting an important premise for improvement measures. *Cyber Physical Systems (CPS)* are coupled with the cloud to assist human workers on shop floor level, providing appropriate pre-processed live data. As an already existing example for the migration towards CPS, the factory of Wittenstein in Fellbach, Germany can be cited [65]. A broad implementation of "Industry 4.0" technologies is aspired in this demonstrator factory for the near future, including the communication and interaction of all machines and products with decentralized intelligence and control mechanisms.

Despite all technological progress, human abilities are still one of the key success factors – accordingly *learning and training environments* are needed, allowing employees to keep pace with changing requirements and technological improvements. For this purpose, Learning Factories can provide realistic experimental and research environments [66]. They are used for teaching purposes and allow for the communication, testing and demonstration of theoretical knowledge in physical learning environments [67]. Many Learning Factories have been established in industry and at universities throughout the last decade. Volkswagen for instance operates several Learning Factories at different sites, e.g. at their headquarters Wolfsburg, Germany, where about 1.6 million € have been invested for a new realistic learning environment in 2012. Its aim is to optimally prepare employees for their work, even giving them the opportunity to make mistakes and see their consequences in a save area [68]. Festo will also operate a Learning Factory at their new "Factory of the Future" in Scharnhausen, Germany. It will be used as training facility for new employees as well as for further qualification of professionals [69]. The company Schmalz in Glatten, Germany, has established an "Ecological Guided Tour", where already implemented improvement measures in terms of economical, ecological and social sustainability are presented to the staff but also to visitors [70]. A good overview about academically driven Learning Factories in Germany is given by Kreimeier et al. [71], also identifying the main focus areas: process optimization, energy & resource efficiency as well as logistics. Another concept in the context of learning and training environments is the so called FabLab, which is designed for sharing knowledge and open access to ideas and inventions [72]. People can design and physically realize their own product creations in the FabLab, using the provided infrastructure like rapid manufacturing machines. By selling free machine capacities to private persons or companies, nearly all existing infrastructure can become part of the FabLab. This approach contributes to more openness of the factory, it supports regional development by catering to specific individual needs of the population and it offers a platform for knowledge transfer to broad parts of society [73, 74].

4. Conclusion

Against the background of associated negative social and environmental impacts of factories as well as the previous strong focus on efficiency measures, this paper proposes a paradigm change towards "Positive Impact Factories". In contrast to making things less bad, the objective is to use factories' opportunities towards positive contributions of the factory in social and environmental aspects. Although this is certainly a vision at this moment, ongoing developments and several examples underline that this factory perception is not unlikely. Current research in context of different elements of the factory and its embedment into the environment go in the same direction and can serve as enablers for the vision of a Positive Impact Factory. Related solutions are at least partly available already - however, at this point there is no industrial example which brings together all aspects of the Positive Impact Factory. For finally achieving the vision, further technical developments and also new methods and tools (e.g. for planning) are necessary. Furthermore, it is also important to consider incentives and the economic feasibility of the positive impact from the perspective of the factory operator. Certainly it is not feasible and necessary that - depending on the specific impact category - all aspects of a Positive Impact Factory are fulfilled by each single factory. From global perspective it is sufficient that all factories within a distinctive area together ("Positive Impact Factory network") create positive impacts.

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