ENERGETICALLY SUSTAINABLE FACTORIES – NEW REQUIREMENTS FOR FACTORY PLANNING APPROACHES

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1 New success factors and motivation

Demands on factories are changing permanently. Besides other trends like demographic change, ecological production is getting more and more important, particularly because of the shortage of resources and climate protection efforts. [1] In view of this background it is to observe that factors of success for industrial enterprises are changing. The success of German enterprises was based on high product quality for a long time. Nowadays quality is only the “entrance card”. New factors of success are transformation ability, service orientation and in the future above all resource efficiency and sustainability. [2-3]

In general companies are focused on cost savings. But with regard to the influence of climate change and the rising ecological awareness they have to consider legal, social und ecological goals concerning resource efficiency, too. [4] Orientation towards all three dimensions of the triangle of sustainability is necessary (figure 1).

At first increasing resource productivity to reduce costs is a big task because of economic reasons. Almost half (45%) of the production costs of German enterprises are spent for material and energy. [5] This is the biggest portion of cost. The amount of the often discussed labor costs is only about 20%. [6] A closer look at the development of electricity prices in Germany suggests that prices have been rising by almost 60% in the last 15 years. Rising taxes and duties due to realize a more ecological energy supply are the main reasons for this fact (figure 2).

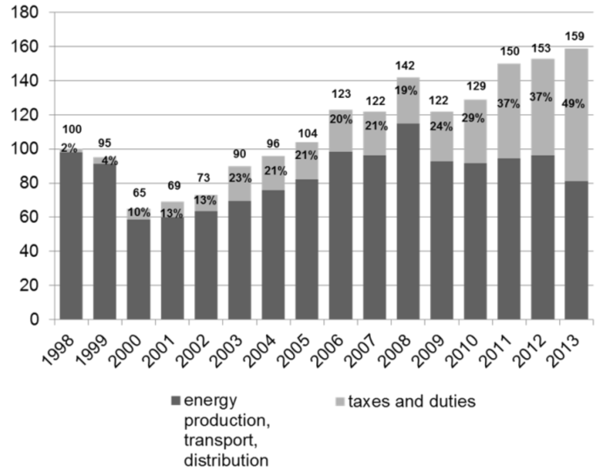

Figure 2: Development of electricity prices for medium voltage powered industry in Germany (annual consumption: 160 – 20000 MWh) [7]

Current studies assume that prize for electricity is rising by up to 70% in the next 20 years. But there are also possible savings of 30% in metalworking industry. [8] Energy efficiency was not in the strategic focus for a long time but it is getting more and more important, because other often time-based economically rationalization measures are more and more exhausted. [9]

Another important aspect is ecology: manufacturing companies have to reduce CO_2 emissions and consume fewer resources in times of climate change. So there are and there will be much more regulations and laws concerning resource efficiency.

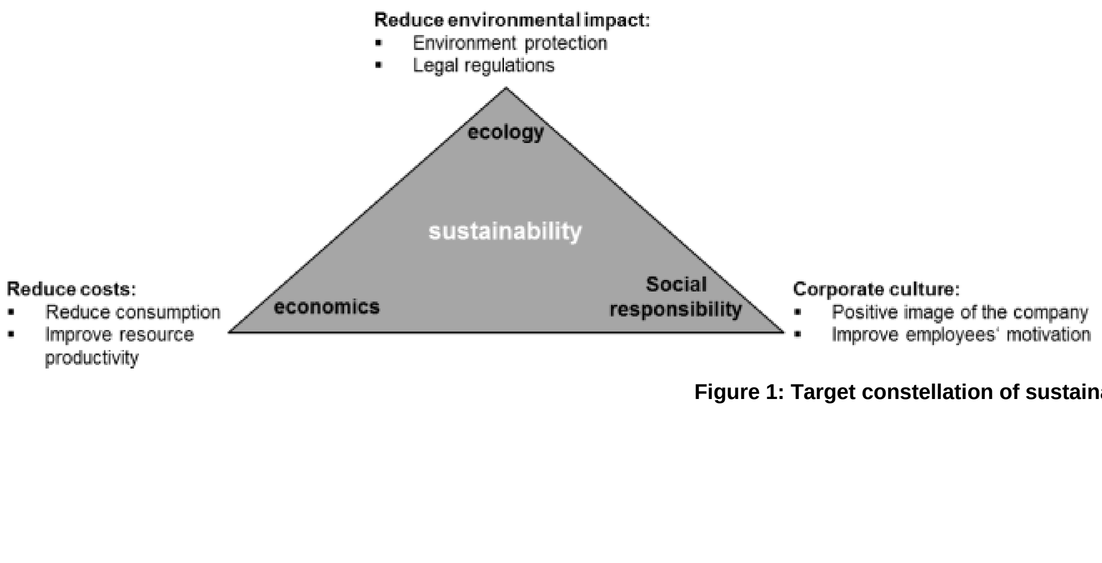

Figure 1: Target constellation of sustainability [4]

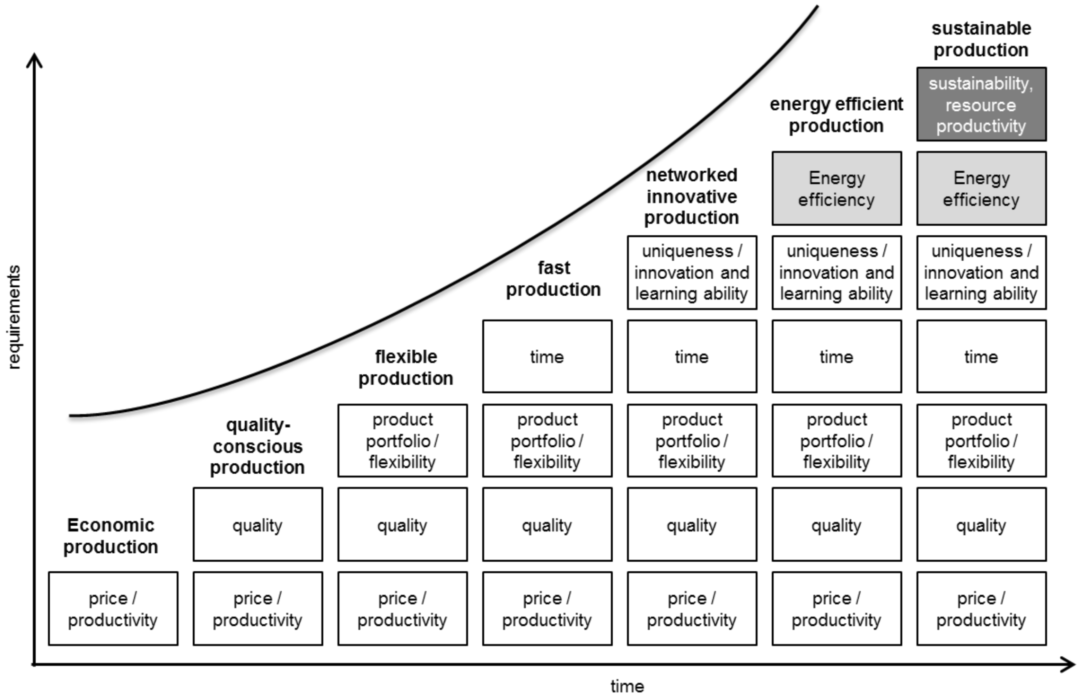

Figure 3: Expanding requirements for production [10]

Last but not least, social responsibility is getting more important. Customers, employees and other stakeholders like general public demand that enterprises will fulfill their responsibility and will produce energy efficient, resource-saving and eco-friendly. In the future this will be mandatory to create a positive image of the company and to motivate employees.

The described trends in the three dimensions economics, ecology and social responsibility lead to expanding requirements for production. Figure 3 shows the development. Besides things like quality and fast and flexible production, energy efficiency and in the future designing sustainable factories is getting more important.

2 Relevance of factory planning

"Task of factory planning is to plan a factory to meet the operational goals as well as social and economic functions by taking account of numerous frame conditions." [11] The mentioned new frame conditions have to be considered in factory planning methods. Figure 4 shows general relations between production and overall social objectives regarding sustainability.

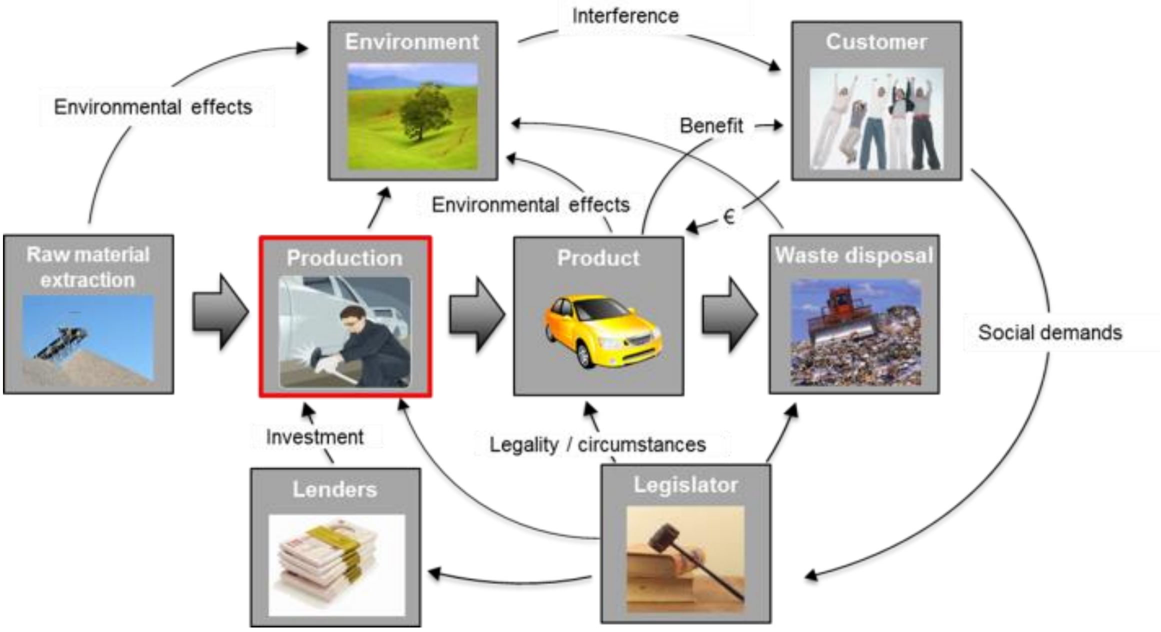

Figure 4: General relations between production, environment and society [12]

Furthermore factory planning is affected by complexity and numerous interdependencies between its elements. [13] Complexity and interdependencies are increasing significantly because of the new demands concerning resource efficiency.

The challenge is to increase resource productivity and design sustainable factories without neglecting traditional success factors. This has to be a central aspect in future factory planning methods. The whole value-added-chain with all its aspects of product design, production and logistics through to waste management and recycling has to be taken into account. Systematic process management is the heart of increasing resource efficiency. [14]
It is very important, because factory planning has a huge influence on resource efficiency of later operations. At this early stage production processes as well as the factory's infrastructure were defined. Most of the later costs are defined at this stage. [15] So it must be assumed that also 70-80% of energy consumption is determined (figure 5). [9]

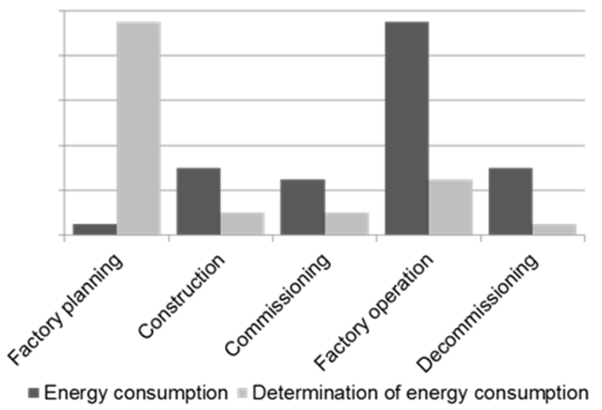

Figure 5: Determination of energy consumption and actual energy consumption during factory life cycle [9]

For this purpose, existing methods to increase resource efficiency of factories and their integration in factory planning are analyzed.

3 Existing approaches

Not practical methods for factory planning:
There are different approaches to integrate resource efficiency in the field of production, e.g. life cycle assessment or material flow management. These methods refer to balance ecological parameters of products or to evaluate material flows of production processes. They can be a good tool for product engineering, for choosing eco-friendly raw or process materials and optimizing existing systems. But they are not an adequate methodology to integrate the concept of sustainability in factory planning. [10]

Local optimization or orientation on existing processes:
Furthermore there are lots of efforts to increase resource efficiency of certain technologies. Mostly specific production processes or cross-sectional technologies are considered. Numerous activities and published papers are focused on optimizing light, compressed air, heat and cold. They often suggest replacement of existing machines with new efficient ones or efficient operational strategies. All these activities only consider local optimization, single processes or are orientated on existing products, processes and factories.

A method to combine process orientation (lean) and resource efficiency is the energy-value-stream method. [4] It is a good tool to analyze existing processes. But it mainly considers energy consumption. Energy distribution and supply are only treated along the way. So it is just one aspect of creating sustainable structures in factory planning projects.

Missing integration of nearby disciplines:
Existing factory planning methods treat resource efficiency often only implicit or in the scope of sustainability strategies or environmental management systems. [9] Electrical power supply from renewable energy, cross-sectional technologies and energy management often play a minor role. These tasks are often designed by planners or specialists of several trades. It would be possible to revert to this knowledge of multiple nearby disciplines as environmental management or energy-related advisory service. [9] But it can be considered that this knowledge and related methods are not adequate integrated in factory planning methods and processes. These methods have to be integrated reasonable. It is to assume that they have to be adapted and new procedure models and project management methods will be necessary.

Missing integration of energy production from renewable sources:
Indeed some approaches like Müller et al. [9] treat planning of energy efficient factories. But especially integration of electrical power supply by decentralized renewable energy, methods and procedures and their integration in the factory planning process are missing. So this is a huge challenge on the way to sustainable factories and the vision of energy self-sufficient and emission-neutral factories.

4 Strategies to increase energy-efficiency and energetic sustainability

There are several measures to increase energy-efficiency and energetic sustainability of factories (figure 6). Erlach [4] names “compensate use of resources”, “reduce consumption” and “reduce environmental impact”. Further strategies are to avoid converting [16] and time-based control of consumption [17]. Cost effectiveness has to be examined for each action. But basically it can be assumed that except the approach “compensate use of resources” all strategies can lead to economic benefits.

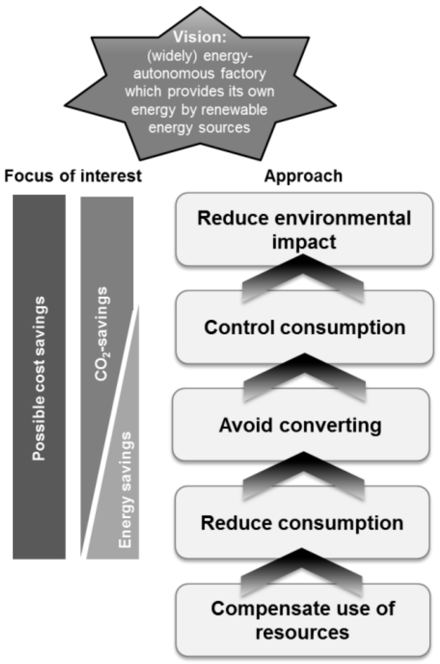

Figure 6: Approaches to increase energetic sustainability

To compensate the use of resources, for example by dues or supporting afforestation, is not an economic strategy. It only helps to compensate former negative influences. Neither energy savings nor reduction of CO2-emissions is achieved. From the lean philosophy’s point of view this would be another kind of waste. [4]

Reducing consumption by efficiency improvement measures is a much better strategy. As explained in chapter 3, there are lots of good approaches focusing on improvement of certain technologies which have to be considered in factory planning. Müller et al. developed a good approach to integrate energy data of processes and machines as well as analysis and evaluation of energy consumption. [9]

The next step is to avoid conversion losses. Examples are cogeneration of heat and power, avoidance of compressed air and shortage of energy conversion chains, such as operating an oven directly with natural gas instead of electric power.

Another course of action is to control and steer energy consumption. Specific monitoring of energy consumption helps to identify saving potentials. Load management systems can help to avoid peak loads. This can often lead to significant cost-savings. In the future there will be the necessity to develop methods and tools which help to influence and control energy consumption of a factory actively, that the fluctuant offered energy from renewable sources can be used the best way. Indeed this does not reduce energy consumption but reduces environmental pollution in a significant extent. These methods can help to solve the problem of energy storage as well. And it can lead to economic advantages.

The last approach is to reduce environmental impact, especially by using renewable energy sources. As already mentioned this does not reduce energy consumption but helps to reduce CO_2 emissions and is a very interesting strategy from the economic point of view. Initial costs for electricity form photovoltaic systems often are about 10 Cents/kWh nowadays. [18] This is much below regular purchasing price.

The overall goal of all these approaches is the vision of an energy-autonomous factory, which produces its own electric power from renewable sources. The challenge is to integrate this vision in factory planning.

5 Integrated holistic factory planning approach

So it is necessary to develop a holistic factory planning approach which focuses that vision and eliminates the existing deficits, which were described in chapter 3. Low energy consumption, the possibility to control energy consumption and energy supply from renewable sources has to be integrated in all aspects of factory planning. This can only be achieved if a holistic approach is used where production processes, factory building and its infrastructure, energy supply and energy management are taken into account accordingly. So many disciplines have to work together to create the total optimum.

For this reason the synergetic factory planning approach is taken up. It ensures the integration of process and spatial view in factory planning. [19] This should help to avoid isolated solutions. The process view contains the following tasks: planning of production and logistics processes, in-house flow of materials, layout planning and production facilities. Designing the factory building and its elements and infrastructure is task of the

architect and the planners for the several trades and represents the spatial view. [19] These two objects groups constitute the production level of factory planning (figure 7).
If they are designed coordinated and dimensioned in the right way, energy efficiency can be increased significantly. [20] But this is not enough to create and operate energetic sustainable factories. The viewing area has to be extended. [21] Especially in chapter 4 described strategies have to be integrated as an energy level of factory planning. Energy supply view and energy management view have to be added to factory planning. Figure 7 shows an overview of this approach based on the idea of synergetic factory planning.

The energy supply view contains all planning tasks of decentralized energy production especially from renewable sources and technical grid connections. This has to be done in close cooperation with the tasks of the spatial view. The technical building equipment is the connection between these two views. Furthermore supply concepts have to be designed according to consumption requirements of production facilities. This is one of the main tasks of the energy management view. The challenge is to describe energy consumption profiles as good as possible at an early phase to harmonize supply and consumption the best way. This is a central aspect to ensure and improve economic efficiency of decentralized energy production from renewable sources. The connection between energy supply and management are possible storage technologies which help to increase the degree of energy self-sufficiency and allows greater freedom of scope in energy management.

The connection to the process view is the energy demand of production processes and its monitoring. In later factory operations this is the basis for continuous improvement and to control energy consumption of production processes and technical building equipment. Therefore process view in form of production planning and control and energy management view in form of energy controlling and load management represents essential elements of factory operations. So these are the “dynamic” parts of this approach. Spatial view and energy supply view are more static objects. Normally they are planned one time and can only be changed with great effort.

6 Conclusion

Designing resource efficient and energetically sustainable factories is a huge challenge, which is not integrated adequate in existing planning approaches. There are some first approaches especially for reducing energy consumption, but there is considerable need for further research. Proper methods and tools to design resource efficient, sustainable factories and production systems have to be identified or developed and integrated in factory planning approaches reasonable. The plurality of disciplines, interactions and creating a total optimum also has

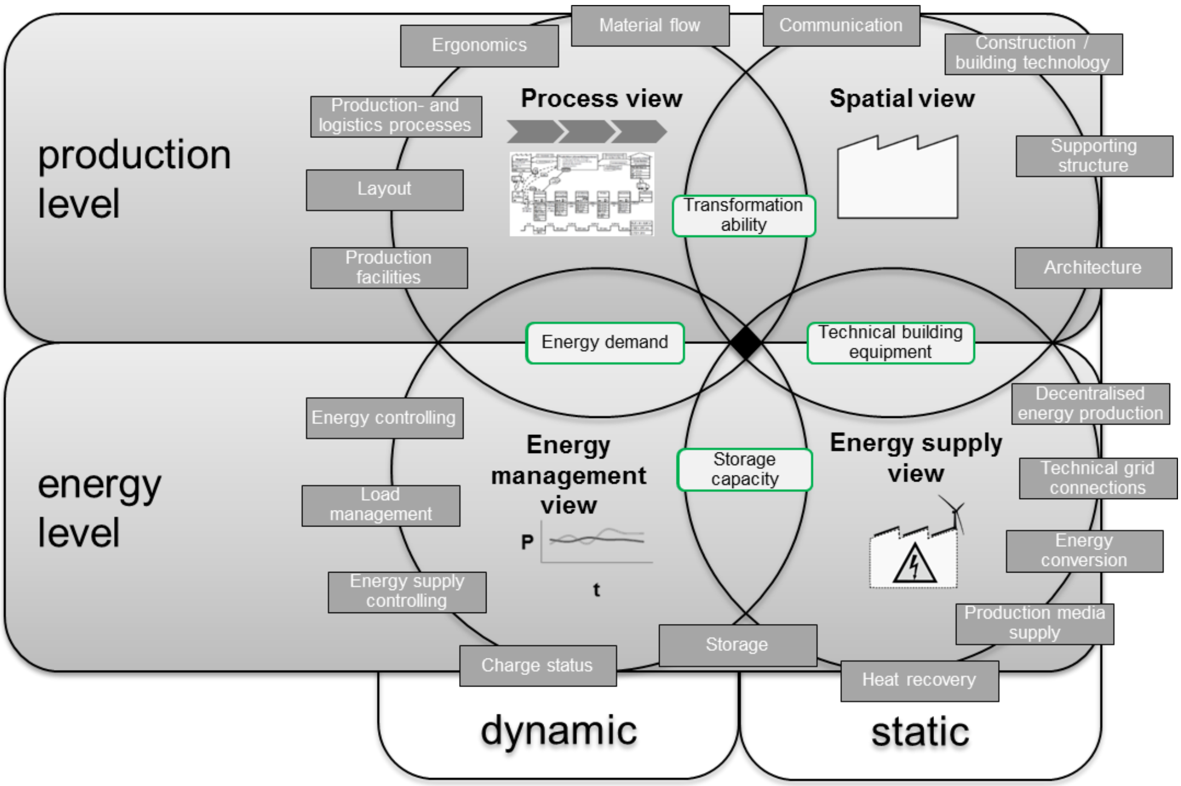

Figure 7: Integrated factory planning approach

special demands on project management methods. It can be expected that traditional clearly structured plans are not suitable. New forms of project management methods for example based on agile process models have to be developed, integrated and applied for factory planning projects. [22]

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