ADVANCES IN SUSTAINABLE ENERGY EFFICIENT MANUFACTURING SYSTEM

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This paper deals with the sustainable energy efficient manufacturing with application of advanced industrial techniques and new methodical approach to advance energy efficiency measures. This integration represents a sustainable development so that more effective use of natural and energy resources is achieved, energy costs are reduced and energy efficiency of manufacturing processes are created. The energy efficiency in a manufacturing enterprise is specially determined in the beginning of its life cycle. The new solution in the form of methodology for increasing energy intensity of manufacturing processes is proposed. The verification can be used to realize and illustrate energy efficiency potentials in production and logistics planning.

KEYWORDS

energy efficient manufacturing, reconfiguration, sustainable production, advanced industrial engineering, system, methodology

1 INTRODUCTION

More and more enterprises increasingly orientate their policy towards environment protection and energy efficiency of production processes.

Enterprise planning and management plays a relevant role for energy-efficient production systems, because the highest influence on the energy consumption of the systems lies in the planning and monitoring process. Despite the importance, there are so far no sufficient tools and methods to integrate energy efficiency in manufacturing processes systematically.

This paper is structured in the form of four main sections, where are demonstrated concepts contributing to the development of energy efficiency-oriented tools and methods in manufacturing processes. In section 1 an explanation of the problem issue and a literature survey is presented.

In section 2, the *"Technical model of energy efficiency improvement in manufacturing"* is presented for supporting the planning process by systematically identifying and implementing energy efficiency improvement opportunities. The research question based on two hypotheses is proposed.

Associated with the *"Technical model of energy efficiency improvement in manufacturing"* and hypotheses, the *"Methodology for reducing energy intensity of production processes"* is designed in four steps: energy planning of measurement, energy implementation and control, reconfiguration of energy system, checking and improvement, which are described in following section 3.

Finally, a short summary of significant results of the verification of methodology, the confirmation of hypotheses and the future outlook are given in the conclusion.

1.1 Overview and problem statement of energy efficient enterprise planning and management

An objective of this research is a visible contribution to realize the vision of an energy efficient manufacturing system while simultaneously reducing the demand for energy as well as increasing the efficiency of resources in manufacturing processes. As part of this, energy efficiency potentials in an enterprise must be identified and developed consistently. The implementation level depends on different knowledge and skill levels of planning participants. The partial missing energy competence of decision makers leads to miscalculations in the design of factory systems and their peripheral facilities [Muller 2009]. Therefore, the search for energy efficiency approaches, methods and aspects of qualification is brought forward. The existing tools supporting factory planning participants in realizing energy-efficient solutions can be classified regarding different criteria. The classification used here divides them into energy efficiency principles and energy efficiency methods.

Energy efficiency principles are more generalized and abstract, such as the general approaches substitution of energy sources, reduction of energy demand, and increase of efficiency of equipment, reduction of process losses, energy recovery and direct use for heating [Muller 2009]. Further examples for energy efficiency principles are described by Muller et al. [Muller 2011]. The significance of a link between ecological dynamics and sustainability is of substantial importance to industrial ecology insofar as it has the potential of tying the normative aspirations of many in the field to a scientific foundation [Ehrenfeld 2004].

Energy efficiency indicators, or more generally energy performance indicators, give the links between energy use and some relevant monetary or physical indicators measuring the demand for energy services. They may be defined at different levels of aggregation in terms of energy demand, e.g. economy-wide, sector, sub-sector, end use, technology, process and device [Ang 2005]. Energy performance indicators can be used to quantify improvements in energy efficiency, use and consumption at the organization, facility, system and process or equipment level. Energy performance indicators are a measure of energy intensity used to gauge effectiveness of energy management efforts. These indicators, previously defined during the preparation of the company's energy policy, express a quantitative value of the energy performance measurement.

Energy efficiency is achieved not only through implementation of adequate equipment, process and operating practice, but also by implementation of energy efficiency management system, which presents various strategies, tools, methods and technologies to optimize present systems and offer effective measures and solutions to face consumption and achieve performance, also production and environmental benefits [Darabnia 2013]. Energy efficiency methods analyse processes concerning their energy efficiency potentials. They can be divided into product- and process-oriented approaches. A product-oriented approach is especially appropriate for accounting a product's environmental effects during its lifecycle (e.g. carbon footprint). A process-oriented approach is more suitable for analysing or designing processes in a company. These approaches can be classified into generic and specific methods [Erlach 2009]. Specific methods only fit to special sorts of processes (e.g. pinch analysis does only fit for thermodynamic processes). Only process-oriented, generic methods are appropriate for the application described here. One example for these methods is the Energy Value Stream.

Many industrial companies still lack appropriate methods to effectively address energy efficiency in production management. Current approaches to integrate energy efficiency performance as a relevant criterion in production management seem to have shortcomings in their comprehensiveness and practicality. Research issue of increasing energy efficiency is formulated into five key areas (Fig. 1):

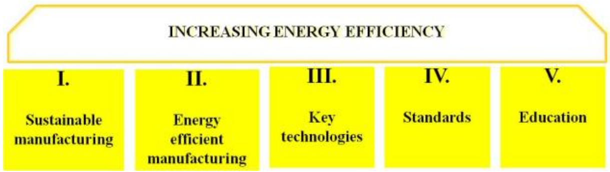

Figure 1. Key research issues of energy efficiency [IMS 2020 2011]

Therefore, the ensuing research question in this context is the following:

– ***What are the industrial challenges and needs with regard to integrating energy efficiency performance in production management?***
  In studying this issue will look for matching problems and needs in the industry, which are linked to energy efficiency. It is needed to utilize all possibilities that are important in the design of manufacturing processes, for example, lighting, and the arrangement of equipment or the training of personnel in order to save energy.
  It could be anything, what should an industrial engineer in the reach so that these problems and needs were able to initially locate, identify, then seek solutions and proposals for action.
– ***How can these requests be approached using new concepts for monitoring, controlling and improving energy efficiency in the context of energy management in production?***
  These requests can be satisfied using the tools of industrial engineering. Here is the hidden meaning of this paper, on which is built of establishing a methodology for reducing the energy intensity of production processes.
  One of the key areas for achieving energy efficiency was known of such energy-efficient production. Consequently, this work focuses (specifically within the Department of industrial engineering) on designing manufacturing systems and processes, so that the real production became at the same time energy efficient production.

This research question is based on two hypotheses:

– ***Hypothesis 1:*** Current approaches to measure, control and improve energy efficiency in manufacturing processes do not address the needs of industrial companies in a comprehensive and practical manner.
– ***Hypothesis 2:*** Information and Communication Technologies (ICT) and standardization are important enablers for measuring, controlling and improving energy efficiency in manufacturing.

2 TECHNICAL MODEL OF ENERGY EFFICIENCY IMPROVEMENT IN MANUFACTURING

The authors have proposed the technical model to eliminate these disadvantages and to add more useful features for energy efficient manufacturing systems. This new reference model for improvement in manufacturing processes is shown in Fig. 2.

Industry holds a large, highly concentrated potential for improving energy efficiency. Whose attractiveness for exploitation are shaped, not only by their technical merits, but also by site-specific energy markets, economic environments, business situations, managerial priorities and implementation barriers. Further, its energy efficiency can be improved by a wide variety of technical actions. Furthermore industrial drivers constituted by rising and volatile energy prices, ever-stricter becoming legislations and increased customer awareness rise the attention to the research field.

Holistic approaches to design and operate modern green production systems are required to cope with those challenges adequately. To analyse production systems with respect to economic, ecological and energy objectives, a specific set of data is necessary as an informational basis. The definition of input and output flows is a prerequisite to determine required economic, ecological and energy information on production systems [Micieta 2013].

This also avoids possible problem shifting, e.g. when measures decrease one input variable but lead to an increase of another variable at the same time. Therefore, ecological and economic process models need to be combined to requirements for energy efficiency in manufacturing systems. The integrated process model represents a description model of production system flows that allows capturing all relevant input and output flows and their quantitative values. The outcomes of the study incorporate a comparative overview of currently used methodologies, tools, indicators and practices in different sectors. Transferring this holistic view on a production plant leads to main partial systems that have to be considered: product design, process planning (with interlinked machines and personnel controlled through production management), energy model (the technical building services and the building shell). Having in mind the integrated process model, all involved input and output flow result in a complex control system with dynamic interdependencies between these subsystems via different internal and external influencing variables.

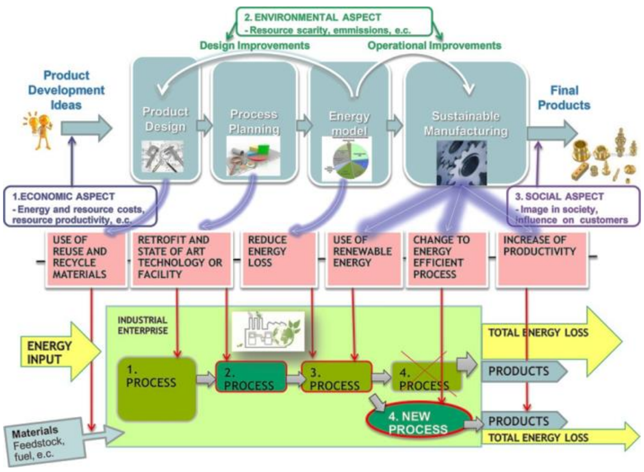

Figure 2. Technical model of energy efficiency improvement in manufacturing

Nevertheless, until now there are still enterprises who have not implemented an energy management system or a continuous improvement of energy efficiency [Trianni 2012]. Several studies ascribe this to various barriers [Sorrell 2000], [Weber 1997], [Palm 2010] and lacks between industrial needs and scientific literature [Bunse 2011].

Energy management systems are internationally standardized within the ISO 50001 and already in industrial use. The structure of the standard includes organizational aspects, systematic and technical aspects. The organizational aspects consist of the organization and the representatives and define the responsibilities and duties of the different roles. Systematic and technical aspects describe the conception, planning, realization and check-up as well as the adaption and adjustment of the management system. Furthermore, a continuous improvement is required [Weidong 2011], [ISO 50001 2011].

3 METHODOLOGY FOR REDUCING ENERGY INTENSITY OF PRODUCTION PROCESSES

3.1 *The request to complement the existing work by a component of the assessment of effective energy management*

By designing the manufacturing system should be taken into account two dimensions:

Dimension 1: Input to existing manufacturing system (planning of new structure)
The methodology provides the support for detailed processing of existing practices from the viewpoint of energy intensity of production processes at the design stage of manufacturing processes.

Dimension 2: The implementation of restructuring (adding, changing, and reducing)
Using the tools of industrial engineering allows you to search the potential for reducing energy consumption in existing factories. To ensure long-term sustainability of production is required to be able to control energy intensity.

The analysis of selected professional studies and scientific work in the area of energy efficient manufacturing showed that between these studies, there is no comprehensive methodology that we were able to control the energy intensity of manufacturing processes. The organization shall identify EnPIs (Energy performance indicators) appropriate for monitoring and measuring its energy performance. The methodology for determining and updating the EnPIs shall be recorded and regularly reviewed. The concept of energy performance includes energy use, energy efficiency and energy consumption.

EnPIs can be a simple parameter, a simple radio or a complex model. Examples of EnPIs can include energy consumption per time, energy consumption per unit of production, and multi-variable models.

Thus the organization can choose from a wide range of energy performance activities. For example, the organization could reduce peak demand, utilize surplus or waste energy or improve the operations of its systems, processes or equipment. [ISO 50001, 2011]

Indicator	Indicator type	Application
Energy intensity	Economic	Aggregated level
	Macroeconomic	
Specific energy consumption	Physical Technical	Disaggregated level Process level Comparison
Energy use per unit of value added	Economic	Aggregated level
Degree of Efficiency	Engineering view	
Final energy efficiency		Energy savings by the same benefits
Ratio of energy consumption	Macroeconomic	
Value added	Macroeconomic	
Thermal energy efficiency of equipment	For single equipment	
Absolute amount of energy consumption	Attended by indication of production volumes	
Energy (costs)/GDP	Macroeconomic	

Table 1. Selection of key energy efficiency indicators

The main task of manufacturing system reconfigurability lies in hardware and software components changing [Micieta 2015]. Reconfigurable manufacturing systems are proposed as a solution to unpredictable fluctuations in market demand and market turbulence [Westkamper 2009]. Realising cost-effective energy efficiency potentials will be beneficial not only for individual energy consumers but also for the economy as a whole [Micietova 2014], [Dulina 2014]. Tomorrow's energy efficient manufacturing will require additional processing power at all levels of its infrastructure [Rakyta 2014]. The biggest savings is generally from the avoided new materials production, but the difference between new manufacturing and remanufacturing can also be significant [Koren 2010]. To gather a better understanding of the current state of research and gap analysis of research and technology development activities specific to information and communication technology usage for energy efficiency in manufacturing, the methodology for reducing the energy intensity is proposed.

3.2 *Reduction the energy intensity of production processes*

Before an implementation of the methodology of improving energy efficiency in production processes need to be addressed by including achieving energy efficiency in business strategy - management decision, that this area will be developed and will be included in the strategic objectives of enterprise, because energy must be regarded as valuable resources needed for business. Information about energy planning of measurement along the objectives of improving energy efficiency in production should be stated in the strategic energy management plan:

- *Energy audit* – steps of energy audit must be carried out by a person or, more commonly, a team of people that are deemed as competent, independent and unbiased.
- *SWOT analysis of energy efficiency of manufacturing processes* - the requests for SWOT analysis are listed in Table 2.
- *Energy management objectives and resources* - examples of strategic objectives and resources of energy management are shown in Table 3.

Strategic objectives and resource of energy management	
Strengths	**Weaknesses**

The measurement of energy consumption in the manufacturing processes, monitoring and evaluation of energy efficiency indicators of manufacturing processes, the design and implementation of corrective actions to optimize the manufacturing processes.	Heat loss or energy loss in the manufacturing process, analysis of the causes and consequences of an energy losses, realization of control and monitoring of energy consumption.
Opportunities	**Threats**
What are the possibilities of renewable energy in production process? Is it possible to compare process in terms of energy consumption with similar production processes? Is it possible to re-use energy in the production process? Is there energy-efficient equipment in production processes?	The rise of energy costs used in the manufacturing process. Exhaustibility of energy sources, the proximity of the energy sources. Grow of customer demand for the manufacturing process. Failures of energy audit requirements.

Table 2. SWOT analysis of energy efficiency of manufacturing processes

Strategic objectives and resource of energy management
Energy management objectives
1. Achieve efficiency in purchasing power for the operation of the business.
2. Implementation of intelligent energy management - the process of monitoring, controlling and conserving energy in an organization.
3. Operations management focuses on carefully managing the processes to produce and distribute products and services.
4. Improve overall operational efficiency.
5. Increase energy efficiency compared to previous years of operation.
Resource to accomplish these objectives
1. Building energy management center (the energy control center),
2. installation of the measuring equipment,
3. energy monitoring and targeting,
4. energy consumption and on-line data transmission to the central energy management,
5. purchase of energy-efficient machinery.

Table 3. Strategic objectives and resource of energy management

All enterprises can save energy by using appropriate principles and techniques of industrial engineering, which are used in business for key resources such as raw materials and work practices [Thiede 2012].

This management must include full managerial responsibility for the use of energy. Management of energy consumption and eliminate wasted loads then brings cumulative savings. The first part deals with the methodology of the evaluation process energy efficiency of production processes. This includes:

Step 1: planning of energy consumption, which is the basis for energy management in production processes for decision-making of measures for improvement and optimization of energy efficiency. This step includes:

– *Report of energy audit* – definition of energy consumption in the manufacturing processes.
– *Management of responsibilities* – appointment of lead managers (coordinator).
– Objectives, structure – policy statement of top management and presentation of benefits.
– *Work plan* – schedule of measurement and control of energy consumption.
– *Setting priorities and motivation of employees* – motivation of work staff in order to help by implementation of methodology.
– *Application of process scoring* – sequence of process scoring – energy leader.
– *Energy audit of manufacturing process* – realization of energy audit by certificated auditor.

These single actions are connected with the PDCA (Plan-Do-Check-Act) cycle. Fig. 3 summarizes the actions of this holistic approach.

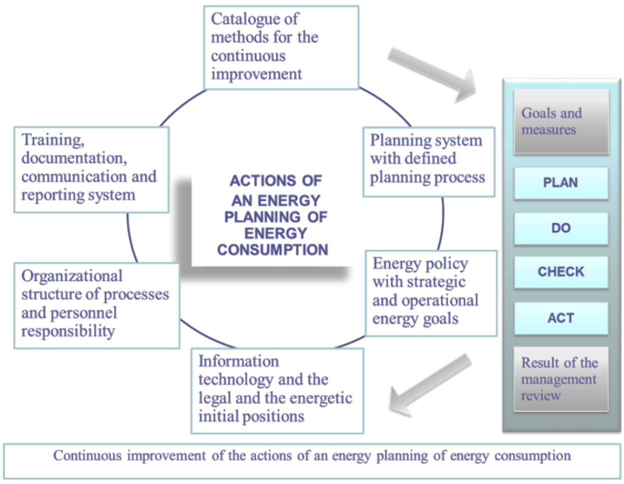

Figure 3. Cycle of improvement of energy consumption

Step 2: control of energy efficiency in production processes, the proposal of factors and indicators of energy efficiency, analysis of energy cost reduction. This step includes:

– *Proposal of factors affecting energy intensity of manufacturing* – external and internal factors affecting the structure of energy consumption in manufacturing enterprise.
– *Classification of waste and energy costs in the manufacturing processes* – establishment of energy costs, determination of total energy costs.
– *Monitoring of the total energy costs* – calculation of statistical indicators, pareto analysis of energy costs, the selection of indicators.
– *Schedule for solving variations of setting goals* – identification of requirements and creation of standards.

The requirements of the standard can be divided into ***organizational and technical aspects***, and an organizational framework and a technical operative system could be deduced. The organizational framework is the basis for actions and defines the system adjustment, the organization, structures and processes. This is where the ***energy management system*** is located and acts as instrument for rough planning.

The technical operative system is the system for actions, measures and realization. This system includes the observation object – product, process or facility. Here, the operating energy management system is located. Between the framework and the operating system a technical control system acts as interface where the detailed planning is carried out and the top-level requirements are broken down in specific operational goals for the observation object. This interrelation is summarized in Fig. 4.

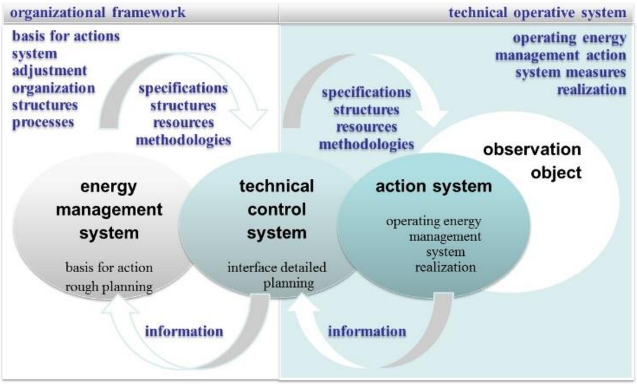

Figure 4. Actions system adjustment enterprise structures processes [Dorr 2013]

Step 3: the request for subsequent re-configuration management system, in which will be realized by monitoring energy consumption and propose corrective action (***CODESA-Prime*: Intelligent Product Agent**) [Durica 2015]. This step includes:

- *Energy monitoring* – structure and planning of energy monitoring, setting goals of energy monitoring, setting measurement techniques, transmission of measured values.
- *Reconfiguration of system management* – selection of system criteria, evaluation of data, optimization of measurement.
- *Implementation of corrective actions* - organizational measures, low cost actions, high cost actions.

Reconfigurable Manufacturing Systems (RMS) constitute a new class of systems characterized by adjustable structure and design focus. A system built with changeable structure provides scalability and customized flexibility and focuses on a part family, thus generating a responsive reconfigurable system. The flexibility of RMS, though really only "customized flexibility", provides all the flexibility needed to process that entire part family. [Koren, 2011]

Based on the results of previous analyses, we have proposed measurable indicators that affect the energy-efficient enterprise. For selection of indicators and on their evaluation for the possibility of comparison with similar firms (plants), production processes and projects increasing energy efficiency among them are divided into three levels:

Level 1: Indicators for international (state) level - Energy efficiency indicators – *fundamentals on statistics* are to identify the main sectoral indicators and the data needed to develop these indicators.

Level 2: Indicators for comparison between industrial sectors.

Level 3: Indicators of energy efficiency at the process level, which are then divided into four specific areas:

- building,
- production process,
- technology,
- energy distribution.

To evaluate the evolution of energy efficiency with respect to the cost, we propose to use statistical methods - basic and chain indices. Calculations of the statistical indicators are based on formulas: Indicator – the base index (I_{vb}) - defines the proportion of the reference indicator in the current period to the baseline period indicator. Where:

N_1 – indicator of the current period,

N_0 – indicator of the base period.

$$I_{vb} = \frac{N_1}{N_0} \cdot 100 \quad (\%) \tag{1}$$

Indicator – the chain index (I_{vr}) - defines the proportion of the reference indicator in the current period with the pointer of the immediately preceding period. Where:

N_n – indicator of the current period,

N_{n-1} – indicator of the previous period.

$$I_{vr} = \frac{N_n}{N_{n-1}} \cdot 100 \quad (\%) \tag{2}$$

Step 4: checking and improvement, management review for continual improvement and controlling. This step includes:

- *Schedule of regular control* – monthly and daily improving of energy efficiency.
- *Kaizen evaluation and implementation* – examine possibilities for continuous improvement.
- *Management review* – the new targets, program guide of increasing energy efficiency.
- *Recommendations for the energy efficient manufacturing* - reduce waste of energy in the production process, promote the overall effectiveness of equipment, improve the performance of workers, establish a free service operations or system hibernation of facilities during breaks, and promote the reduction of energy costs.
- *Energy value stream mapping (EVSM)* – it is important to look at the value stream as a whole. Energy value stream mapping is a graphical technique that allows identifying the level of energy use and, thereby, discovering saving opportunities at each step of different processes either in production or in facility support. EVSM is a holistic approach to recording, analysing, and optimizing process-related energy consumption. The example of value-stream mapping that systematically shows value-adding and non-value-adding time and energy in the manufacturing process with the lead time and processing time is shown in Fig. 5.

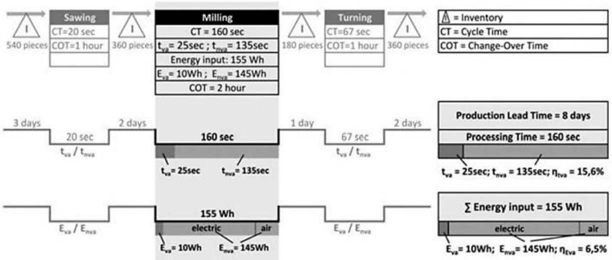

Figure 5. Example of energy value-stream mapping

The second part of the methodology involves enabling and supporting energy efficiency of production processes. In addition, ***information and communication technologies (ICTs) and standardization*** will play an important role and are essential in creating energy-efficient production. For example, ISO 50 001:2011. The purpose of this international standard is to enable organizations to establish the systems and processes necessary to improve energy performance, including energy efficiency, use and consumption [ISO 50001 2011]. Digitizing, modelling, simulation and emulation are used to understanding of comprehensive manufacturing processes and creation of new knowledge, which is used for optimization of real production systems [Gregor 2015]. Depending on the model, especially lightweight materials are used for the individual parts, for example, aluminum in the front end and chassis [Kohar 2014]. ***Intelligent manufacturing systems*** represent the actual answer to the solution of the above mentioned problems in order to create energy-efficient manufacturing. Intelligent manufacturing systems are socio-economic system with the ability to autonomously identify system changes and impulses from the environment, their causes and to use the obtained knowledge for self-learning, adapting and responding to all changes of the surrounding environment in a way similar to human response [Krajcovic 2013]. Energy efficiency within a factory can be tackled at a number of levels, as indicated by Duflou [Duflou 2012]. Improvements at each level will derive benefits and these benefits will be additive. Hence benefits from machine tool level changes can be enhanced by changes at the manufacturing system level. Therefore, concentration at only one level will miss opportunities at other levels. The interface between organization and technique is the technical control system. This interface allows for a continuous process improvement on technical level by providing required information and knowledge. Fig. 6 relates a standard energy efficiency project to the necessary extensions in the technical control system. Methodology for reducing energy intensity of production processes consisting of two above mentioned basic parts [Binasova 2014]. Its component parts are shown schematically in Fig. 7.

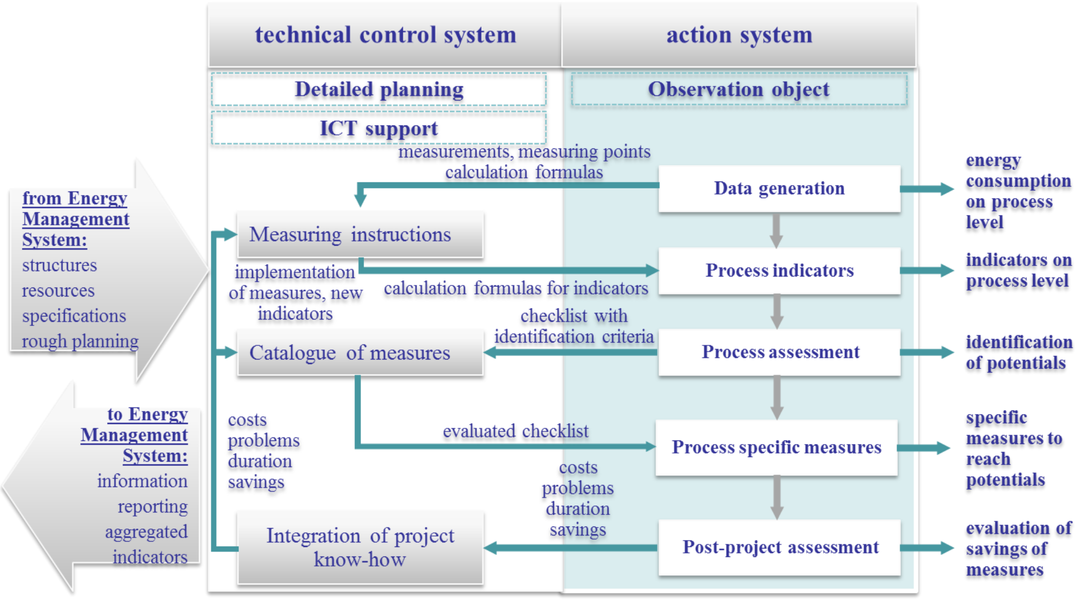

Figure 6. The approach of integrating technical control system and action system [Dorr 2013]

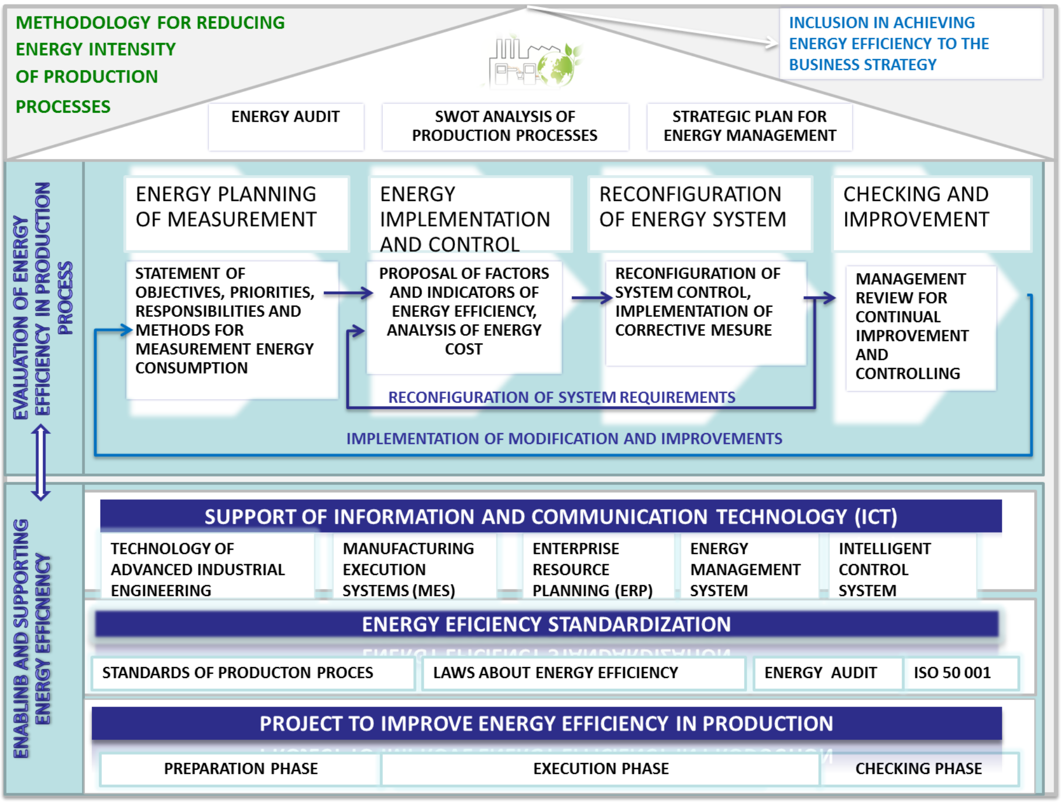

Figure 7. Methodology for reducing the energy intensity of production processes

Also, the implementation of this methodology should be treated as a unique project; therefore, it is necessary to use methods of project management. These assumptions are different for every manufacturing enterprise depending on the tangible assets, intangible assets, financial and human resources.

The verification of methodology was realized in a manufacturing enterprise. This enterprise deals with the production and sale of tires and conveyor belts for the rubber industry. For large content of data and range of the methodology, we present the final conclusions. The final solution leaded to the improvements:

- implementation of the awareness-raising campaign about the opportunities and benefits of reducing energy consumption has led to optimization of production process in terms of energy use and to increase the overall equipment effectiveness,
- creating space for mutual communication and cooperation of production teams and energy management teams led to the development of optimization measures in the production processes,
- optimizing of use of the energy software has been allowed to generate monthly reports of energy consumption in the production process,
- the graphical evaluation and visual management boards has enabled monitoring of key performance indicators in production,
- application of standards for the promotion of the impact of energy efficiency regulations on equipment efficiency and prices,
- staff training for correct and efficient implementation (setting state of hibernation mode of equipment, the implementation of autonomous maintenance, switch lighting during breaks, etc.) allows reduction of energy consumption of individual facilities,
- introduction of information system has contributed to the exchange of experience about the possibilities of rational use of various energy devices,
- energy management team (based on established energy monitoring) has created the project to purchase additional diagnostic equipment and energy efficiency technologies into the production processes.

4 CONCLUSIONS

In any case, the successful implementation of concepts contributing to the development of energy efficiency-oriented tools and methods in manufacturing processes begins with a strong organizational commitment to continuous improvement of energy efficiency.

The global market are imposing strong changing conditions for companies running their businesses, something comprising complex and large scale systems [Leitao 2013].

The main scientific contribution is the methodology for reduction energy consumption of manufacturing processes that can be used to control and coordinate the energy intensity of manufacturing processes and determine visions, key research topics, barriers, impacts, key business scenarios and priorities, which can influence energy costs with low associated investment costs. New sources of productivity growth in the following stages of development will be certainly Artificial Intelligence (AI), application of knowledge-based systems and intelligent holonic solutions.

Industrial energy accounts for roughly one-third of total global energy consumption and is expected to continue with a similar share in the foreseeable future, therefore the efficient use of energy and energy saving are important issues for the industrial sectors. Energy efficiency is a crucial factor for energy cost-benefits and waste reduction also environmental management, and can be improved by different approaches. Especially in this paper the energy saving through implementation new approaches was illustrated. Energy efficiency was achieved by use of methodology which presents various strategies, tools, methods, technologies, and effective measures to face energy saving and consumption issues, that also includes energy strategies, energy audits, monitoring, control, reconfiguration and continuous improvement of the manufacturing processes.

In particular in this work energy saving through maintenance (corrective and preventive) and operative procedures were addressed. Maintenance operations are fundamental in granting machineries and processes energy saving, given the capability of optimising them thanks to the predictive models. The major challenge of maintenance optimization is to implement a maintenance strategy, which maximizes availability and efficiency of the equipment, controls the rate of equipment deterioration, ensures the safe and environmentally friendly operation, and minimizes the total cost of the operation which means the both production and energy cost.

As was mentioned earlier, the verification of the methodology was realized in rubber industry. Energy efficiency in manufacturing can be improved by a wide variety of technical actions including:

- Maintaining, refurbishing and returning equipment to counter natural efficiency degradation and to reflect shifts in process parameters.
- Retrofitting, replacing and retiring disused machine and equipment, process lines and facilities to new and state of art technologies.
- Using heat management to decrease heat loss and waste energy by, for example: proper use of insulation; utilization of exhausted heat and materials from one to other processes.
- Improving process control, for better energy and materials efficiency and general process productivity.
- Streamlining processes-eliminating processing steps and using new production concepts.
- Re-using and recycling products and materials.
- Increasing process productivity.
- Decreasing product rejects rates and increasing materials yields.

This is basic benefits of implementing a methodology for reducing energy intensity. Other benefits of implementing methodology for reducing the energy intensity are shown in Table 4.

Reduced operating costs [Thousands of euros]	Investment costs [Thousands of euros]	Return on Investment (ROI) [Years]	Internal Rate of Return (IRR) [%]	Net Present Value (NPV) [%]
365	730	2	53,6	3645

Table 4. Strategic objectives and resource of energy management

Policy facilitates those technical efforts. A policy of energy efficiency should also be able to exploit the potential in various fields, in particular in the industrial sector where efficiency means greater competitiveness and thus trigger a virtuous circle for the country's economy. The successful use of policy for energy efficiency improvement depends on how policy can finally give incentives for each possible technical improvement, directly or indirectly, to industry sector.

There is also a need for a deeper look into policy packages - how the components complement one another, and how policy coherence is maintained to ensure overall efficacy and cost efficiency in sustainable manufacturing as the philosophy of eliminating waste within a process, and place them in a form of continuous flow energy consumption to better meet customer demand. Specific challenge is an implementation of innovative technologies for resource and energy efficiency. It will require a consistent sustainability assessment across sectors and along the value chains.

Development of automation and intelligent manufacturing systems require energy-efficient design and its application. The proposed research is focused on analysis and optimization of tools for flexible energy use. Material flow integration should be developed, aiming at a holistic approach for resource management in process industries. Further research intends to specify the concept and to develop a demonstrator for using these methods by next case studies. The verified methodology for reducing the energy intensity of production processes can be implemented in other manufacturing enterprises.

The two hypotheses introduced in section 1.1 can be confirmed: current approaches to measure, control and improve energy efficiency in manufacturing processes have shortcomings in addressing industrial needs in a comprehensive and suitable manner *(Hypothesis 1).*

Information and communication technology and standardization can be significant enablers for supporting the measurement, control and improvement of energy efficiency in manufacturing processes *(Hypothesis 2).*

Reducing energy waste in manufacturing enterprises helps reduce manufacturing costs, and helps keep our industries competitive [Staszewska 2013]. Using the concrete example, the paper shows a methodology of successful development of energy management system where demanding research claims had to be fulfilled. To carry out this research, it was necessary to use method of industrial engineering and energy software to gain the optimum effectiveness.

Advanced industrial engineering is focused on three main subgroups: industrial networks (cloud manufacturing, new form of cooperation), adaptive production (adaptive assembly, intelligent manufacturing system) and digital engineering (digital factory, virtual reality) [Micieta 2014].

From this point of view, the ambition of future research work is to further develop a new practical sustainable concept in order to search for opportunities, not only in undertaking energy saving technical actions, but also in introducing of reconfiguration of system requirements.

There is a need for further study, for example, selected case studies, for actual implementation of reconfiguration of energy system.

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