SLOVENSKÁ TECHNICKÁ UNIVERZITA V BRATISLAVE
FAKULTA ELEKTROTECHNIKY A INFORMATIKY

Ing. Peter Hofmann

Autoreferát dizertačnej práce

Ways of improving energy efficiency
in small and medium- sized enterprises

na získanie akademickej hodnosti doktor (philosophiae doctor, PhD.)

v doktorandskom študijnom programe: **Elektroenergetika**

v študijnom odbore 5.2.30 Power Engineering

Forma štúdia externá

Miesto a dátum: Bratislava, 24.06.2017

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Cesty k zvyšovaniu energetickej efektívnosti v SME

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Dizertačná práca bola vypracovaná v externej forme doktorandského štúdia

Na: Ústav elektroenergetiky a aplikovanej elektrotechniky,Fakulta elektrotechniky a informatiky

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Thesis and purpose of the dissertation

This thesis corresponds in objective and content, in particular of solutions for current and possible future-oriented questions of the practice. So the attempt is made to provide recommendations on principle suitable options for increase energy efficiency.
Practice-relevant conclusions should be derived. Additional the results should initiate further applications, publications and research.

1. **Development and design of an standardized, strategic phase model for increasing energy efficiency in small and medium sized companies.**

2. **Optimization with an energy turnaround /reversal using the example of the investigated medium- sized company.**

3. **Identification and development of an energy storage system in case of an holistic renewable energy aproach for the investigated medium- sized company.**

4. **Identification of supporting and inhibiting factors in the context of energy efficiency measures in small and medium sized companies.**

As the result that shoud lead to:
The combination of theoretical model and practical data as a representation of reality.

The formula would be:
Theoretical model + practical data = real model

1 Introduction

1.1 Problem Situation

Energy is a topic of the future.

Climate change and rising energy costs are now increasingly in the public and political debate.

The energy that is used in the companies is still wasted to a considerable extent and causes disproportionately high environmental impacts and costs.

Topics that describe the energy efficiency of companies and their remediation possibilities have gained a permanent place in the engineering journals.

The energetic structures in the companies are becoming more and more complex.They are in an increasingly tighter web of dependencies and interactions. Those who have to make forward-looking decisions in this situation are dependent on quality informations and advice.

Without concept implemented individual measures do not lead to the desired result, and only reinforce the widespread skepticism about energy refurbishment measures.

Additional the technical possibilities are now very extensive, often leading to enlargement of the insecurity. Complete avoidance is often the result.

These factors are therefore also a growing scientific and engineering challenge.

Because the optimization process is usually distributed not only on one single measure, but on several pillars within a continuous improvement process.

The result should be a "tailor-made specific company suit" with regard to building physics and systems engineering as well as the costs and therefore its optimum of the energetic and economic efficiency.

The five groups of efficient energy use measures are:

1. Avoidance of unnecessary consumption
2. Improved efficiency rates
3. Recovery of energy
4. Using renewable energies
5. Energy controlling

(compare Bayerisches Landesamt für Umwelt, 2009,
“Leitfaden für effiziente Energienutzung in Industrie und Gewerbe“ p.8) [1]

1.2 Definition of key terms

1.2.1 Energy and energy efficiency

Energy can neither be created nor consumed but always only transformed from one form to another. In the very last consequence all the energy originates from the sun.

Primarily energy demand:

Final energy taking into account the energy needs of the preceding process chains such as extraction, transportation, processing and conversion of primary energy carriers.

Useful energy:

Energy at the end of a conversion chain available to the consumer for various applications for example light, heat or mechanical energy.
(see also Recknagel, Sprenger, Schramek 2003/ 2004 p.361) [2]

Grey energy: (indirect energy):

As embodied /grey energy (not renewable) primary energy is referred that is needed to construct a building.
Embodied energy includes energy for the extraction of materials for the manufacture and processing of components for the transportation of people, equipment, components and materials to the building site, for installation of components in the building as well as disposal. Through the use of local materials and sustainable construction the built-in building embodied energy can be minimized.
Compare: www.baunetzwissen.de/ graue energie (grey energy)

Efficiency:

Efficiency is understood in general in improving the yield or increased utilization, reduce of losses and economic use (optimized use factor).In the technical sense it means the ratio of benefit to effort (efficiency) and under commercial consideration the ratio of earnings to the invested resources.

Energy Saving:

The best energy is that which is not “consumed” at all.

1.2.2 Small and medium- sized enterprises in Germany

“The Institute for SME Research Bonn defines independent companies with up to 499 employees and an annual turnover to less than 50 million € as small and medium-sized enterprises (SMEs)” .European Commission defines them only up to 250 employees.

Small- and medium-sized enterprises are widely regarded as the backbone of the german economy, and stand out in comparison to large group companies by greater flexibility and innovation dynamics and through greater cooperation.

They are also the site of new business ideas. While large companies tend to cut off jobs, they are created by SMEs.

„In a competitive international economy large enterprises ensure the survival of the national economy, small and medium enterprises ensure the survival of large companies, both together ensure the survival of the national economy. The market economy itself provides the greatest welfare of the people.“

(Source:Niehues, Dr.Karl, **„Unternehmenserfolg statt hausgemachter Unternehmenskrisen“** KMU-Institut GmbH, Waldeyerstr. 61, 48149 Münster, 1997) [3]

1.3 Eco political necessities and energy reversal

Todays global population currently is about 7,3 billion people, of which only about 1 billion is living in wealth. In addition there is a further annual growth of about 80 million people. Fossil fuels such as coal, oil and natural gas are not unlimited.

This naturally results in increasing energy prices. But their use is also associated with some environmental problems. Viewing scientific studies indicate that worldwide more than 24 billion tons of the greenhouse gas carbon dioxide CO_2 emitted into the atmosphere. This in turn results in dramatic climatic changes or natural disasters.

Mainly responsible for this draw are the industrialized nations. They emit about 80% of the greenhouse gases.

The last decade has been marked by growing public concern and widespread media coverage surrounding the topic of global warming due to an increased greenhouse effect process chain.

2 Reseach method

2.1 Principle way to energy efficiency

The development of a standardized phase model, which may also be universal, taking into account industry-specific requirements, demands a successive and structured procedure.

In addition further synergies can be achieved through a holistic implementation. At its beginning in principle an initial consultation with an energy consultant or an engineer of the relevant disciplines should take place. After analysis i.e. determination of the actual state of the company and its immanent potential, respectively the individual matching optimization opportunities of the strategic action plan are prioritized, selected, and energetically and economically compared, i.e. how they behave in the cost and profitability comparison. Because the optimization process is usually not only distributed to a single measure, but on multiple columns within a continuous improvement process, it may be necessary to carry out the success monitoring already for each of the individual measures.

That leads in a first approach to the following coarse expiration:

Assessment of the actual state –
Determined and formulated as precisely and detailed as possible.

Operationalization –

The terms and variables that are connected to the problem clarification, are worked out and defined.

Data collection –

Measures are selected, and afterwards the measures are conducted and documented.

Data analysis –

The data is sorted, analyzed and compacted in their meaningfulness by various methods.

Choice of measures and method –

The method of choice arises from the target position as well as the specific possibilities. Then the instruments are developed (check list, questionnaire, etc.).

Presentation and controlling of results.

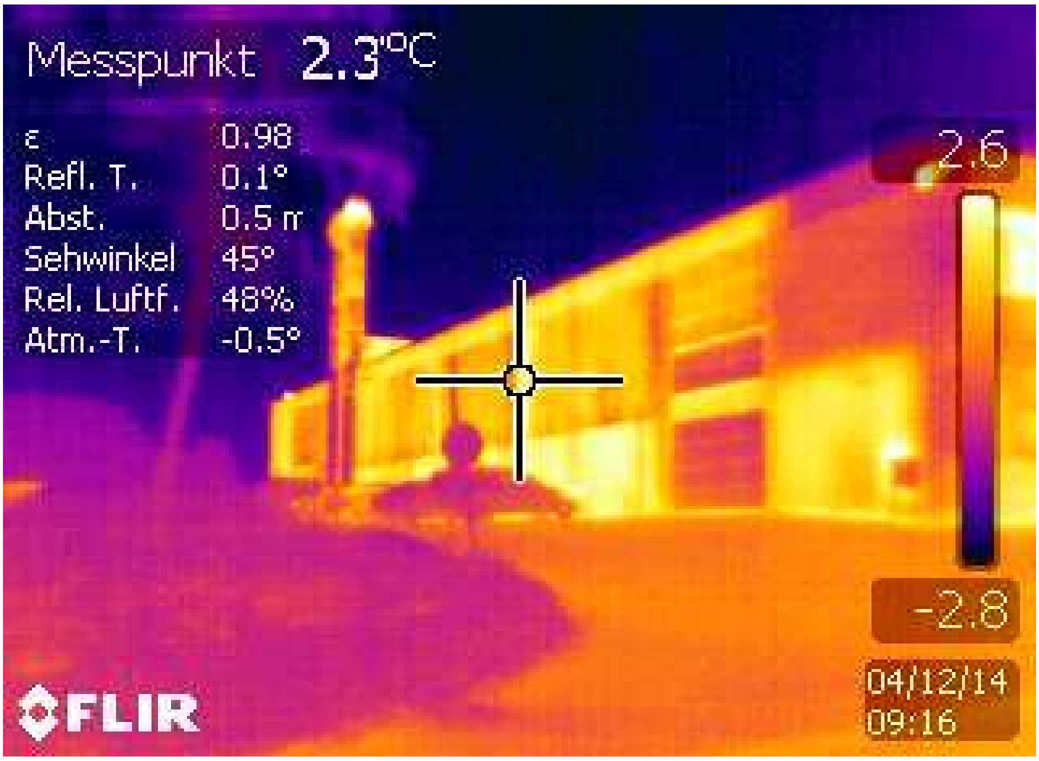
2.2 Technical and methodological measurement

The following calculations and measurements are to be done:

One of these measurement is the noncontact infrared thermometry.

In addition to this measurement there are also be measurements of the real power and gas consumption, of air exchange rates, of burner efficiency and room / system temperature levels, circulation pump speeds, etc. Due to the fact that the wall areas of the building are the largest heat transfer surfaces not only at this point is a particular importance, to verify the theoretically calculated values through real measurements.

In the context of the detection of the actual state of the investigated company this noncontact infrared thermometry will be applied. Where an actual refurbishing measure is done, also a result control is performed. The building physical measurements are performed using an infrared thermographic camera and visually represented in the form of color gradation images (see Pic.1).



Picture 1: Investigated company (actual state). View from east.

This "thermal images" indicate the regions with different surface temperatures and heat radiated emissions on a building by various colour gradations.

2.3 Economic efficiency and amortization of energy refurbishment measures

Rising energy costs burden increasingly the companies.

Economic efficiency calculations are used to assess the economic viability of projects or measures. These are methods of calculation of the investments, costs, revenues or profit of a project to determine financial parameters. The comparison of these parameters then allows the decision for or against specific projects or measures. Their aim, therefore, is to make statements about the resulting benefit of a proposed investment decision. It is about the optimization of alternative choices.

2.4 Strategic measures to increase energy efficiency

2.4.1 Applications in companies

Not all the companies have the same energy consumption structure. It depends on their sector. Inter alia particularly high savings potentials occur in the field of cross-cutting technologies:

They include all energy saving measures that can be used for all sectors equally. They are sector independent.

All other measures are to be checked industry-specific regarding the individual case.

2.4.2 Building physical measures

All buildings in common have a continuous, energetic interaction with the environment which leads to heat losses caused by transmission and building leakiness. A crucial aspect of an energy-efficient building is the technical quality of its thermal insulation and heat transfer components.

The optimal building envelope has essentially to satisfy the following requirements:

- Lowest possible heat transfer coefficient ,
- Air and wind tightness,
- Prevention of thermal bridges

Possible measures i.a.:

- Building insulation and thermographic weak point analysis,
- Air tightness of buildings, - Hall doors, windows, skylights (improve or renew)
- Solar protection of glass (reduction of air conditioning),
- Daylight steering

2.4.3 Technical measures

The choice of technical measures can not considered isolated. They have to be selected in each individual case on the basis of a holistic overall concept. Here several factors such as the building physical conditions,the priorities, local conditions, investment costs, life cycle costs, etc. are to be evaluated.

Measures i.a.:

- Combined heat and power (CHP), - Heating and condensing technology
- Process heat optimization, - Biomass / Biogas,
- Heat pump and zeolite technology
- Efficient machines and motors, - Heat distribution and insulation,
- Hydraulic balancing with lowest supply and return temperatures,
- Concrete core tempering, - Ventilation technology (with heat recovery)
- Efficient steam generation, - Air conditionig and chilling
- Thermal solar technology, - Photovoltaics, - Hybrid collectors
- Storage technology (electrical / thermal),- Efficient use of compressed air
- Hydro power, - Wind power, - Water consumption / domestic water
- Waste water recycling / heat recovery, - Drying technology
- Logistics and transport, - Efficiency of light and illumination
- Control, regulation- and communication technology / Smart metering
- Information technology and office equipment

2.4.4 Organizational measures

Besides all the technical efforts to reduce the energy demand a prudent use of energy plays also an important role. Often small adjustments in the workflow or a deliberate switching off of unneeded equipment and systems are already sufficient to reduce the energy costs. These organizational measures require no or only minimal costs.
(see Dena GmbH, 2009 “Handbuch für betriebliches Energiemanagement“, p.35) [4]

These are i.a.:

- Energy consultancy and public subsidization,
- Optimization of energy purchasing
- Increasing the kwowledge about energy efficiency in all company levels
- Regularly technical maintenance,
- Establishing of an energy manager,
- Employee training in terms of energy efficient behaviour,
- Predictive energy demand planning (i.a.using the weather forecast)

2.5 Theses and objectives of the dissertation work

This thesis corresponds in objective and content, in particular of solutions for current and possible future-oriented questions. Practice-relevant conclusions should be derived. Additional the results should initiate further applications, publications and research. Knowledge transfer is not only the transfer of scientific knowledge out of competence areas of the university into business practice, but also the transfer of practical issues and impulses towards science.

1. **Development and design of an standardized, strategic phase model for increasing energy efficiency in small and medium sized companies.**

This first approach is a systematic identification that should be based on a catalog of strategic measures, that even taking into account industry-specific requirements through a successive and structured method.

As the result, an energy efficiency algorithm for small and medium sized companies is to be evaluated that can be applied universally .

This strategic phase model is to be divided into operational steps to achieve a defined aim with appropriately defined resources, investment etc.

It is a concept which combines methodological ,technical and economic aspects within one integrative framework.The result is a "tailor-made specific company suit " with regard to building physics and systems engineering as well as the costs and therefore its optimum of the energetic and economic efficiency.

2. **Optimization with an energy turnaround /reversal using the example of the investigated medium- sized company.**

The second aim is the systematic application that should be based on the previous evaluated strategic phase model for increasing energy efficiency. As the result, the question is to be answered if it is possible only by using of todays high efficiency and renewable energy technologies to refurbish an existing company in the way that it produces enough or more energy than it consumes. (Self sufficient respectively autark or plus energy decentralized approach).

3. Identification and development of an energy storage system in case of anholistic renewable energy aproach for the investigated medium- sized company.

As infrastructure optimization respectively energy optimization is not the core business of the manufacturing companies, the existing engineering capabilities are often not optimal or used only with second priority. Renovation and plant expansions, the energy supply is indeed adapted but a holistic optimization is often not carried out, because these adjustments are implemented gradually.

The objective of this analysis is to answer the question whether an approach like described before is technically possible without an energy storage system. Further it has to be checked whether such a system is cost-effective that means that there is an appropriate economic efficiency.

4. Identification of supporting and inhibiting factors in the context of energy efficiency measures in small and medium sized companies.

As mentioned before the energetic structures in the companies are becoming more and more complex.They are in an increasingly tighter web of dependencies and interactions. Those who have to make forward-looking decisions in this situation are dependent on quality informations and advice.

Without concept implemented individual measures do not lead to the desired result, and only reinforce the widespread skepticism about energy refurbishment measures. Additional the technical possibilities are now very extensive, often leading to enlargement of the insecurity. Complete avoidance is often the result. For this reason, for an successful implementation of energy efficiency measures it is necessary to identify these supporting or inhibiting factors in the decision-making process.

As the result that shoud lead to:

The combination of theoretical model and practical data as a representation of reality.

The formula would be:

Theoretical model + practical data = real model

The result of the research project will be a synthesis of theoretical model and and practical application for an reciprocal knowledge transfer.

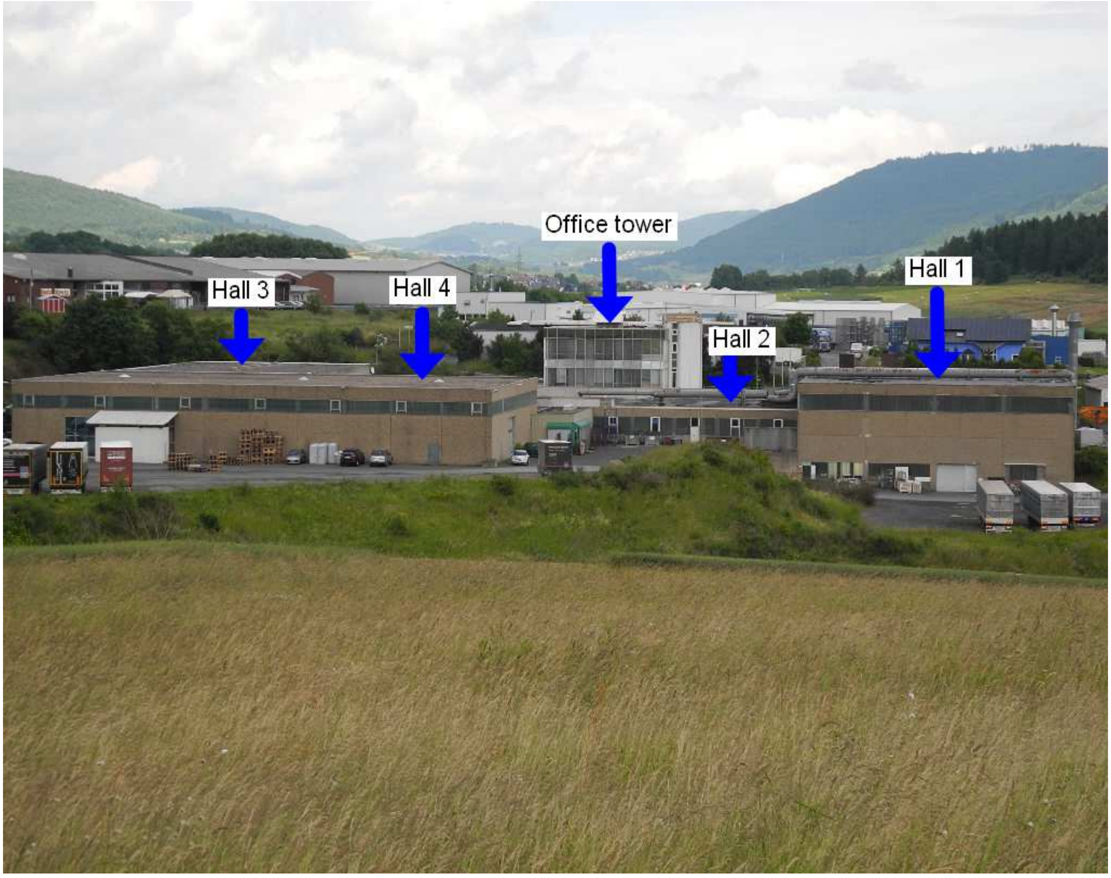
2.6 Introduction of the investigated existing company

2.6.1 Typification of the building and structure

The investigated company building (see Pic.2) is a complex of halls consisting of two production halls, a storage hall and a logistics center (hall) each with office areas. Further connected is a wholesale area and an office tower. The building is exploited by a surface treatment and lacquering company with attached logistic center. The first hall was built in 1970. Thereafter, the complex was successively extended until the eighties.

Location:

Traffic favorable location in a commercial area in 35685 Dillenburg-Manderbach, Dillenburg road 66-72 in Germany.
Land area: 29687 m²
Building area: 7135m²
Height above sea level: 270 m



Picture 2: The investigated company complex (actual state).View from south- west

Floor plan (see Fig. 1):

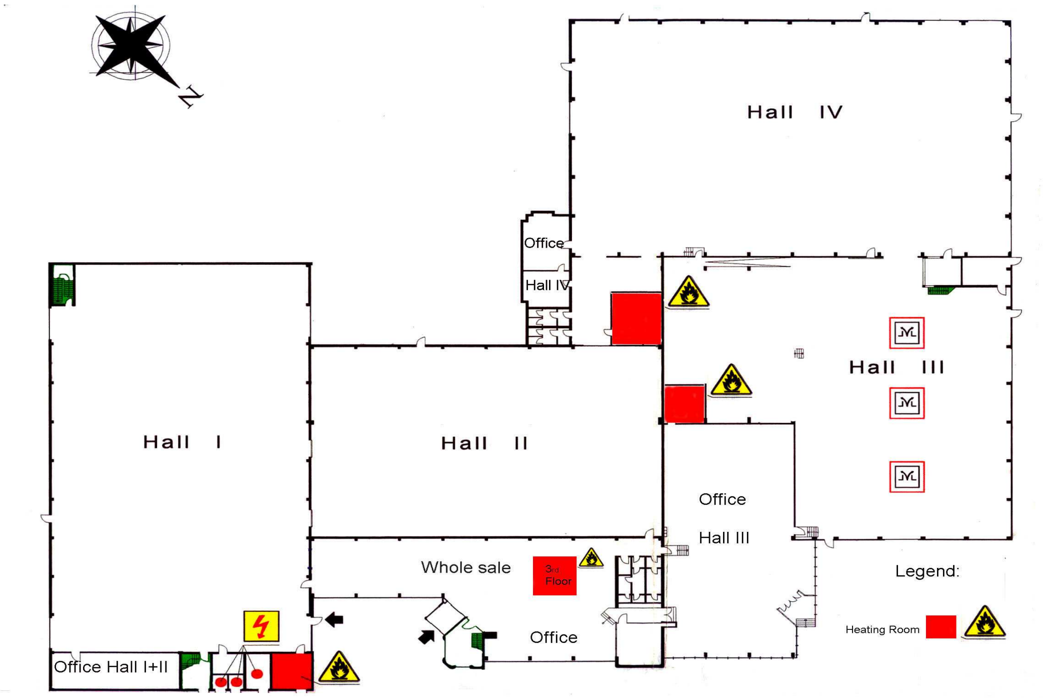


Figure 1: Floor plan of the whole building complex

Utilization: - Hall 1: Production / office,- Hall 2: Production, -Hall 2: Whole sale /office, Hall 3: Logistic and distribution /office, Hall 4: Storage, Tower: 1. floor: Office, 2. floor: Office

2.6.2 Energy consumption (actual state see Fig. 2)

	Total [kWh/a] [kWh/(m²a)]	Heating [kWh/a] [kWh/(m²a)]	Chilling [kWh/a] [kWh/(m²a)]	Ventilation [kWh/a] [kWh/(m²a)]	Illumination [kWh/a] [kWh/(m²a)]	Warm water [kWh/a] [kWh/(m²a)]
Useful energy	2540189	2354823	0	0	183978	1388
	356,02	330,04	0	0	25,79	0,19
Final energy	4002128	3806628	0	7986	183978	3536
	560,91	533,51	0	1,12	25,79	0,50
Primarily energy	4339853	3870655	0	19167	441546	8486
	608,25	542,49	0	2,69	61,88	1,19

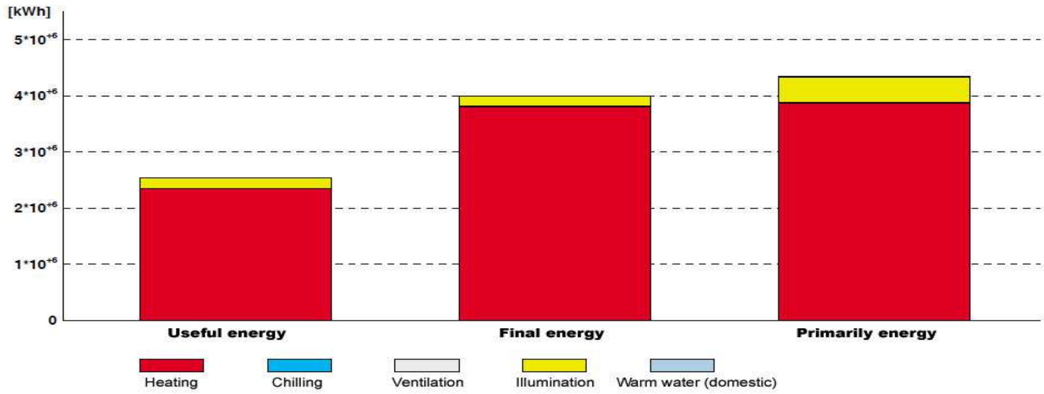


Figure 2: Calculated results of the actual state

As clearly recognizable, the consumption of heating energy with 2.354.823 kWh per year (actual state) constitutes the largest part of the total energy consumption. This results mainly from the bad building physical conditions as well as the partially outdated plant technology. The rest is caused by the illumination and small proportion even by the domestic warm water. Moreover, in the diagrams of the primarily and final energy nor the ventilation losses are included. The evaluation of the useful- energy consumption statistics of the past 10 years revealed a gas consumption for heating on average of 2.014.300 kWh per year (compare useful energy 2.354.823 kWh per year).

As can be seen in Fig.2 (theoretical model calculation) there is a high congruence between these results and its real consumption. (Average of the last decade).

3 Results and discussion of the study

3.1 Developed standardized, strategic phase model

The evaluation of the strategic phase energy efficiency model yielded the in the (not yet used) following 5 steps algorithm that can be applied universally.

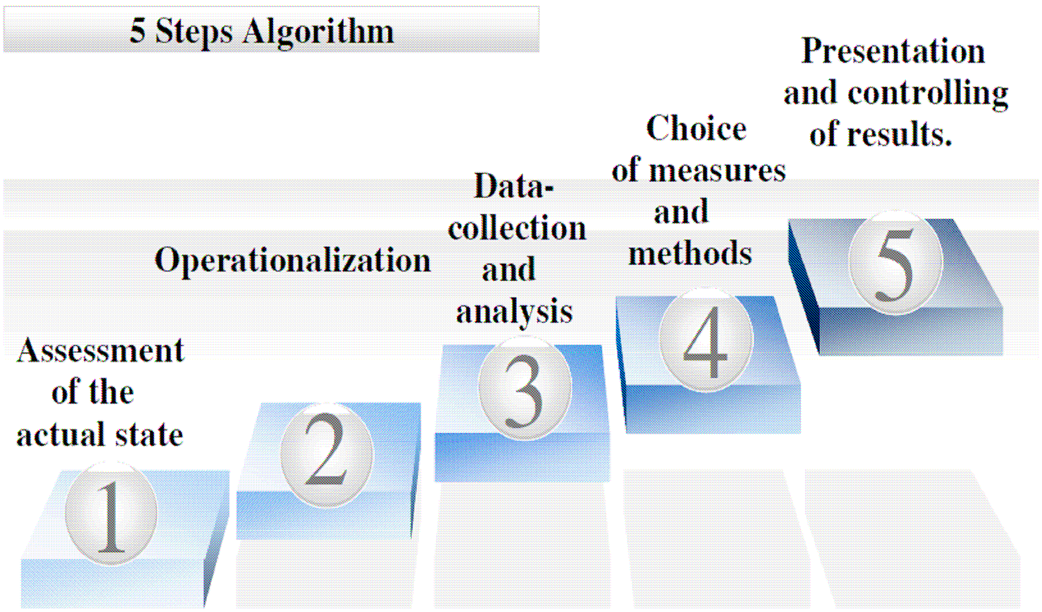


Figure 3: Developed 5 Steps Algorithm

Algorithm integration into applied software analysis:

Basically its course is based on the problem description followed by the problem decomposition towards the problem solution.
The software includes the calculation and balancing of the entire building physics and all currently available and state of the art plant technologies. The integration of the applied 5 Steps Algorithm into the implemented software analysis enabled thus an holistic approach. The results were calculated using the integral approach of the standard DIN 18599 within the calculation kernel of the Fraunhofer Institute. It took into account the mutual interactions between building physics, standardized usage and plant technology.
The software was always used in compliance with the guidelines of this algorithm.

Step 1: Assessment of the actual state

Basis for the creation of the refurbishing concept is the detection of the actual state. In this context, the energy status quo of the company in terms of the existing plant technology, building physics, the organizational situation as well as its energy demand was captured detailed.

Step 2: Operationalization

The objective and variables that are connected to the problem clarification, are worked out defined to enable measurability.
Intented Result:
The combination of theoretical model and practical data as a representation of reality. The formula would be: Theoretical model + practical data = real modelThe result of the research project will be a synthesis of theoretical model and and practical application for an reciprocal knowledge transfer.
The corresponding energy and economic calculations and simulations are to be carried out. In addition, the use of appropriate technical tools such as, inter alia, data logger, thermal imagers, tightness measurement equipement have to be used.

Step 3: Data collection and analysis

In order to ensure a comprehensive inventory a data inquiry sheet was specifically developed. It is stored in the appendix. Then the instruments are developed (check list, questionnaire, etc.). Measures are selected, and afterwards the measures are conducted and documented.

Step 4: Choice of measures and methods

The methods of choice arised from the target position as well as the specific possibilities also taking into account all company-specific economic factors. With regard to necessary clarification the following nine-field decision making matrix was developed.

High energy savings	**I** High savings Low costs	**II** High savings Medium costs	**III** High savings High costs
Medium energy savings	**IV** Medium savings Low costs	**V** Medium savings Medium costs	**VI** Medium savings High costs
Low energy savings	**VII** Low savings Low costs	**VIII** Low savings Medium costs	**IX** Low savings High costs
	Low investment costs	**Medium investment costs**	**High investment costs**

Figure 4: Developed nine-field decision making matrix

Economic efficiency calculations are used to assess the economic viability of projects or measures. These are methods of calculation of the investments, costs, revenues or profit of a project to determine financial parameters. The comparison of these parameters then allows the decision for or against specific projects or measures.

Step 5: Presentation and controlling of results

Central importance is the phase sequence, taking into account all the energetic and economic factors must be strictly observed. This becomes clear, if one imagines the entire optimization process as steps of a staircase at whose end the final goal achievement is.In the first place the recognition and weighting of the measures to be prioritized has to be done. In order to achieve a holistic approach is the compliance with the order the remedial measures taking into account all energy and economic factors of central importance. For example, for the case of a replacement of the existing heating boiler and subsequent optimization of the building physics.

In this case, the previously conducted, on the basis of the old or more worse building physics, the calculation of the required performance of the new boiler would have been led to an corresponding oversized system.

In the result i.e. taking into account the new and more efficient building physics, the new boiler is significantly too large dimensioned and was equally unnecessarily expensive.

3.2 The energy turnaround /reversal of the investigated company

As mentioned in chapter 2.6, and its result regarding the actual state revealed clearly that the investigated company is not nearly state of the art.

For this reason, the question had to be asked if it is possible only with todays state of the art technologies to refurbish an existing Enterprise in that way that it produces enough or mor energy than it consumes. The choice of technical measures were not considered isolated. They were selected in each individual case on the basis of the developed standardized phase model. Here several factors such as priorities, local conditions, investment costs, life cycle costs, etc. were regarded as well. In this first step, an approach was developed and calculated still without an storage system. An even more advanced approach consisting of an efficient storage system in combination with todays state of the art technologies including an 300 kWp photovoltaic system was developed and calculated in the second step described in section 3.3. In this first step, different models and variations have been developed, simulated and calculated by which the energtic and economically most efficient (still without storage system) is represented in its result as explained below. Finally the following approach evealed as the best system wit regard to energy saving and investment costs.

First optimization step:

Building physical measures:
(simulated, calculated and partly already implemented)

Insulation of roof and outside walls, industrial glazing insulation with transparent thermal insulation, skylights (roof) insulation with transparent thermal insulation, solar protection of glass with sunshade slats (reduce of air conditioning).The combination with an ventilation system made it possible to avoid an active air conditioning system for the office tower. In addition, the uppermost 6 slats can illuminate the room indirectly. About these the incoming daylight is directed into the room. (Daylight steering)

Technical measures:
(simulated, calculated and partly already implemented)

- Heating: 2 Combined heat and power system
  3 Heat pumps (both as replacement of the old gas- and oil-fired low temperature boiler).
- Domestic water: Instantaneous electrical water flow heater
- Demand-controlled ventilation system with heat recovery
- The entire heating distribution system has been hydraulically balanced (saving potential approx. 15 %), newly insulated and refurbished with ceiling mounted radiant panels (replacement of the old fan heater).
  They as well as the physical building measures enabled significantly lower system temperatures. These supply- and return temperatures were decreased from formerly 90/70° C to 50/40° C
- High efficiency circulation pumps
- Thermostatic with an additional a new energy harvesting system
- Efficient use of compressed air (sealed piping system and reduced system pressure
- Information technology and office equipment with high-efficiency class A^{+++} (european energy label) equipement

- Photovoltaic power plant

The plant with nominal power output of 300 kWp is currently in the construction phase.This plant has an annual electricity production in total of 294751 kWh. The calculated annual electricity demand of the whole complexes is about 288679 kWh, so that there is in sum a theoretical coincidence of production and consumption.

- Efficiency of light and illumination

All ligth systems (halls,offices and outside lighting) were replaced with LED systems with presence detectors and automatic light shutdown.

Organizational measures:

(simulated, calculated and partly already implemented)

- Introduction of an energy management system,
- Regularly technical maintenance
- Establishing of an energy manager (from the workforce of the company)
- Workforce and managemnt training in terms of energy efficient behaviour
- Energy benchmarking
- Best practice examples
- Energy management
- Predictive energy demand planning
- Optimization of energy purchasing

Energy consumption after first optimization:

	Total [kWh/a] [kWh/(m²a)]	Heating [kWh/a] [kWh/(m²a)]	Chilling [kWh/a] [kWh/(m²a)]	Ventilation [kWh/a] [kWh/(m²a)]	Illumination [kWh/a] [kWh/(m²a)]	Warm water [kWh/a] [kWh/(m²a)]
Useful energy	843948	701489	0	0	141072	1388
	118,28	98,32	0	0	19,77	0,19
Final energy	502630	504004	0	21988	141072	3526
	70,45	70,64	0	3,08	19,77	0,49
Primarily energy	624953	628252	0	52770	338572	8462
	87,59	88,05	0	7,40	47,45	1,19

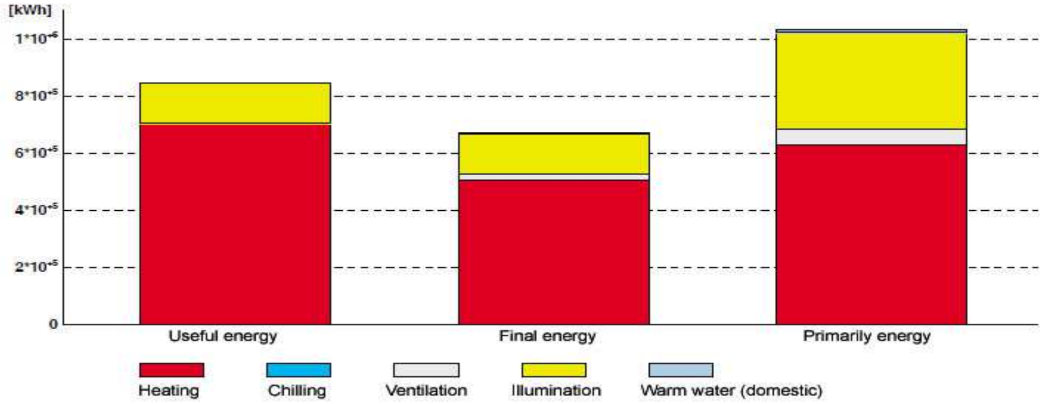


Figure 5: Calculated results of the first optimization

As can be seen the primarily energy demand for the entire commercial park after first optimization step decreased from 608 kWh/m²a to 87,6 kWh/m²a (86 %). The total final energy demand decreased from 560,91 kWh/m²a to 70,45 kWh/m²a. Moreover, the use of the "energy-producing plants" the heat pumps can be seen. For this reason, in this case the final energy is now lower than the useful energy

Economic efficiency and amortization of energy refurbishment measures (first optimization):

Actual annual fuel costs		
Actual State	259846,92	€
First Step	23228,03	€
Boundary conditions		
Calculatory interest rate	3%	
Inflation rates		
Fuel (actual state)	4 %	
Fuel (first step)	4 %	
Measures	3,5 %	
Maintenance	4,5 %	
Investment tax rate for fiscal depreciation	32 %	
Calculation parameters		
Observation period (years)	30	
Averaging factors		
Fuel (actual state)		
Fuel (first step)		
Measures		
Maintenance		

Results	
Investment	
Total Investment costs	2025863 €
Costs of anyway necessary maintenance expenditure	448568 €
Costs of energy saving measures	**1577295 €**
Average annual costs of observation Period (30 years)	
Costs of capital	101559 €/ Year
Costs of Fuel	41441 €/ Year
Costs of maintenance	+ 47083 €/ Year
Total costs	**190083 €/ Year**
Av. costs of fuel without measures	
Average annual saving	**273503 €/ Year**
Internal Interest	**14,61 %**
The investment is economically. Its internal rate of return is higher than the calculatory interest rate	
Armortization time	**9 Years**
Price of the saved kWh	**0.0425€/kWh**

Table 1: Economic efficiency and amortization calculation of first optimization

3.3 Developed energy storage system for the investigated company

The objective of this analysis is to answer the question whether an approach like described before is technically possible without an energy storage system. Further it has to be checked whether such a system is cost-effective that means that there is an appropriate economic efficiency. Therefore a suitable ice storage system was developed, simulated and calculated.The buildings physical measures and illumination, photovoltaics etc. are equal to the first optimization approach. Only those described below are different from the first approach.

Technical measures:

(simulated, calculated and partly already implemented)

Heating: 1 Combined heat and power system

1 Biomass (pellets) heating system

As part of the evaluation of a suitable energy storage system for the investigated company a variety of storage approaches were considered. Ranging from the electrical energy storage systems, inter alia, the electrochemical, compressed air or a power to gas (methane) approach.

In the field of thermal storage possibilities, taking into account their energy density storage capacity, among others the possibilities of water reservoirs, latent heat storage with phase change materials (PCM) or the thermochemical storage systems for instance with sorption materials such as zeolite were considered.

Energy balance: Commercial Park with Storage System (see Fig. 6)

	Total [kWh/a] [kWh/(m²a)]	Heating [kWh/a] [kWh/(m²a)]	Chilling [kWh/a] [kWh/(m²a)]	Ventilation [kWh/a] [kWh/(m²a)]	Illumination [kWh/a] [kWh/(m²a)]	Warm water [kWh/a] [kWh/(m²a)]
Useful energy	735674	593545	0	0	140742	1388
	103,11	83,19	0	0	19,73	0,19
Final energy	1096863	1075293	0	21988	140742	3524
	153,73	150,71	0	3,08	19,73	0,49
Primarily energy	268819	217050	0	52770	337781	8458
	37,68	30,42	0	7,40	47,34	1,19

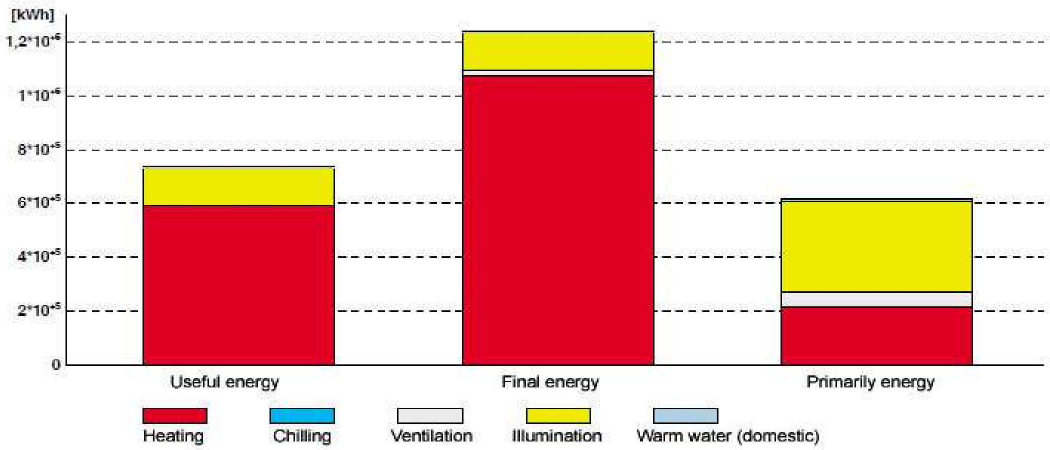


Figure 6: Calculated results of the developed storage system

As can be seen the primarily energy demand for the entire commercial park after first optimization step decreased from 608 kWh/m²a to 87,6 kWh/m²a (86 %) and once again with a storage system to 35,4 kWh/m²a. The total final energy demand decreased from 560,91 kWh/m²a to 153,73 kWh/m²a.

The following Table 2 shows that in addition to the described energetic efficiency the economic efficiency is given.

Economic efficiency and amortization of energy refurbishment measures (storage system):

Actual annual fuel costs

Actual State	259846,92	€
Storage system	30349,41	€

Boundary conditions

Calculatory interest rate 3%

Inflation rates

Fuel (actual state)	4 %
Fuel (first step)	4 %
Measures	3,5 %
Maintenance	4,5 %
Investment tax rate for fiscal depreciation	32 %

Calculation parameters

Observation period (years) 30

Averaging factors

Fuel (actual state)
Fuel (first step)
Measures
Maintenance

Results

Investment

Total Investment costs	2115251 €
Costs of anyway necessary maintenance expenditure	464001 €

Costs of energy saving measures 1651250 €

Average annual costs of observation Period (30 years)

Costs of capital	103287 €/ Year
Costs of Fuel	54146 €/ Year
Costs of maintenance	+ 47268 €/ Year
Total costs	**204701 €/ Year**
Av. costs of fuel without measures	
Average annual saving	**258885 €/ Year**

Internal Interest **13,68 %**

The investment is economically. Its internal rate of return is higher than the calculatory interest rate

Armortization time	**9 Years**
Price of the saved kWh	**0,0495€/kWh**

Table 2: Economic efficiency and amortization calculation of storage system

Actual state as well as the two variants in direct comparison:

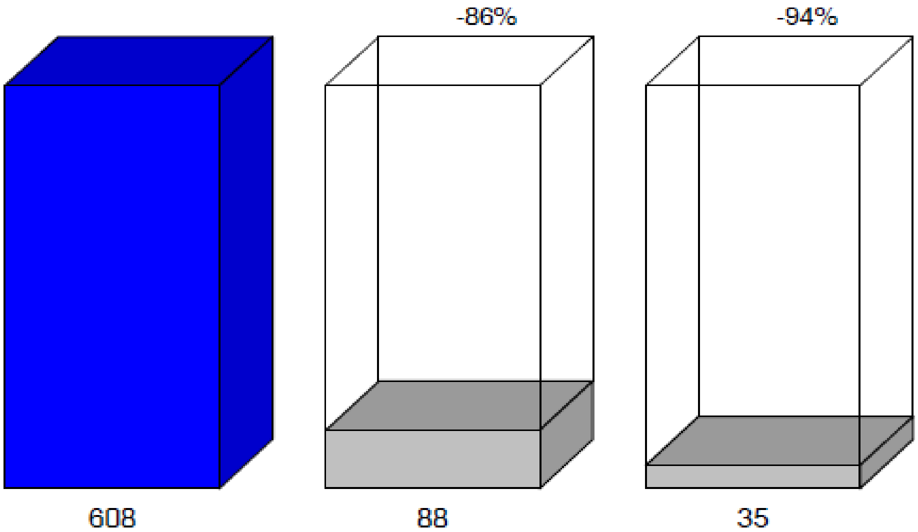


Figure 7: Primarily energy demand (kWh/m²a)

(actual state) (first optimization) (storage system)

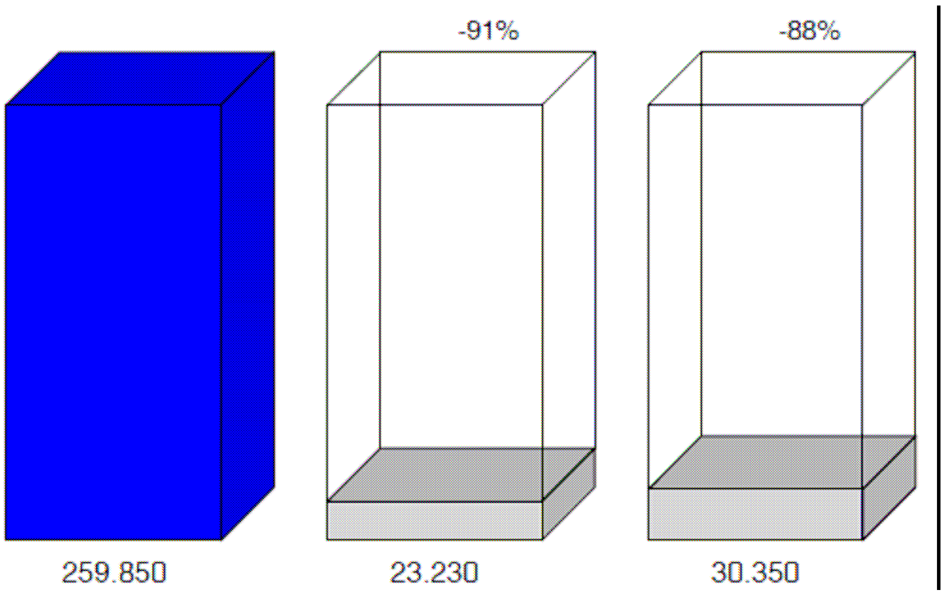


Figure 8: Fuel costs (€/a)

(actual state) (first optimization) (storage system)

In the present case the overall approach, taking into account all costs and benefits and regarding the internal interest rate of 13,68 %, is economical.

The energy consumption decreased again.

But the here simulated storage system itself led to no further increase in profitability (under economic reasons) in comparison to the first optimization step.

In general, the economic benefit of a storage system, however, inter alia, depends on the sector of the company and its specific conditions, for example such as waste heat, or request to air conditioning and chilling.

That means it has to take into account the entire plant engineering and its energy consumption structure of the whole company.

A storage system needs to be fundamentally designed for each individual case and for each company especially.

Particularly in the area of energy storage systems there is still a high development potential and a concomitant high demand for further research.

3.4 Identified supporting and inhibiting factors in the context of energy efficiency measures

Within the framework of the carried out investigation, the following main factors towards energy efficiency measures have been identified.

Supporting and inhibitory factors of energy refurbishment measures:

Monetary reasons:

Supporting factors:

- Cost reduction and increased profit,
- Increasing competitiveness
- Short payback time
- Long-term improvement of the entrepreneurial value chain
- Government assistance programs, tax relief,
- Insurance collectively agreed preferential treatment
- Subsidies and incentives of the State
- Increasing Energy taxes
- Low level of interest rates / Cheap loans

Inhibitory factors:

- Inadequate knowledge of the various financing options
- High investment costs
- Lack of equity capital,
- Long amortization periods
- Still comparatively low energy costs
- Widespread great uncertainty of costs and benefits of energy efficiency measures

Non-monetary reasons:

Supporting factors:

- Positive impact on the company's image,
- Environmental and climate protection / Carbon reduction
- Increasing public pressure towards the companies
- Implementation of an energy monitoring and management system
- Implementation of an energy manager out of the companies workforce
- Future orientation

Inhibitory factors:

- Missing or insufficient consultation with regard to energy efficiency measures
- Lack of technical knowledge
- Lack of information regarding the existing opportunities an their potentials
- Lack of knowledge of energetic interactions throughout the whole production process
- Current high workload, lack of motivation outside of the own core tasks
- Missing energy management
- Seemingly high personnel expenses for the company
- Lack of knowledge regarding an strategic approach
- Seemingly high expenditure of time
- Misleading medial reports
- Missing policy framework

In summary, it can be concluded that the willingness that is, the overcoming of innovation blockades for energy efficiency measures will grow with rising energy procurement costs.In addition, the governmental frameworks should be improved. Here higher government subsidies and tax incentives could be an appropriate way.

Furthermore, an improved awareness training (information campaigns etc. would be necessary e.g. through best practice examples and through benchmarking approaches.

4 Conclusion and outlook

One of the main conclusions of this thesis is that there was no holistic approach for SMEs taking into account the latest building physics possibilities, the organizational possibilities and all the todays state of the art technologies in addition with the incoming future technoligies. Not at least regarding the costs respectively the investment and its efficiency.And finally the combination of them all. Nearly all of the existing companies are not state of the art. State-of-the-art technologies are available in a large selection but they remain largely unexploited.

For example more than 80% of the german industrial heat generators are out of date.

Many companies have not yet been considered energy efficiency as an intelligent energy source.As it has been shown, there are a variety inhibitory factors of energy refurbishment measures that need to be overcome.The companies should recognize that it is possible to get a sustained reduction of their energy consumption without supposedly high investment costs or decreasing their productional efficiency rates.

One of the main problem here are the highly simplified and insufficient economic calculation methods as they are widespread and repeatedly can be found in the management offices.

What measures may be technically and economically appropriate carried out depends in each individual case on the present energy concept.

Objective of economic and technical optimizations are minimum capital bonded and lowest operating costs.

The amortization of the investment costs, realized through future energy savings, so to say implies a "money back guarantee".

Rising energy prices combined with decreasing fossil fuel reserves will continue to strengthen the positive economic impacts for the companies (Leverage effect). Here, energy refurbishment measures can prove as a good innovation engine, both for the company itself and for the entire energy european technology industry as a production factor.

Anyone planning energy refurbishment measures for companies faces major challenges. Energy-efficient companies taking into account all energy-related factors that are technically feasible today.

Foresight for the company's development and joint development work by the entrepreneur, planners, top management, employees, industry and trade is necessary in order to optimize business over its entire life and operating time in economic, ecological and functional terms.

Objective is the generation of further synergy effects in which the total benefit is higher than that of the additive individual performances.

The balancing act between economy and ecology, that is, the balance between the objectives of efficiency, safety and environmental compatibility can succeed.

Sustainability management is a core competency of the future even for the companies and even for a green and sustainable economy.
Energy efficiency is a win-win situation for all. Improving energy efficiency will save money, help protect the environment, create new jobs, spur economic growth as well as creating jobs and technological leadership.
Setting the course in the field of innovative energy technologies in terms of technological leadership, is accompanied with securing the future of large parts of the entire european economy. It serves as a sort of investment in the enhancement of global competitiveness.
Here the use of renewable energies is of particular importance.
In the field of energy efficiency measures a high information and communication requirement towards the the companies is remaining to trigger a initial impetus here.
For each type of company the optimal constructional and plant-specific remediation measures can be determined.
For this reason, a professional status analysis (diagnosis) followed by measure planning (therapy) taking into account economic aspects is indispensable. In the future, the companies must be able to use their self-produced energy (electricity / thermal energy) in large amounts. Without innovative storage systems self sufficient respectively autark or plus energy decentralized approach are not possible.
But that does not mean that it is not possible to refurbish an existing company in an high efficcient way by using todays state of the art technologies without an energy storage system. This shows the great advantage of a holistic approach as previously explained.It allows the companies to plan already today such an high end plus energy approach and complete it step by step with the upcoming innovative technologies. Here the decisive aspect is the once done mental anticipation of the whole process.Only with this approach the implemented refurbishing measures carried out in the correct sequence lead to the optimum results. With adequate advice and supervision the company of the future so to speak the “company 4.0” is possible not only with regard to energy technology.

In general:

There is not one special energetic measure which is equally applicable for every company, but there are for each company its specific measures. Energy efficiency has to be understood as an intelligent energy source (see also Hofmann, Peter, 2014“Energy efficiency and cost reducing applications in companies p.89) [5].

So through the research and developments of this study, that was based i.a. on previous available knowledge, it was possible to create new knowledge.

Further research demand:

Particularly in the area of energy storage systems there is still a high development potential and a concomitant high demand for further research above all i.a. regarding their storage capicity and costs.

Scientific work, is not only an unilaterally approach from one side but from many sides taking into account all of the latest scientific state to reach a justifiable conclusion.There are also impulses and knowledge transfer from industry into research and science as well as vice versa. Relationship between knowledge and application can be created. Additional to improve an constructive exchange between knowledge-oriented and application-oriented research. Moreover there is an increasing demand for quaternary education not only regarding energy efficiency.

From the results of this study further questions can be derived also relevant for the other engineering disciplines, for example i.a. the whole construction- or power-engineering industry, for control- technology or for increasing use of renewable energies in the companies.

Finally:

The energy will be (without a functioning nuclear fusion) increasingly the gold of the 21st. century. Saving energy as well as energy efficiency in companies is the present.

The future, however, are the energy-producing, energy-autonomous and plus energy companies.

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