WORLD ENERGY COUNCIL
CONSEIL MONDIAL DE L'ÉNERGIE
For sustainable energy.

Energy Efficiency Technologies

ANNEX I

Technical Report

Energy Efficiency Potentials and Barriers for Realization in the Industry Sector

WEC Knowledge Network

July 2013

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Content

1 SUMMARY

- The biggest part of the energy demand in industry will still be needed to produce products. If in short-term 10 %, 20 % or 30 % of energy can be saved depends on the state of the art technology, the energy prices and the political and economic framework conditions (e.g. desired ROI, investment risk)
- Regarding energy efficiency potentials it has to be distinguished between technical, economical and realizable potentials
- The potentials in the particular branches are depending on energy demand, energy prices, processes and efficiency measures which have been already realized.
- The difference between realizable and economical potential increases over-proportional due to short payback targets (realizable potential) less than one third of the economical potential is realized and the required investment.
- In countries where energy prices are relatively low the technical energy saving potential is higher but nevertheless the economical energy saving potential is only about 20%.
- Numerous barriers even restrain the achievement of realizable potentials
- To achieve all energy efficiency potentials new framework conditions in the industry (Life-Cycle-approach) and in policies (incentives) need to be created:
    - Targeting realizable potentials within 3 years better information, best-practice-sharing, etc. with regard to the knowledge about potentials and technologies can help to achieve the potentials
    - Regarding economical potentials (payback period up to 10 years) a rethinking in business praxis towards a long-term life cycle approach is needed as well as incentives by politics for investments, funding and promotional programmes, tax incentives etc.

2 BACKGROUND AND OBJECTIVES

Siemens AG realized in 2012 the study ”Analysis of energy efficiency potentials – part I“ which aimed at analyzing energy efficiency potentials in the sector industry. The focus of the study part I was on energy efficiency technologies in the industrial sector in Germany.

In a second step, in the course of the study “Energy efficiency potentials and barriers of realization in the industry sector – part II”, this analysis has been extended and deepened. Objective has been to create a profound basis of data and information in order to answer questions and create statements in the field of energy efficiency.

Regarding the relevance of the topic energy efficiency in whole Europe the focus has been enlarged to six further European countries (UK, France, Italy, Austria, Sweden and Turkey). Besides, an analysis for EU27 and a global calculation have been done.

Furthermore an in-depth analysis for three particular technologies/products of the sector industry (energy efficient motors, frequency converters for speed control and energy data management systems) for the German market has been realized. Also an analysis of energy efficiency potentials in three branches (food & beverage, minerals, pulp & paper) has been done.

3 METHODOLOGY

Based on the results and the methodology of part I of the study first of all the energy saving potentials for the chosen fields of analysis (countries, technologies/products and branches) have been calculated. According to this the market potentials have been estimated.

Three different types of potentials have been regarded:

- The energy saving potential, in others words the potential regarding electricity, fuels and heat amounts
- The energy cost saving potential, meaning costs for electricity, fuels and heat
- The market potential, meaning the needed investment sum to achieve a certain energy efficiency potential.

Moreover potentials for diverse framework conditions have been calculated:

- The “technical potential” comprises the use of the best available energy efficiency technologies in all applications without taking in consideration economical constraints.
- The “economical potential” contains the use of energy efficiency technologies in applications when the use of the technology is economical taking into account the life cycle of the technology (meaning the internal rate of return (IRR) is bigger than 8 %)
- the “realizable potential“ takes into consideration that energy efficiency technologies mostly are only used when a certain payback time is fulfilled (here: 3 years)

No estimations have been done within this study for the “realistic potential”, meaning the potential taking also in consideration further barriers like political, financial, barriers as to timing etc.

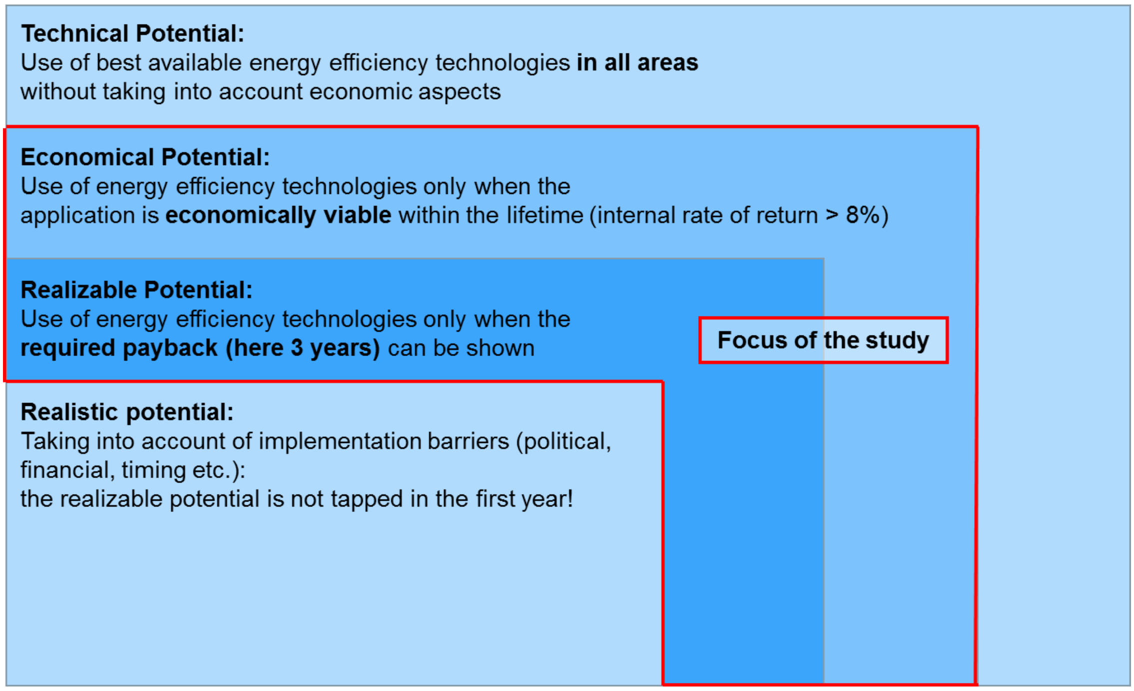


Fig. 1: Definition – potential

For the country analysis, including EU27 and global, the methodology of part I of the study for Germany has been used, meaning a top-down-approach. Therefore the individual energy demand of the country for the industry sector as well as a specific categorisation of technologies/applications is used.

The example of the technology resp. application “motion” (electrical drives for transport or conveyor systems etc.) for Germany according to the following two pictures shows how the economical and realizable market potential is deduced for each technology. The mentioned percentages for the energy saving potential differ a) by technology/application and b) according to the considered time period (average life cycle versus payback period of 3 years). These numbers are based on experiences of Siemens and they are considered the same for all the chosen countries regarding the particular technologies/applications. Calculating the sum over all relevant technologies/applications (motion, EDMS, compressed air etc.) both the economical and the realizable market potential can be deduced for a country.

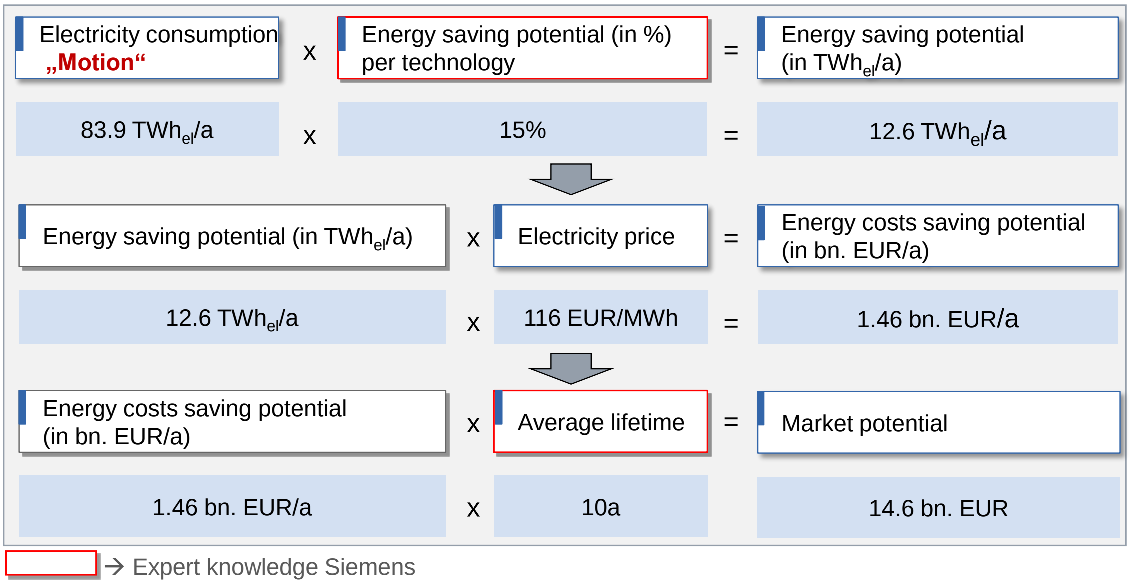


Fig. 2: Calculation of the economic potential using the example motion in Germany

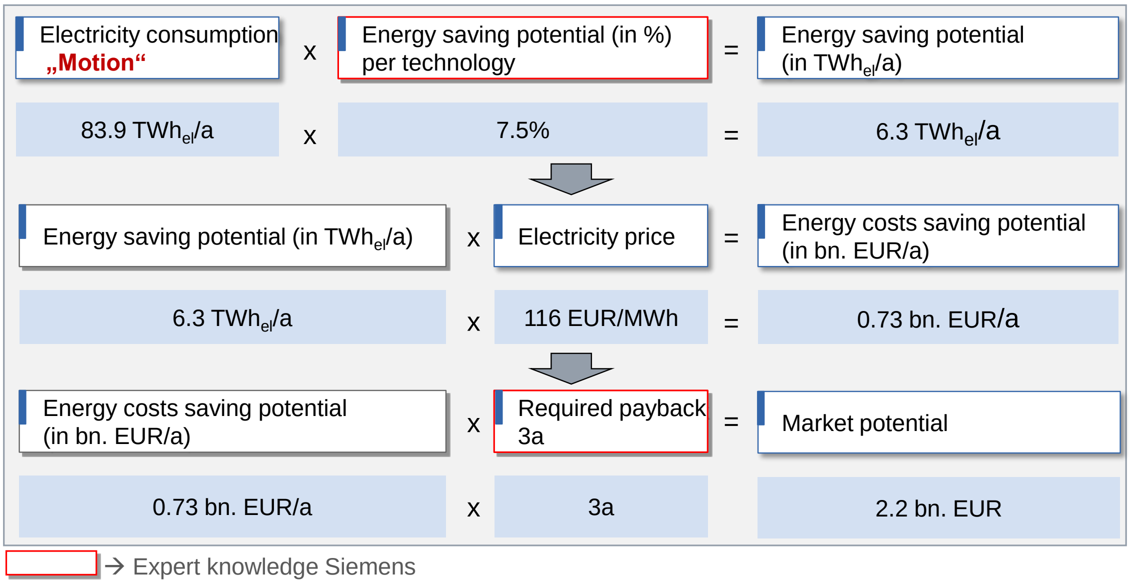


Fig. 3: Calculation of the realizable potential using the example motion in Germany

In a second step detailed analysis have been done for three chosen branches in the German market. Within a top-down-approach firstly a prioritisation of sub-branches has been done, followed by a description of the energy demand per energy source and divided in electrical and thermal energy.

Then, the energy demand has been clustered for diverse applications, with focus on electrical applications (e.g. pumps, drives, cooling, compressed air etc.); the results of the sub-branches have been aggregated than for each branch. Finally, the economical and realizable market potential could be determined using the typical energy saving potentials, a calculation over life time respectively over a payback time of 3 years and an assumption of an average electricity price for each branch.

The choice of the particular technologies has been done taking into account core products of the industrial sector. To get best possible meaningful results the analysis for energy efficient motors and frequency converters for speed control have been done using a bottom-up approach. Based on the choice of relevant motors (low voltage) respectively relevant applications for frequency converters a determination of the number and distribution over the particular power classes and applications has been done. Moreover, the share of already installed efficient motors resp. applications with speed control has been taken into consideration. Finally, the economical (considering life time) and the realizable (considering 3 years payback time) market potential has been calculated taking into account the defined costs for motors respectively the average price for frequency converters.

Contrary to this approach a top-down approach has been used for the analysis for energy efficiency potentials of energy data management systems (EDMS). A bottom-up approach was not possible to realize as no utile data for currently used EDMS in Germany is available. Also an exact definition of the product is difficult.

First of all the yearly energy costs have been determined for the industry branches based on the calculation of the electrical and thermal energy demand in the industry divided in branches. The calculation of the economical energy saving potential of the energy efficiency technologies until 2020 has been done using the study “Energy efficiency – the intelligent energy source” by BMU (2009); so, finally the economical (life time) and the realizable (payback time 3 years) market potential could also be calculated.

4 OVERVIEW KEY RESULTS

This analysis of energy efficiency potentials provides – taking into account the mentioned assumptions – the following key results for the chosen countries, branches and technologies.

4.1 COUNTRY ANALYSIS

4.1.1 GERMANY

The sector industry in Germany needed in 2010 222 TWh electricity and 498 TWh thermal energy.

The economical energy saving potential amounts **42 TWh_{el}/a** (19 %) respectively **157 TWh_{th}/a** (31.5 %) and can be achieved with an investment of **44 bn Euro in the field of electricity and 49 bn Euro in the field of thermal energy**.

Considering a payback time of 3 years usually required by industrial companies the energy saving potential is "only" **15 TWh_{el}/a** and **63 TWh_{th}/a**; requiring an investment sum of **5 bn Euro in the field of electricity resp. 8 bn Euro in the field of thermal energy**.

It is remarkable that the economical energy saving potential in the German industry amount to about **80 TWh_{th}/a** (16 % of 498 TWh_{th}/a) thermal energy used for process heat.

Large economical energy saving potential for electrical applications exist especially in the field of **motion** with **12.6 TWh_{el}/a** out of 83.9 TWh_{el}/a (15 %). The potential in the field of energy are currently also in the focus of policies.

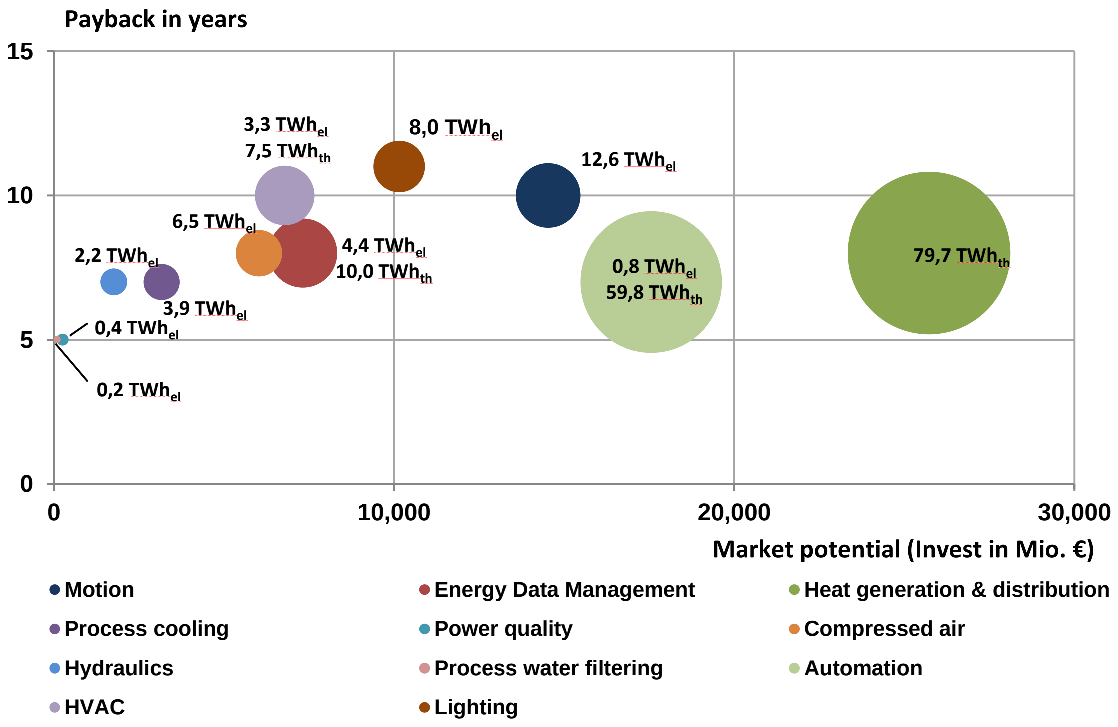


Fig. 4: Economical potentials in Germany

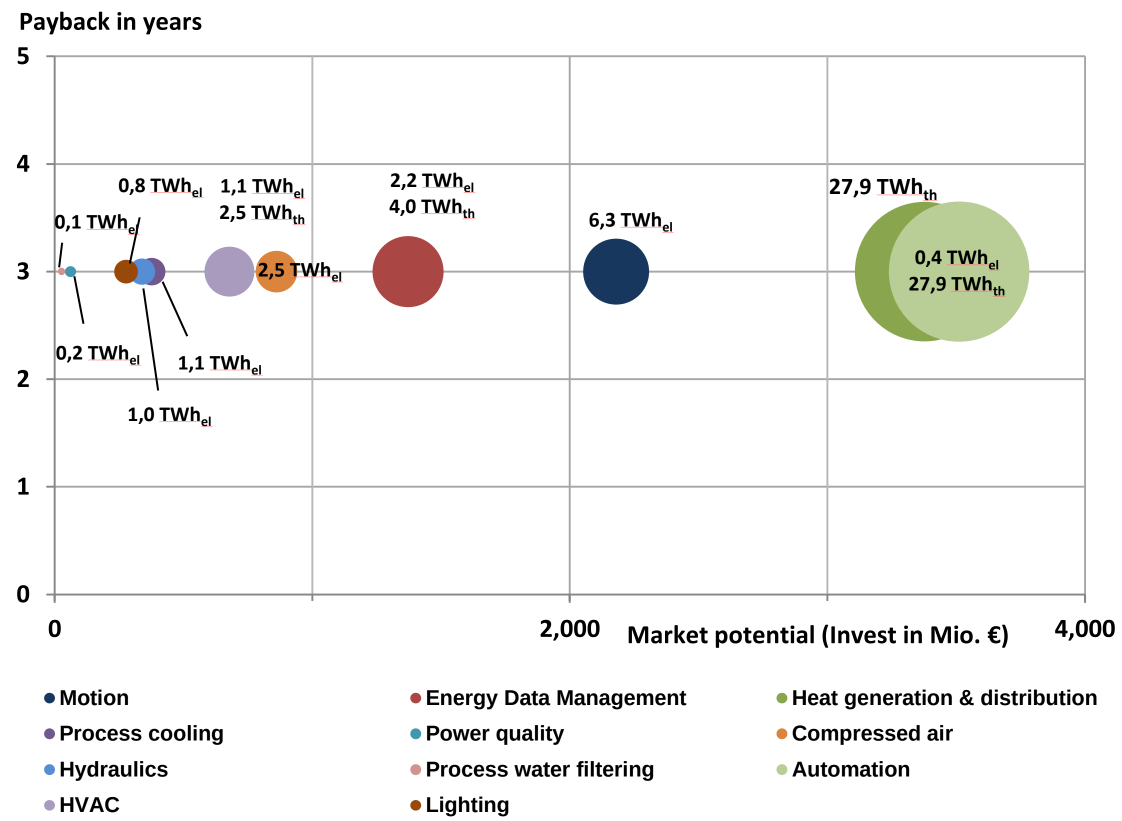


Fig. 5: Realizable potentials in Germany

4.1.2 Further European Countries

France:

1. Economical energy saving potential of **25 TWh_{el}/a** and **70 TWh_{th}/a**, which requires investments of **17 bn Euro in the field of electricity and 18 bn Euro in the field of thermal energy.**

2. The realizable energy saving potential (within 3 years) amounts to **9 TWh_{el}/a** resp. **28 TWh_{th}/a** and requires an investment of **2 bn Euro respectively 3 bn Euro**.

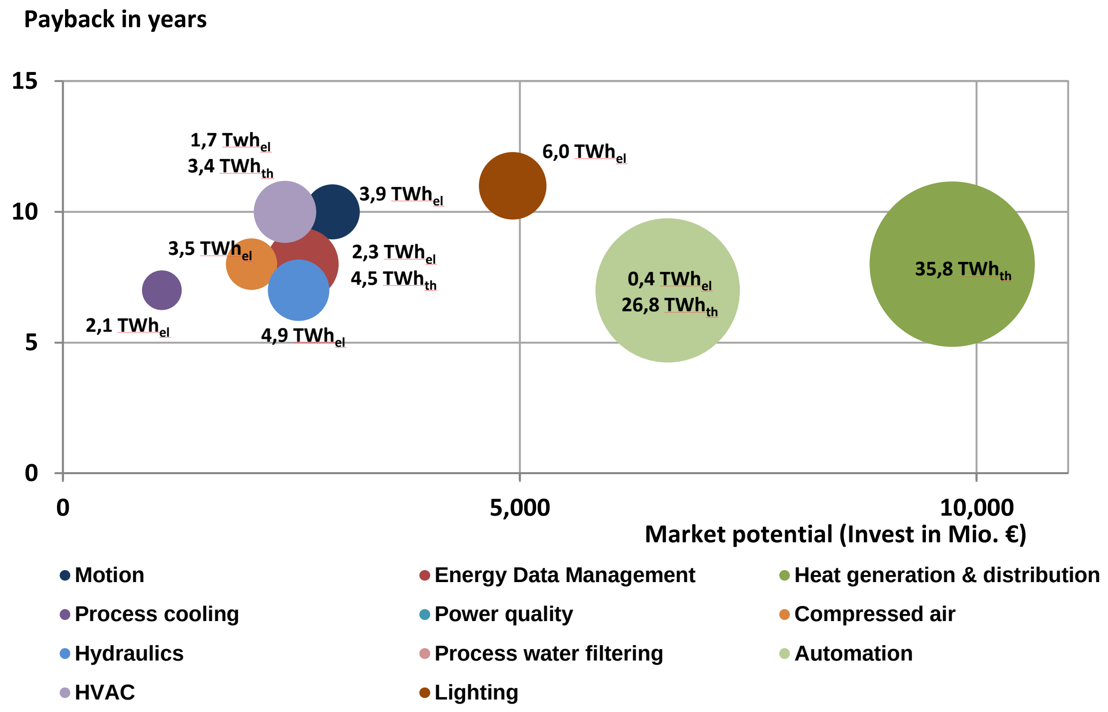


Fig. 6: Economical potentials in France

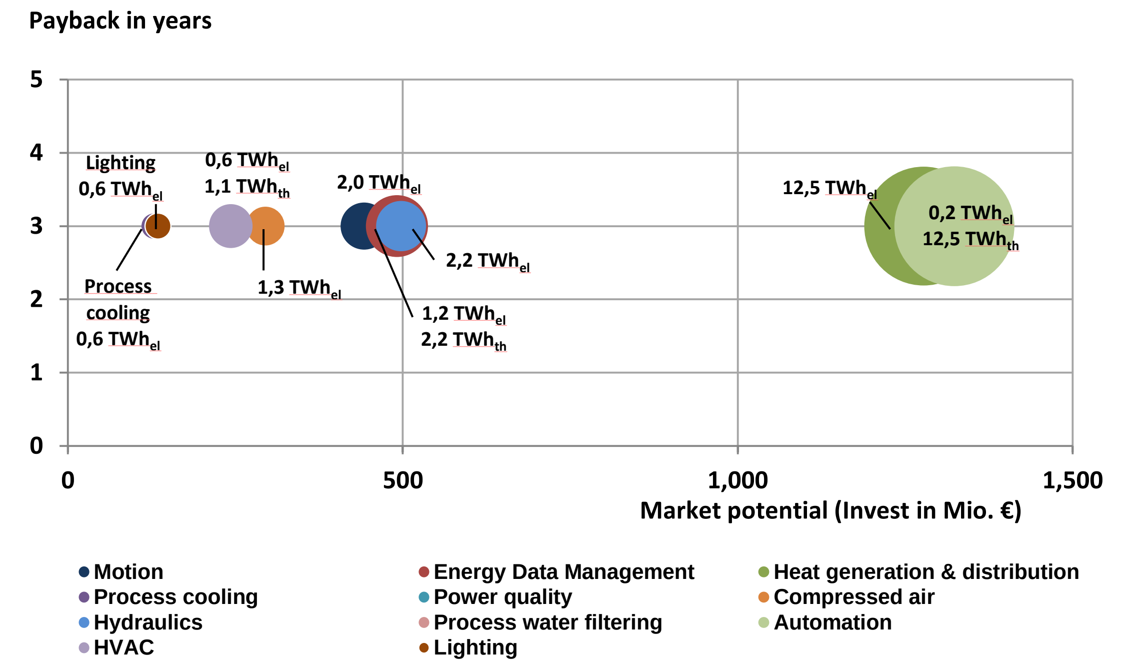
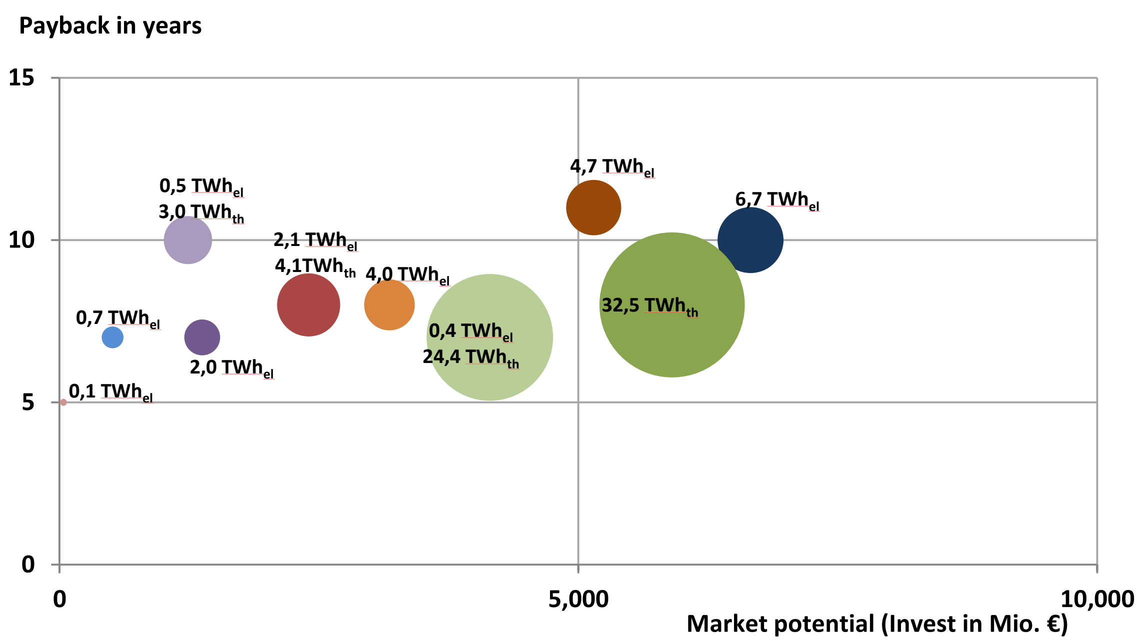


Fig. 7: Realizable potentials in France

UK:

1. Economical energy saving potential of **21 TWh$_{el}$/a** resp. **64 TWh$_{th}$/a**; needed investment to achieve this potential: **20 bn Euro in the field of electricity** and **11 bn Euro in the field of thermal energy.**

2. Realizable energy saving potential (within 3 years) of **8 TWh$_{el}$/a** resp. **26 TWh$_{th}$/a**; required investment **2 bn Euro (electrical) resp. 2 bn Euro (thermal)**.



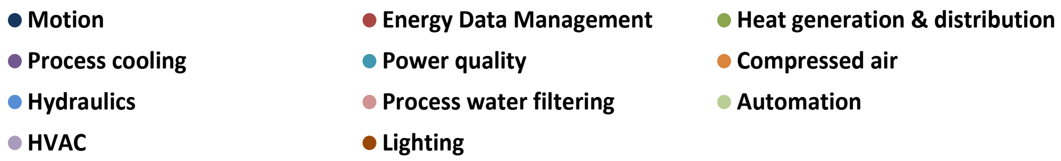


Fig. 8: Economical potentials in the UK

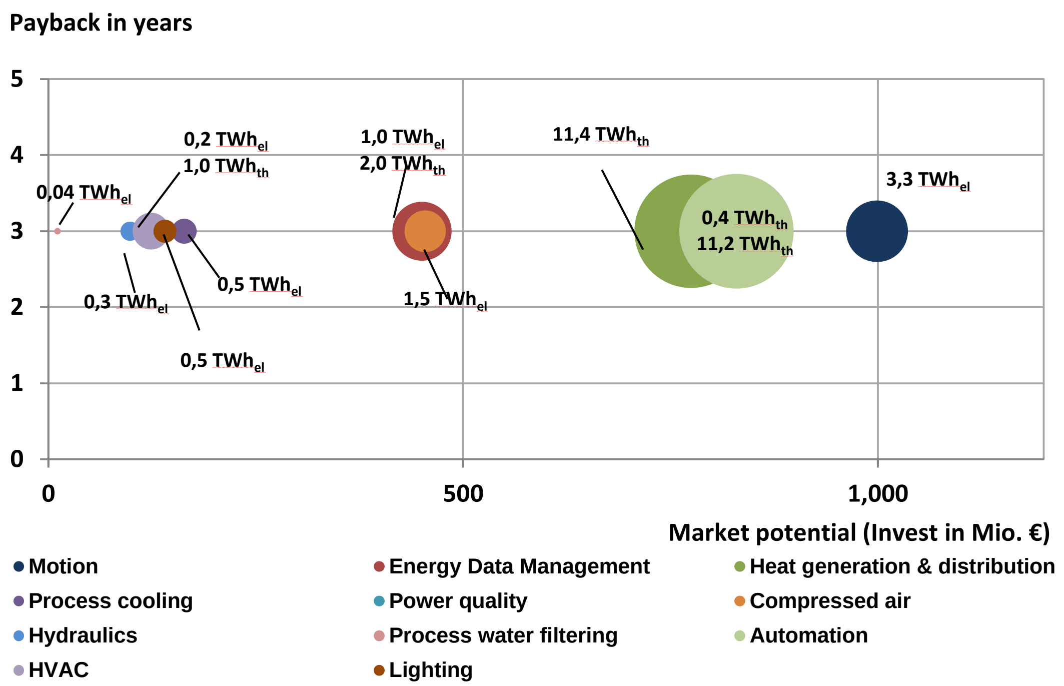


Fig. 9: Realizable potentials in the UK

Italy

1. Economical energy saving potential of **25 TWh$_{el}$/a** resp. **69 TWh$_{th}$/a**; required investment **31 bn Euro in the field of electricity and 16 bn Euro in the field of thermal energy.**

2. Realizable energy saving potential of **9.4 TWh$_{el}$/a** and **28 TWh$_{th}$/a**; required investment of **3 bn Euro (electrical) resp. 3 bn Euro (thermal)**.

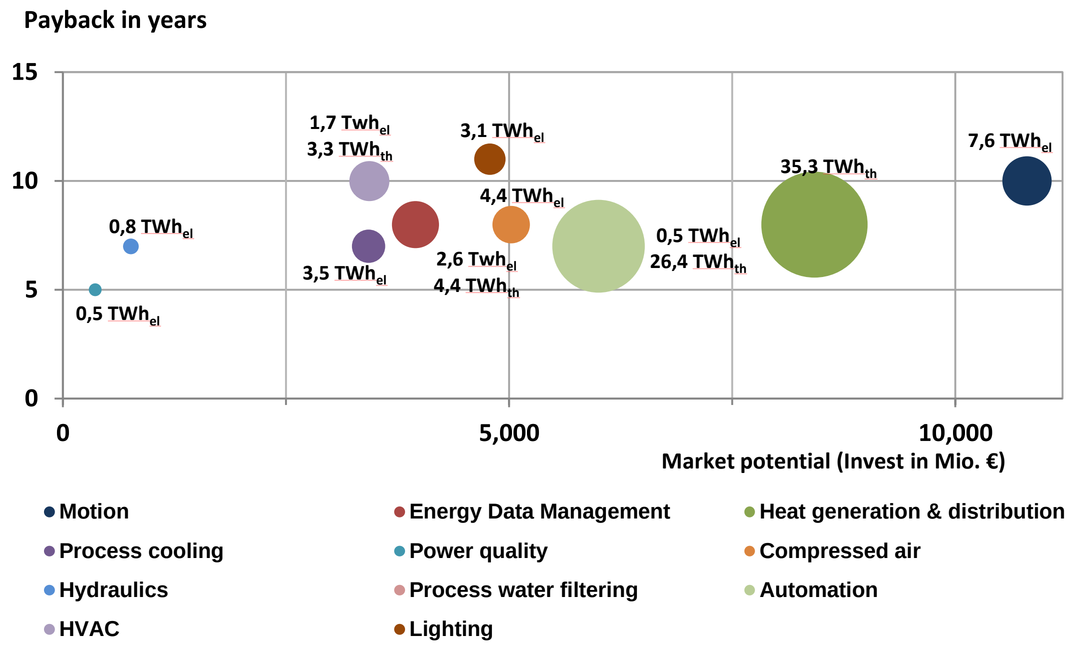


Fig. 10: Economical potentials in Italy

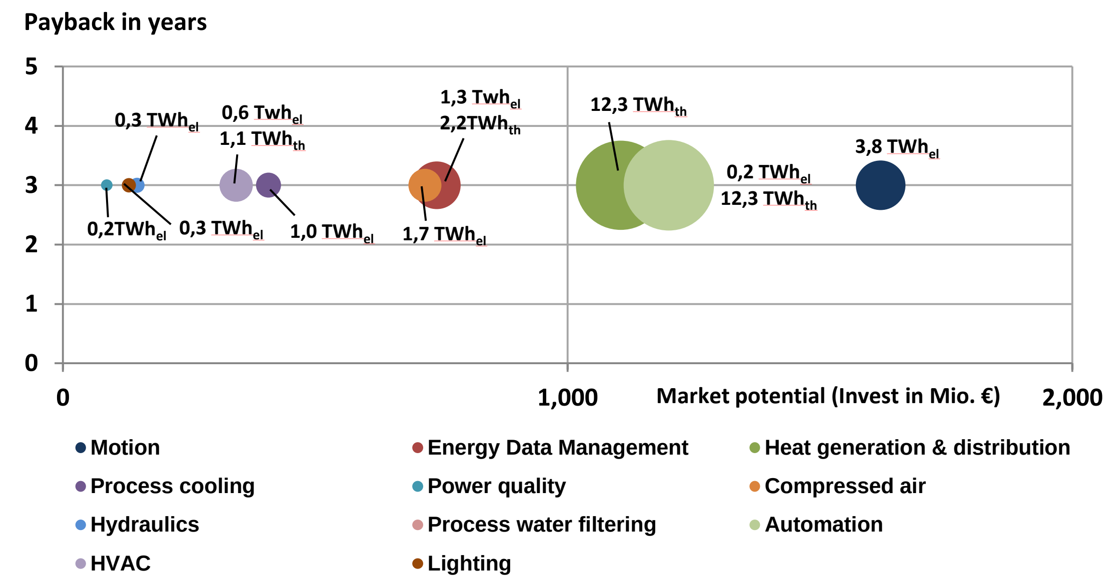


Fig. 11: Realizable potentials in Italy

Sweden:

1. Economical energy saving potential of **10 TWh$_{el}$/a** and **27 TWh$_{th}$/a**, which requires an investment of **7.4 bn Euro in the field of electricity** and **9.6 bn Euro in the field of thermal energy.**

2. Realizable energy saving potential (within 3 years) of **3.6 TWh$_{el}$/a** and **11 TWh$_{th}$/a**, which required an investment of **0.5 bn Euro resp. 1.5 bn Euro**.

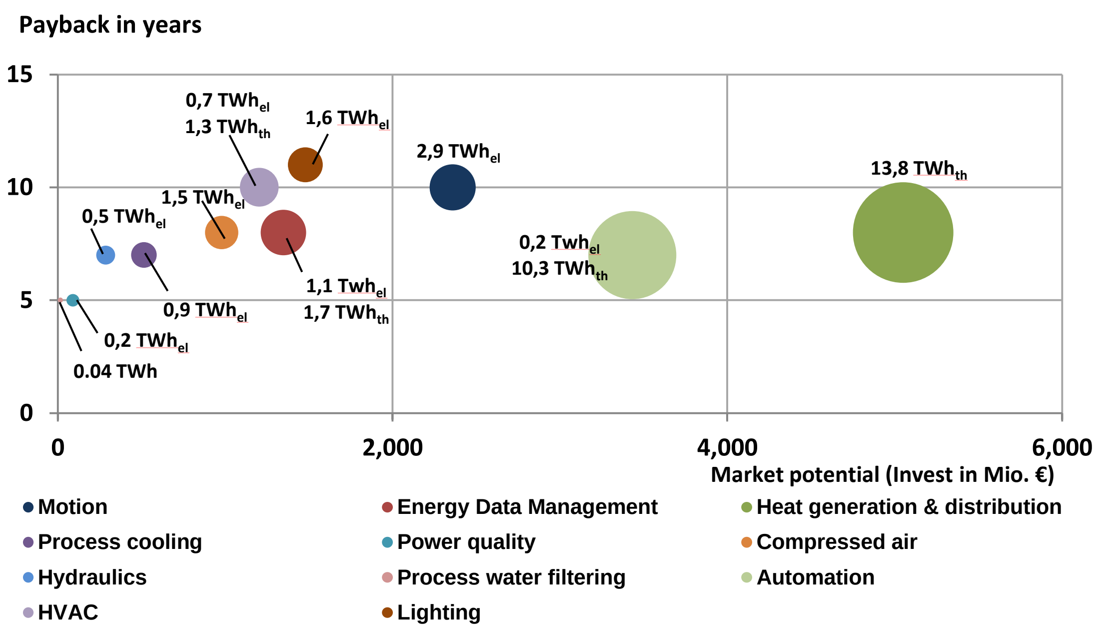


Fig. 12: Economical potentials in Sweden

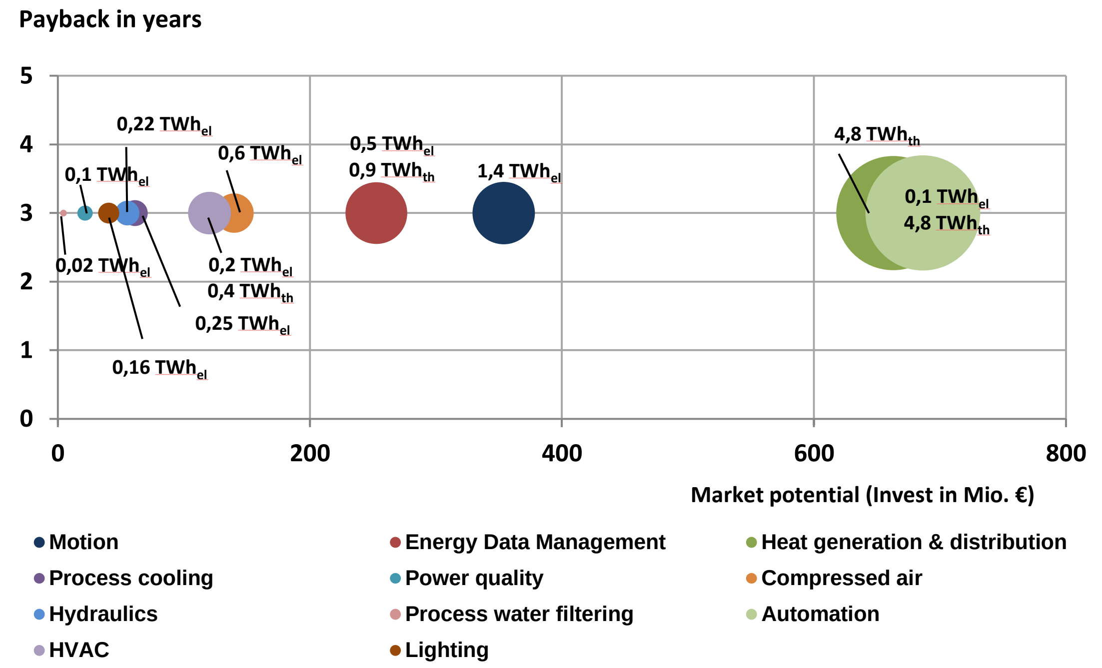


Fig. 13: Realizable potentials in Sweden

<u>Austria</u>:

1. Economical energy saving potential of **5 TWh$_{el}$/a** and **19 TWh$_{th}$/a**, which needs an investment of **5 bn Euro in the field of electricity and 5 bn Euro in the field of thermal energy.**

2. Realizable energy saving potential of **2 TWh$_{el}$/a** and **7.8 TWh$_{th}$/a**, which requires an investments of **0.7 bn Euro in the field of electricity** and **0.8 bn Euro in the field of thermal energy**.

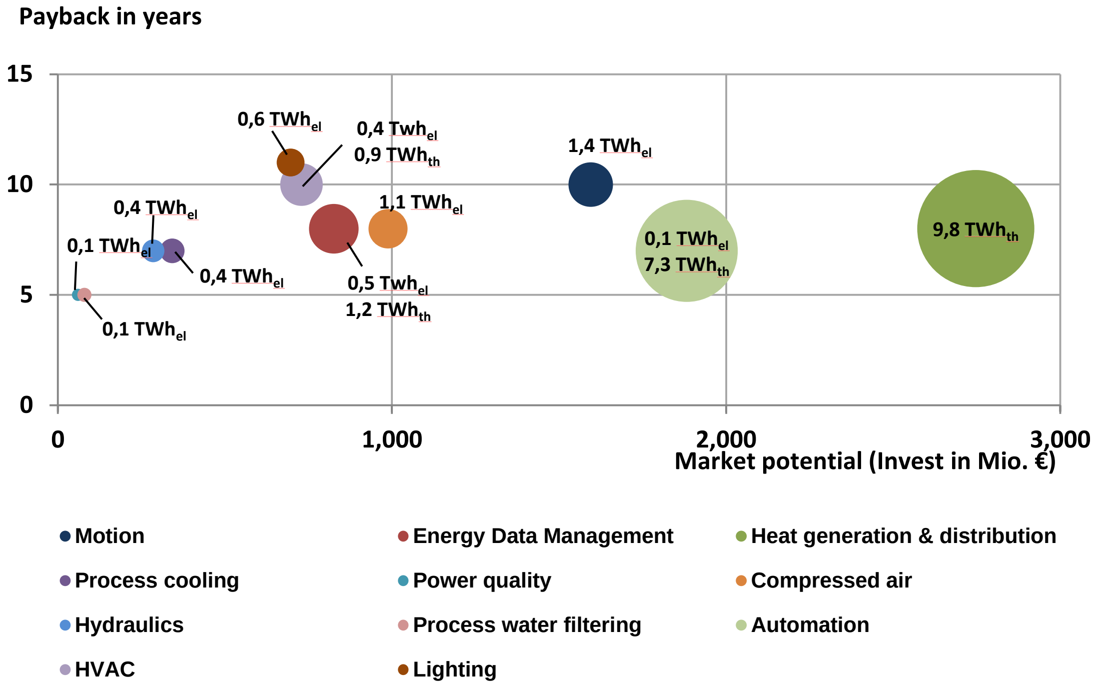


Fig. 14: Economical potentials Austria

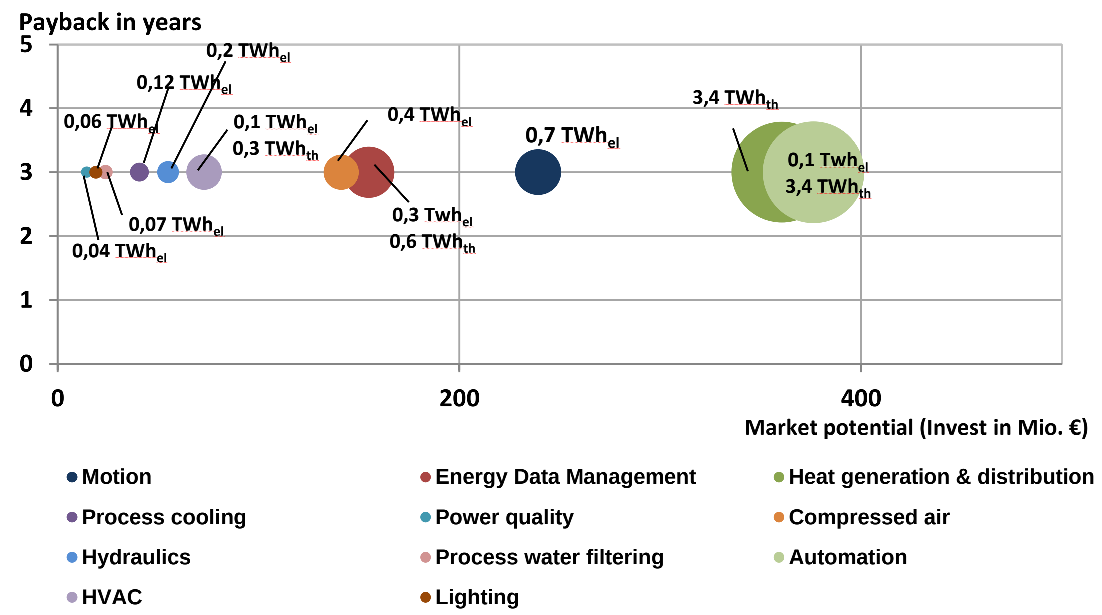


Fig. 15: Realizable potentials Austria

<u>Turkey</u>:

1. Economical energy saving potential of **14 TWh$_{el}$/a** and **58 TWh$_{th}$/a**, which require an investment of **12 bn Euro in the field of electricity** and **11 bn Euro in the field of thermal energy**

2. Realizable energy saving potential of **5 TWh$_{el}$**/a and **24 TWh$_{th}$/a**, which requires an investment of **1.4 bn Euro resp. 1.7 bn Euro**.

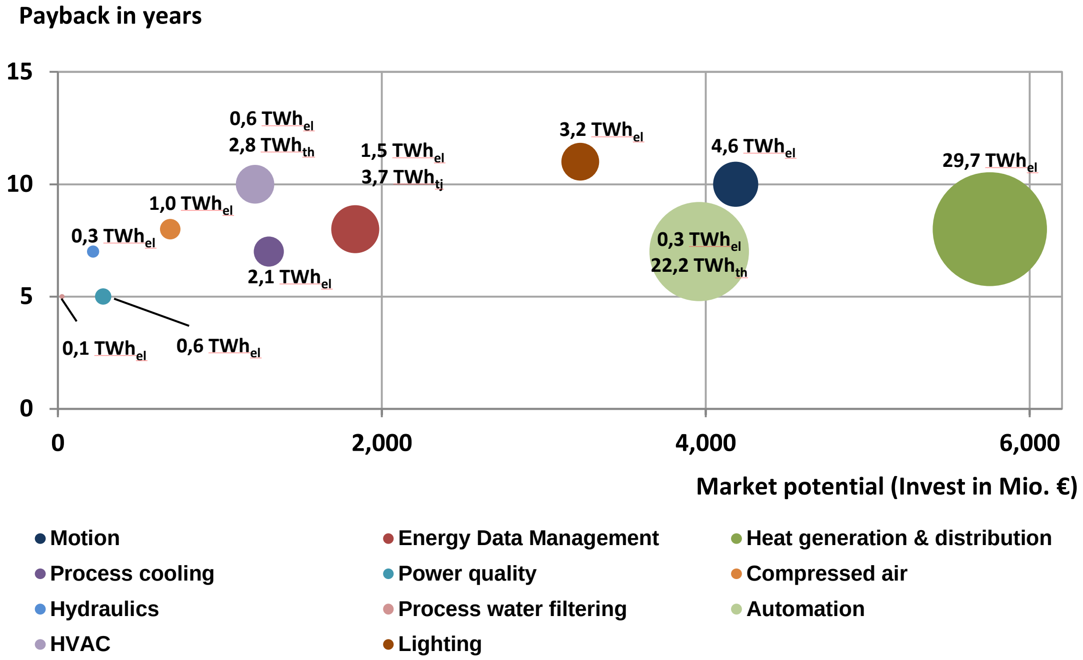


Fig. 16: Economical potentials Turkey

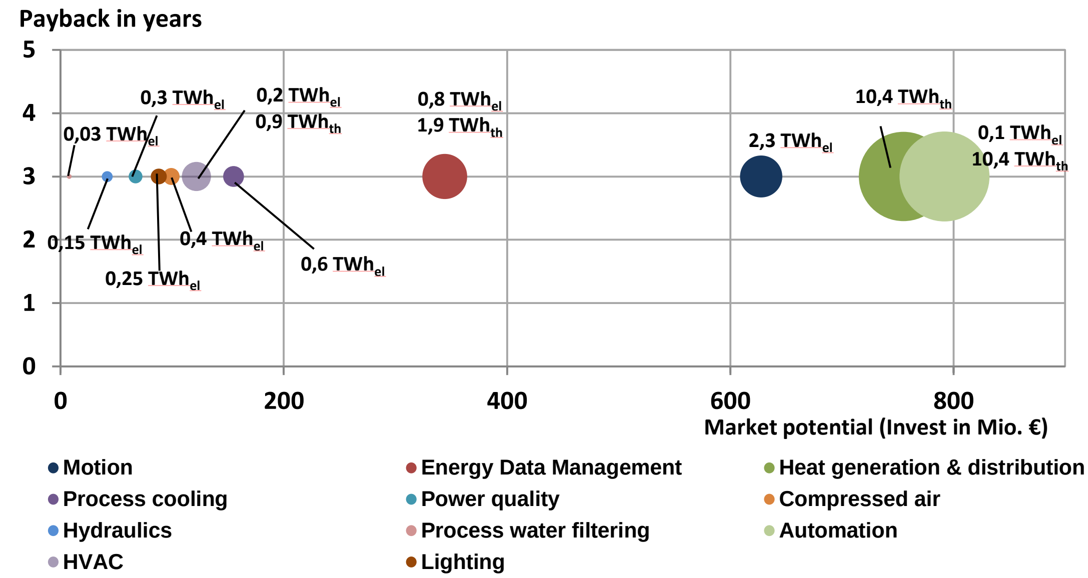


Fig. 17: Realizable potentials Turkey

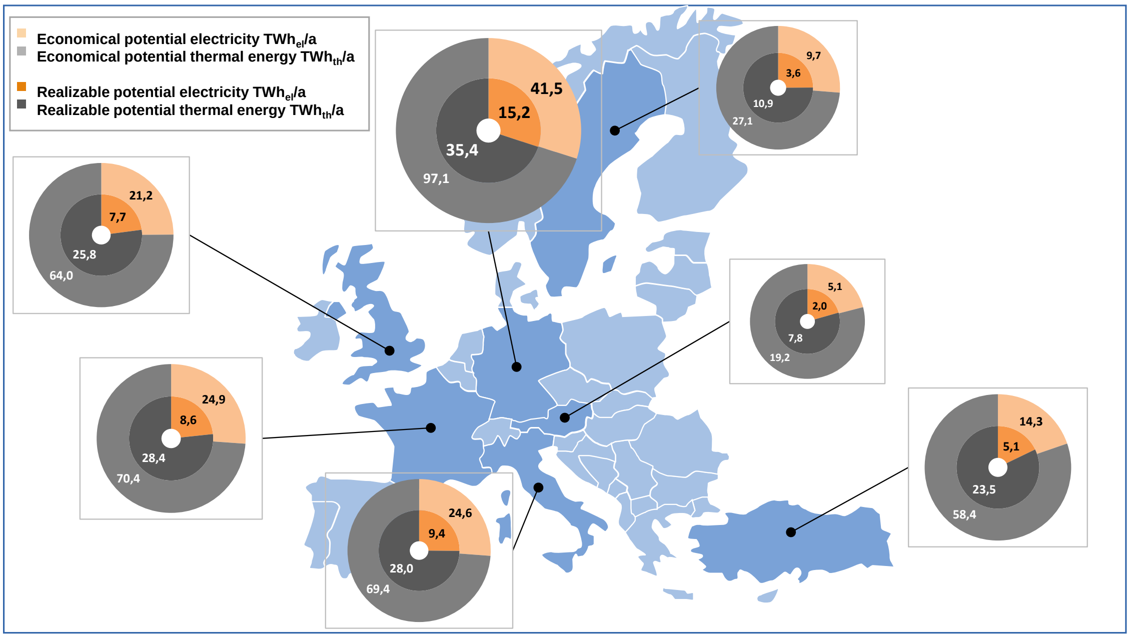


Fig. 18: Energy saving potentials in the chosen countries in TWh$_{el}$/a resp. TWh$_{th}$/a

The largest realizable market potential the field of electricity shows in all analyzed countries and EU27 as well as globally the application "motion"; with the exemption of France where "hydraulics" show the largest potential. Further fields with high market potential are: compressed air and EDMS as well as heating, ventilation and climate (Germany, Sweden, global) and cooling for processes (Turkey). Besides, in the field of thermal heat huge potentials exist, especially for process heat and automation..

4.1.3 EU27 AND GLOBAL

For EU27 the following potentials result from our analysis: 1. Economical energy saving potential of **250 TWh$_{el}$/a** and **788 TWh$_{th}$/a**, which requires an investment of **238 bn Euro in the field of electricity** and **198 bn Euro in the field of thermal energy.** 2. Realizable energy saving potential (within 3 years) of **92 TWh$_{el}$/a** and **318 TWh$_{th}$/a**, which requires an investment of **29 bn Euro resp. 31 bn Euro**.

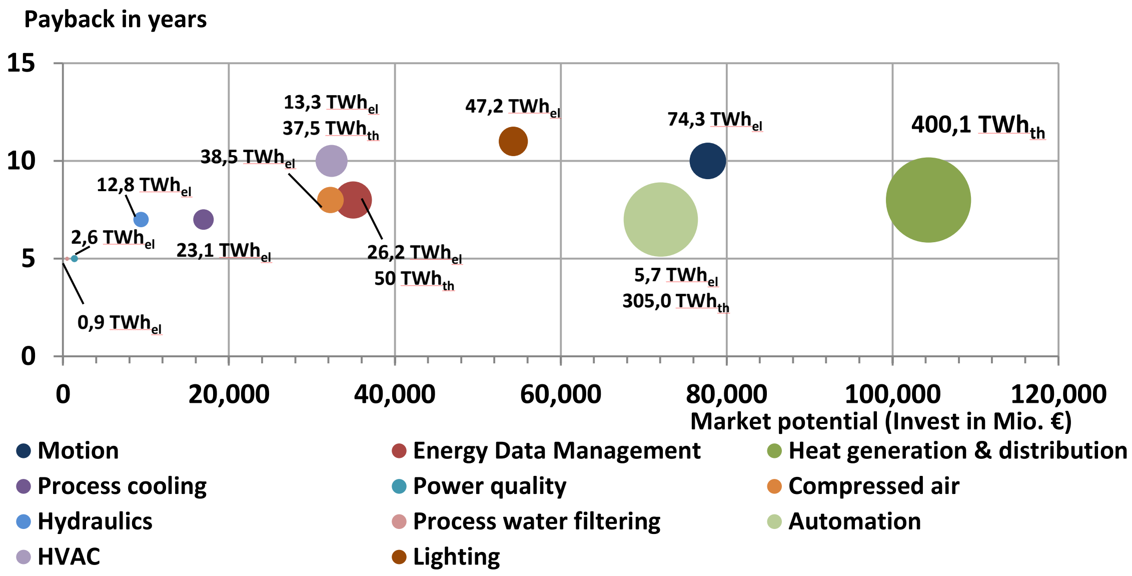


Fig. 19: Economical potentials in the EU27

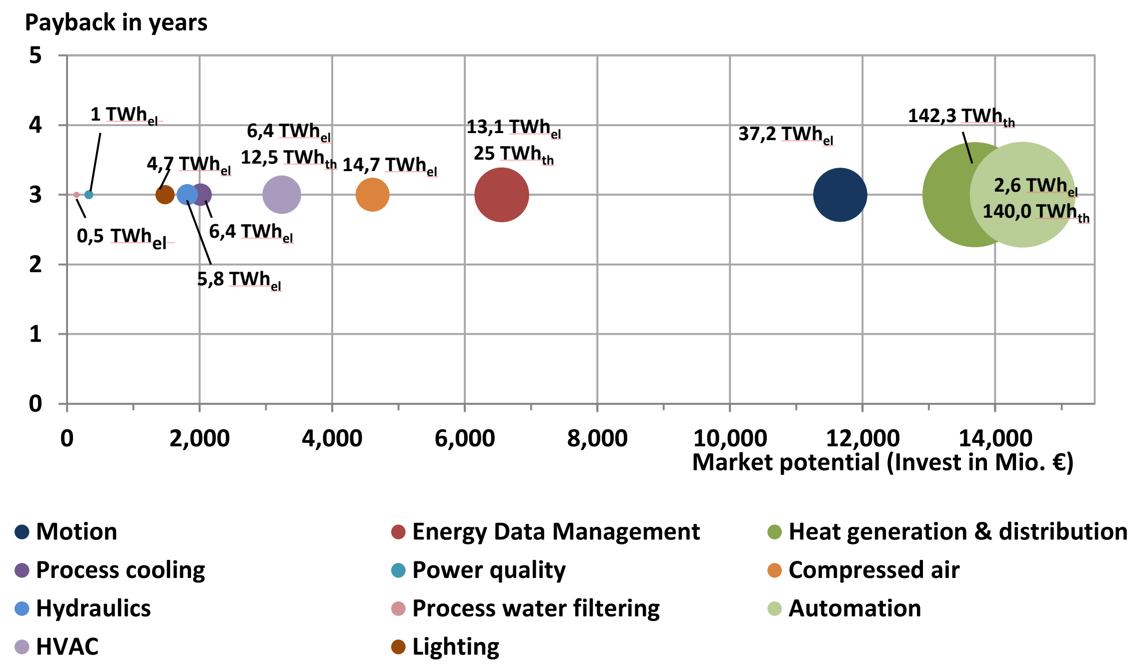


Fig. 20: Realizable potentials in the EU27

Globally the following potentials result: 1. Economical energy saving potential of **1,400 TWh_{el}/a** and **6,500 TWh_{th}/a**, which requires an investment of **900 bn Euro in the field of electricity** and **1.500 bn Euro in the field of thermal energy.** 2. Realizable energy saving potential of **520 TWh_{el}/a** and **2,600 TWh_{th}/a**, which requires an investment of **109 bn Euro in the field of electricity** and **236 bn Euro in the field of thermal energy**.

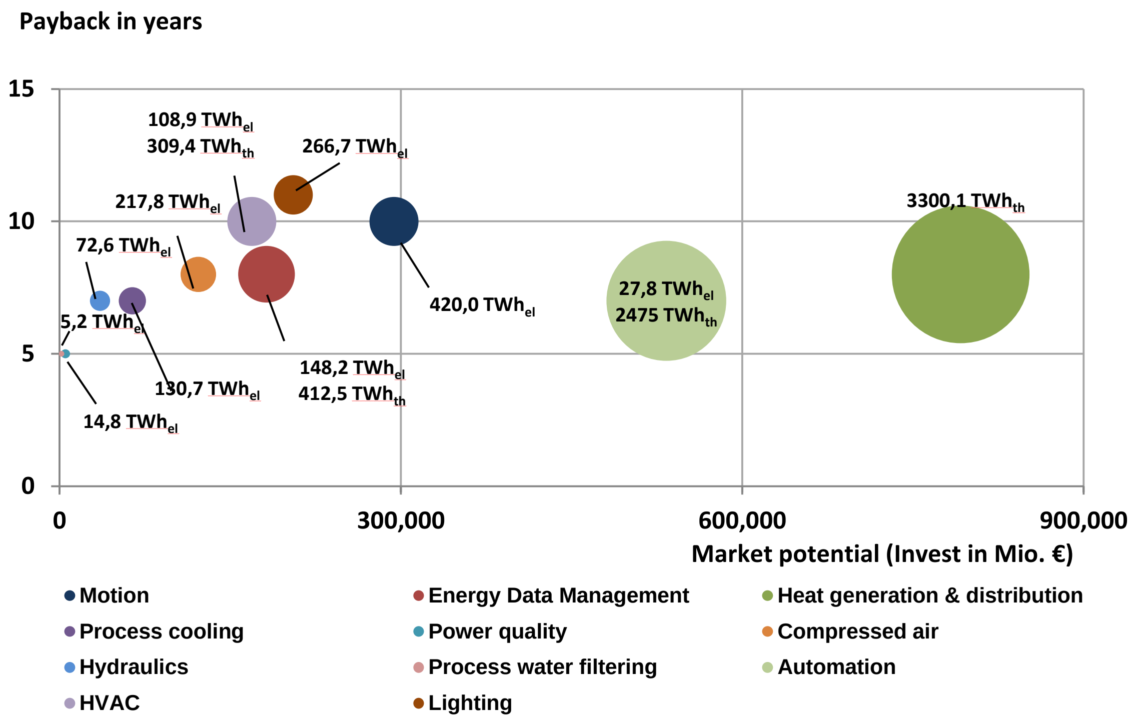


Fig. 21: Economical potentials globally

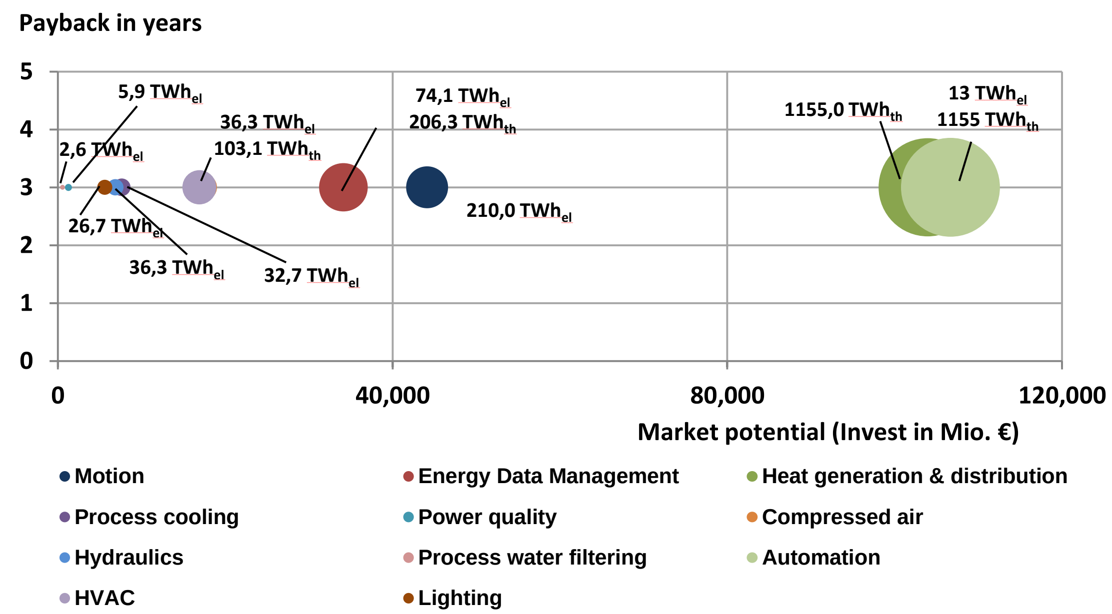


Fig. 22: Realizable potential globally

4.2 ANALYSIS OF THE BRANCHES

Energy saving potentials related to electricity in the particular branches are basically depending on electricity demand, electricity prices, the particular processes and measures which have been already implemented to save energy. According to our analysis for the chosen branches in Germany the following efficiency potentials are as follows:

4.2.1 FOOD AND BEVERAGES

In **Food and Beverage sector** partly significant differences exist in the sub-branches with regard to energy demand and energy costs. Thus, principally differentiated analyses as to energy efficiency potentials are recommended.

In all, the economical energy saving potential (taking into account life time measures, 9 years) for the branch is about **1.5 TWh_{el}/a** and requires an investment of **1.8 bn Euro** to achieve this potential. Considering the usually required payback period of 3 years "only" a potential of **0.6 TWh_{el}/a** results, which requires an investment of **253 bn Euro**.

4.2.2 MINERALS

The **Minerals sector** (cement, lime, gypsum, glass[1], etc.) the economical energy saving potential (average life time of 9.2 years) amounts to **1.4 TWh_{el}/a** and needs an investment **1.2 bn Euro**. Taking into account the usual required payback time of 3 years a potential of "only" **0.6 TWh_{el}/a** results which needs an investment of **181 bn Euro**. Especially in the cement industry the electricity is used for only a few very large drives or process components and energy efficiency is in a special focus, also due to requirements in turn for special energy cost deductions.

4.2.3 PULP AND PAPER

In the sector **pulp and paper** the economical energy saving potential (meaning considering an average life time of 9 years) amounts to **2.9 TWh_{el}/a** and can be achieved with an investment of **2.4 bn Euro**. Considering the usually used payback time of 3 years an energy saving potential of "only" **1.4 TWh_{el}/a** results which needs an investment of **387 m Euro** to be achieved. The branch shows in both absolute and relative numbers the largest energy saving potentials amongst the three analyzed branches. Taking into account a broad heterogeneity amongst the paper plants a focus of energy efficiency measure can be set generally on improvements of paper machines and waste paper treatment.

[1] According to the WZ categorization glass is not part of minerals; integrating glass here is according to internal Siemens considerations

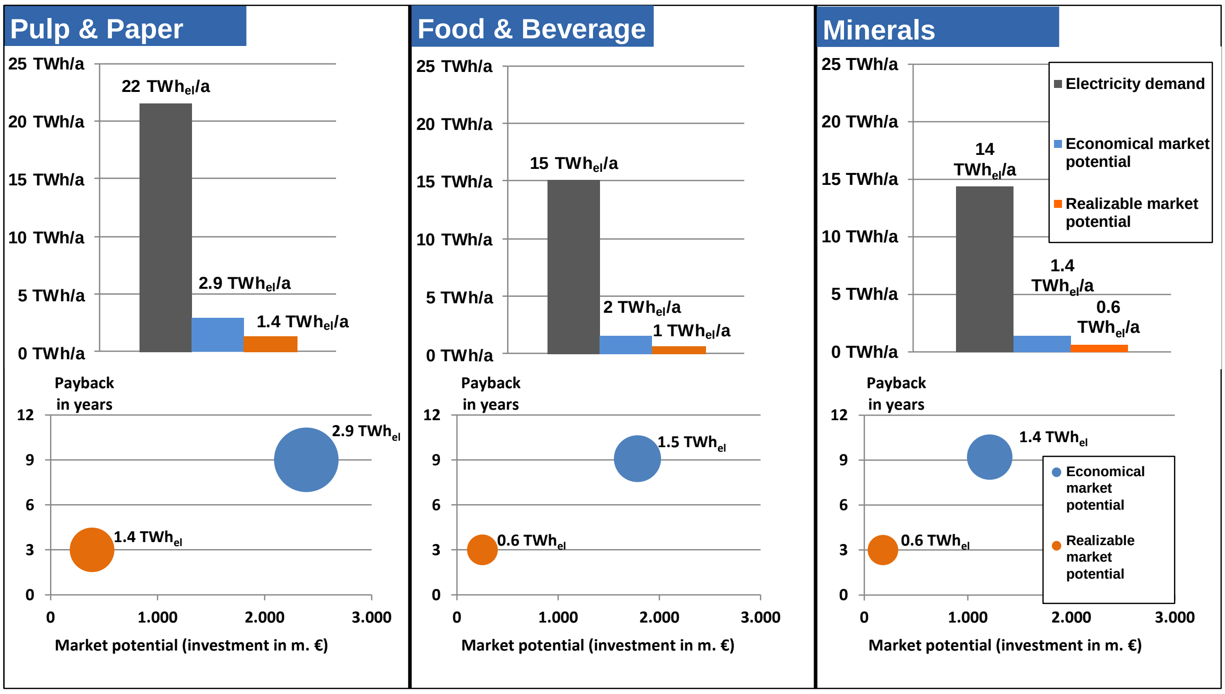


Fig. 23: Potentials in the chosen branches

4.3 PRODUCT ANALYSIS

The following chart provides an overview of the chosen energy efficiency technologies.

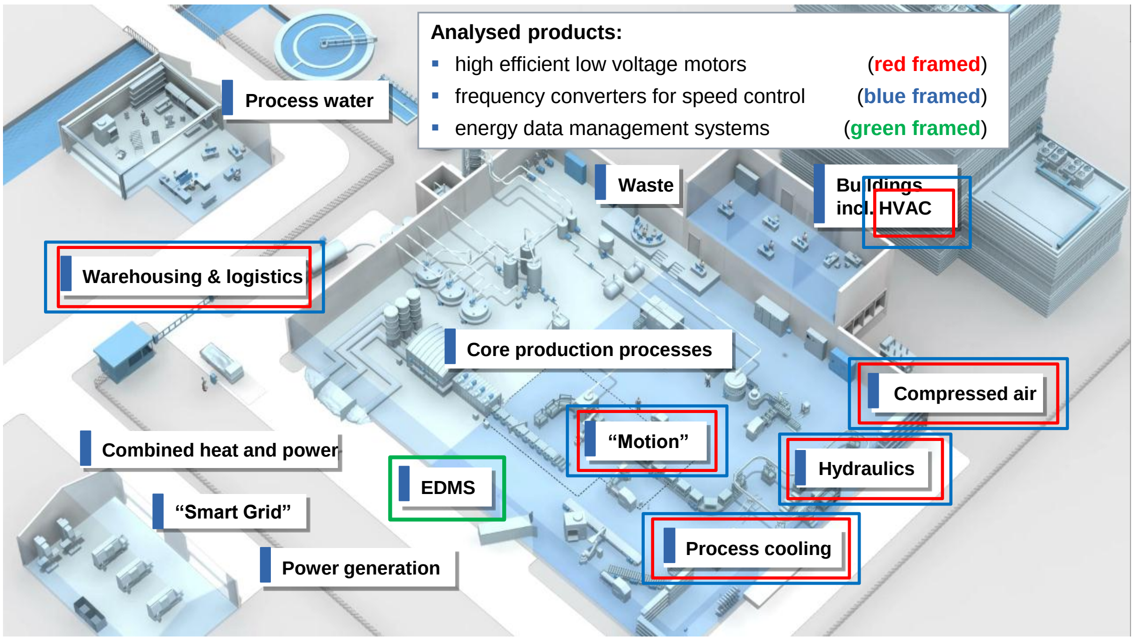


Fig. 24: Energy-efficiency-technologies in the industry

4.3.1 ENERGY EFFICIENT MOTORS (LOW VOLTAGE)[2]

With the use of energy efficient low voltage motors (0.75 – 375 kW, motor class IE3) economically **2.4 TWh_{el}/a** electricity can be saved. This potential requires an investment of **1.4 bn Euro**. The realizable energy saving potential is assessed with about **1.6 TWh_{el}/a** requiring an investment of **419 m Euro**.

4.3.2 FREQUENCY CONVERTER FOR SPEED CONTROL[3]

By using energy efficient frequency converters for speed control (in field of pumps, ventilation and compressors) economically **4.2 TWh_{el}/a** electricity can be saved with an investment of **2.5 bn Euro**. The realizable energy saving potential amounts to **2.8 TWh_{el}/a** and requires an investment **757 m Euro**.

4.3.3 ENERGY DATA MANAGEMENT SYSTEMS (EDMS)

Although energy data management systems (EDMS) don't save energy directly they are an essential element to identify energy efficiency potentials and to conclude efficiency measures. EDMS measure how much energy is used for which processes. Comparing the data with target data energy efficiency potentials can be concluded. Depending on the initial situation companies can save already 1-10% in the first year by implementation of EDMS.

According to our moderate assessment the economical energy saving potential with the support of EDMS in the German industry amounts to **2.4 TWh_{el}/a** and **5.4 TWh_{th}/a** (slightly more than 1 %). This requires an investment of **1.5 bn Euro in the field of electricity and 1.2 bn Euro in the field of thermal energy**. The realizable energy saving potential amounts to **1 TWh_{el}/a** and **2.2 TWh_{th}/a** associated with an investment of **340 m Euro in the field of electricity and 260 m Euro in the field of thermal energy**.

[2] Calculation the potentials only the costs of the motors of the particular power class has been used. Costs for installation etc. of the motors vary largely depending on the project partner and thus haven't been taken into consideration here.

[3] Calculating the Potentials only the costs of the frequency converters in the particular power classes have been considered. The costs for the installation etc. depend largely on the individual project partner and thus have not been taken into consideration here.

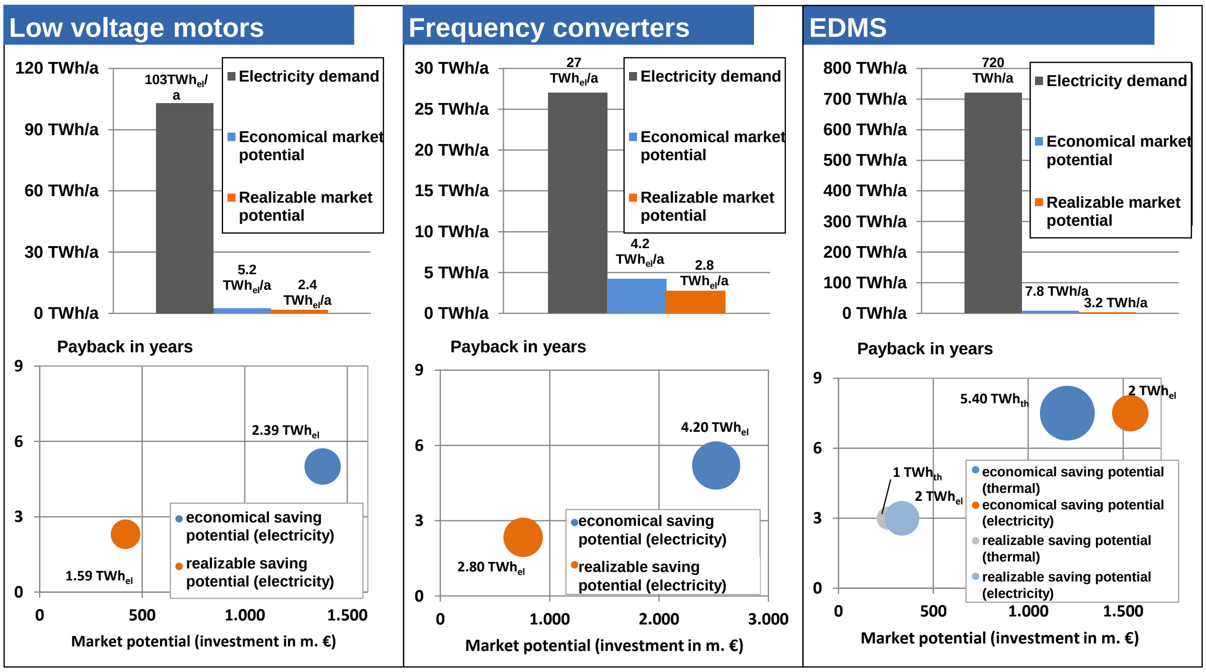


Fig. 25: Product analysis

4 CRITICAL APPRAISAL AND ANALYSIS OF THE BARRIERS

4.1 CRITICAL APPRAISAL

A few points need to be mentioned which need to be regarded critically in regards to their significance and validity despite the fact that the methodology has been chosen conscientiously and the analyses have been realized carefully and thoroughly.

- **Consistence of data:** Differences between national and international statistics, based on diverse system boundaries or non-disclosure bring along difficulties for data consistence.
- **Electricity prices and own electricity production:** as electricity prices vary largely by country, size of companies, energy demand etc. the analyses have been done using average prices. These aspects have to be taken into consideration while interpreting specific potentials for branches and technologies. Electricity which is produced within plants is very difficult to assess and thus has not been done within our analyses.
- **Internal rates of invest:** Calculating the internal rate of invest makes only sense in regards to the economical market potential (considering life time usage); regarding a payback period of 3 years usually requirements as to the internal rate of investment are fulfilled.

- **Bottom-up-approach versus Top-down-approach:** Depending on the data base the appropriate approach for the analysis has been chosen. Due to data availability it was not possible to use one approach for all assessments.

- **Realizable market potential**: the realizable market potential usually is not the same as the realistic market potential due to the following reasons:
  - Assumptions can vary from real conditions (prices, energy saving potential in %, etc.)
  - Non-financial barriers e.g. culture-linked characteristics (acceptance of solutions), business cultures in companies (no adequate staff, decision processes etc.).

4.2 ANALYSIS OF BARRIERS

In the course of the project also barriers have been assessed which limit the realization of energy efficiency potentials. Therefore Siemens experts in the chosen countries and branches as well for analyzed products have been interviewed as to the relevance of different predefined barriers (high, medium, low relevance). In the result the following main barriers for investments in energy efficiency measures have been mentioned – independent of the country and branch: uncertain economic market situation of the companies, limited access to capital, too long payback times of the energy efficiency measures and a lack of political incentives.

For the particular branches the following barriers have been pointed out especially:

- pulp and paper industry: political incentive system, market situation of the companies
- food and beverage: too long payback times, lack of resources (human, time)
- minerals: limited capital, too long payback times and technologies/products which are not already mature

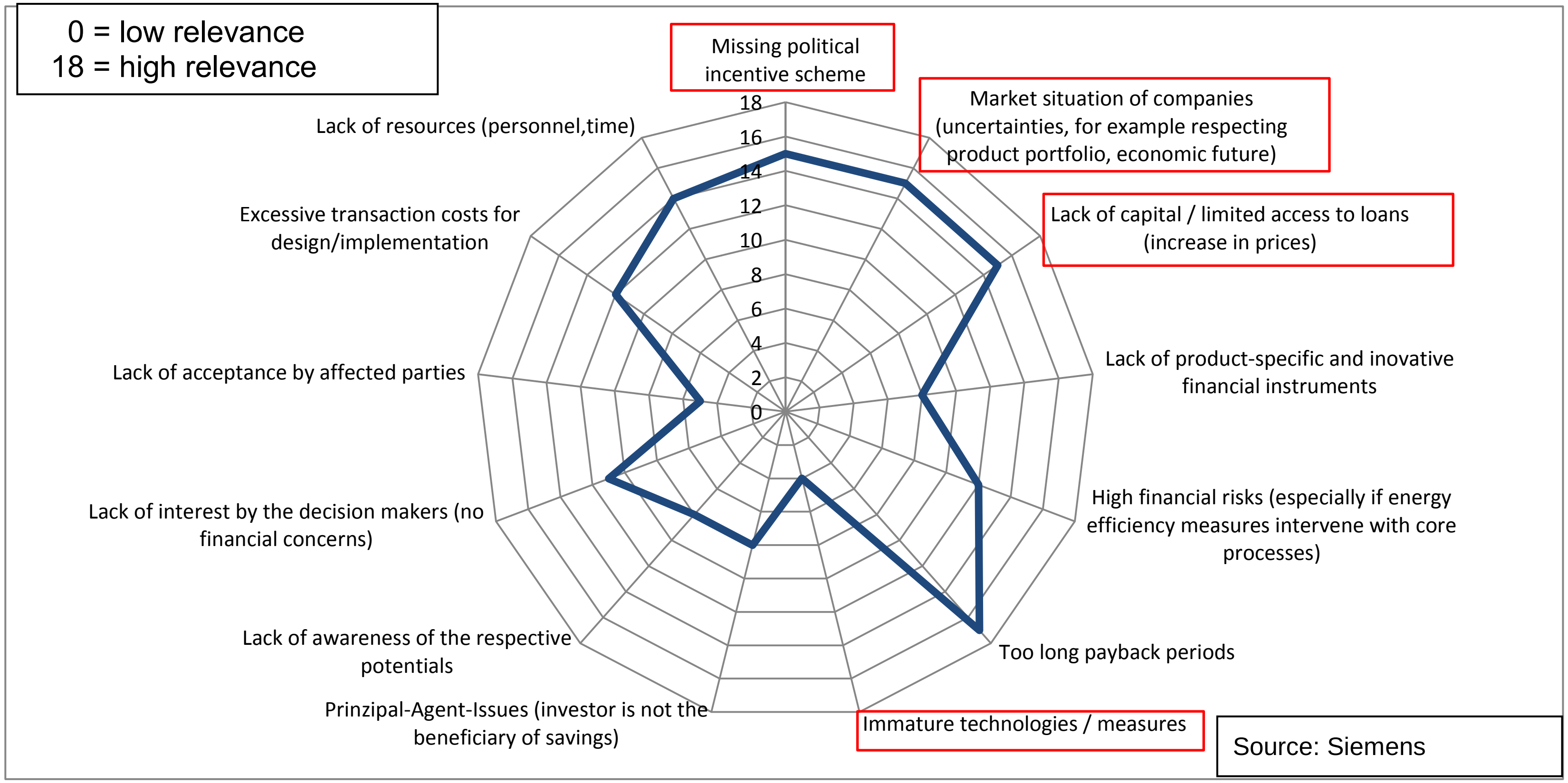


Fig. 26: General barriers[4]

[4] Results of questionnaire survey provided by country-, branch- and technology experts;
Sum of the number of interviewed persons (11) by weighting of answers on a scale of 0 (no relevance) to 2 (high relevance)

5 APPENDIX

5.1 SOURCES

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5.2 ABBREVIATIONS

Abbreviation	**Term**
AGEB	Arbeitsgemeinschaft Energiebilanzen e.V.
A	Austria
BMU	Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit
DESTATIS	Statistisches Bundesamt
EDMS	Energy data management system

EC	European Community
EU	European Union
Eurostat	Statistics agency of the European Union
F	France
Fraunhofer ISI	Fraunhofer-Institut für System- und Innovationsforschung
FC	Frequency converter
I	Italy
IE	International Efficiency
IEA	International Energy Agency
kW	Kilowatt
MWh	Megawatt hours
SWE	Sweden
TR	Turkey
TWh	Terawatt hours
UK	Great Britain
VB	Sales
ZVEI	Zentralverband Elektrotechnik und Elektronikindustrie e.V.

5.3 GLOSSARY

Term	Explanation
Distribution of energy consumption	Distribution of energy consumption of typical appliances with focus on electric appliances (e.g. pumps, drives, cold generation etc.); upscale of results of sub-branches to the whole branch.
Energy consumption / Energy balance	Definition of energy consumption oft he according sub branches priorized by Siemens defirentiated by energy types (electricity and thermal energy)
Energy saving – and market potentials	Definition of market potentials by analysis of typical energy saving potentials and consideration of lifetime of or payback of 3 years respectively.
Total energy demand	Demand of fuels, heat and electricity
IE1, IE2, IE3	EN 60034-30:2009 Efficiency classes of single-speed, three-phase, cage-induction motors (IE-code) in the range of von 0.75 kW to 375 kW: • IE1 = Standard Efficiency (comparable EFF2) • IE2 = Improved Efficiency (comparable EFF1) • IE3 = Premium Efficiency
ISO 50001	Energy management systems – Requirements and guidance for implementation Die ISO 50001:2011 is a worldwide valid norm, which supports organizations in setting up an energy management system.
Classification according to WZ 2008	Classification of economic sectors, published in 2008 (valid for Germany)
Low voltage motor	Here 3-phase three-phase, cage-induction motors in the range of von 0.75 kW to 375 kW
Payback	Amortisation of an investment in years
Realizable potential	Implementation of energy efficiency technologies only when the payback of 3 years is given
Realistic potential	Taking into account of barriers (political, financial, time etc.): the realizable potential is not tapped completely every year
Technical potential	Implementation of best available energy efficiency technologies in all areas and applications without considering the economic aspects

Economical potential	Implementation of energy efficiency technologies only in applications, where the economic criteria are fulfilled over the life time of the technology (the internal rate of return (IRR) is higher than x%, here higher than 8%)