STEAM UP

Evaluation of Audits

Results of the steam audits

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Description of the deliverable

This report describes the methodology and presents the results of the in-depth steam energy audits conducted within the Steam Up project. Firstly, the Steam Up audit methodology is specified. Secondly, the acquisition process of the companies to engage in the audits is illustrated. Thirdly, 78 energy audits are then described by giving details about the number, industry, and energy consumption of the participating companies as well as about the main features of the steam systems, already implemented saving measures (before audit actions), the status of the energy management system, and the suggested energy savings. Finally, information on the implementation of the energy-saving measures (after-sales support) is summarized.

Summary

The audits present a complete picture of the technical and energy management including energy-saving measures of all areas of a company's steam system. The total energy-saving potential of the 78 audits identified is 226 GWh, total monetary savings would be EUR 8.4 million. On the other hand, a total investment of EUR 36.6 million would be necessary. The average payback time of these actions is 4 years.

At the time this report was prepared, measures corresponding to 133 GWh energy savings or EUR 5.2 million p.a. money savings have already been or will be implemented during this or the next year. The average saving potential – by also including companies where no energy-saving potential was identified – is 1.7 GWh per company audited. The total investment triggered will be EUR 18.1 million p.a., achieving CO_2 savings of 31,755 t.

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1. Introduction

The Steam Up project aimed to assess the substantial and easily accessible energy-saving potential of steam systems in industries in order to support the EU objectives for energy efficiency. Steam Up presented concrete business cases to decision makers, based on 78 detailed audits from several European countries.

Energy experts were trained in the Steam Up methodology and body of thoughts, as well as energy managers, end users, technical staff from all types of companies of various size and from all over the country.

This report describes the methodology and presents the results of the in-depth steam energy audits conducted within the Steam Up project:

Specifically, this paper clarifies in detail the work performed within Work Package 6 of the Steam Up project („Carrying out the in-depth steam audits on site“), which consists of conducting energy audits in order to test the Steam Up audit methodology for its usability and applicability through an energy audit campaign and to improve it subsequently.

The objective of this work package was threefold: first, to organize the in-depth steam audits in the targeted industries; second, to reach real energy savings and to create awareness and acceptance in the companies concerned; and third, to collect all information necessary to present the business cases (energy-saving measures) for improvement of industrial steam systems, namely by:

- identifying the saving potentials within the steam audit,
- measuring initial energy performance indicators,
- finding solutions and expressing saving potentials as target energy performance indicators,
- elaborating a to-do list for realization,
- and by calculating rentability and quantifying non-energy benefits.

This deliverable is structured in the following way:

Firstly, the Steam-Up audit methodology is described. Special focus will be given to involving top management, working with an energy action team, analyzing non-energy benefits, and implementing energy management for steam systems.

Secondly, information on the acquisition of the companies within the project is given. How did the consortium engage companies to participate?

Thirdly, the process for the on-site visits is described, as it was performed by the partners.

Then, the 78 energy audits are specified. In this part, the number, industry and energy consumption of the participating companies are specified. Also, the main features of the steam systems, already implemented saving measures, the status of the energy management system and the suggested energy savings are illustrated.

Finally, information on the implementation of the energy-saving measures (after-sales support) is summarized.

2. Description of the Steam Up Audit Methodology

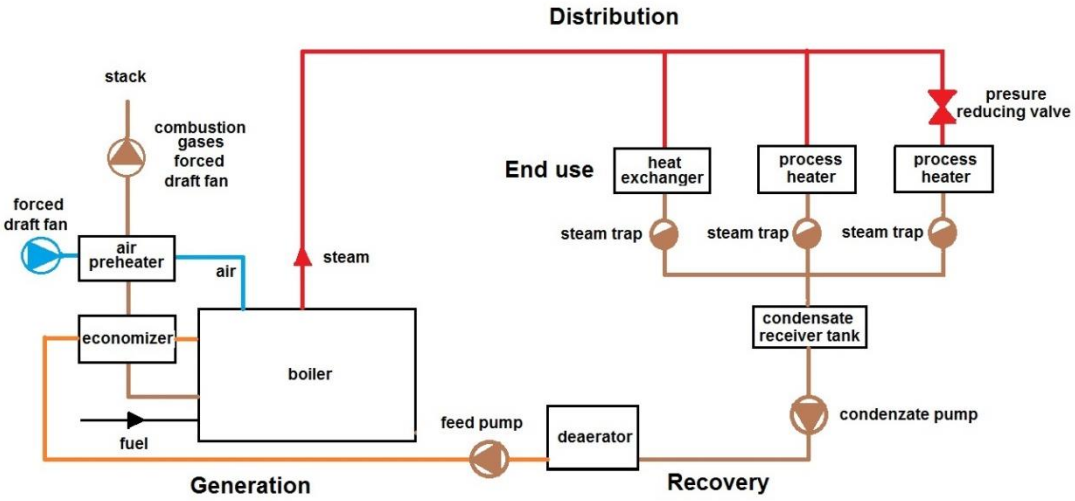
In this chapter, the main elements of the Steam Up audit methodology are outlined. A detailed description is provided in the document “Steam Up Audit Methodology”.

An in-depth steam audit helps an organization to identify opportunities to improve energy efficiency of steam processes. It can be a stand-alone audit or become a part of a site-wide energy management system.

Definition of scope

The boundary of the system concerned extends from the energy input to the heating system, whether via burning of a fuel or consuming electricity, to the point where the business purpose of generating the heat is achieved. For example, that business purpose may be to provide heat for a cooking process (in the case of an oven), to provide heat for a drying process (such as in the case of a lumber kiln) or to induce a chemical reaction. It is important to understand the ultimate goal of a process to ensure that any potential system changes are compatible.

The system boundary is therefore defined by the points beyond which any change to the system no longer has any effect on the business purpose that the system is serving.



Source: ENVIROS

Figure 1 Definition of border of the steam systems (generation, distribution, end use and recovery of condensate)

Within the system border elements to be audited are:

- Steam production (utility): boiler, burner, boiler blowdown, flue gas, economizer, pre-heating of feed-water, use of flue gas for preheating of e.g. domestic water, including water treatment
- Steam distribution, steam traps, insulation of network
- Steam heat exchangers: incl. control of heat exchanger, deareation, steam traps, temperature and heat demand (kW), etc.
- Steam usage: for buildings (heating, humidifying) and for processes (heating, drying, sterilization, etc.), indication of temperature, steam demand, operating time
- District heating, only when it is just a secondary part of the installation
- Condensate transport: incl. network-piping, insulation, condensate pumps, flash steam recovery vessels

But **excluded** from the Steam Up audits are (in general, but this exclusion has to be set and agreed with the customer):

- Other utilities, such as combined heat and power plant (CHP), turbines, steam motors
- District heating (as primary purpose)

Steam Up Audit Methodology

Steam Up audits follow a comprehensive review outlined in the following figure:

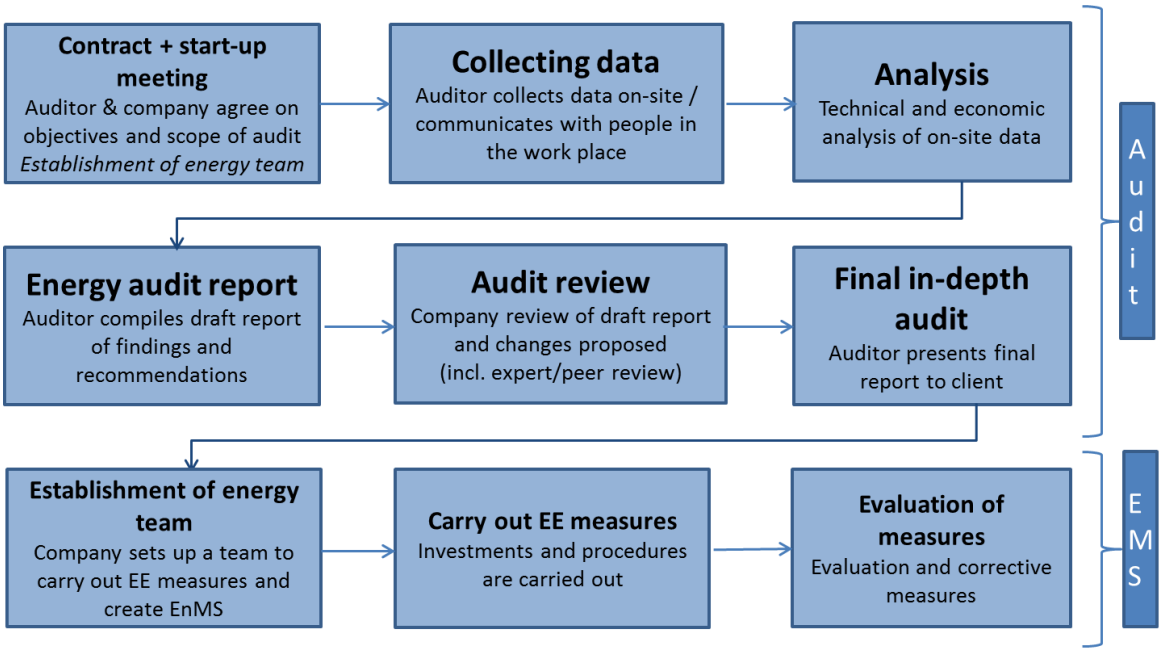


Figure 2 Steam Up audit approach (EE: energy efficiency; EnMS: energy management systems)

The main activities of some steps are explained in the following:

Within the contract and during the startup meeting, the scope of the audit is agreed with the company. For the data collection, checklists, which are adapted to each step of the process, are used during the audit. For the analysis, calculations that have been made are indicated including the purpose of the calculation. When establishing the energy team, some members of the company management should be involved.

Furthermore, the following points are included in the energy audit process to ensure a high involvement of the company, to increase the portion of implemented saving measures and to change the energy culture of the company:

- Consideration of corporate strategy and involvement of high level management
- Application of a systems approach
- Use of an organizational approach
- Focus on energy management
- Attention to non-energy benefits

In the next paragraphs, these points are described briefly.

Consideration of the corporate strategy, involvement of high level management

Before the first visit to the company and starting the audit, it is important to get insight into and to gather preliminary information about the corporate strategy, the market and market developments and trends in the sector, where the company is operating.

It is crucial to get a basic overview of the problems characterizing a specific company's industry ideally even before consulting the company or, at the latest, before the first site visit. It is recommended to get engagement of top management already during this first stage of the process, that is during the first talk or when negotiating the steam audit.

Application of a Systems Approach

A systems approach in handling the whole steam system, as opposed to handling it as a sum of single components, is required as only such an approach enables a company to fully optimize the savings potentials of said system.

The checklist adapted to analyze a steam system, therefore, asks e.g. the following (consecutive) questions:

- Why is steam used (for what purpose)?
- How is it generated?
- How is it used (by what means)?
- How is it distributed?
- How does the steam recovery work?
- Could steam in one or more processes be replaced?

Before starting with the in-depth energy audit, these basic questions should be answered.

Use of an Organizational Approach

In addition to the systems approach, we can also define an organizational approach:

- Who is involved?
- Who is the engineer?
- Who is knowledge owner?
- Who are the steam users?
- Who decides what? Etc.

These questions should be answered and are part of the in-depth audit.

Before starting the actual audit, it is important to reach out to all personnel involved in the steam process. This means: maintenance, users, investment deciders, engineering. In SMEs, the investment decision maker is top management. A stakeholder matrix will help to get the broader picture of who decides what and when.

Focus on Energy Management

Energy management systems (EMS) have emerged over the last two decades as a proven best practice methodology to ensure proactive and effective energy management. EMS offer

a structured and systematic approach for integrating energy efficiency into an enterprise management culture and to daily practices through the provision of:

- A framework for understanding energy use and consumption
- Action plans to continually improve energy performance, including energy systems and production processes
- Metrics to track and quantify energy performance against a baseline of energy consumption
- Data and documentation to sustain and demonstrate energy performance improvements over time

Energy management as part of the Steam Up project does not aim to be a full-sized energy management but focuses on relevant energy management system aspects and principals, that can be used to build a management system around the steam operations.

During the energy audit, therefore, numerous questions regarding energy management in the field of steam systems are dealt with in detail (e.g. responsibilities, targets, energy performance indicators, trainings, information legal compliance, maintenance information).

Attention to Non-Energy Benefits

Non-energy benefits (NEBs) are traditionally not included in energy efficiency project implementation economics since there is no commonly recognised method for calculating their value, nor has the area been prioritized so far. However, research indicates that if NEBs are included, the true value of the energy efficiency projects might be up to 2.5 times higher than if looking at the energy efficiency improvements alone.

3. Acquisition Process

In each country the following organizations were responsible for the acquisition and implementation of the energy audits:

Table 1 Responsible partners for the acquisition and implementation of Steam Up audits

Country	Responsible Partner
Austria	AEA + External Consultants
Czech Republic	ENVIROS
Denmark	AURA
Greece	CRES
Germany	Adelphi + External Consultants
Italy	ISNOVA Consul System
Netherlands	Industrial Energy Experts
Spain	ESCAN

To get feedback from the auditors, all participating countries filled in questionnaires for (almost) each audit, answering questions concerning the acquisition process.

In some countries broad announcements of energy audit possibilities were executed, however, in some countries only existing customers of energy auditors were informed.

In most of the countries the contacts to companies had already existed prior to the project. Additional contacts were recommendations from other clients, cooperation and private contacts. The companies were contacted mainly via telephone and email.

The contact persons were mostly the heads of building equipment and appliances, energy managers, the heads of facilities, maintenance managers, project managers, technical managers and QESH-coordinators (Quality Environment Safety and Health). Partly, the CEOs (esp. in kick-off meetings) or persons of the top management were involved.

For acquisition purposes, the advisors used short power point presentations, leaflets, mails with the link to the Steam Up website, Steam Up flyers and a list of references.

In most cases, the advisor described the offer to the company and received a written order.

The main discussion points during the first contact were the internal time expenses, the costs for the company and optimizations in the past as well as the confidentiality of the data provided and possible energy cost savings and security of supply.

In Germany, the discussions were merely focused on costs for new steam systems,

how to reveal losses, the (existing or non-existing) data collection, the technical options for improving the cooling and steam systems and applications, tax options, reducing costs for steam production and maintenance. If the contact was with the management level, often issues of strategic planning and payback periods were discussed.

The challenges of the companies were discussed in all advices, but the answer to the question about strategic business models was generally not concrete. Here is an example: A participant has a high market share in Austria but the pressure on costs from China is noticeable whereas the quality, sustainability and service of the Austrian product are much better.

The main reasons for participating in the action were cost savings, the start-up of energy management, reliability and security of supply, energy-saving opportunities and non-energy benefits. Further reasons were improving sustainability, the client's satisfaction with the advisor in previous projects, and the opportunity to check whether the steam system was efficient.

Specific reasons from individual companies were: the requirements of an EU project and the necessity of implementing measures in five to six years anyway; the satisfaction of the companies' involvement in an EU project, which should give an added value to their sectorial reputations; the imminent adaptation of the steam system due to capacity expansion of production; the confirmation of own ideas and the possibility to learn.

Concerning general challenges for the project and recommendations to improve the acquisition process, comments were:

In some countries the audits (or not all) were for free, some of the participants had to pay a part of the costs. This was good as in most cases the CEO or plant manager was involved in the project.

The main discussion points were about the commitment of the companies and the internal costs. Two companies decided not to go along with the project once it was made it clear that measures with a payback period lower than five years need to be implemented.

The customers are challenged with various projects focusing more on quality, safety, health, and less on environmental issues. The expenses on internal time mostly were an important issue before the project started, but once the project had begun it did not seem to be an issue anymore.

Subsidies are very helpful to convince companies to think about or implement efficiency measures – the higher the better. A quote of an advisor: "As soon as you are in the company, it is easier as they know what is possible." An important subject in the Czech Republic was how crucial steam for the production process is. The German advisors say: "It is important to keep materials simple, two pages max., and as an advisor you are also a mentor and 'spin doctor'."

Generally, the first companies that are interested were first served. There was no need to select companies in addition to the criteria mentioned below as the number of the

companies interested in Steam Up audits was not higher than the number of planned audits per country.

- Soft factors: Contact with company, willingness to conduct and order an energy audit (under the specific Steam Up conditions, e.g. timeline, content, price), ambition to implement energy-saving measures
- Technical facts: sectors where steam is used, relevant use of energy for steam production

4. Process for the On-Site Visits

This chapter illustrates the results of the questionnaires filled out by the auditors concerning the process of the on-site visits.

Time Used On-Site

On average, each company was visited twice to three times. Each visit took two to six hours. In some cases (esp. very large companies), the auditors had already known the company from other audits. In some cases data collection was organized in much more visits.

Data Collection

The data collection was done internally and externally. In most of the cases the data were provided and collected by the customers, some of which requested the advisor to give guidance on this job. In Germany, in most of the cases the data were provided and collected by the external specialist, partly in teamwork with the customer. In general, the data collection was accompanied by a detailed visit of all applications.

Persons Involved in the Audit

There were mainly one to two persons involved in the audit: they were the heads of the technical unit or facilities, the CEOs, heads of production, risk managers, experts for steam application and technical engineers.

In almost all cases experts of different units were included, mainly from the production unit because they have experience in the operation of the system and in frequently occuring problems.

In the Netherlands, although most of the companies were or are involved in Long Time Agreements and had made action plans in the past, for all of the companies technical measures were recommended.

In most of the cases management was not involved in the process because it was not necessary. In Germany, the management was directly involved in most cases. In several cases, management was not interested in the activities due to lack of time. The results and the audit report were presented on management level.

Process of Identifying Measures

Measures were mostly identified by examining the steam process and pointing out and discussing the facilities and machinery in question with the contact persons. Sometimes, there was a brainstorming and discussion in the company. Energy consumption bills were used as a data basis and standard measures were checked. Furthermore, standard questions for steam boilers were worked out (Steam Up methodology, klimaaktiv guideline, UNIDO guideline), own experience was brought in and the companies' own ideas were clarified.

In the Netherlands, a measure for reversed osmosis as water treatment to prevent chemicals has not been accepted in all of the four cases this measure was advised.

Use of Non-Energy Benefits

In all countries non-energy benefits were used to drive the implementation of energy efficiency projects. Here is an example from Denmark: If some of the steam production was

substituted, then maintenance could be lowered and the requirement for monitoring reduced (see chapter results for a detailed list of non-energy benefits).

In Germany, lower maintenance costs could be well quantified. Many companies seem to be unaware of the relevance of NEBs. Therefore, NEBs are often ignored or not examined.

The Italian steam auditors could put a monetary value on NEBs for expenses for water and materials.

Generally NEBs are very difficult to quantify. Here are some sample questions from Austria regarding the quantification of faster production: Has this an effect on quality? When is the next process ready? How can an increased fire safety be quantified? What is the monetary value of an award?

In Spain, a low value was accepted by the company (in the range of 5% of the energy savings).

Elements of ISO 50001 Suggested

In 50% of the Austrian cases elements of ISO 50001 were not suggested. Three companies have already implemented the ISO 50001 system. In two other companies a more detailed energy monitoring and installing measuring devices were suggested. Several of the Danish companies and two in the Czech Republic had already implemented the ISO 50001 system or ISO14001. In two other Czech companies a more detailed energy monitoring and installing measuring devices were suggested. The steam system has high priority in all companies. In Germany, elements of ISO 50001 were suggested in some cases, especially energy performance indicators. One company had already implemented the ISO 50001 system. In other companies, a more detailed (or sometimes even simpler) energy monitoring and installing measuring devices were suggested. Some companies are too small for implementing ISO 50001 (or other management systems). According to the Italian law, the adoption of ISO 50001 is an obligation for high energy intensity industries, however, nowadays more and more SMEs are interested to implement the standard and are evaluating the possibility. In Spain, elements of the ISO 50001 suggested were monitoring of the energy and policy/plans for energy efficiency.

Difference to Other Audits

The main difference compared to other audits which follow a broader approach was the focus on steam. Qualified professionals on this energy carrier are necessary because of the interaction with other systems. A special topic was the energy price optimization and developing economic saving measures. In Germany, the management was addressed and therefore the way of communication was different to that in other cases.

5. Results of Steam Up Audits

All audits were reported via the Steam Up audit template. This template is based on the Steam Up methodology and includes a general part for the summary and a checklist for evaluating the status of energy management for steam systems within the audited company.

Description of Participating Companies

Between May 2016 and January 2018 a total of 78 audits were conducted in the participating countries within the Steam Up project.

The audits were conducted in accordance with the Steam Up audit methodology and were documented in a uniform reporting format. The duration for completion of the audit was individually adapted to the company. The audits were conducted from experienced energy consultants and auditors. In one country also technological suppliers in the field of steam systems were invited for the on-site visits.

All participating countries, with the exception of Italy, conducted ten audits. Italy conducted eight audits, but audited quite large energy consuming companies (e.g. paper mills, electronic company).

Industries

Participating companies came from the food industry (32 companies), chemical industry and industrial laundries (ten companies each), pulp and paper sector (eight companies), pharma industry (four companies), textile industry (three companies) and several others. Figure 3 and Table 2 provide details about the companies.

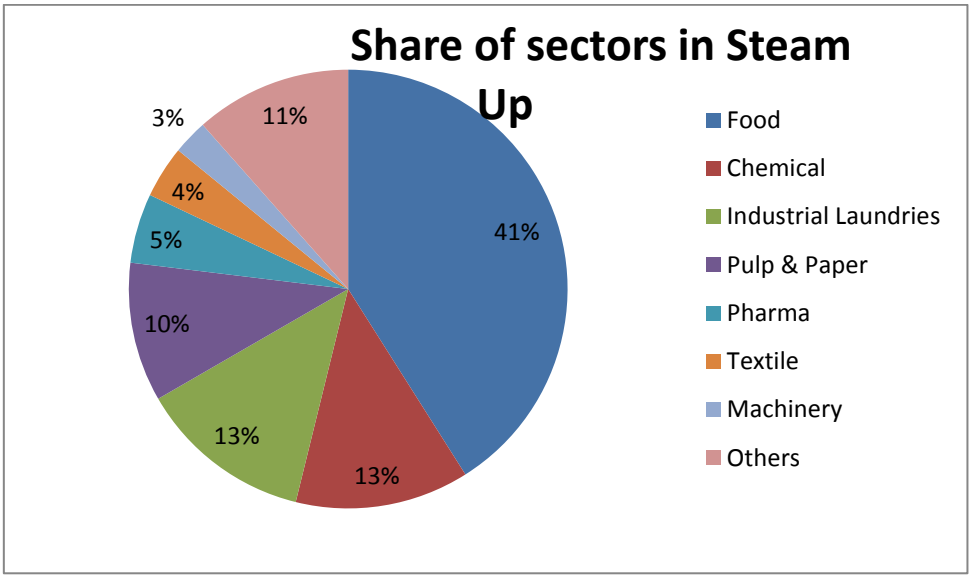


Figure 3 Share of sectors of participating companies

Table 2 Number of participating companies per sector

Sectors	**Number of companies**
Food & Beverage ○ Dairy, milkpowder, cheese and yoghurt production (8) ○ Meat production, slaughterhouse (6) ○ Brewery (4) ○ Vegetables (4) ○ Processed Food (3) ○ Bakery (2) ○ Sugar ○ Juice production ○ Rice production ○ Pasta production ○ Flour mill	32
Chemical Industry ○ Plastic ○ Soap production ○ Expanded Polystyrene (EPS) production, etc.	10
Industrial laundries	10
Pulp and Paper	8
Pharma	4
Textile	3
Machinery	2
Printing and service activities related to printing	1
Coke production	1
Waste incineration	1
Tyre manufacturer	1
Façade roofing	1
Electronics	1
Tobacco	1
Road material	1
Business park	1
Sum	**78**

Steam Use

Examples of steam use for the sectors analyzed are summarized in Table 3:

Table 3 Examples of steam using processes in various sectors

	Main steam users, with share of process for steam consumption in the audited companies
Pulp and Paper	Evaporation plant: 25% Feed water degassing: 16% Wood chip cooking plant: 16% Drying machine: 16% Sodium evaporation plant: 13% Oxygen bleaching: 4%
Pulp and Paper	Yankee drying cylinder: 100% (210°C)
Paper	Pre-drying: 61.8% Glue-presses: 13% Bleaching: 9.8%
Coke production	Ammonia stripping: 43% Benzol: 18% Autoclave sulfur: 3% Coke of coke gas: 12% Coke battery: 12% Heat exchange station: 6% Gasholder: 6%
Cheese production	Heating Cooking Sterilization Packaging Cleaning of equipment
Diary Yoghurt production	Pasteurization Yoghurt maturation (40°C) CIP (Clean in Place)
Dairy Milk production	Pasteurization: 46% Sterilization tanks: 8%
Dairy Milk powder production	Dry tower: 32% (above 200°C) Evaporation: 57% (100–200°C) Pasteurization CIP Heating
Brewery	Bottle hall: 35% Wort kettle: 19% Brew water heating: 15% Sparging heating: 11% Mash tun: 7%
Brewery	Brewing: 60% Bottling: 30% Heating: 10%
Juice production	Extractor: 30%; purification: 11%

	Main steam users, with share of process for steam consumption in the audited companies
	Production of thick juice: Refinery, brewing house: 24% Evaporation: 12.4% Heating: 8%
Slaughterhouse	Animal by-products not destined for human consumption: 50% Ovens: 20% Rest of process (washing, pot, dryers): 20%
Meat processing	Steam baking in ovens: 85% Pot and tank for cooking: 10% Shrink wrapping machine: 10%
Meat processing	Slaugtherhouse, smokehouse, dryers, cooked production, steam cooking boilers: 86% Steam for heating, hot water production: 14%
Meat processing	Oven: 80%
Juice production	Concentration process
Food production	Heating, cooking, sterilization, packaging and equipment cleaning
Vegetable oils	Heating vegetable oil: 75.4% (230–250°C) Production of vacuum: 7.9% Keeping oil tanks warm: 15.2% Hot water for CIP: 1.5%
Pharma industry	HVAC: 56% Drying Coating
Pharma industry	Production of high purity steam: 25% Ethanol distillation: 22% Preparation of specific product: 12% Autoclave: 12% CIP: 9%
Industrial laundry	Washing machines: 34% Dryer, presses: 40%
Printing of textiles	Steamer: 40% Drying: 20% Washing: 20%
Textile	Dyeing machines: 28% Scouring and padding: 27% Utility: 19% Heating: 12% Graphic division: 5% Airbag tenter: 3% Coating: 3% Sizing: 3%
Chemistry – plastic production	Heating of batch reactors for monomer polymerization EPS drying

Information on Energy Consumption

Total fuel consumption for steam in the audited companies was between 0.33 GWh and more than 2,000 GWh. The average fuel consumption for steam was 91 GWh, the median was 7.3 GWh, meaning that 50% of the companies had an energy consumption for steam of lower than 7.3 GWh.

Total energy consumed for steam within the Steam Up project was 7,069 GWh (reported in the audit reports). The main energy carriers used for the production of steam were gas (48%), biomass (41%), oil (4%), coal (3%) and waste (3%). Biomass includes mainly black liquor in selected paper mill, but also vegetable oil and rice husks. More than 50 companies (out of 78) use gas as the main energy carrier for the production of steam.

Table 4 Energy carriers used for steam in the audited companies

Energy carrier	**Heating value (MWh)**
Gas	3,417,437
Oil	285,910
Waste	200,000
Biomass	2,875,101
Liquified petroleum gas (LPG)	18,739
Gasoil	617
Coal	189,773
Steam bought, source not named	82,115
Sum	**7,069,692.2**

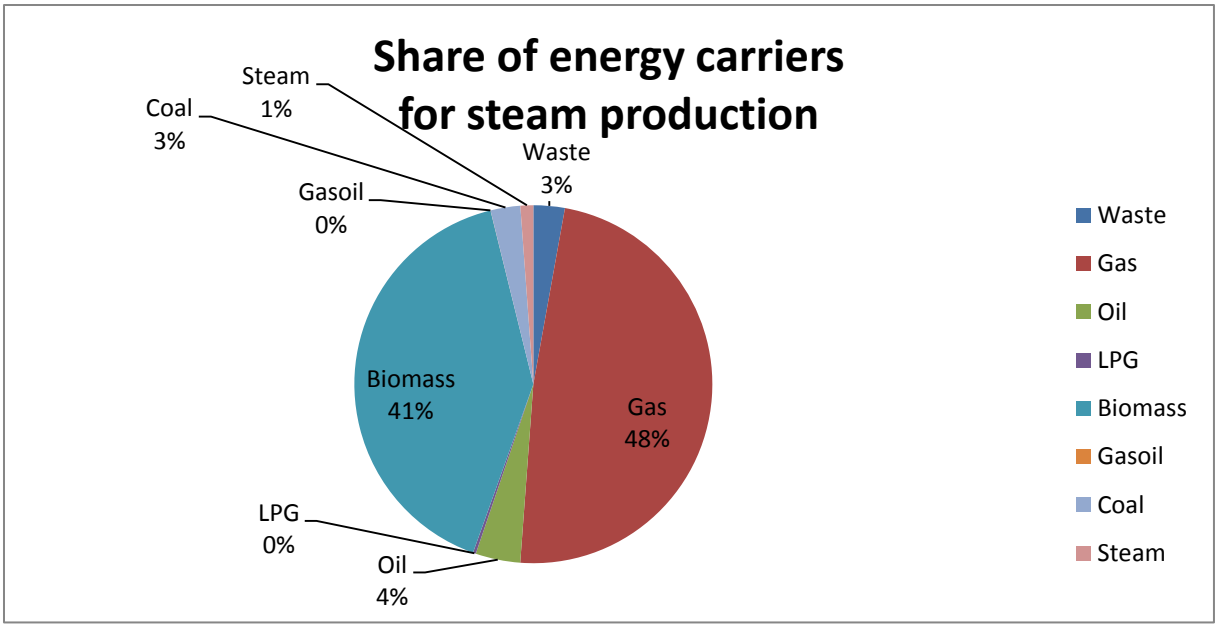


Figure 4 Share of energy carriers for steam production

Description of Steam Boiler

In this section some key features of the analyzed steam boilers are mentioned. Not all information is available for all steam boilers, furthermore, several big boilers and CHPs were not included in the following analysis.

The average boiler size of 66 boilers in the audited companies was around 4.7 MW_{th}, the average year of the boiler installation year was 1995 (between 1950 and 2015). Running hours were between 400 und 8,760 h (average is approx. 5,650 h).

The average exhaust gas temperature of 70 boilers was 170°C, the oxyen level of 60 boilers was around 5%. As shown in the figures below, there is still quite a high saving potential in lowering the exhaust gas temperature and the oxygen level in the exhaust gas. For example, for gas boilers, exhaust gas temperatures of 120°C (without flue gas condensation) and oxygen level of around 1.5% should be technical standard. As the average age of the boilers is above 20 years, this saving potential should be realized during the next years.

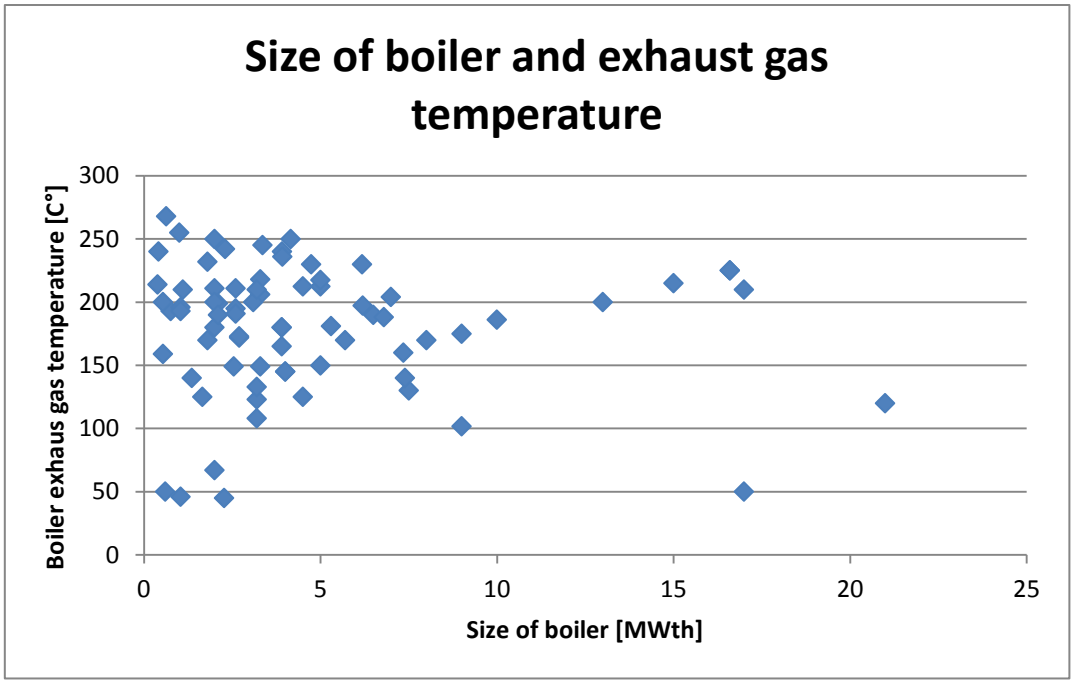


Figure 5 Thermal nominal power and exhaust gas temperature of analyzed boilers

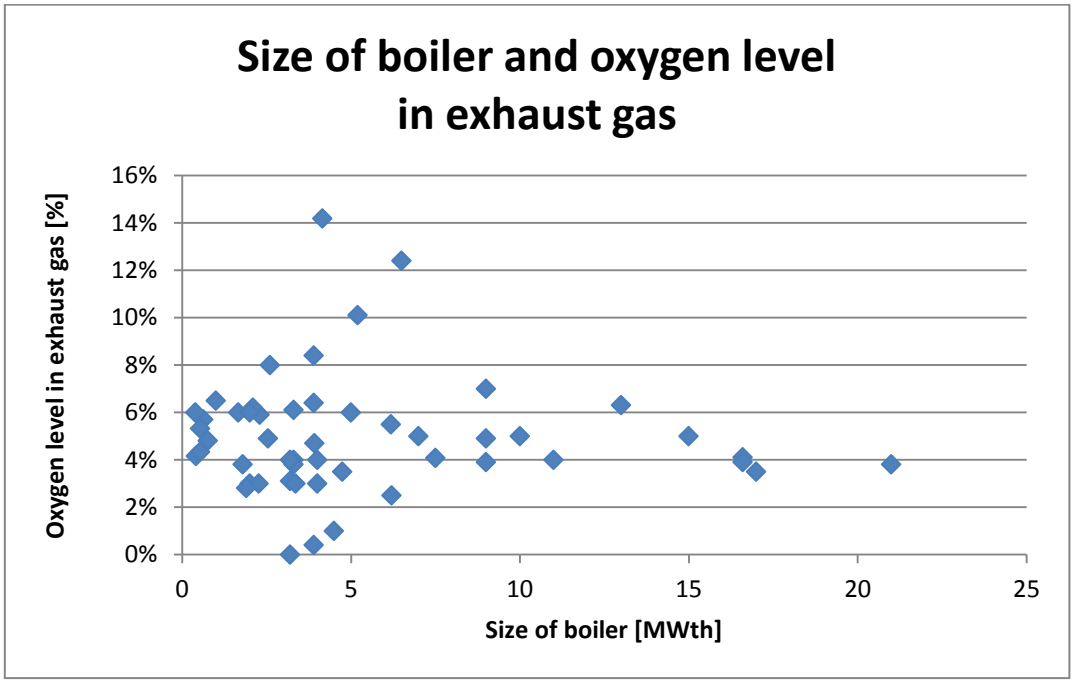


Figure 6 Thermal nominal power and oxygen level of analyzed boilers

Steam Distribution Information

The rate of condensate returned varied between 0 and 100%, the average was 62%. The minimum temperature of the condensate returned was 35°C, the maximum 100–105°C, the average was 85°C.

Status of implemented measures in the area of steam use, -distribution, and -production

During the energy audits, information about already implemented energy-saving measures in the field of steam generation, steam distribution and steam end use were collected.

Steam End Use

Figure 7 presents the implementation of saving measures in the field of steam end use and shows that, for the reduction of steam used by processes, saving potential is still to be expected. For 22% of the companies the steam consumption for processes could be reduced.

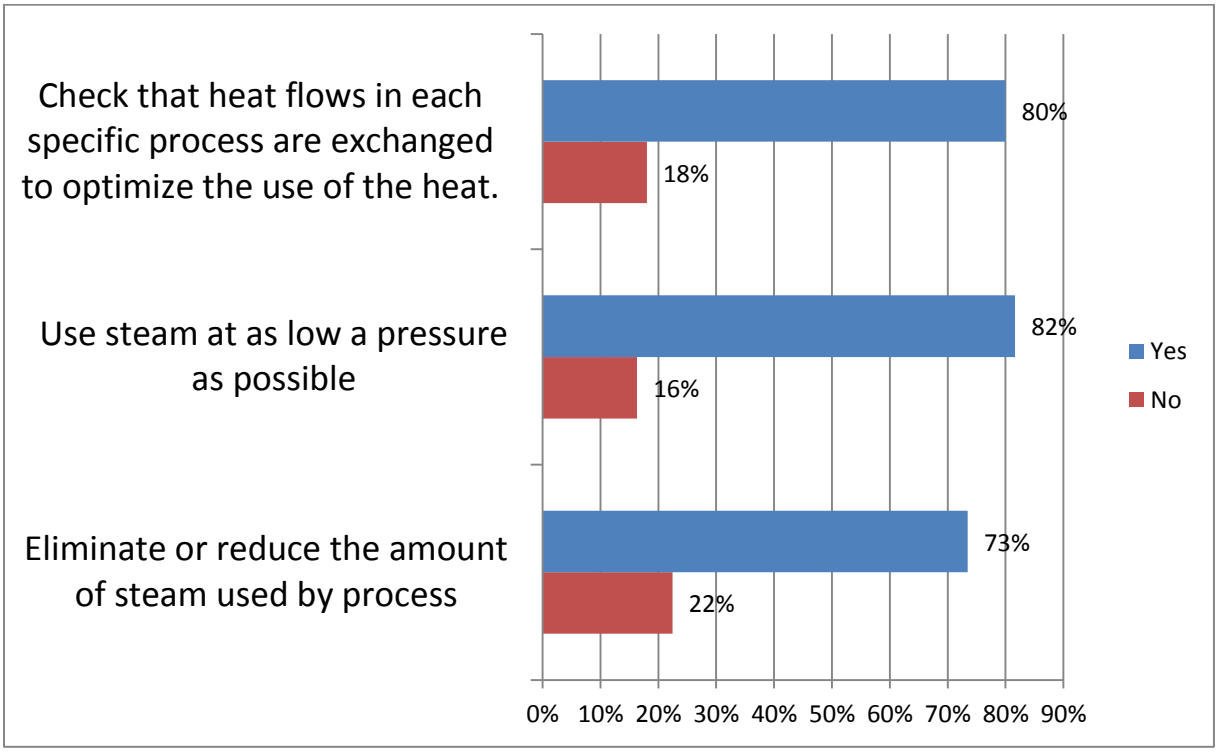


Figure 7 Implemented measures for steam end use

Steam Generation

Figure 8 presents the implementation of saving measures in the field of steam generation and illustrates that possibilities for improving are expected especially in the following areas: steam accumulators (69%), recovery of energy from boiler blowdown (66%), and minimization of excess air, e.g. by oxygen rate sensors (64%).

For recovery of energy from boiler blowdown, it must be mentioned that this is not economic in all cases: first measures in this field should, for example, include water treatment to avoid boiler blowdown. Other things to consider is the share of water to be fed in the system, e.g. if the condensate return is high, boiler blowdown may be quite low, so that the recovery of that energy is not economic.

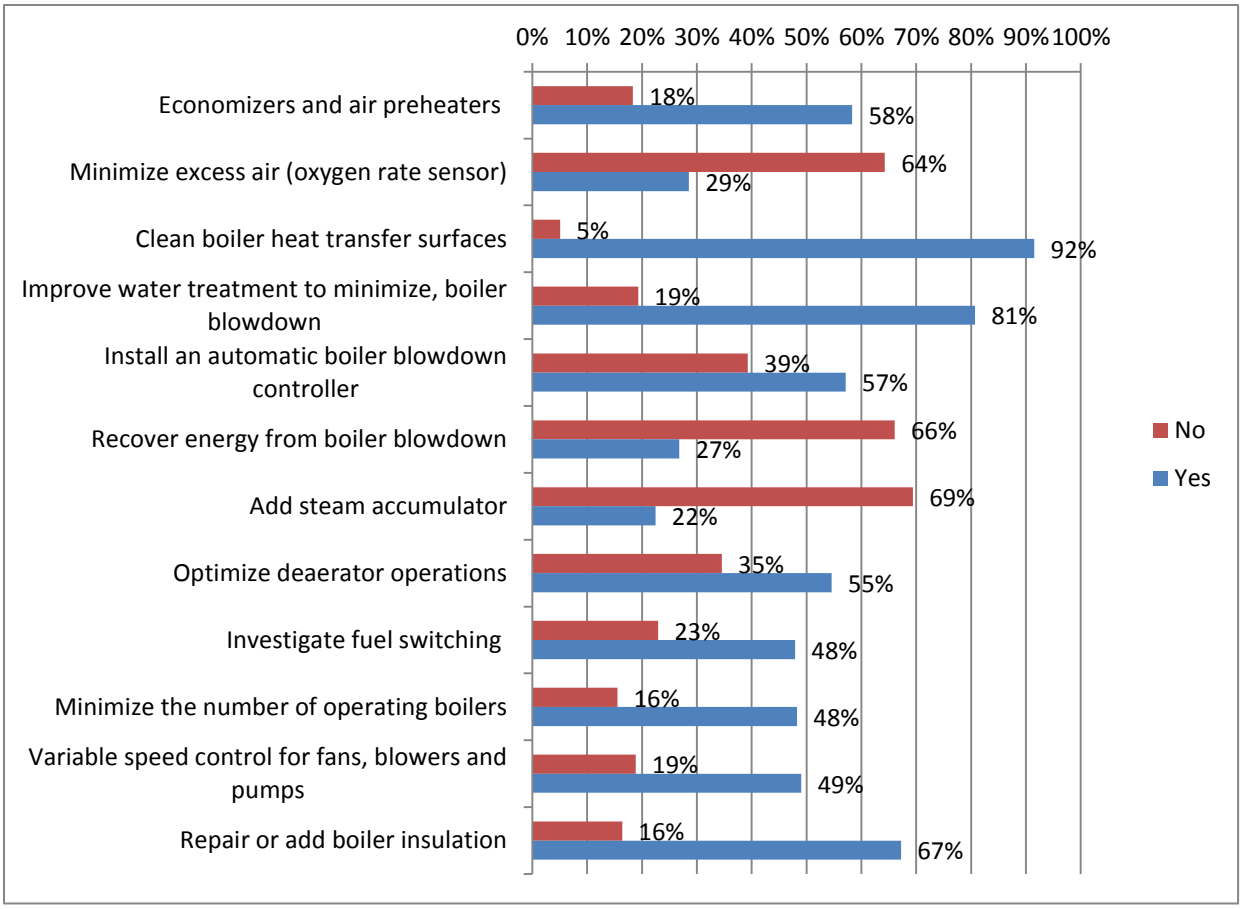


Figure 8 Implemented measures for steam generation

Steam Distribution

Figure 9 presents the implementation of saving measures in the field of steam generation.

Possibilities for improving are expected especially in the following areas: minimization of vented steam (51%) and implementation of effective steam trap maintenance programmes (27%).

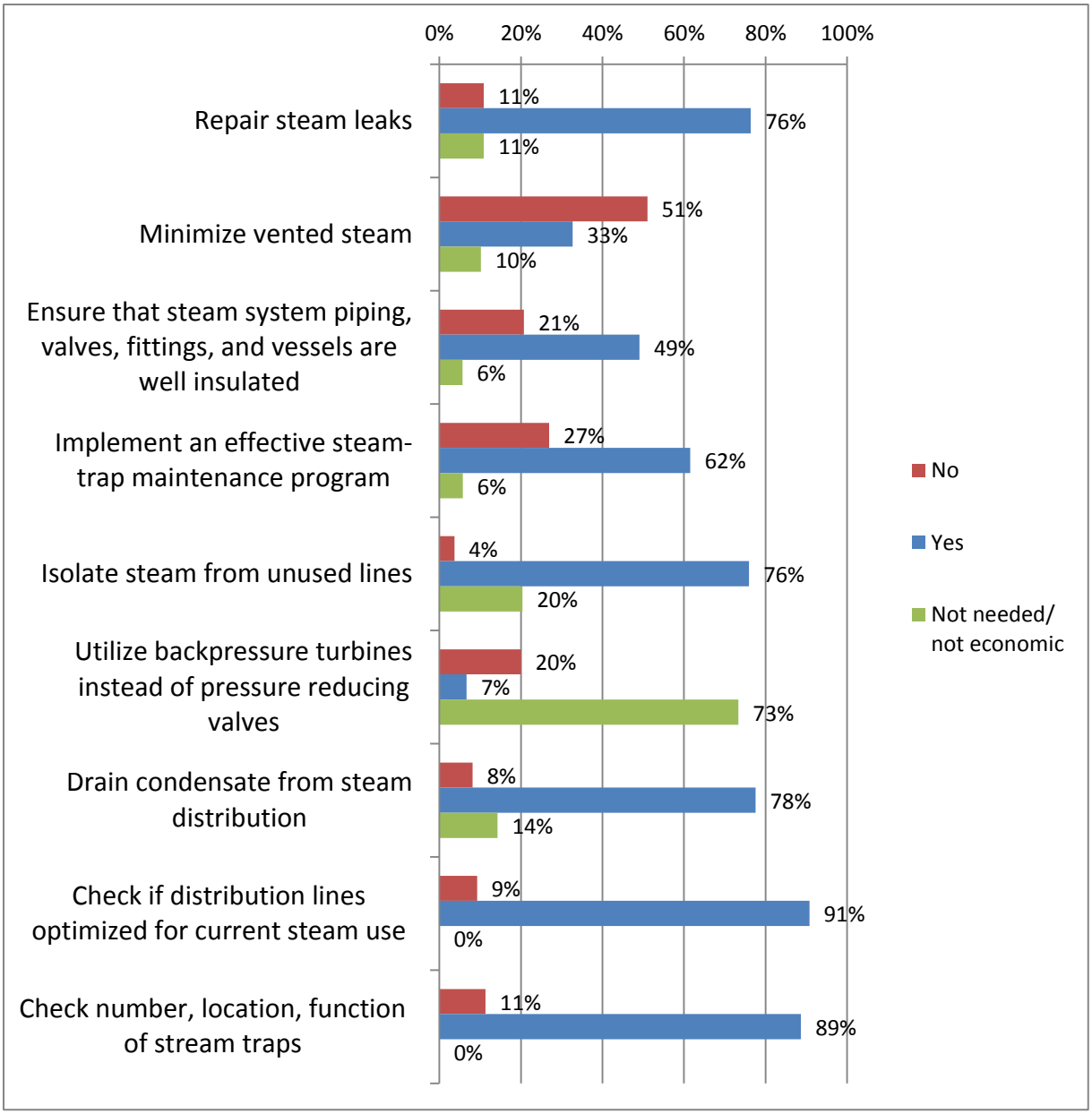


Figure 9 Implemented measures for steam distribution

Implementation of Energy Management

One focus of the Steam Up project was the implementation of energy management in the field of steam systems. During the energy audit, therefore, also questions regarding energy management are dealt with. Selected results are given in Figure 10:

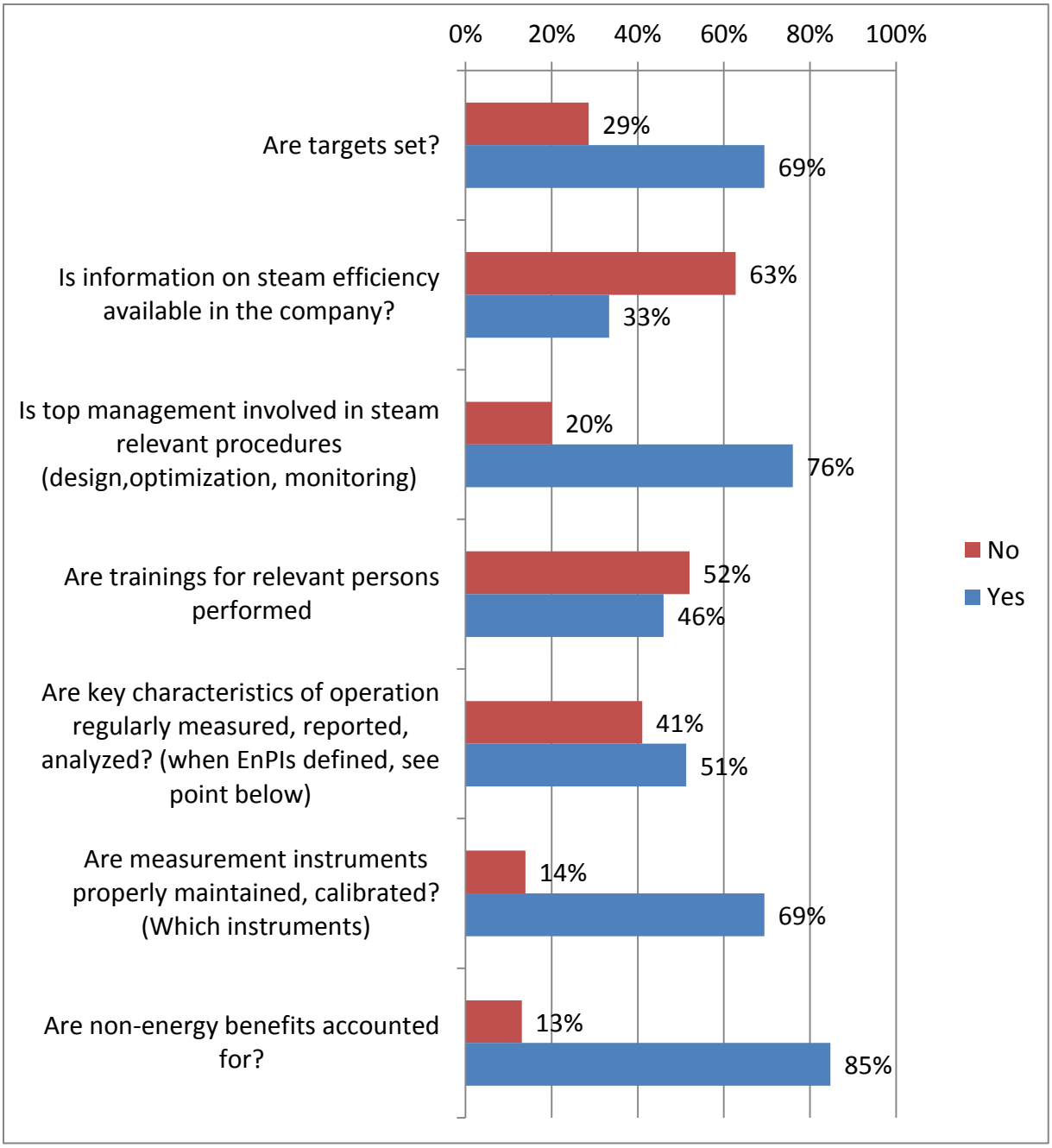


Figure 10 Selected implemented measures in the field of energy management

85% of the companies already consider non-energy benefits for investment decision. These were mainly safety issues. In 76% of the analyzed companies top management is involved in steam-relevant procedures.

In 69% of the companies targets were set. In the Netherlands, an energy efficiency target of 2% p.a. is mandatory within the “Long Term Agreements” (negotiated agreements aimed at promoting energy savings in industry); in most cases the targets are not steam specific but aim at the reduction of energy or gas consumption.

69% of the companies calibrate their measuring equipment. This answer refers quite often to the pressure measurement of the boiler.

In the following areas possibilities for improvement were detected: dissemination of information on efficiency possibilities in steam systems, training of personal within companies.

Examples of used indicators in the field of steam systems are:

- Mass of burned waste
- Energy consumption for steam
- Tons steam produced
- Costs for steam/energy content of steam
- Tons steam per tons of product in percent
- In several cases it is energy consumption per month /and product

The following non-energy benefits of energy-saving measures in steam systems were mentioned during the energy audits:

- Improvement of global performance
- Increase of competitiveness
- Marketing of sustainability
- Increased accuracy of process
- Higher reliability
- Increased safety issues
- Lower risk
- Less maintenance costs and time
- No boiler inspection needed
- Better quality of steam
- Increased quality of installation in distribution network
- Quicker heating of wash water
- Quicker process
- Faster start-up
- Easier operation
- Increased security of supply
- Reduced insurance costs
- Less heat content of waste water
- Less emissions of pollutants
- Reduced fresh water costs
- Reduction of CO_2 emissions
- Reduction of steam plume
- Reduction of corrosion problems
- Reduction of water consumption for steam generation
- Reduction of consumption of chemicals for water supply
- Reduction of chemical agents used for deaeration
- Prevention of corrosion of pipes by deaerating makeup water
- Reduction of chemical agents used for deaeration

Energy-Saving Measures

After a thorough analysis of the steam consumption, generation and distribution as well as of the main information on the steam energy management system, the auditors defined detailed action plans for each company. Approx. 235 actions were specified. Most of the actions (56%) recommended referred to the field of generation, 30% of the actions would optimize the steam distribution and condensate system, and approx. 10% of the actions targeted the steam use. By implementing all actions approx. 226 GWh of energy would be saved.

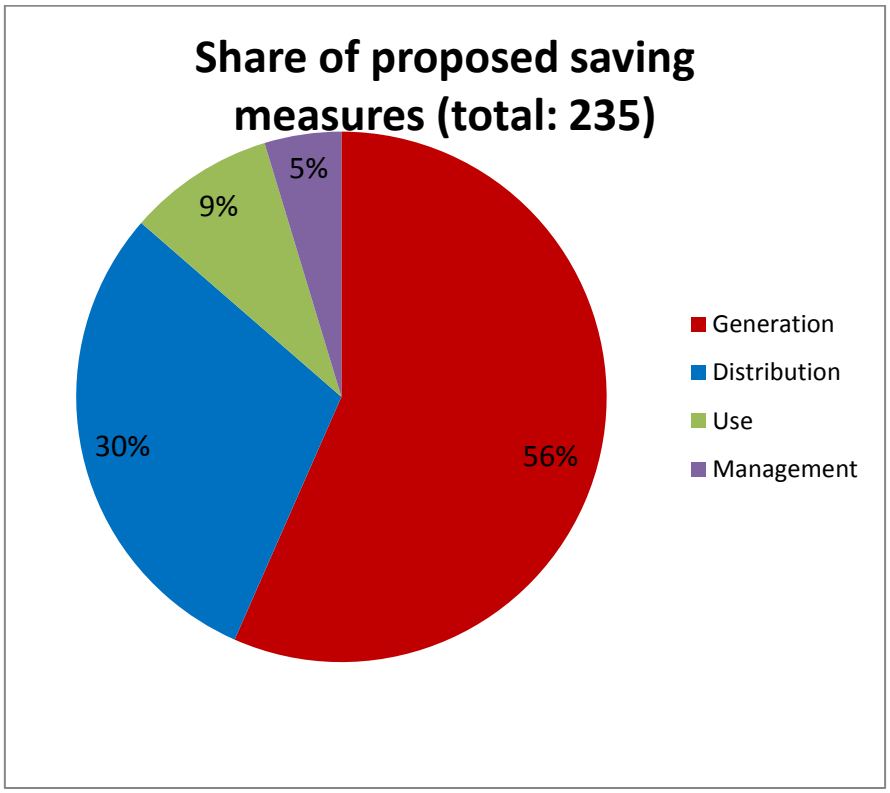


Figure 11 Share of proposed saving measures to individual parts of the steam system

For the following analysis, all actions of the audit reports were clustered along the topics: steam generation, steam distribution and steam use.

Furthermore, for each area (generation, distribution, use) measures proposed within the audit reports were ranked according to the share of potential energy savings in relation to the total energy consumption for steam. The 15 (for steam distribution and use: 10) saving measures with the highest share are included in the list.

By far, the most important area in optimizing the steam system was the optimization of the generation with 133 actions quoted in the audit reports.

Within this area, the installation of a new steam boiler was mentioned 28 times. This would lead to energy savings from 8 to 35% of the energy used for steam.

Other relevant energy-saving measures for steam generation were:

- the optimization of the oxygen level (quoted 13 times)
- the installation of economizers (up to 7% energy savings possible – quoted 13 times)
- insulation of un-insulated surfaces in the boiler room (quoted 13 times)

Furthermore, the following saving measures were proposed in several cases:

- optimization of the boiler blowdown (incl. heat recovery)
- optimization of the deaeration process
- use of frequency converters for blowers
- closing or repair of open or locked valves
- reduction of boiler operation time

Table 5 Energy-saving measures in the field of steam generations, ranked by share of energy savings to total steam demand (saving measure replacement of steam boilers refers to different companies)

Saving measure	Percentage of total energy demand for steam saved
New biomass boiler, waste heat re-use	100%
Control of blower with frequency converter	75%
Reduction of boiler operation	65%
Substitution of the boiler by a new gas boiler	37%
Flue gas heat exchanger for hot water	36%
New boiler	35%
New steam generator	35%
New steam boiler	30%
New steam boiler	25%
CHP system (running 15 h)	24%
Insulation of hot surfaces	22%
New steam generator	21%
Adjustment of boiler size	21%
New efficient steam generator	20%
New steam boiler	20%

A total of 70 energy-saving measures were recommended in the field of the steam distribution and condensate system, the most important of which were:

- Insulation of the distribution pipes, valves and condensate pipes (1–3% energy savings) (28 measures were recommended in this field)

- Increase of condensate return, waste heat recovery of the condensate system (approx. 5% energy savings), installation of a high pressure condensate system (19 measures were recommended in this field)
- Checking and/or changing steam traps (7–12% savings), around seven measures were quoted referring to steam traps
- Redesign and reconstruction of the pipe network (steam, condensate)

Table 6 Energy-saving measures in the field of steam distribution and condensate, ranked by share of energy savings to total steam demand

Saving measure	Percentage of total energy demand for steam saved
Exchange station reconstruction	15%
Change steam traps	12%
High pressure condensate	7%
Check of steam traps	7%
Modernization of steam and condensate pipes	6%
Insulate steam distribution and condensate pipes	5.3%
Changing steam traps	5%
Insulation of valves, mountings	5%
Extension of condensate return system	5%
Increase rate of condensate recovery	4.5%

Finally, the end use in steam systems could be improved by the following suggested saving measures: optimization of tank cleaning (currently done by steam), replacement of steam supplied hot water system, warm water production by heat pumps, adjustment of dryers, heat recovery in a washing process and reduction of the system pressure. For several measures energy savings of 10–30% are possible, for certain cases even higher saving rates were calculated. In total around 20 actions were defined in this field.

Table 7 Energy-saving measures in the field of steam use ranked by share of energy savings to total steam demand (saving measure pressure reduction refers to two different companies)

Saving measure	Percentage of total energy demand for steam saved
Optimization of tank cleaning and recovering emulsion	150%
Warm water production with heat pumps	30%
Hot water heating system: Replacement of the steam source with hot water source Replacement of central steam pipeline with hot water distribution plus reconstruction of heat exchanger stations Changing of heat supply system	18%
Feasibility study: phasing out steam for space heating	16%
Adjustment of the dryer	13%
Heat recovery laundry	10%
Installation of a sludge dryer	9%
Heating technologic water by waste heat from compressor (110 kW)	7%
Pressure reduction	5%
Pressure reduction	3%

Selected energy-saving measures which have already been implemented include:

- New steam boiler installations in Austria, the Czech Republic, the Netherlands, and Spain
- Optimization of steam boiler: improvement of steam boiler control, pressure reduction, change in O_2 settings, installation of economizer, new frequency converter for feed water pumps and for fans, closing of open valves, replacement of valves, etc.
- Insulation: insulation of water tanks, insulation of boilers and hot surfaces (flange, valves, collectors, pipes), insulation of steam distribution and condensate lines
- Condensate management: repair of condensate return network, steam trap management, use of unused steam accumulator as condensate tank
- Steam use: additional insulation of hot water baths, change of steam blowing heat transfer surfaces, etc.

In general, for each company the specific energy and cost savings for the measures are affected by numerous influence factors, which were considered or estimated during the on-site visit and during the audits.

6. After-Sales Implementation of Energy-Saving Measures

Steam Up concentrates on the link between energy audits and the implementation of energy-saving measures. Therefore, the following topics are/were addressed during the energy audits conducted:

- Involving the top management
- Focusing on an energy management system
- Concentrating on NEBs (non-energy benefits)

Thus, it is expected that the implementation rate of the energy-saving measures will be high. Furthermore, a tool was developed within Steam Up to provide a link between the energy-saving measures proposed in the energy audit report and the implementation phase, the Energy Management Centre:

Methodology for the Calculation of Energy Savings Achieved

For an overview of the implementation of all saving measures. all proposed actions for each company were listed in an Excel file per country, in addition to the Energy Management Centre. All auditors filled in their latest information on the status of implementation of the energy-saving measures during February 2018.

For this, they could choose between various options for the implementation. For each option a percentage for an implementation rate was defined within this project. Usually, in companies, the investment plans are defined for a longer period (e.g. one year). Therefore, also investments planned for the following years were considered.

Table 8 Options for status of implementation and corresponding implementation rate used for calculation of energy savings triggered

Status of implementation	Implementation rate
Implemented	100%
Ordered	100%
Planned for this year	100%
Postponed 1–2 years	50%
Cancelled	0%

Finally, for all actions the implementation rate (in percentage) was multiplied with the proposed values for energy and costs savings and investment. Furthermore, the carbon dioxide emissions were calculated on the basis of these calculated values and on the information of the relevant energy carrier used for the production of steam.

For the calculation of the carbon dioxide emissions, the values in Table 9 were proposed, for some countries they were slightly adapted based on national values. For some companies, using a mixture of different energy carriers, the CO_2 factors were calculated on the basis of this information. A few companies purchase the steam from external heating plants, for these, the fuel mixture of the heating plant was considered.

Table 9 Emission factors for the calculation of carbon dioxide emissions achieved

Emission factors	CO_2 [t/MWh]
Gas	0.24
Oil, heavy fuel oil, heating oil…	0.27
Coke (Czech national value)	0.378
Coal (Czech national value)	0.34
Gasoil	0.23
Black liquor, biomass	0

Summary of Energy Savings Proposed and Achieved

The following table summarizes the results. For each country the sum of actions proposed is listed, in addition, in a second row the parameters for the actions triggered are given. These values were calculated on the basis of the implementation rate per action, filled in by the auditor based on the information of the companies.

Table 10 Energy savings achieved by Steam Up in the participating countries and in total

Values per country, suggested in audit report and triggered*	**Fuel demand for steam [MWh] (of companies with saving potential)**	**Energy saved [MWh]**	**Costs saved [EUR]**	**Investment costs/ triggered [EUR]**	**Average payback time [years]**	**CO_2 reduction [t]**
AT suggested	320,725	14,194	583,874	2,228,784	5.8	
AT triggered		2,396	160,689	716,355		608
CZ suggested	2,462,989	51,906	1,008,468	12,459,899	6.9	
CZ triggered		12,191	364,785	2,431,470		3,142
DK suggested	84,238	5,945	320,224	334,862	1.3	
DK triggered		3,760	139,925	107,231		491
ESP suggested	455,888	27,703	2,831,555	10,746,134	3.4	
ESP triggered		22,833	1,781,980	5,776,369		5,402
GER suggested	21,714	3,988	268,162	1,425,727	4.9	
GER triggered		2,866	199,256	1,175,227		729
GR suggested	68,532	7,464	272,957	699,500	2.7	
GR triggered		4,088	153,223	251,600		775
IT suggested	2,906,590	75,168	2,314,152	8,154,815	1.9	
IT triggered		64,635	1,972,386	7,325,615		15,477
NL suggested	308,463	39,849	859,386	605,500	3.2	
NL triggered		20,644	426,321	335,500		4,955
All Countries suggested	**6,629,140**	**226,216**	**8,458,778**	**36,655,221**	**4**	
All Countries triggered		**133,414**	**5,198,564**	**18,119,366**		**31,577**

*Country codes: AT: Austria, CZ: Czech Republic; DK: Denmark; ESP: Spain; GER: Germany; GR: Greece; IT: Italy; NL: the Netherlands; for calculation of “triggered” values see chapter methodology above

The total fuel demand (e.g. gas, oil) for the production of steam of all companies with identified saving potential is 6,600 GWh. This differs from the total fuel demand for steam of all companies.

The total energy-saving potential of 78 audits identified is 226 GWh, total monetary savings would be EUR 8.4 million, for the implementation a total investment of EUR 36.6 million would be necessary. The average payback time of these actions is 4 years.

At the time this report was prepared, measures corresponding to 133 GWh energy savings or EUR 5.2 million p.a. money savings have already been or will be implemented during this or the next year. The average saving potential to be realized is 1.7 GWh per company audited. This includes companies where no energy-saving potential was identified. The total investment triggered will be EUR 18.1 million p.a., achieving CO_2 savings of 31,755 t.

Feeback to Energy-Saving Measures

As feedback and opportunity for improvement for the Steam Up methodology, a questionnaire was used for collecting experience from the auditors and/or the auditors‘ company responsible for acquisition.

43 companies from five countries answered. Of these, nine companies are from Austria, ten from Denmark, seven from Italy, seven from the Netherlands and ten from Spain.

In the following, the main results of the clients are summarized:

Concerning energy management procedures being implemented, most companies mentioned energy management in the overall industry (9), followed by steam production monitoring (steam management, improvement in the overall industry) (8), insulation management and thermograhic measurement (4), and steam trap management (4).

28 companies answered that they monitor their steam system; in addition, eight companies reported that they monitor their energy consumption. Two companies check their steam generation and distribution periodically and the remaining 15 answered non-specifically.

The most frequent key performance indicators (KPIs) being used in the companies answering the survey were “energy consumption per month” (mentioned ten times); two of them mentioned additionally “and per product unit”. Furthermore, six times “kWh/ton of finished product” was mentioned. One company referred to boilers’ efficiency, steam traps’ conditions and condensate temperature.

Reasons for Implementing Energy-Saving Measures

According to this survey, the main reasons for implementing saving measures were cost savings (34%), energy savings (33%), improvement of security of supply (10%) and non-energy benefits (8%). 16 companies said that NEBs rose up during/after implementation. All 44 companies answered that there were no negative experience with implemented saving measures.

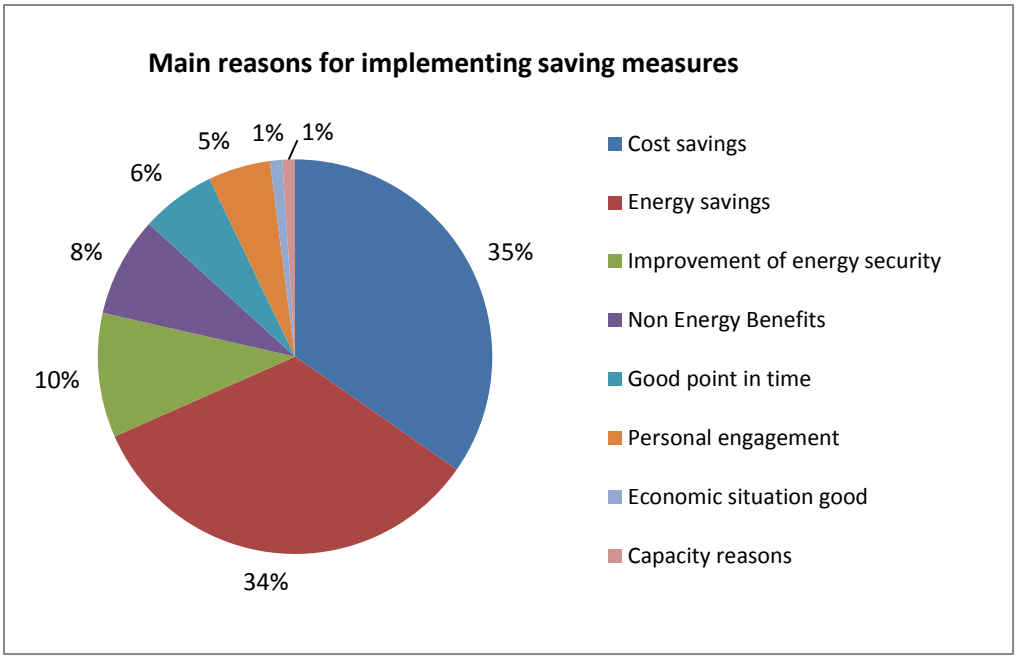


Figure 12 Reasons for implementing energy-saving measures in steam systems

Reasons for not Implementing Energy-Saving Measures

According to the survey conducted by the auditors at the end of the project, the main reasons for not implementing saving measures were “not good point in time” (22%), “new energy-optimized steam system already running” (16%), “responsibility not clear” (16%) and “personal reasons” (14%). 18% of the respondents mentioned financial reasons: no funding available (8%), payback time too long (5%) and too high initial costs of equipment (5%).

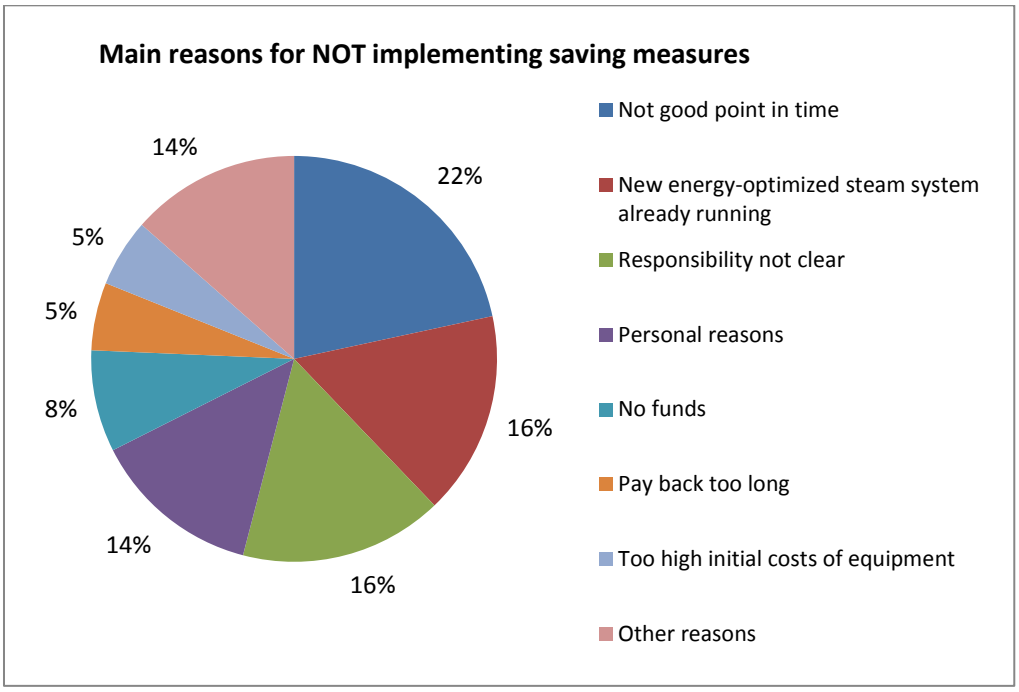


Figure 13 Reasons for not implementing energy-saving measures in steam systems

Almost half of the companies surveyed (47%) are interested in further support.

Auditors view

The auditors themselves commented on the implementation rate and reasons for implementing and not-implementing in qualitative manner. Answers were collected with questionnaires filled in for each audited company by the country representatives and/or the auditor:

Implementation Rate and Reasons for Not Implementing

Measures are in process of implementation and, at the same time, there will be some delays due to other priorities: In several countries the proposed efficiency measures have been accepted and it is expected that the implementation rate will be about 50% or even higher. In some cases the company is expanding in production and will implement measures afterwards.

The reasons for not implementing measures were already high efficiency, an insecure economic situation, a too long payback period, a budget not allocated for this purpose and a lack of internal resources.

Subsidies that are easy to handle, a comprehensible and convincing presentation, and frequent contacts can help raise the implementation rate.

Recommendations for High Implementation Rate

In the questionnaire auditors were asked how to increase the implementation rate:

Generally, it can be said that in cases where the top management was involved, the implementation of the measures was easier. The top management decides and ensures the required resources (time, staff, money).

If the share on energy costs for the production were higher or internal resources were available, more measures would be implemented.

Often, there are no financial possibilities for implementation of the measures. Therefore, subsidies that are easy to handle are needed.

The companies require better forecasts and strategic planning for the next years (utilization of production, energy prices, prices for services and maintenance, etc.) to be able to decide for or against investments in new technologies, esp. steam systems. The size of the steam system often depends on the utilization or expansion of the production.

Companies need precise preparation, funding/money and also motivation and time for a successful implementation of the measures. The measures have to be technically feasible and economically viable and should have further advantages like an increase in quality or satisfaction of employees (NEBs).

Often, a very good and very specialized company for realizing the optimization and implementation of measures and for a continuous support is necessary.

In a number of cases there are no further ideas for increase the implementation rate because measures are actually implemented or projected, the system is already very efficient, or there is no budget available at the moment.

After-Sales Support

Every advisor made appointments with the companies about follow-up (not only for steam issues). In all cases, customer care is standard and regular information is taking place. In the more advanced cases the advisor will contact the company from time to time to talk about the implementation of measures.

Comment on Energy Management Centre (EnMC)

The EnMC is a web-app (Open Source, free of charge) that seeks to reduce the effort for energy managers. Auditors use the EnMC as a digital reporting solution. Energy managers directly apply it for organizing the realization process. The EnMC offers:

- an interactive Gantt chart for time planning, the allocation of responsibilities and the description of tasks
- a dashboard with action plans (prepared by the auditor) and a reminder for deadlines
- the generation of business case descriptions and management reports
- a monitoring solution
- a social network for energy managers and energy auditors

The Energy Management Centre served as tool of tracking implementation and supported the energy managers in implementing their energy-saving measures.

In Austria, in 50% of the advices the Energy Management Centre was used and explained. The advisors think that the Energy Management Centre is not necessary for small projects, but a useful tool for larger projects.

In the Czech Republic, in only 20% of the advices the Energy Management Centre was used and explained. Some energy managers appreciated the possibility of printable energy reports as pdf, the EnMC can create an action plan with little effort.

In Denmark, the Energy Management Centre was put to the companies' disposal. Many contact persons could not accept this tool simply because of the way things are normally handled there. The advisors have experienced that there is no need for such a comprehensive accounting system decision due to the direct contact with the decision makers.

In Germany, the Energy Management Centre was used just in one case. Most of the auditors see the EnMC as not helpful. It depends on the size and complexity of the project.

In Italy, the Energy Management Centre was used and explained by all steam auditors. The advisors used the Energy Management Centre to report the audit outcomes. So far, the EnMC is only a tool for reporting audit outcomings and monitoring the follow-up of the audits. It is valuable for larger projects. It would be more useful if the EnMC included some simple finance formulas and calculators.

In the Netherlands, the Energy Management Centre may have a role in the after sales and the development of a good energy management system, where tasks and role involvement of the employees need to be implemented. Though some of the larger companies do have the wish to develop energy management, the EnMC will be discussed further along with the implementation of energy management and proper procedures.

In Spain, the Energy Management Centre is a helpful tool, but its use depends on the industry needs. Sometimes the companies are already using other tools for the overall

management of the projects and, in this case, the EnMC might not be necessary for management but for awareness and communication.

7. Summary and Conclusions

The participating companies came from the following sectors: food industry (32 companies), chemical industry and industrial laundries (ten companies each), pulp and paper (eight companies), pharma industry (four companies), textile industry (three companies) and several others.

Total energy consumed for steam within the Steam Up project was approx. 7,000 GWh. Fuels providing this energy were gas (48%), biomass (41%), oil (4%), coal (3%) and waste (3%).

After a thorough analysis of the steam consumption, generation and distribution as well as of the main information on the steam energy management system, the auditors defined detailed action plans for each company. Approx. 235 actions were specified. By implementing the actions approx. 220 GWh of energy would be saved.

By far, the most important energy-saving measure proposed was the installation of a new steam boiler. This would lead to energy savings from 8 to 35% of the energy used for steam.

Other relevant energy-saving measures for steam generation were the installation of economizers (up to 7% energy savings possible), reduction of boiler operation time and the optimization of the oxygen level.

The most important energy-saving measures in the field of the steam distribution and condensate system included: increase of condensate return (approx. 5% energy savings), installation of a high pressure condensate system, checking and/or changing steam traps (7–12% savings), and insulation of the distribution pipes, valves and condensate pipes (1–3% energy savings).

Finally, the end use in steam systems could be improved by the following suggested saving measures: optimization of tank cleaning (currently done by steam), replacement of steam supplied hot water system, warm water production by heat pumps, adjustment of dryers, heat recovery in a washing process and by reduction of the system pressure. For several measures energy savings of 10–30% are possible, for certain cases even higher saving rates were calculated.

Selected energy saving measures which were already implemented include:

Selected energy-saving measures which have already been implemented include:

- New steam boiler installations in Austria, the Czech Republic, the Netherlands, and Spain
- Optimization of steam boiler: improvement of steam boiler control, pressure reduction, change in O_2 settings, installation of economizer, new frequency converter for feed water pumps and for fans, closing of open valves, replacement of valves, etc.
- Insulation: insulation of water tanks, insulation of boilers and hot surfaces (flange, valves, collectors, pipes), insulation of steam distribution and condensate lines

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- Steam use: additional insulation of hot water baths, change of steam blowing heat transfer surfaces, etc.

The total energy-saving potential of 78 audits identified is 226 GWh, total monetary savings would be EUR 8.4 million. Therefore, a total investment of EUR 36.6 million would be necessary. The average payback time of these actions is 4 years.

At the time this report was prepared, measures corresponding to 133 GWh energy savings or EUR 5.2 million p.a. money savings have already been or will be implemented during this or the next year. The average saving potential to be realized is 1.7 GWh per company audited. This includes companies where no energy-saving potential was identified. The total investment triggered will be EUR 18.1 million p.a., achieving CO_2 savings of 31,755 t.

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If the share on energy costs for the production were higher or internal resources were available, more measures would be implemented.

Often, there are no financial possibilities for the implementation of the measures. Therefore, subsidies that are easy to handle are required.

The companies need better forecasts and strategic planning for the next years (utilization of production, energy prices, prices for services and maintenance, etc.) to be able to decide for or against investments in new technologies, esp. steam systems. The size of the steam system often depends on the utilization or expansion of the production.

Precise preparation, funding/money and also motivation and time for a successful implementation of the measures are necessary. The measures have to be technically feasible and economically viable and should have further advantages like an increase in quality or satisfaction of employees (NEBs).