An insight into the ecodesign process – the example of steam boilers

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Abstract

Within the European Union's energy policy, the reduction of the energy demand is one of the three major targets. Focussing on the energy use of products, Ecodesign is a successful instrument in European energy efficiency policy, driving the technological development and leading to significant energy savings. The Ecodesign process is ongoing, extending its scope to currently about 40 different product groups. One of the product groups currently under investigation is steam boilers. They are widely used in industry for steam generation and important energy consumers. According to estimates, industrial steam systems account for about one third of overall industrial energy demand. Thus, improved energy efficiency in steam generation is of significant interest to both industry and policy making. The Study on Amended Ecodesign Working Plan under the Ecodesign Directive states a saving potential of 177 PJ/a (VHK 2011).

At the current state, little information is available on steam boilers in Europe. Within our paper, we will discuss the process of the Ecodesign preparatory study on industrial steam boilers. According to the defined methodological steps, we will present the market situation, as well as user and technological issues for this product group. Furthermore, we will present first results of the environmental and economic assessment of various measures to improve energy efficiency.

Introduction

Within the 20-20-20 targets of the European Union, the reduction of the energy consumption is one of the three intended impacts. For the reduction of the energy use of products, the Ecodesign directive has proven a successful instrument over the last years to drive the minimum standards of energy using products and thus reducing their energy demand. A broad variety of products has been subject to regulation. Due to its success the recast of the directive in 2009 extended the focus of the directive from energy-using products to energy-related products. This extended approach resulted in the inclusion of products like insulation, windows and power cables in the recent working plan.

Nevertheless there are still some "white spots" in the energy-using product variety. Those products groups currently under investigation cover a broad range of uses and users. Under the supervision of DG Enterprise, which is responsible for the business-to-business products within the Ecodesign process, currently three product groups are in the first phase of the Ecodesign process. The first group are power cables as a group of energy-related products. The second product group are enterprise servers, which have a broad relevance in industrial and commercial appliances. The third product group are the industrial steam boilers, on which this paper will focus.

The Study on Amended Ecodesign Working Plan under the Ecodesign Directive identified industrial steam boilers as one of the top ten product groups for further investigation in the ecodesign process. Nevertheless in this preparatory step, the lack of information has already been highlighted as one of the major issues to be dealt with in the subsequent analysis (VHK 2011).

As an overview we will describe the Ecodesign process defined by the European Commission. Afterwards we will give some insight into the Ecodesign process using the example of industrial steam boilers. For this, we will define the scope of a steam boiler (system) and its application in industry. Some exemplary legal requirements already imposed to steam boilers will be shown. Afterwards we will present exemplary results of analyses accompanying the preparatory study. We will then have a look at potential technological improvements as well as the market situation. We will finish with an outlook to the further steps of the Ecodesign process and some general considerations.

The Ecodesign Process

GENERAL PROCESS

The Ecodesign process is highly regulated and follows clearly defined procedures. The basic principles of the Ecodesign process are laid down in the Ecodesign Directive (2009/125/EC), which sets the framework for Ecodesign activities. The recast of the directive substituted the former Ecodesign directive (2005/32/EC). The main objectives of the directive are to ensure the free movement of energy-using products within the EU, to improve the overall environmental performance of these products and thereby protect the environment, to contribute to the security of energy supply and enhance the competitiveness of the EU economy, and to preserve the interests of industry, consumers, and other stakeholders.

Ecodesign regulation does not prescribe the technological options to improve the environmental performance but only the required objective. Thus, the manufacturers are free to determine their own technological solution.

While the application of the Ecodesign directive has mainly focused on energy use until now, the scope of Ecodesign is beyond energy efficiency only. The assessments and the resulting regulation should consider all phases of the life cycle (manufacturing, transport, use, disposal) and thereby should not only take into account energy-related issues, but should consider the essential environmental aspects (consumption, material, emission, waste etc.) for each phase. Nevertheless, due to the characteristics of most of the products, energy efficiency or energy consumption levels in the use phase have been the major focus.

To determine potential products for regulation, the European Commission develops a working plan in which the market for energy-using and energy-related products is analyzed and potential candidates for regulation are identified (EC 2012). Based on this working plan, the Commission selects the specific products for which the Ecodesign process is initiated.

The first step in considering whether and which Ecodesign requirements should be set for a particular product, is a preparatory study. The preparatory study results in recommendations for a potential improvement of the environmental performance of the product. The preparatory study provides the necessary information for the next phases in the policy process (to be carried out by the Commission). It comprises a technical, ecological and economic analysis of the product. Based on the preparatory study a working document is prepared by the European Commission to prepare the Consultation Forum. In this Forum, the stakeholders are able to express their views on the working document and the possible implementing measures presented in it. In the Consultation Forum there are seats for member state experts, industry groups and NGOs. Simultaneously an impact assessment of the proposed rules is prepared. The final version of the proposed legislation is sent to the Regulatory Committee on the Ecodesign of Energy-related Products (EEP) that consists of officials from all member states. The committee is allowed to make adjustments to the proposal and should reach a qualified majority to allow the Commission to present the proposal to the European Parliament and the Council. After voting, the European Parliament and the Council have three months to apply scrutiny, in which they can review the final proposal and potentially still block its introduction. After three months the World Trade Organization (WTO) is notified and the implementing measure is accepted after publication in the Official Journal of the European Union.

PREPARATORY STUDY

The first step in considering whether and which Ecodesign requirements should be set for a particular product, is the preparatory study. The preparatory study results in recommendations for potential regulations to improve the environmental performance of the assessed product group. The preparatory study provides the necessary information for the next phases in the policy process (to be carried out by the Commission). It comprises a technical, ecological and economic life cycle analysis (LCA) of a product. In this study, efficiency and market data are presented, enabling determination of parameters like Best Available Technology (BAT), Best-Not-Yet Available Technology (BNAT) and Least Life Cycle Cost (LCC) of the product (Figure 1). Since the introduction of the Ecodesign directive, about 50 energy-related products have been subject to an analysis with regard to their environmental impact or are currently undergoing a survey. An overview of these products is given in Table 1.

The overall task structure of an Ecodesign preparatory study is shown in Figure 1. Within the first four tasks general properties of the product under investigation are analyzed. Task 1 deals with the general scoping, including a product definition and an analysis of relevant standards and legislation relevant for the product. Task 2 results in a description of the market situation of the product. Within Task 3 the users of the products are analyzed. This task results in the description of different typical use cases of the product. In Task 4 the technological properties are analyzed resulting in a base case definition. Upon completion of Tasks 1 to 4, the impact of potential regulation will be determined in the next tasks. As a first step, the environmental and economical impacts are estimated using a standardized LCA and LCC methodology in Task 5. For selected design options for the product, the potential impacts are calculated using the same methodology in Task 6. Finally, in Task 7 several scenarios are defined and modelled to analyze potential impacts of policy measures and sensitivities of the measures.

Steam boilers are one of the products currently subject to the preparatory study. The study is carried out under the supervision of DG Enterprise by PWC, NTUA and Fraunhofer ISI. Building on our experiences from the study, we will show examples for some of the tasks within the preparatory study.

Table 1. Overview of product groups currently covered by the EuP/ErP process (source: Oekopol 2014, clusters based on Ploetz et al. 2012).

Cluster	Product group
Lighting	Office lighting (ENER 8), Street lighting (ENER 9), Domestic lighting (non-directional) (ENER 19), Domestic lighting (directional) (ENER 19)
Electronics	Simple Set-Top Boxes (ENER 0), Desktop- and Laptop-PCs, monitors (ENER 3), Imaging Equipment (ENER 4), TV (ENER 5), Standby and off-mode losses (ENER 6), Complex set-top boxes (ENER 18), Networked standby losses of energy using products (ENER 26), Sound and imaging equipment (ENTR 3), Enterprise Servers (ENTR 9)
White goods	Commercial refrigerators and freezers (ENER 12), Domestic refrigerators and freezers (ENER 13), Domestic dishwashers (ENER 14), Domestic dishwashers (ENER 14), Household tumble driers (ENER 16), Vacuum cleaner (ENER 17), Domestic and commercial hobs and grills (ENER 23), Professional washing machines, dryers and dishwasher (ENER 24), Non-tertiary coffee machines (ENER 25), Refrigerating and freezing equipment (ENTR 1)
Motors and und motor-powered aggregates	Electric motors (ENER 11), Circulators (ENER 11), Fans (ENER 11), Water pumps (ENER 11), Wastewater pumps (ENER 28), Large clean water pumps (ENER 29), Other motors and drives (ENER 30), Compressors (ENER 31)
Ventilation and Air Conditioning	Room air conditioning (ENER 10), Residential Ventilation (ENER 10), Comfort Fans (ENER 10), Air-conditioning and ventilation systems (ENTR 6)
Heat production	Boilers and combiboilers (ENER 1), Water heaters (ENER 2), Solid fuel small combustion installations (ENER 15), Local room heating products (ENER 20), Central heating products using hot air (ENER 21), Domestic and commercial ovens (ENER 22), Industrial and laboratory furnaces and ovens (ENTR 4), Steam Boilers (ENTR 7)
Miscellaneous	Medical imaging equipment (ENER 0X), Battery chargers and external power supplies (ENER 7), Uninterruptible power supplies (ENER 27), Transformers (ENTR 2), Machine tools (ENTR 5), Windows (ENER 32), Power Cables (ENTR 8), Taps and Showers (JRC)

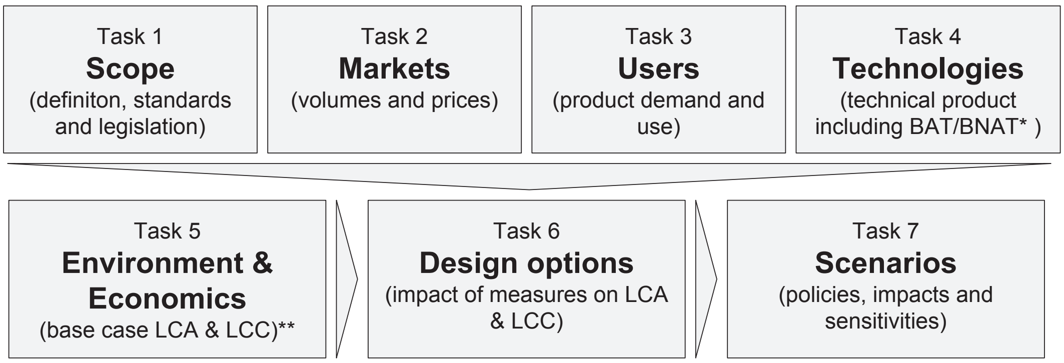


Figure 1. Overview of tasks of an Ecodesign preparatory study (based on Kemna et al. 2011).

Steam Boilers

Within this chapter we describe applications of steam in industry as well as boiler technologies used to provide steam.

APPLICATIONS OF STEAM

To define requirements for steam boilers it is important to know which branches of industry make use of steam boilers. The following paragraphs give a rough overview of steam using industries and processes. According to Therkelsen et al. (2013), one third of the industrial energy consumption of the United States is due to steam production. It is used in nearly all major processes. Steam using industries are often energy intensive companies. Typical users include the paper, food processing, chemical, metal and petroleum refining industry (Therkelsen et al. 2013). The share of steam use per industry sector in the United States is shown in Figure 2.

The industrial processes which use steam vary greatly. Table 2 lists some examples for steam using processes and respective industries applying them. Especially the chemical and petroleum refining industry rely on steam.

For the preparatory study, an upper limit of 50 MW thermal output power has been defined in the Ecodesign working plan. The information above does not yet consider this maximum output capacity. It has to be clarified where the steam production exceeds this limit. Therefore the boiler size for different sectors is shown in Table 3. This table shows that the food processing industry relies mainly on small boilers whereas the pulp and paper as well as petroleum refining in-

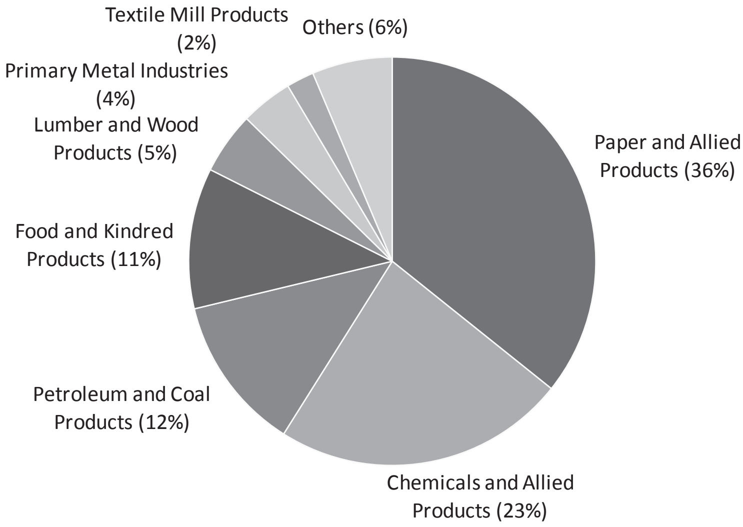


Figure 2. Share of steam use per sector in the United States of America (source: Einstein et al. 2001).

Table 2. Major steam applications by sector (source: USDoE 2012).

Steam using processes	Chemical Industry	Petroleum Refining	Pulp and Paper	Steel production	Metal casting	Forest product	Food processing	Textile	Glass
Fractionation	X	X							
Drying	X		X				X	X	
Power generation or drive for other rotating machinery (e.g. pumps, fans, compressors)	X	X			X	X			X
Distillation	X	X							
Evaporation/Concentration	X			X		X	X	X	
Heating process air & water storage tank	X	X		X	X	X			X
Hydrogen generation	X	X							
Agitation/Blending	X	X				X			
Cracking	X	X							

Table 3. Distribution of boilers capacity by size and major industrial sector in US industry (source: GRI 1996 according to Einstein et al. 2001).

	3–15 MW		15–29 MW		29–73 MW		>73 MW		Total
	MW	%	MW	%	MW	%	MW	%	MW
Chemicals	37,514	25.7	22,923	15.7	41,971	28.8	15,659	29.8	145,846
Food	27,381	35.9	19,130	25.1	19,439	25.5	10,273	13.5	76,225
Paper	10,912	10.1	1,184	10.9	26,915	24.9	58,558	54.1	108,227
Refining	9,651	15.7	8,315	13.5	14,058	22.9	29,474	47.9	61,498
Primary Metals	15,650	28.2	6,829	12.3	12,137	21.9	20,893	37.6	55,509

dustry run large boilers. The chemical manufacturing industry needs both.

STEAM BOILER TECHNOLOGIES AND SYSTEMS

To determine the environmental impact of a product, it is important to define the system boundaries used for the analysis. Figure 3 shows all parts of the steam system. Different types of system boundaries can be selected. The dashed line is the system boundary for a strict product/component scope. It has been chosen based on the European standard EN 12952 for water tube boilers. EN 12952-1 defines in general those components belonging to the steam boiler assembly. EN 12952-15 deals with performance acceptance tests. This standard defines which parts belong to a regular system. Furthermore it defines how to calculate boiler efficiency. All energy flows out of and into the system have to be considered to calculate this value. Next to the essential parts of a steam boiler shown in Figure 3, further devices belong to the strict product/component scope:

- All pressure parts (from feedwater inlet up to and including steam outlet).
- Safety accessories & interconnecting tubing (heated by means of the gases of combustion and not capable of isolation from main system by interposing shut-off valves).
- Means of preparing and feeding the fuel to the boiler including the control system.
- The pressure expansion vessels and tanks of hot water generating plant.

All parts in the graphic marked with an asterisk (*) are optional parts, i.e. not all steam boilers are equipped with them. However, they can often be used to increase boiler efficiency.

Economizers can be designed either as belonging to the system or as separate units. In the strict product scope, they are included because 80 % of all water tube boilers with an output over 2 MW are equipped with one (EC 2009). The feedwater pump, on the contrary, is not part of the strict product/component scope because it is not included in the calculation of efficiency. Moreover the pump is regulated by other Ecodesign regulation. The same is true for the circulating pump. Nevertheless the efficiency evaluations are based on the European standard EN 12952-15 includes the circulating pump. Thus, the circulating pump is included in the strict product scope as well.

Next to the strict product scope, the extended product approach includes the same parts as the strict product/component scope. Thus, the system boundary does not change. However, the focus shifts from the nominal operation to varying conditions of use (e.g. part load, start-up behaviour, operating hours).

The technical system approach covers the whole system as shown in Figure 3, including steam distribution and condensate recovery.

To gather insights on state of the art boiler efficiencies an internet based screening on randomly chosen products has

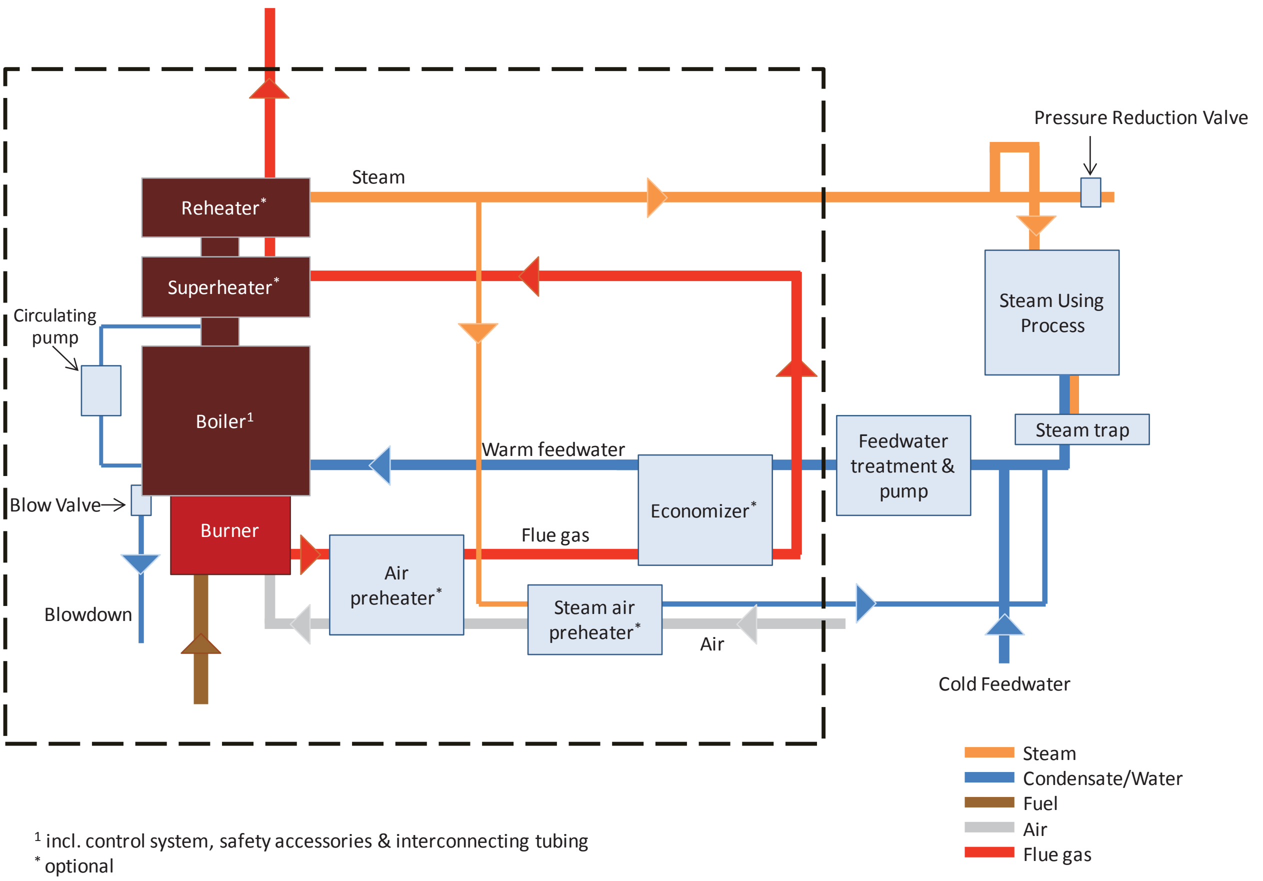


Figure 3. System boundary of a steam boiler system (product approach framed by broken line).

been conducted. Therefore data sheets and advertising information published public on manufacturers websites has been screened with regard to boiler efficiency. For industrial steam boiler equipped without economizer 31 efficiency values have been found. Thus 48 % of the manufacturers claim to achieve a boiler efficiency of equal or higher than 90 %. Furthermore 39 % claim to achieve a boiler efficiency of equal or superior than 85 % (Figure 4). For products equipped with an economizer only six efficiency values has been found. The claimed values range between 94 % and 96 % boiler efficiency with the exception for one product (Figure 5).

The products shown in the graphs are not completely comparable as the appropriate loads are unknown and/or not identical.

Legal framework for steam boilers

The legal environment for steam boilers in the EU is directly and indirectly affected by various directives and regulations. In the following we describe the most relevant energy-related directives with regard to their impact on the product definition (except the Ecodesign directive which has been discussed in the foregoing). We then present conclusions of a review on national legislations for Germany, France, the Netherlands, the USA and China with respect to industrial steam boiler.

EUROPEAN LEGISLATION

Industrial Emissions Directive

The directive on industrial emissions 2010/75/EU of 24 November 2010 (Industrial Emissions Directive – IED) lays down rules on integrated prevention and control of pollution arising from industrial activities. It aims to achieve a high level of protection of the environment as a whole by preventing and reducing emissions into air, water and land and the generation of waste. The regulations of IED cover a range of different industrial activities and installations including combustion plants, waste incineration plants, installations using organic solvents, installations producing titanium oxide as well as industrial activities defined

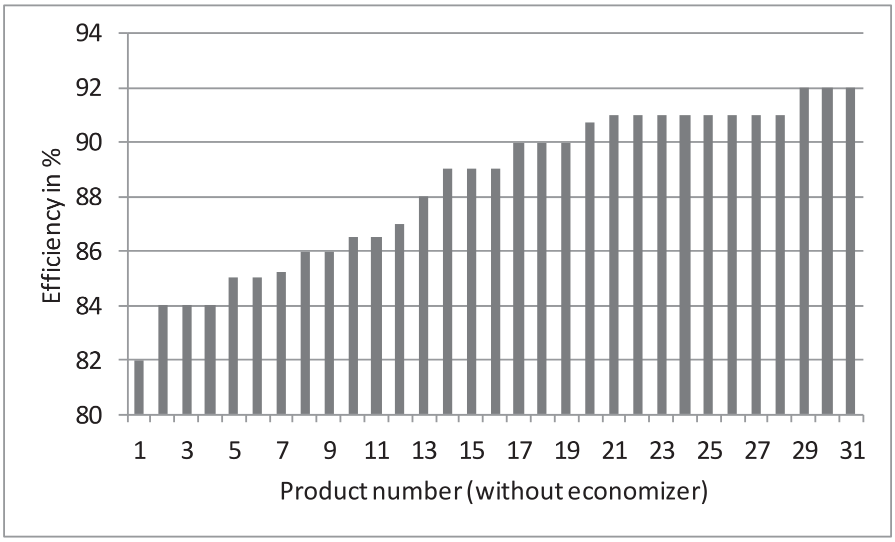


Figure 4. Extract of efficiencies of industrial steam boilers without economizer.

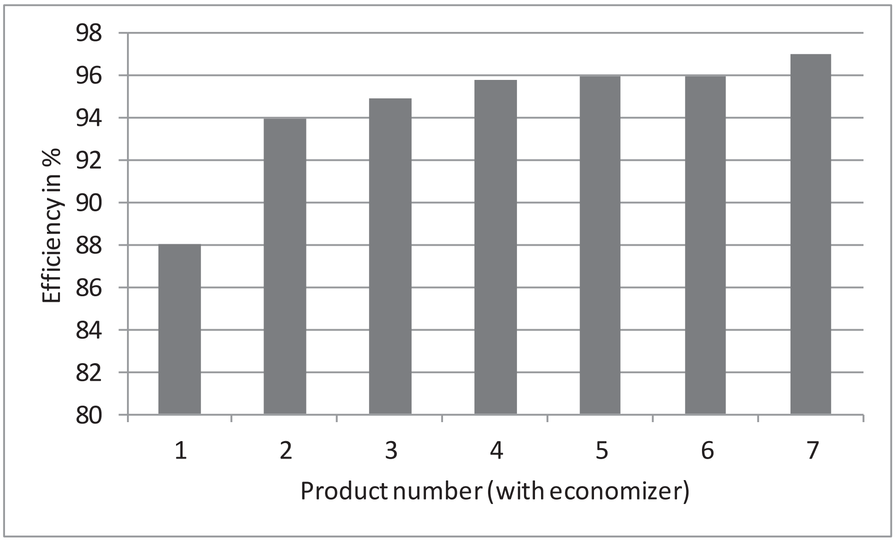


Figure 5. Extract of efficiencies of industrial steam boilers with economizer.

in Annex I of the directive. Article 3 of the IED describes installations as stationary technical units where any of the activities in Annex I are carried out and "any other directly associated activities on the same site which have a technical connection with the activities listed [there] and which could have an effect on emissions and pollution." Furthermore, Article 3 of the IED defines a combustion plant as "any technical apparatus in which fuels are oxidized in order to use the heat thus generated". As steam boilers provide steam by burning fuels, they can be considered as combustion plant and are thus furthermore subject to the regulations on combustion installations.

In consequence, steam boilers are likely anchored twice in the list of activities provided in Annex I of IED: As combustion installations if they have a rated thermal input of equal to or exceeding 50 MW or in conjunction with activities specified in Annex I (e.g. steam boilers for paper production).

Emission Trading Directive

The Emission Trading Directive (2003/87/EC) establishes a scheme for trading greenhouse gas emission within the European Union. The aim of this trading scheme is to reduce green house gas emissions in a cost-effective manner. The directive introduces a system of tradable permits. Operators of certain installations as defined in Annex I of the directive have to hold a sufficient number of permits for operating their installations.

Based on the list of activities provided in the directive, steam boilers are covered in two cases: either as combustion installations or as part of other production activities. For the combustion installations, the minimum threshold for inclusion into the directive is a total rated thermal input of 20 MW. If steam boilers are considered as a functional part of other activities defined in Annex I, they may also be subject to the directive, e. g. as part of paper production installations with a capacity exceeding a stipulated threshold value of 20 tons per day. Thus, larger steam boilers installations or those included in other industrial activities are subject to the regulation of the ETS directive.

NATIONAL LEGISLATION

Binding national laws and ordinances differ among the compared states for manufacturer and user of industrial steam boiler in terms of environmental pollution and energy efficiency. A review of existing legislation carried out within the study has provided the following conclusions.

The first outcome is that in any case basically two dimensions are being used in order to set limits for pollutants of firing places, respectively industrial steam boiler among the compared states. Therefore in any reviewed structure the net rated thermal input and the used fuel are dimensions in order to categorize these limits. However there are also more complex laws using additional dimensions such as technology and operation parameters. One example is the German administrative directive "TA-Luft" setting different NO_x emission limits in dependence of the boiler operating temperature. That is why finally comparison of national emission limits for industrial steam boilers is not directly possible. However the review is indicating that there are countries with more ambitious legislations compared to other countries within the compared member states. Let us assume an industrial steam boiler with a net rated thermal input of 15 MW, which is fuelled with natural gas from the public grid having an operating temperature of 150 °C. Then the emission limit for NO_x is 110 mg/m³ in Germany, whereas the emission limit for the same is 70 mg/m³ in the Netherlands (both referred to 3 % O_2 content in the flue gas).

The second outcome of the review on national legislations is that legal binding energy efficiency criteria for industrial steam boiler (with at least a capacity of higher than 400 kW) are quite rare within our research. Therefore binding energy efficiency criteria has been found only in France and Germany within the EU and in China for other countries. Furthermore no efficiency criteria for part load behaviour of industrial steam boiler have been found.

This leads us finally to the conclusion, that there is no harmonized legislation in the EU affecting the environmental balance of industrial steam boilers during the utilization phase.

Market

An essential step for analysing possible measures to improve the environmental performance of products is to derive suitable base case products for the analysis. The MEErP methodology indicates the official European production statistics from the PRODCOM database should be used as a preferential data source for the analysis. In the following we will briefly outline the results when using the PRODCOM data and will use some other approaches to gain some insights on market data for the analysis.

MARKET ANALYSIS BASED ON PRODCOM DATA

PRODCOM provides information on manufactured goods in the European Union listing about 3,900 different types of manufactured products (EUROSTAT 2014a). PRODCOM data is publicly available with information on production since 1995 with an increasing coverage due to the expansion of the European Union since its introduction. For each type of product and member state, information is given in terms of monetary production value, in terms of sales with different natural units (e.g. kg, m², units, volume) and in terms of total volume in natural units. In some cases, data is estimated or not provided due to reasons of confidentiality.

With regard to steam boilers, the PRODCOM database distinguishes three individual products including water tube boilers (code 2530 1110), vapour generating boilers (code 2530 1150) and super-heated water boilers (code 2530 1170). Figure 6 provides an overview of the corresponding data in terms of produced units for the EU15 and the EU27.

As visualized in Figure 6, the strong increase in the production of watertube boilers in the years 2007 to 2008 is not plausible. Thus, for a first analysis of the market, we exclude these data points from the analysis and use the average from the years before. We also exclude 1995 data for vapour generating boilers due to a strong decrease in the produced numbers in the following years. Furthermore, we scale the market data only available for the EU15 before 2003 to the EU27 using an overlap in data reporting between 2003 and 2005. Note that according to PRODCOM data, there is only a very small difference between the EU15 and EU27 figures for all types for products. For calculating the overall stock of boilers, we further use an average lifetime of 20 years for the analysis with all boilers sold since 1992 still in operation. Additionally, as no reliable data on import and export of steam boilers is available,

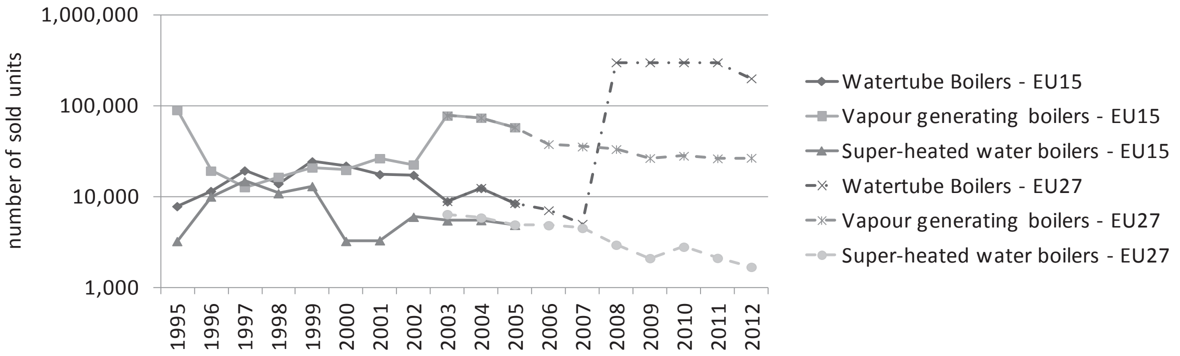


Figure 6. Historical development of sold boilers by type according to PRODCOM database.

Table 4. Stock estimation for steam boilers in Europe.

	Food	Paper	Chemicals	Refining	Metals	Other	Total
US: Original data	10,610	3,460	11,980	1,200	3,330	12,435	43,015
Approach 1: Per capita	31,831	6,358	19,959	1,576	9,586	37,705	122,816
Approach 2: Per firm	135,559	15,789	26,523	598	170	99,107	354,215
Approach 3: Per energy use	10,396	2,235	7,969	–	4,112	–	34,747

we assume that imports and exports are more or less balanced over the years. Using this data set, we obtain results that indicate a total stock of about 1,111,671 boilers in the EU27.

MARKET ANALYSIS BASED ON OTHER DATA SOURCES

As this number of boilers appears to be very high as compared to expectations, we continued by conducting additional analyses on the number of boilers. Unfortunately, there are no other statistics on the use of steam boilers in Europe. We therefore opted to transfer data from a study on boilers in the US (EEA 2005) to the European Union. This study differentiates the boiler population by different sectors in the US. As the study does not clearly describe what type of boilers is specifically analyzed, we assume that all boilers described as industrial boilers in the study are steam boilers. We further assume that sales can be used as proxies for today's boiler population in the US. For adapting the data to the EU, we chose three similar approaches. In each approach, we first calculated a specific boiler capacity for the US industry based on either data from Census 2012 or data from EIA 2013. Then we transferred this data to the EU based on data from EUROSTAT 2014b. Our first approach is based on the calculation of the average specific steam boiler capacity by industry sector and employee in the US. This value is then multiplied by the number of employees in the respective sectors in the EU based on Eurostat data. The second and third approaches rely on calculating the average specific steam boiler population per firm and sector and by energy use and sector in turn.

The results of these approaches are summarized in Table 4. Obviously there are considerable deviations in the results due to the different factors of influence that are taken into account when estimating the European population. Note that for the third approach no suitable average data could be calculated for some sectors. Despite the considerable deviations in the results, the number of boilers is 3 to 30 times lower than those calculated using the PRODCOM statistics.

As additional evidence, we have outlined some sectors where steam is intensively used (Figure 2). Assuming that every company in these sectors has exactly one steam boiler (Approach 4) and combining this assumption with information on the number of companies in the respective sectors in the EU provides a total stock of boilers of approximately 580,000 units.

Figure 7 summarizes our results on the stock data. It shows the already mentioned deviations between the approaches. As very little reliable information is available, the main challenge is to combine the existing pieces of information to allow a sound estimation.

Technological Improvements

In this chapter we give a general overview of sample results on the analyses accompanying the preparatory study. The data presented is based on the US Industrial Assessment Centres (IAC) database (Rutgers 2012). The IAC are funded by the U.S. Department of Energy and organize energy assessments in small and medium sized manufacturing firms. During an assessment, a team of students, instructed by a university professor, collects site specific energy-related data and generates a report with recommendations. The results of the recommendations are integrated in a publicly accessible database. This database holds information on the implementation status, possible dollar and resource savings, implementation costs as well as on the assumed payback period, the standard industrial classification (SIC) of each firm and further firm specific details on e.g. sold products, annual sales and production hours. The implementation status can either be implemented, not implemented or pending.

Assessments started in 1981 and up to now over 120,000 recommendations have been made during more than 16,000 assessments (Rutgers 2012). We have taken 43 different types of recommendation into account, assuming that all measures affecting boilers can be applied on steam boilers. Based on this assumption, about 9,000 recommendations are relevant with half of them being implemented and the other half not.

To sort these recommendations, we subdivided them by two dimensions. The first dimension sorts the recommendations by the area of the steam systems for which they are relevant. Thus it is possible to distinguish between generation, distribution and recovery as well as the overall steam system. It should be noted that *Recovery* does not refer to waste heat recovery but to condensate recovery. The second dimension concerns the type of modification in a more detailed way. Following the corresponding classification proposed in Fleiter et al. (2012), we distinguish organizational measures, technology add-on as well as technology replacement. Using those two dimensions, we sorted the 43 types of recommendations as shown in Table 5 in the appendix.

Figure 8 shows the resulting distribution of the recommendations: 63 % of all recommendations can be allocated to the subcategory generation. This is the most relevant category for the preparatory study as it affects the strict product scope. Another interesting observation is that 49 % of all recommendations are organizational measures. These recommendations are not relevant for our study as they cannot be affected by an improved product design.

A further analysis on the recommendations for the sub-category "generation" equalling 5,788 recommendations shows the following split of measures: 53 % are organizational measures including maintenance, 41 % are measures for technology add-on and 6 % are measures for technology replacement. Therefore only 2,750 of all recommendations for the sub-category "generation" are relevant for product design and can thus be addressed by the preparatory study. This is an interesting observation because the process of steam generation can be optimized by simple measures such as regular maintenance that cannot be covered by a product-based approach such as the Ecodesign.

Although the results from the analysis are highly interesting, the database has certain limitations which we have to bear in mind. These limits concern the information of the database itself and the transferability of data between US and the European market. Having used the IAC database in a slightly different context Cagno et al. concluded a high transferability of the IAC data to the European marked (Cagno 2010).

The information included in the database does not give a holistic overview of possible measures because it focuses only on small and medium sized manufacturing firms that fulfil certain criteria. One important criterion is that the firms do not employ technical staff with the primary duty of energy analysis.

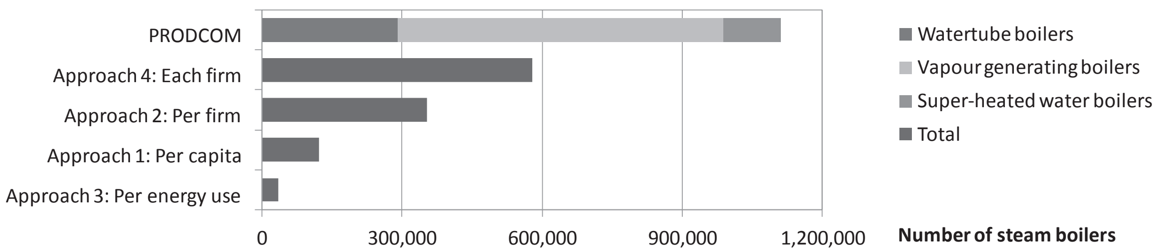
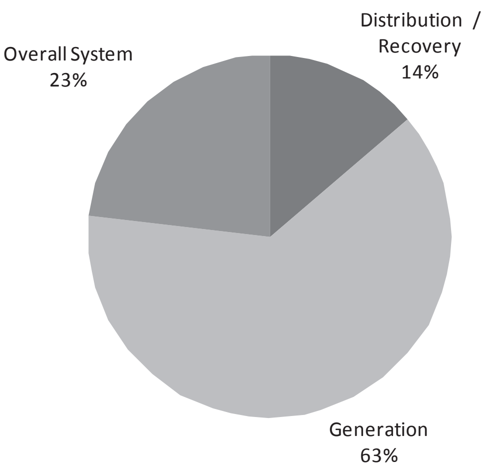


Figure 7. Results of different approaches for estimating the stock of boilers.



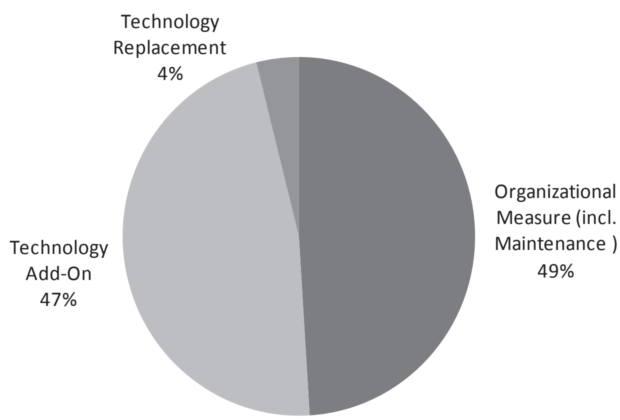


Figure 8. Distribution of recommendations by category steam cycle (left) and by type (right) (n=9202).

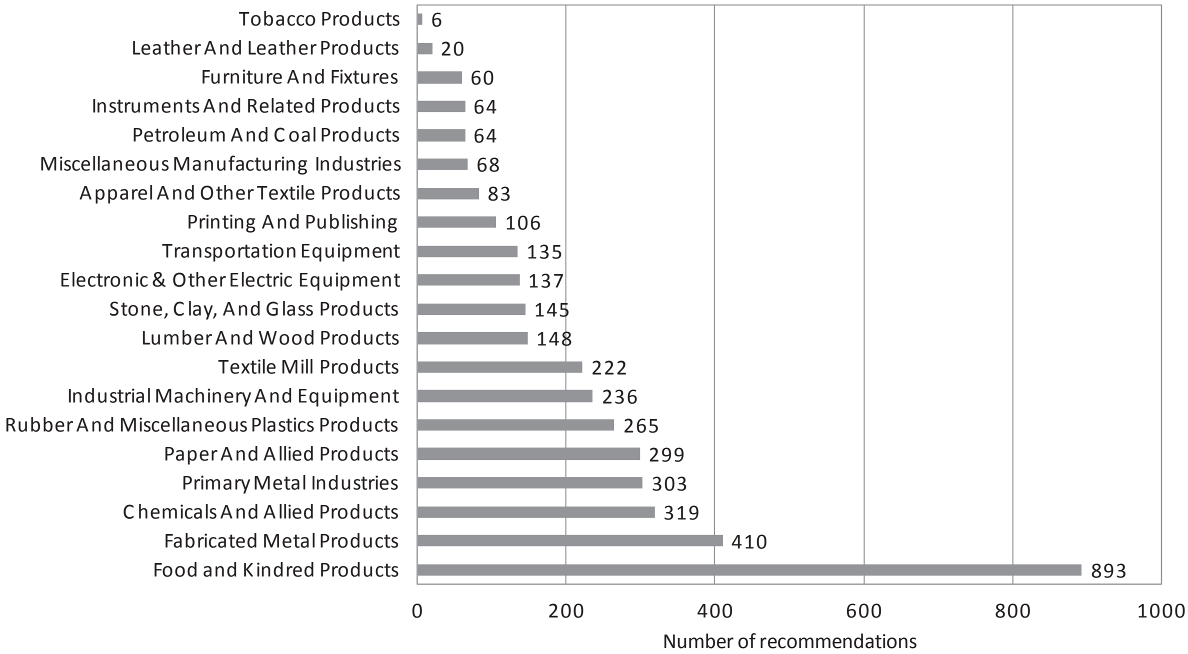


Figure 9. Number of recommendations for "generation" by sector (n=3983).

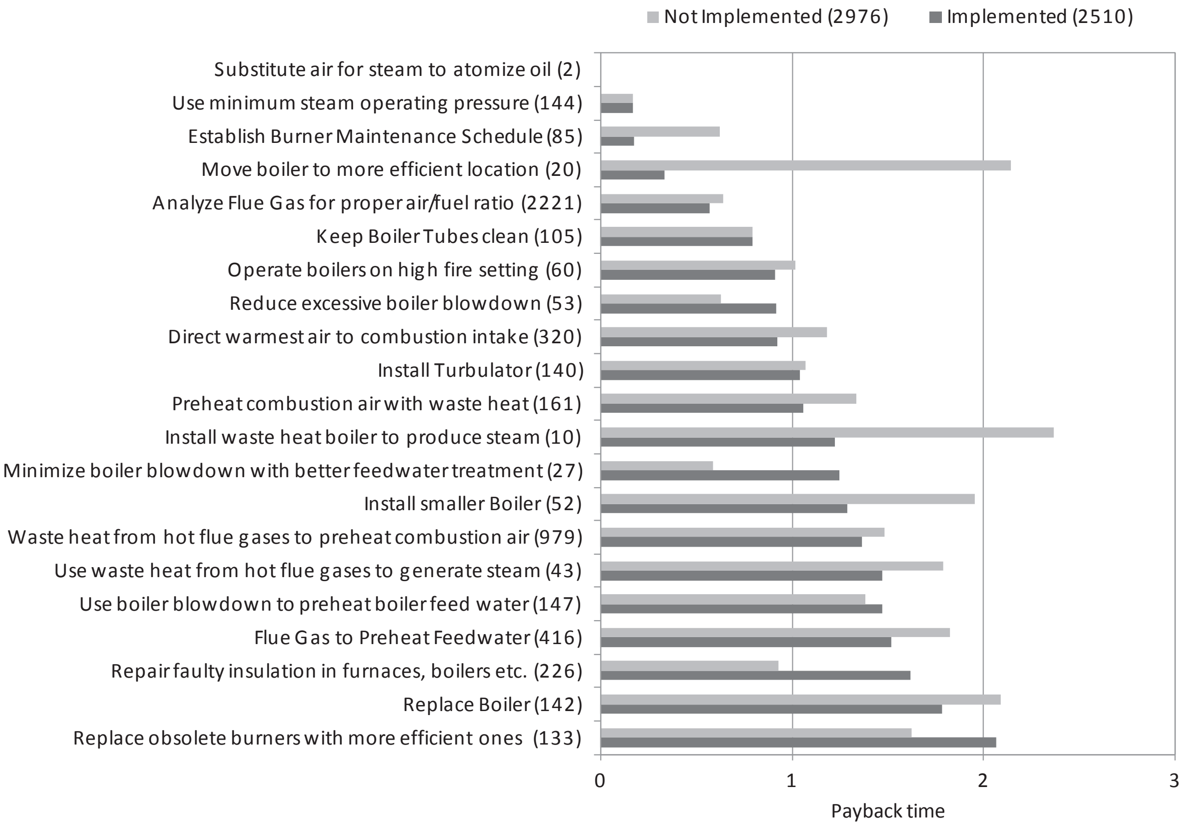


Figure 10. Average payback time of the measures of the subcategory generation listed in the IAC database.

Therefore they might be more inefficient than the ones employing technical staff.

Furthermore there might be differences between small and medium sized enterprises and larger companies employing more than 500 employees. Figure 9 shows that especially the food sector has be subject to many assessments concerning the use of steam. As the food processing industry relies mainly on small boilers (Table 3) we conclude that the measures recommended by the IAC database are mostly applicable for boilers with a lower capacity.

Figure 10 shows the average payback time of those measures of the subcategory generation that were either implemented or not implemented. Due to these results we presume that the recommendations are in general measures with short payback periods because they are most likely to be implemented by firms. Other measures, maybe even more efficient ones in the long term, might not be listed in the database as they have a longer payback period. Nevertheless, the analysis of the IAC database helps us to gain a better understanding about typical measures to increase efficiency and on their relevance.

Conclusions

In this paper, we provided an overview of the Ecodesign process as well as some insights into this process at the example of industrial steam boilers. As it is an ongoing process, the final findings presented in the preparatory study may differ from the presented results. Nevertheless some specific results are highlighted in the following, as they might not only apply to steam boilers, but also to similar products.

Steam boilers are used in different branches for different applications. Even though the product itself might seem comparable to domestic heating boilers, the large differences in terms of application require a different assessment. As steam applications are very heterogeneous, the requirements to the product of the boiler, i.e. steam, vary strongly. The installed overall systems therefore are quite heterogeneous in their design. Due to this fact the system approach leads to a broad variety of different design options.

The boilers themselves have nevertheless reached a rather high level of efficiency if they use an economizer. Further improvements may be achieved, when looking at the whole system instead of at the single product. Furthermore, maintenance and sound operation have been identified as important determinants of the product and system efficiency. Due to the variety in system designs, such an approach may be challenging for Ecodesign implementation. Using a (simpler) product approach helps to improve energy efficiency to a certain extent, but it excludes substantial parts of saving potentials.

Especially larger steam boilers are not an "off-the-shelf" product in a classical sense, as they are always part of a larger system and customized to a certain extent according to the customer requirements. The shipment of the "boiler" itself may also be quite different. For example, the feedwater pump is not always – but sometimes – delivered together with the boiler.

As steam boilers are normally subject to environmental legislation there might be an overlap with existing legislation. This has to be considered in the Ecodesign process, as it may lead to multiple regulation of one technological feature.

And finally, we observed that PRODCOM data is not useful for the analysis as it is neither transparent nor suitably aggregated. Furthermore it includes implausible values. Therefore input from manufacturers is an essential requirement for the analysis. A technological segmentation more detailed than in PRODCOM is necessary for a sound analysis. Detailed market and prize data is rare, which is a common feature of business-to-business products.

The common methodology for the preparatory study allows a straightforward analysis within a clearly defined methodological framework. Nevertheless, the specific properties of a product may lead to specific challenges within the analysis as shown in this paper.

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Acknowledgements

This paper presents research carried out in the wider context of the preparatory study on industrial steam boilers for the European Commission. This study is performed in cooperation with pwc Italy and the University of Athens. The results shown in this paper are preliminary and do not necessarily represent the opinion of the European Commission.

Appendix

Table 5. Measurement Categorization.

	Organizational Measure (incl. Maintenance) (n=4511)	**Technology Add-On (n=4333)**	**Technology Replacement (n=358)**
Generation (n=5788)	• Keep boiler tubes clean • Move boiler to more efficient location • Operate boilers on high fire setting • Reduce excessive boiler blowdown • Use minimum steam operating pressure • Analyze flue gas for proper air/fuel ratio • Establish burner maintenance schedule for boilers • Repair faulty insulation in furnaces, boilers etc.	• Install turbulator • Direct warmest air to combustion intake • Minimize boiler blowdown with better feedwater treatment • Use heat from boiler blowdown to preheat boiler feed water • Flue gas to preheat feedwater • Preheat combustion air with waste heat • Waste heat from hot flue gases to preheat combustion air • Install waste heat boiler to produce steam • Use waste heat from hot flue gases to generate steam • Substitute air for steam to atomize oil	• Replace obsolete burners with more efficient ones • Replace boiler • Install smaller boiler
Distribution/ Recovery (n=1273)	• Repair/replace steam trap • Turn off steam tracing during mild weather • Close off unneeded steam lines • Use correct size steam traps • Shut off steam traps on superheated steam lines not in use • Increase amount of condensate returned • Lower operating pressure of condenser (steam) • Eliminate leaks in high pressure reduction stations	• Install steam traps • Install/repair insulation on condensate lines • Insulate feedwater tank • Install deaerator in place of condensate tank • Flash condensate to produce lower pressure steam • Waste process heat to preheat makeup water • Use steam condensate for hot water supply (non-potable)	–
Overall System (n=2141)	• Repair faulty insulation • Repair leaks in lines and valves • Repair and eliminate steam leaks • Reduce excess steam bleeding	• Insulate steam/hot water lines • Substitute hot process fluids for steam • Use heat exchange fluids instead of steam in pipeline tracing systems	–