# ASSESSMENT OF BOILER'S OPERATING PERFORMANCE IN DIFFERENT ENERGY SECTORS IN THE PROVINCE OF VOJVODINA

by

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Original scientific paper
DOI: 10.2298/TSCI120215065K

*Creating database enables the wide range of possibilities for implementing energy management approach and for critical evaluation of accepted practices in the field of energy efficiency. This paper contains besides the existing database also measurements in the group of randomly selected boilers. The sample formed in such a way covers approximately 25% of all boilers in the Province of Vojvodina. This provides reliability and relevance of obtained results. With reference to users, it can be the indicator of a need to undertake concrete activities for the purpose of increasing energy efficiency of plants and improving observed situation. The last section concerns relevant authorities responsible for developing and amending the energy policy.*

Key words: *energy, operating performance, boiler efficiency*

## Introduction

This paper is aimed at identifying patterns for investigating possible actions which can be taken in order to improve energy efficiency and also to estimate expected savings and rationalizations. The methodology is based on sample analysis and extrapolated conclusions.

The creation of the database of the population of regional boiler plants will give numerous possibilities for implementing energy management approach and for critical evaluation of accepted practices in the field of energy efficiency. A clear look or an added awareness, which this survey is aimed at in combination with expert assistance can recommend and specify opportunities for increasing energy efficiency of boiler houses and reduce irrational energy use and related costs. Boilers in the Province of Vojvodina are organized in different sectors, and industry, district heating system and healthcare facilities are the subject of the analysis. The paper presents data which originate from 2006 to 2008. The situation from 2009 to 2011 is a little bit different since overall energy efficiency has been slightly improved.

In terms of practicality, the approach can, in general, assist by indicating recommendations and guidelines for activities such as applying improved operational management and procedures, efficient use of the plant's equipment, improving maintenance of the plant's re-

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sources, establishing evidence and improved measurements, *etc.* Such activities can provide preconditions for effective and systemic changes in all aspects of boiler house operations.

At the sectoral level, this approach can contribute to the creation of new incentive programs at the state or provincial level, promote new technological solutions, and provide subsidies for the most urgent and effective investments and introduce many other possibilities.

## Intention of the analysis

The intention of the approach applied here lies in providing extensive possibilities for the identification of inefficiencies. It can also be effectively used to analyze and assess operating performance of a wide boiler population at the sectoral level due to established optimum operational procedures and created systematic energy conservation measures.

Steam and hot water are used throughout industry, commerce and in the public sector for a wide range of processes and space heating requirements, and can represent significant proportion of the organization's energy costs. It is, therefore, important for owners and operators of boilers to ensure that the plant is designed, installed, commissioned and operated with due regard to energy efficiency, as well as safety and reliability. This paper provides an insight into key issues that decision makers, policy developers, and plant managers should consider.

Most companies want to know how well they manage their energy use – whether their performance is improving through conscious actions that have been taken and whether there is space for further improvement in terms of energy and carbon savings. Performance can be compared ('benchmarked') with either previous performance or with other organization's performance (*i. e.*, internal or external benchmarking).

There are two stages in assessing energy performance: a) Establish how energy use is related to appropriate variables such as square meters, volume, production tonnage, *etc.* (This allows energy use to be estimated under different conditions such as lower output levels) and b) Make meaningful and valid comparisons of performance under equivalent conditions [1].

All sectors, industrial, commercial and public, use specific energy consumption as the basic performance indicator. However, defining, assessing and predicting energy efficiency is not easy, primarily because it is affected by additional factors that cannot always be anticipated. In those circumstances, a solution can be an approach which combines expert and soft computing capabilities with the performance evidence presented in this paper. Through such a concept, it becomes possible to locate, recommend and specify opportunities for increasing energy efficiency of boiler houses and for reducing irrational energy use and related costs.

Energy efficiency is one of the most potent and cost effective ways of meeting sustainable development demands. The author [2] has analyzed energy usage and what has gone wrong, he has examined energy efficiency policies and measures in other countries and has examined possibilities for the adoption of these lessons in local context.

Energy surveys reveal opportunities for investment in energy efficiency. Energy surveys also reveal irrational use of energy and energy efficiency improvement possibilities [3].

### *Importance of energy efficiency*

There are numerous reasons for the desire to improve energy efficiency in boiler operation but perhaps the most compelling one is the waste of money for energy costs reflected in the balance sheet bottom line. In many cases, improvements can be made at low or no costs and involve slight changes to the way a process or equipment is operated in order to optimize their performance rather than to purchase expensive equipment. Saving energy has many benefits including: reduced energy costs (increasing profits or releasing resources for other activities); improved environmental performance due to reduced carbon dioxide emissions; improved competitiveness of products or services; enhanced public image with customers and other stakeholders and reduced exposure to the Government's drivers such as the Climate Change Levy.

Energy saving or increase of energy use and supply efficiency is the most efficient measure to implement all other priorities of the EU Sustainable Energy Policy: increased security of energy supply, reduced pollution and environmental energy impact, reduced vulnerability of low-income population in energy affordability and ensured competitiveness and growth of the economy and employment. The effective energy efficiency policy can, therefore, make major contribution to the EU competitiveness and employment which are central objectives of the Lisbon Strategy [4].

## Auditing methodology

The analysis of operating performance based on energy surveys for randomly selected 100 boilers is carried out at over 75 sites covering the representative range of industrial, public and commercial users of steam and hot water. The sample covers approximately 25% of all boilers in the Province of Vojvodina. Sectors are industry, district heating system and healthcare facilities.

The first step is to select necessary parameters for each site and for each particular boiler plant. The parameters and the information selected as relevant are divided according to boiler nameplate information, boiler operational performance, occupation dynamics, capacity engagement, flue gas composition and the state and conditions of the plant and its subsystems.

The techniques used to carry out each audit includes: metering, internal monitoring records analysis, engineering calculations and specifics based on the opinion of operational staff in the energy department of each company [5]. In the second phase of the procedure, techniques used for analyzing, arranging and structuring database are mathematical models, engineering calculations and visualization conclusions.

Information collected through measurements, physical audit, and direct communications and interviews with the staff members in charge of energy departments in each company or institution are gathered and organized into the following 9 categories:

(1) General information about the company: activity; sector.
(2) General information about selected boiler: basic/optional fuel; boiler type (steam or hot-water boiler); exploitation time (years); boiler purpose (technology or heating); capacity [$th^{-1}$] and [MW]; operational parameters [°C per bar]; plant engagement (permanent, seasonal).
(3) Boiler operational performance: most common load range in terms of nominal load capacity [%]; annual number of operational hours [h per year]; and specific fuel consumption [$m^3h^{-1}$, $kgh^{-1}$].
(4) Measurement parameters: flue gas temperature [°C]; flue gas velocity [$ms^{-1}$]; load range during measurement of flue gas composition [%].
(5) Calculated performances: flue gas flow rate [$m^3h^{-1}$], boiler efficiency according to GCV [%], boiler efficiency according to NCV [%], flue gas losses [%]; annual fuel consumption [GWh per year]
(6) Combustion quality (flue gas composition): $O_2/\lambda$ [%], $CO_2$ [%]; $SO_2$ [ppm], CO [ppm], NO [ppm], $NO_x$ [ppm], $H_2$ [ppm], MCO [$kgh^{-1}$] and $MNO_X$ [$kgh^{-1}$].

(7) Monitoring and existing controls: stationary and continuity oxygen control; measurement of heat energy delivery rate; flow rate measurement of boiler feed water and condensate return; combustion quality control; *etc.*
(8) Control type: manual; semiautomatic; automatic.
(9) Reconstruction and/or revitalization record: burners and associated equipment; heat recovery systems (economizer); pipes, automatic control equipment; *etc.*

## Operating performance in different energy sectors

The review of boiler operating performance in different energy sectors in the Province of Vojvodina starts with sector analysis. Selected sectors are industry, district heating system and health-care facilities. The main reason for adopting mentioned sectors arrangement is dominant participation rate of large and middle scale boiler plants in these three sectors in the overall energy activities. The fig.1 presents percentage distribution according to the sector structure.

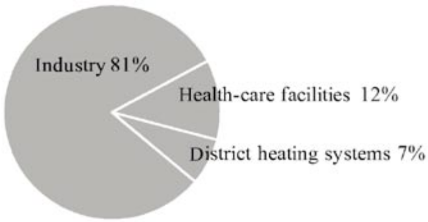


**Figure 1. Distribution according to the sector structure**

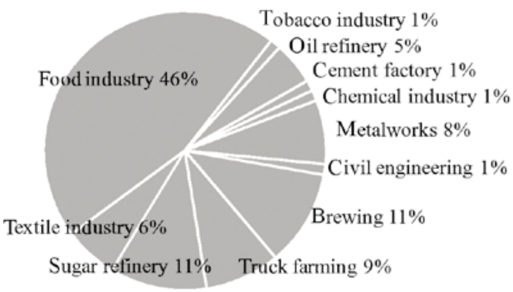


**Figure 2. Activity structure for industry sector**

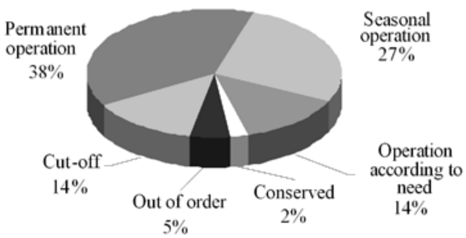


**Figure 3. Distribution according to occupational intensity of current state of boilers in the industry sector**

Inside the industrial sector, companies are structured according to their activities, as shown in the fig. 2.

### *Industry sector*

Generally, in the Republic of Serbia, occupation dynamics and capacity engagement in energy departments are critical obstacles for reaching satisfactory energy efficiency. By establishing reliable patterns for assessing rational use of energy, the energy audit includes information about the type of work and the current state of the plant. For this purpose, the following categories are adopted and itemized by occupational intensity: permanent operation, seasonal operation, operation according to need, conserved, out of order, and disconnected.

Figure 3 shows distribution in the industry sector.

The dominant boiler type categories in the industry sector are steam boilers presented as boilers in operation. The second category is hot water boilers also presented in operational state. All types of boilers out of operation are grouped separately. Distribution according to the boiler type in the industry sector is shown in fig. 4.

In the Province of Vojvodina, dominant fuel types are natural gas and heavy oil, and

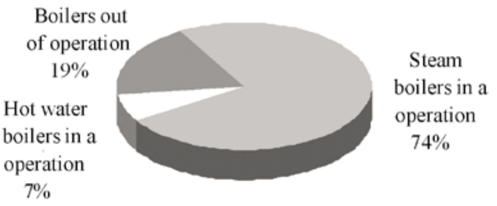


**Figure 4. Distribution according to boiler types in the industry sector**

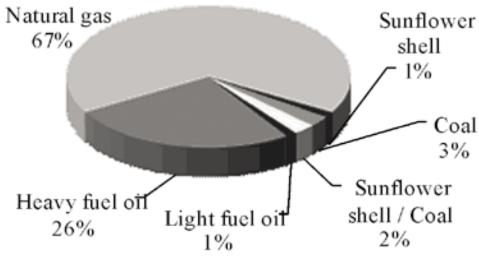


**Figure 5. Distribution according to the type of fuel type in the industry sector**

then sunflower shell, coal, combined sunflower shell and coal, light oil and this is shown in fig. 5.

Key results of measurements and calculations for the sample of entire boiler population in the industry sector are presented in the tab. 1, structured by minimum, maximum and average values.

**Table 1. Results of measurements and calculations**

| Value | Minimum | Average | Maximum |
|---|---|---|---|
| Exploitation [years] | 3 | 29 | 46 |
| Capacity [$th^{-1}$] | 0.6 | 14.1 | 121.0 |
| Capacity [MW] | 0.9 | 11.8 | 40.0 |
| Normalized capacity[1] [MW] | 0.4 | 10.5 | 81.6 |
| Load range [%] | 15 | 72 | 100 |
| Oxygen content [%] | 0.61 | 7.09 | 18.00 |
| Efficiency [%] | 60.1 | 87.8 | 94.0 |
| Flue gas temperature [°C] | 115.3 | 203.3 | 330.8 |
| Operating hours [h per year] | 480 | 4,462 | 8,664 |
| Flue gas flow [$m^3h^{-1}$] | 1,727 | 23,460 | 133,542 |
| Fuel energy input [GWh per year] | 0.57 | 34.02 | 376.22 |

[1] The capacity of saturated steam boilers is specified per steam flow rate [$th^{-1}$]. For the sample to be uniform, their capacity is calculated in MW by using mean steam and condensate parameter values. The capacity of hot water boilers is expressed in MW.

Gas fired steam boilers in industry are dominant category today in the Province of Vojvodina with constant tendency to increase their share. Such a tendency is based on very developed natural gas network in the region and many advantages which provide proven gas technologies, reliability and security of supply, lower running costs, lower environment pollution, *etc.*

### *District heating system*

In the sector of district heating system, all boilers operate seasonally. The high percentage of all boilers is hot water boilers and primary fuel is natural gas and optional fuel is mostly heavy oil. Key results of measurements and calculations for the sample of entire boiler population in the district heating system is presented in the tab. 2, structured by minimum, maximum and average values.

**Table 2. Results of measurements and calculations**

| Value | Min | Average | Max |
|---|---|---|---|
| Exploitation [years] | 20 | 26 | 34 |
| Capacity [MW] | 6.8 | 14.0 | 23.0 |
| Load range [%] | 50 | 64 | 75 |
| Oxygen content [%] | 1.70 | 4.69 | 9.36 |
| Efficiency [%] | 85.5 | 91.3 | 97.6 |
| Flue gas temperature [°C] | 49.3 | 135.1 | 203.5 |
| Operating hours [h per year] | 1,650 | 3,300 | 4,500 |
| Flue gas flow [$m^3h^{-1}$] | 11,768 | 18,425 | 25,083 |
| Fuel energy input [GWh per year] | 7.51 | 27.43 | 51.59 |

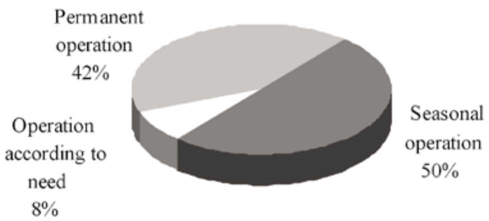


**Figure 6. Distribution according to occupational intensity in healthcare facilities**

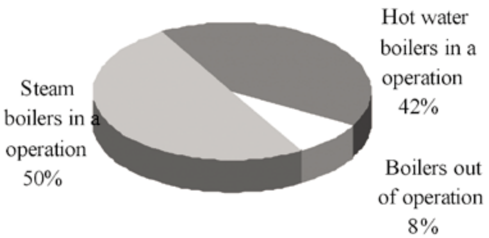


**Figure 7. Distribution according to boiler types in the industry sector**

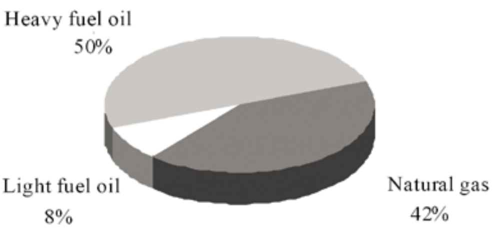


**Figure 8. Distribution according to the type of fuel type in the industry sector**

### *Healthcare facilities*

In the sector of healthcare facilities, the analysis includes occupational dynamics and capacity engagement in energy departments in the similar way as in the industry sector. Permanent and seasonal operations and operation according to need division is show in fig. 6.

The dominant boiler type category in the sector of healthcare facilities does not exist. Steam boilers and hot water boilers in operational state take up 92%. Both types of boilers out of operation are grouped separately. Distribution according to the boiler types is presented in fig. 7.

Also, the dominant fuel type category in the sector of healthcare facilities does not exist but it is notable that there is large share of heavy oil. Distribution relations are shown in fig. 8.

Key results of measurements and calculations for the sample of entire boiler population in the sector of healthcare facilities is presented in the tab. 3, structured by minimum, maximum and average values.

### *Thermal capacities overview*

Total installed capacities are unknown and only estimated data are available. The estimation is based on collected data through this analysis and formulated database including 25% sample coverage. The number of companies and institutions and the total number of boilers with installed thermal capacities [MW] is shown in the tab. 4 [5]. Roughly, total thermal capacities of all boilers in the industry sector is approximately 2,900 MW (tab. 2), in 13 thermal plants, approximately 1,180 MW, in 4 thermal power – plants, approximately 1,500 MW and nominal electrical capacity is 420 MW, and in 8 major healthcare facilities, approximately 150 MW.

In total, installed estimated thermal capacities are approximately 5,730 MW. The analysis has established the value of 3,140 MW as installed total thermal capacity in permanent and seasonal operations. It can be considered as very low level of capacity engagement but positive circumstances are the existence of increasing trends in occupational dynamics and increasing number of implemented energy efficiency projects in recent times.

**Table 3. Results of measurements and calculations**

| Value | Minimum | Average | Maximum |
|---|---|---|---|
| Exploitation [years] | 2 | 24 | 40 |
| Capacity [th$^{-1}$] | 2.2 | 4.3 | 10.0 |
| Capacity [MW] | 0.5 | 2.3 | 5.8 |
| Normalized capacity [MW] | 0.5 | 2.6 | 6.7 |
| Load range [%] | 40 | 69 | 95 |
| Oxygen content [%] | 2.21 | 8.31 | 18.1 |
| Efficiency [%] | 61.1 | 86.0 | 93.4 |
| Flue gas temperature [°C] | 136.3 | 199.1 | 284. |
| Operating hours [h per year] | 1,200 | 4,387 | 8,650 |
| Flue gas flow [m$^3$h$^{-1}$] | 1,304 | 7,028 | 21,105 |
| Fuel energy input [GWh per year] | 0.4 | 8.45 | 30.40 |

**Table 4. Installed capacities according to sectors**

| Sector | Companies and institutions | Total number of boilers | Installed thermal capacities [MW] |
|---|---|---|---|
| Industry | 132 | 312 | 2,900 |
| Thermal plants | 13 | 43 | 1,180 |
| Thermal power plants | 4 | 17 | 1,500 |
| Healthcare facilities | 8 | 19 | 150 |
| Total | 157 | 391 | 5,730 |

## Findings and recommendations

Serbian industrial companies are mostly run by old-fashioned energy technologies and energy intensive production technologies. Measuring and automation equipments are also old-fashioned and often inoperative. In the last ten years, it is notable that there is a low level of investments in the energy sector. Inadequate maintenance additionally aggravates existing low energy efficiency which is expectable.

Above facts indicate that energy production processes are accompanied by high specific energy consumption and low energy efficiency. Not only is it necessary to start again production capacities in some cases but also to reconstruct plants and installations. In order to improve energy efficiency, it is necessary to make investments which will produce benefits and energy savings on the long run. After resuming production capacities and essential rebuilding of plants and installations, investments in energy efficiency improvement are essential [6].

With the proper choice of plant, equipment and fuel, innovative technologies, and better organization, we can reduce costs and the use of resources and achieve higher quality in the energy production process.

In all mentioned energy sectors, systemic solutions required for improving the current situation in the Republic of Serbia and also in the Province of Vojvodina do not exist.

This particularly refers to the aspect of energy efficiency related to the introduction of energy management system, modern energy and environmentally friendly technologies and regulatory activities aimed at improving the current situation.

General recommendations are the improvement of care (through better maintenance) for plant resources, existence and observing of energy procedures, establishing evidence, measures and other activities which are aimed at systemic changes and continuous care for energy and energy plants and other aspects of boiler house operations. Such systematic approach in changing the situation and attitudes towards these issues is both important and necessary. The change is equally important and indispensable not only for the community itself but also for end users of final energy [2].

## Conclusions

Unfortunately, many opportunities for obtaining substantial energy and financial savings have not been realized in the Province of Vojvodina in spite of availability of well known improvement methods and measures and necessary background data.

The investments in energy efficiency are still great challenge for local authorities, policy makers and business leaders. Unfortunately, many businesses and small and medium size enterprises or especially institutions have misconceptions about the importance of energy management in their operations. Very few public or commercial companies are aware of business benefits generated by efficient energy use and how it can help in cutting costs and keeping them ahead of their competitors.

At the sectoral level, this approach can contribute in creating new incentive programs at the state or provincial level, promote new technological solutions, and provide subsidies for the most urgent and effective investment, and introduce many other possibilities.

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Paper submitted: February 15, 2012
Paper revised: March 19, 2012
Paper accepted: March 27, 2012