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CASE STUDY ON THE USE OF QUALITY MANAGEMENT TOOLS IN IMPROVING BIOMASS-FIRED BOILERS

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***Abstract*—**Globally, energy consumption has constantly increased in the last decades. The production and sale of biomass-fired boilers have considerably gone up in Romania. Considering the increasingly fierce competition in this field, this paper puts forward the use of established quality management methods and techniques in order to improve biomass-fired boilers. The case study has been made for an SME (small- and medium-sized enterprise) in Sibiu, Romania.

***Keywords*—**biomass, costs, customer, heating.

I. INTRODUCTION

THE beginning of the 21st century was marked by a great energetic challenge. Globally, energy consumption has constantly increased, yet reserves of hydrocarbons are only available for a few decades and are concentrated in just a few countries. The import of energetic resources is constantly growing in many countries, and so are the economic and political risks it engenders.

On the other hand, the emissions of greenhouse gasses are increasing, too, mainly as a result of the burning of fossil fuels. Soil and water are more and more polluted, and, consequently, they turn into more and more serious threats to human health and to the possibility of irreversible climate change on Earth. All these have been strong reasons for making and promoting global, European and national decisions directed towards the implementation of renewable sources of energy–solar, wind-powered, hydraulic, biomass-fired, etc. – as environmentally friendly sources [1].

In this context, the production and sale of biomass-fired boilers have considerably gone up in Romania [2]. Considering the increasingly fierce competition in this field, this paper puts forward the use of established quality management methods and techniques in order to improve biomass-fired boilers. The case study has been made for an SME (small- and medium-sized enterprise) in Sibiu, which we have called TERMA Ltd. The names of the companies referred to in this paper are all fictitious.

II. CASE STUDY

The QFD (Quality Function Deployment) analysis shows an organizational environment conducive to the manufacturing of better products at lower costs. The method involves building a "Quality House" in order to organize the processes of product design and manufacturing into more detailed levels.

For the new product to be competitive on the market, we must meet, by appraising the technical feasibility and economic efficiency, the customers' expectations and requirements. For this, we have carried out a detailed market analysis and compiled a customer questionnaire.

Table I shows the comparative costs of the old and newly proposed products, recorded by one of the customers, who owns both heating systems (with similar characteristics) in different locations in Romania. That client of TERMA Ltd. has provided us data in the table I.

TABLE I
COMPARATIVE COSTS OF THE OLD AND NEWLY PROPOSED PRODUCTS

Product	Fuel type	Unit (€=Euro)	Initial costs	Annual maintenance costs	Annual fuel costs
Old	Liquid Fuel	10^3 (€)	11	0.9	17.9
Old	Methane	10^3 (€)	12	0.7	17.8
New	Wood Chips	10^3 (€)	16	0.4	1.7

TABLE II
AVERAGE COST OF HEAT – POSSIBLE ALTERNATIVES ([3], P. 36)

Fuel type	*Price*	*Unit*	*Average cost of heat (Euro/GJ)*
Methane	0.37	€/m^3	20.07
Liquid Fuel	680	€/m^3	20.23
Electricity	0.1	€/kWh	35.42
Wood Chips	80	€/10^3 kg	6.42

Table II presents several fuel prices.

For a building of 800 m^2 with a high of 6 m and a heating system of 240 kW, we have summarized in Table III the calculated results in the case of four alternative types of fuels. To heat up 1 m^3 of water from 10ºC to 55ºC we need the energy Q (in MJ = 10^6 J):

$$\mathbf{Q = 4185(J/kg/^oC) \cdot 1000(kg) \cdot 45(^oC) = 188.3\ (MJ)} \quad (1)$$

TABLE III
COSTS FOR HEATING UP 1 M^3 OF WATER FROM 10^{0}C TO 55^{0}C – CALCULATION OF FUEL CONSUMPTION IN FOUR ALTERNATIVES

Calculation data	*Methane*	*Black Oil (Liquid Fuel)*	*Electricity*	*Wood Chips*
Caloric power q **or electricity needed** E **(taken from [3])**	**q** = 35.5 (MJ/m^3)	**q** = 42.035 (MJ/kg)	**E** = 60 (kWh)	q = **14.655 (MJ/kg)**
Real approximate price (all fees includes – transportation, maintenance, distribution, etc.)	0.6 (€/m^3)	0.907 (€/kg) → → 680 (€/m^3)	0.1 (€/kWh)	**0.08 (€/kg)**
Plant yield η **(see [3])**	85%	80%	90%	**85%**
Fuel needed	**Q/q/η** = 6.3 (m^3)	**Q/q/η** = 5.6 (kg)	**E/η** = 66.67 (kWh)	Q/q/η **= 15.11 (kg)**
Fuel cost	**2.33 (€)**	**5.08 (€)**	**6.67 (€)**	**1.21 (€)**

So, we used the value obtained in relation (1) in the calculation made in table III. For the marketing research, we eliminated the most expensive variant of the boiler, those with electricity.

III. THE BENCHMARKING AND THE QUALITY HOUSE

Following the marketing research, we identified the customers' requirements with regard to the product and the importance of the required characteristics.

Benchmarking is the method and/or process by means of which one can determine (through quantification) who is the best in a field, which sets the standards and in what this standard consists ([4], p. 87).

After centralizing the marketing research results, we selected from product functions the most requested by customers. Then, we gave scores for the importance of these requirements (Table IV).

TABLE IV
IMPORTANCE OF CUSTOMER REQUIREMENTS FOR THE BOILER

Product characteristics	*Score (points)*
The boiler will heat quickly	4
It will have easy access to fuel	4
It will work with cheap fuel	5
It will not pollute	3
It will have a short investment payback period	4
It will work safety	5

The scale was: 1 point for a "very unimportant" characteristic, 2 points for "unimportant", 3 for "neutral", 4 for "important" and 5 for "very important".

The questionnaires were designed in order to enable customers to point out how the TERMA products as well as those of its two stronger competitors – ALFA and BETA – meet their requirements; thus, the so-called "client benchmarking" was performed. The scores given by clients are centralized in Table V. In order to follow the methodology for building the Quality House, we rounded the averages obtained from customer opinions to the used scale values: 1, 2, 3, 4, or 5.

TABLE V
SCORES GIVEN BY CLIENTS (ROUNDED VALUES)

	PRODUCER (Fuel type)		
REQUIREMENTS The boiler will…	**TERMA (Wood chips)**	**ALFA (Methane)**	BETA (Liquid fuel)
… heat quickly	**2**	**4**	5
… have easy access to fuel	**2**	**4**	3
… work with cheap fuel	**5**	**2**	3
… not pollute	**5**	**3**	2
… have a short investment payback period	**5**	**4**	3
… work safety	5	3	2

The products of the company were tested as well. The technical data were determined for the three products; thus, technical benchmarking was performed. Its results are presented in Table VI.

TABLE VI
TECHNICAL BENCHMARKING RESULTS

Technical performance specification	*TERMA*	*ALFA*	*BETA*
Constructive model/ FUEL	Hot water boiler/ WOOD CHIPS	Hot water boiler/ METHANE	Hot water boiler/ BLACK OIL
Level of CO_2 emissions	baseline	20 times the baseline	30 times the baseline
Environmental hazards caused by fuel transportation	low	average	high
Yield (%)	85	85	80
Expenses for fuel storage and transportation	average	average	average
Type of fuel supply	Semi-automated cycle	Automated cycle	Semi-automated cycle
Investment costs of 240kW central heating (€)	18.000	11.000	12.000
Annual maintenance costs (€)	400	700	900
Costs for heating up 1 m^3 of water from 10^{0}C to 55^{0}C (€)	1.21	2.33	5.08
Overall dimensions (length/ width/ height)	1.01 m/1.20 m/1.57 m	1.00 m/0.89 m/1.40 m	1.09 m/0.67 m/1.25 m
Weight (kg)	558	487	456

Considering these data, we obtain the QFD matrix (Fig. 1).

After calculating the importance indices of product characteristics, we determined the following measures to be taken by TERMA ltd.:

Customer Requirements — The boiler will...	Importance of Customer Requirement	Product Characteristics: Constructive model/ Fuel	Level of CO_2 emissions	Environmental hazards caused by fuel transportation	Yield [%]	Expenses for fuel storage and transportation	Type of fuel supply	Investment costs of 240kW central heating	Annual maintenance costs	Costs for heating up 1 m^3 of water from 10^0C to 55^0C	Overall dimensions	Weight [kg]	Customer's Benchmarking: TERMA	ALFA	BETA	Objectivs for products improvements (maximum of scores)
… heat quickly	4	3	0	0	9	0	1	0	0	3	0	0	2	4	5	5
… have easy access to fuel	4	3	0	0	0	9	1	0	0	0	3	1	2	4	3	4
work with cheap fuel	5	0	0	0	1	3	0	1	3	9	0	0	5	2	3	5
… not pollute	3	1	9	3	0	0	0	0	0	0	0	0	5	3	2	5
… have a short investment payback period	4	0	1	0	0	0	0	9	1	0	0	0	5	4	3	5
… work safely	5	1	3	1	0	0	3	0	0	0	0	0	5	3	2	5
Importance of Product Characteristics		32	46	14	41	51	23	41	19	47	12	4				
Technical Benchmarking																
TERMA		Hot water boiler/ Wood Chips	baseline	low	85	average	Semi-automated cycle	16000 €	400 €	1.21 €/kg	1.01m/1,20m/ 1.57m	558kg				
ALFA		Hot water boiler/ Methane	20 times	average	85	average	Automated cycle	12000 €	700 €	2.33 €/m^3	1.00m/ 0.89m/ 1.40m	487kg				
BETA		Hot water boiler/ Black Oil	30 times	high	80	average	Semi-automated cycle	11000 €	900 €	5.08 €/l	1.09m/0.67m/ 1.25m	456kg				

Fig. 1. The Quality House (QFD Matrix)

1) Reducing the initial costs of the investment: adopting a strategy of product renewal, the target market segment consisting of companies that already have their own heating system, to which a boiler with wood chips and the other parts of a biomass-fired central heating system can be accommodated while preserving district heating and existing facilities.

2) Reducing fuel storage and transportation costs: another category of customers targeted by TERMA Ltd. includes companies belonging to the wood processing industry, where the production process generates wood waste. These companies usually have dedicated facilities (in compliance the laws in force) for the safe storage of waste.

Thus, following these measures, three priority market segments, on which the company will mainly focus its marketing program, take shape (Fig. 2).

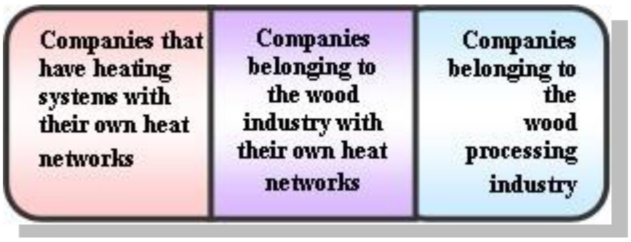

Fig. 2. Market segments targeted by the company in a first stage.

3) Expanding on the rest of the industrial market: the product promotion strategy will use, in order to persuade customers, four basic advantages of biomass-fired heating systems:

a) Cheaper heat;
b) Immediate environmental benefits;
c) Long-term climate protection;
d) Easy access to fuel.

4) Applying the concept of business to business marketing: industrial customers will be provided with biomass-fired heating systems that bring long-term economic benefits. They will be able to build urban or rural heating systems, with short heat networks, to service other utilities (administration buildings, schools, hotels, guesthouses, residential areas, greenhouses, etc.).

5) Using the multiple win situations in the future partnerships: TERMA Ltd. must involve in clusters or networks that develop sustainable projects in the field of efficient use of biomass.

An example of good practice is the intention of partners Corbion, Uniper, RWE and the Port of Rotterdam Authority to establish a biorefinery [5] that will convert wood chips in two categories of products: fuel and feedstock for plastics.

Ethanol will be the fuel obtained in this bio-refinery and lactic acid PLA the feedstock for plastics and other chemical products [5].

Polylactic acid or polylactide (PLA) is a biodegradable thermoplastic aliphatic polyester [6] derived from biomass. Since 2010, it is one of the most used bioplastics of the world [6].

The bio-refinery of the four previously mentioned partners will limit the consumption of fossil combustibles and reduce the CO_2 emissions [5]. Another advantage is the circular shape of the entire process that allows the recycling of all residues [5]. Of course, it is a win situation for each business partner.

This type of partnerships explains why "about 75% of all biofuels consumed in the EU" in 2015 "were produced within the Union" [7].

TERMA ltd. has to find partners with experience in the use of biomass, in order to design and offer sustainable products for small, medium and large enterprises.

IV. Conclusions

Because of escalating environmental and climatic disturbances on a planetary scale, caused by modern human activities, the worries expressed by the population and the concern for protecting the natural environment have increased significantly in recent years.

The QFD matrix is an effective technique for the presentation and processing of data structures related to product quality meant to protect the natural environment and extremely useful in production.

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