COMPARATIVE ANALYSIS OF PRODUCTION AND PROCESSING OF GLASSWARE AND TECHNICAL GLASS

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The article is an integrated approach of energetic efficiency and environmental impact in the field of glass industry. The article is also targeting at improving of energetic and economic efficiency, a reduction of the environment impact and new equipment implementation in the field of glass manufacturing industry in Romania. The model aims at increasing energy and economic efficiencies and decreasing environmental impact, as well as finding new clean technologies for the Romanian glass manufacturing industry. New methodologies techniques and technologies and also the new developed evaluation models might have a replication potential for other industrial sectors.

Keywords: glass, analysis, energy, economic, environment

1. Introduction

For elaboration of solutions for technical, economic and environmental optimisation of processes from the glass industry it is necessary to highlight the main characteristic aspects of the today's technologies for production and processing of glassware and technical glass. It is important to know all the technological processes, phases and consumption zones that have low energy efficiency and high pollutant emissions.

In this respect it is necessary to analyse different technologies taking into consideration the following: type of technology, different specific aspects, main phases of the technological processes, main equipment and technological devices specific to processes, characteristics of raw materials and final products.

There are different technologies for glass production and processing including: continuous processes (for large scale production) and discontinuous processes (for small scale production).

From the point of view of energy use for the glass furnaces (the main equipment from the technological process) there might be used fossil fuels (usually for continuous processes) and electricity (for discontinuous processes).

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2. Characteristic aspects of technologies for glassware production and processing

The glassware includes a wide range of different products. The main characteristic of these products is the exterior design. That is why the glassware should have high optical quality, should be transparent and/or without visible flaws. The colored glassware should have clear and uniform colors. There is also important the products should be stable from chemical point of view. The glassware products have a large range of composition, see table 1 [1].

Table 1

Composition of glassware

Nr.crt.	SiO_2	Al_2O_3	CaO	MgO	K_2O	Na_2O	PbO	ZnO	As_2O_3	Sb_2O_3	TiO_2	BaO
1.	75	-	9-9,5	-	-	15,5-16-	-	-	-	-	-	-
2.	73-75-	-	8,5-10,5	-	-	15-16	-	-	-	-	-	-
3.	74,5	0,5	6,5	2	2,5	14	-	-	-	-	-	-
4.	72,18	1,12	5,83	3,17	-	16,65	-	-	-	-	-	-
5.	62	-	-	-	16	2	19	1	0,5	-	-	-
6.	55,5	-	-	-	14,5	-	30	-	0,5	-	-	-
7.	60	-	-	-	10	10	-	10	-	0,3	-	10
8.	58,7	18,0	10	11	-	-	-	4	0,8	-	0,8	4

For manual glass production there may be used composition 1. For automatic devices composition 2 should be used. In these type of glass approximately 3 % of CaO can be replaced with MgO and it is recommended to introduce 1 % of B_2O_3, 0.5 % of BaO and up to 3 % of K_2O. In this way we have composition 3 for manual production or composition 4 for automatic production.

For art and design products there is used crystal glass that has in composition important quantities of PbO. The composition of some crystal glass is: SiO_2 = 55-62 %; K_2O = 14.5-16 %; Na_2O = 2 %; PbO = 10-30 %. The crystal glass with composition 5 has the refraction index of 1.531 and contains no PbO. Composition 8 is used for thermo resistant products [2].

3. Characteristic aspects of technologies for technical glass production and processing

There is a large variety of technical glass, and every type has its own characteristics depending on domain of utilisation and its characteristics. Therefore, there will be presented main aspects from the composition and technological process points of view.

Borosilicate glass

Borosilicate glass contains B_2O_3 and a great per cent of SiO_2. The typical composition of borosilicate glass is: 70-80 % SiO_2, 7-15 % B_2O_3, 4-8 % Na_2O or KaO and 2-7 % Al_2O_3. Compared to other type of glass this type has better chemical and electrical properties and low value for the coefficient of linear thermal dilatation.

This type of glass is characterised by high resistance to chemical corrosion and to temperature variation.

The borosilicate glass has a wide range of utilisation. It can be used in the chemical industry, pharmaceutical industry, for production of special lighting equipment, for production thermo resistant glassware, for cooking devices, etc. Another use of borosilicate glass is for optic fibre production. There should be mentioned that for optic fibre production there are now composition with a low content or without Bohr.

Optic glass with selective absorption

Optic glass is the glass that is perfect transparent and homogenous with and any chemical composition. The main optical characteristics of this glass are refraction and dispersion.

This type of glass should satisfy the following conditions:

- Good chemical homogeneity;
- Good physical homogeneity;
- Very high transparency;
- Very low number of gas bubbles;
- High chemical stability.

The optical devices used in different areas have different type of optical glass with different properties, and thus, different composition. Table 2 presents optical properties and composition for some optical glass. Apart from these composition, there are also produced glass with very high refraction index (more than 2) [2].

Table 2

Composition of technical glass

Glass	Optical constants		Containt (%)											
	n_D	$(n_F-n_C)\ 10^{-4}$	SiO_2	B_2O_3	Al_2O_3	As_2O_3	PbO	BaO	ZnO	CaO	MgO	K_2O	Na_2O	F
Crown light	1,4700	701	53,30	16,20	8,8	0,2	-	-	-	-	-	16,30	-	5,30
Crown	1,5100	805	72,00	8,15	-	0,20	-	-	-	1,55	0,45	10,45	7,20	-
Crown with Ba	1,5688	1015	49,55	4,80	-	0,20	2,60	21,55	12,50	-	-	7,55	1,25	-
Crown heavy	1,6126	1046	32,70	13,20	3,15	1,60	-	45,90	3,50	-	-	-	-	-
Flint light	1,5480	1195	61,00	-	-	0,20	26,30	-	-	-	-	8,00	4,50	-
Flint	1,6169	1691	47,00	-	-	0,20	46,40	-	-	-	-	6,35	-	-
Flint with Ba	1,6259	1601	41,85	-	-	0,20	33,40	11,55	5,25	-	-	8,25	-	-
Flint heavy	1,7550	2743	31,60	-	-	0,20	6,35	-	-	-	-	2,85	-	-

4. Hypotheses used for comparative analysis

Utilisation of energy, economic and environmental analysis imposes to know a series of data regarding the technological processes. There should be performed the monitoring of all energy flows and pollutant emissions for a long period of time. The recommended duration for monitoring is the complete technological cycle, for the glass industry it is 1 year [4].

There should be mentioned that these data characterises the activity of the entire factory and not only one equipment or device. All monitoring data should include direct and indirect energy consumers.

After the monitoring is complete, there should be analysed all data in order to calculate different indicators, i.e. specific energy consumption, specific pollutant emissions, etc.

In Romania companies from this industrial sector have not yet installed and used an on-line monitoring system. Such a system can be used not only for increasing efficiency but also decreasing environmental pollution.

The entire process of glass production can be divided into the following phases:

- Preparation of raw materials;
- Melting and conditioning in the furnace;
- Moulding;
- Thermal treatment;
- Finishing, sorting, packing.

All the above mentioned phases are similar from the point of view of quantity of materials, apart from the last one which includes rejected products [5].

The per cent of rejected products is different depending on the type of glass. These rejected products are then re-used inside the factory as raw materials.

For applying the proposed comparative analysis there have been chosen three types of glass:

- Glassware from a large capacity production line (1 tonne/hour of gross glass production);
- Glassware from a small capacity production line (500 kg/12 hours of gross glass production);
- Optical glass (1200 kg/48 hours of gross glass production).

The main phases of the production process are the same, but the production capacities and some characteristics of some equipment are different from one type to another.

Glassware from a large capacity production line uses a continuous process, mechanically controlled with modern equipment. The furnace uses fossil fuel, and has automatic raw material feeding and final product packing. The furnace for thermal treating uses electricity and the process lasts 8 hours.

Glassware from a small capacity production line uses a discontinuous process and many operations are performed manually. The furnace uses fossil fuel and has manual raw material feeding and final product packing. The furnace for thermal treating uses fossil fuel and the process lasts 24 hours.

Optical glass production is a special technology where many operations are performed manually. The process is also a discontinuous one and lasts 48 hours. The melting furnace uses fossil fuel with partially manual partially automatic raw material feeding. The furnace for thermal treating uses electricity and the process lasts 30 days.

5. Results of comparative analysis

Tables 3-5 present the main results of calculation for the glassware from a large capacity production.

Table 3

Results for glassware from a large capacity

No	Specific energy consumption	UM	Preparing	Melting	Thermal treatment	Finishing	Total
1	Natural gas	Nm^3/t	0	333	0	2	335
2	Electricity	kWh/t	70	150	350	0	570
Specific equivalent consumption of primary energy:			27.5	GJ/t	785.9	mcn/t	

Table 4

Results for glassware from a large capacity

Nr	Pollutant emissions		Value
1	CO_2	kg/t	1155.8
2	CO	kg/t	28.9
3	NO_2	kg/t	17.3
4	NO	kg/t	14.0

Table 5

Results for glassware from a large capacity

Nr	Costs for net production		Value
1	Raw materials	lei/t	489.2
2	Energy	lei/t	778.5
3	Other costs	lei/t	**950.0**
4	Total 1	lei/t	2217.7
5	Eco-tax	lei/t	80.9
6	Total 2	lei/t	**2298.6**

[grey] Values in kg/t, GJ/t, Nm^3/t and lei/t are for 1 net tonne of glass production.
Values in kg/t, kWh/t, Nm^3/t and lei/t are for 1 gross tonne of glass production.

Tables 6-8 present the main results of calculation for the glassware from a small capacity production.

Table 6

Results for glassware from a small capacity

No	Specific energy consumption	UM	Preparing	Melting	Thermal treatment	Finishing	Total
1	Natural gas	Nm^3/t	0	1000	60	0	1060
2	Electricity	kWh/t	0	100	0	0	60
Specific equivalent consumption of primary energy:			58.7	GJ/t	1677.9	Nm^3/t	

Table 7

Results for glassware from a small capacity

Nr	Pollutant emissions		Value
1	CO_2	kg/t	3208.2
2	CO	kg/t	91.3
3	NO_2	kg/t	34.0
4	NO	kg/t	30.7

Table 8

Results for glassware from a small capacity

Nr	Costs for net production		Value
1	Raw materials	lei/t	489.2
2	Energy	lei/t	1677.0
3	Other costs	lei/t	1950.0
4	Total 1	lei/t	4116.2
5	Eco-tax	lei/t	224.6
6	Total 2	lei/t	4340.8

Values in kg/t, GJ/t, Nm^3/t and lei/t are for 1 net tonne of glass production.
Values in kg/t, kWh/t, Nm^3/t and lei/t are for 1 gross tonne of glass production.

Tables 9-11 present the main results of calculation for the technical glass production.

Table 9

Results for technical glass

No	Specific energy consumption	UM	Preparing	Melting	Thermal treatment	Finishing	Total
1	Natural gas	Nm^3/t	0	4500	0	0	4500
2	Electricity	kWh/t	400	0	8000	600	9000
Specific equivalent consumption of primary energy:			1273.3	GJ/t	36380.1	Nm^3/t	

Table 10

Results for technical glass

Nr	Pollutant emissions		Value
1	CO_2	kg/t	41837.2
2	CO	kg/t	1260.0
3	NO_2	kg/t	399.9
4	NO	kg/t	378.2

Table 11

Results for technical glass

Nr	Costs for net production		Value
1	Raw materials	lei/t	43027.6
2	Energy	lei/t	35999.6
3	Other costs	lei/t	12950.0
4	Total 1	lei/t	91977.2
5	Eco-tax	lei/t	2928.6
6	Total 2	lei/t	94905.8

Values in kg/t, GJ/t, Nm^3/t and lei/t are for 1 net tonne of glass production.
Values in kg/t, kWh/t, Nm^3/t and lei/t are for 1 gross tonne of glass production.

6. Conclusions

The quantities of raw materials and rejected products are in conformity with the technology, and using these quantities results the composition of the glass and the flue gasses. The energy consumptions for the melting process have been estimated using the available data. The obtained values can be considered as being accurate for every analysed type of glass [6].

The input data for every type of glass have been analysed in order to use them for calculation of energy, economic and environmental criteria.

The output data from the analysis are the following:

- Specific equivalent energy consumption (natural gas), which includes effective consumption of natural gas and electricity;
- The values for the pollutant emissions;
- Total specific production costs, calculated with and without eco-tax.

From the analysis of the results the might be drawn the following conclusions:

- The three chosen types of glass differ one from another by all aspects of this complex analysis;
- The obtained values for the specific energy consumptions are close to those indicated in literature, and are between 0.5 and 50 Nm^3 for 1 kg of final product;
- Comparing the two production lines of glassware (large and small) shows that using the large one is more efficient from energy and economic points of view and has lower impact on the environment;
- Comparison between the glassware and optical glass shows the large difference in quality between the two types of glass.

R E F E R E N C E S

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