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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

Improving Energy Efficiency and Promoting Renewable Energy in the Agro-Food and Other Small and Medium Enterprises (SMEs) in Ukraine
Project GF/UKR/11/004

REPORT

Energy Efficiency Benchmarking in the Vegetable Oil Subsector of the Ukraine's Agro-Industrial Sector

Drafted by: M. Maslikov

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SUMMARY

This report has been prepared in the scope of the Global Environmental Facility (GEF) and UN Industrial Development Organization (UNIDO) "Improving Energy Efficiency and Promoting Renewable Energy in the Agro-Food and Other Small and Medium Enterprises (SMEs) in Ukraine" Project.

This analysis is primarily aimed at identifying energy efficiency of the agro-food enterprises, in particular, those in the vegetable oil sector, via application of benchmarking. In future, the approaches, methods and findings of this analysis will be disseminated among all the stakeholders.

This report covers the findings of energy efficiency benchmarking in the vegetable oil sector through comparing specific indicators of energy consumption per unit of output. These indicators are compared both among the sector enterprises and the best practice enterprises of the relevant profile.

We hope that this report would promote benchmarking and provide an impetus to agro-food enterprises in Ukraine to apply it.

INTRODUCTION

The growing competition encourages domestic enterprises to seek new ways and methods to raise management efficiency, ensure stable competitiveness based on identifying and launching of innovations. The pressure of energy costs has become so high that threatens not only competitiveness of the enterprises but rather their existence.

Benchmarking is an effective tool enabling the company to continuously increase productivity, improve performance, be energy efficient.

Benchmarking is the process of analysis and comparative assessment of the methods used in an organization to carry out its functions. This assessment may be conducted either inside an enterprise or organization (comparison of individual units or levels) or by comparing an enterprise performance results with those of other enterprises. Based on the comparison findings, the enterprise may identify weaknesses in its production processes, find new effective ideas and select the best ways to improve based on the other companies' lessons learned.

Benchmarking stipulates ongoing analysis and assessment of the existing methods of production used at an enterprise through comparing it with the best internal and external practices with further launching of the most effective approaches.

Benchmarking is a very common practice in the world. The main idea underlying benchmarking emerged at the beginning of XX century. The most striking example was Henry Ford's visit to the slaughterhouse in Chicago. The carcasses hung on the hooks and the conveyor moved them from one worker to another with each worker doing his portion of processing. This manufacturing method inspired Mr.Ford and he launched it in the form of automobile conveyor.

The term "benchmarking" was introduced by Xerox in 1979 and within the fifteen years benchmarking spread all over the world at an incredible speed with its applications being available almost in all spheres of manufacturing and service provision. This analysis may be applied to any enterprise or organization operations, starting with performance of first aid stations and fire-fighting crews and ending with the strategic benchmarking at Coca-Cola, Sony, Kraft, etc. The enterprises establish benchmarking associations to perform unbiased analysis, where the main goal is its absolute confidentiality. So, enterprises may share the best practices while not disclosing their business secrets.

They are the following associations *inter alia*:

The Association for Benchmarking Health Care

ISO Benchmarking Association

Electric Utility Benchmarking Association

Knowledge Management Benchmarking Association

Technology Assessment Benchmarking Association and

Unfortunately, the threat of hostile takeover induces enterprises to protect all their information related to energy consumption and product output, therefore benchmarking applications in Ukraine are very limited.

POTENTIAL ROLE OF BENCHMARKING IN INCREASING ENERGY EFFICIENCY OF AGRO-FOOD ENTERPRISES

Energy efficiency of industrial enterprises in Ukraine has been and remains low. This is a result of the long-run decline in production, and cheap fuel and energy upon production revival. However, the situation with the energy source prices has dramatically changed. In the latest five years, the cost of energy for Ukrainian enterprises has grown:

eight times - for natural gas;

twice – for electricity.

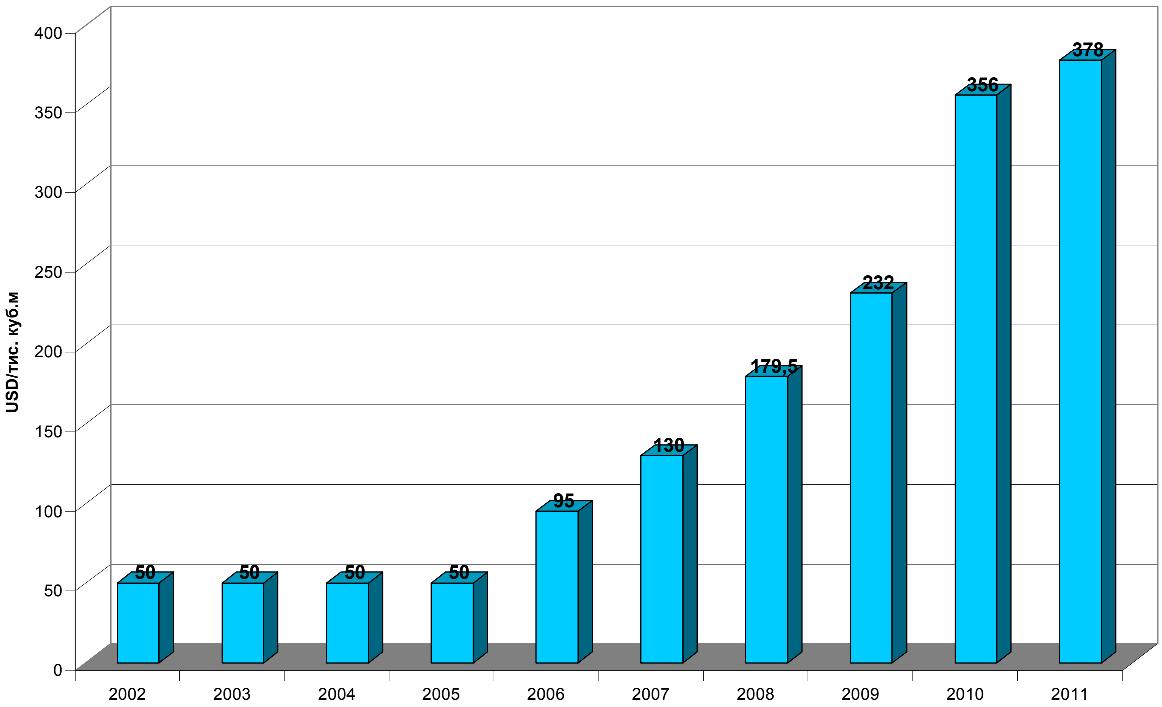

Diagram 1. Dynamics of natural gas price increase.

Every enterprise endeavors to save energy in various ways. However, the lack of experience in taking certain steps or wrong notion of the expected savings result in overspending of the finance, which are extremely scarce. This is the consequence of the lack of energy management systems and the lack of energy efficiency benchmarking.

Significant energy consumption values are inherent to the food production. This is attributable to the need of product thermal processing and sanitary rules, and cause an extensive use of thermal energy and natural gas, at the same time product preservation requires cold generation thus causing high electricity consumption.

And, the enterprises' generating facilities are mainly obsolete. For instance, steam generation by 25-year-old boilers characterized by lower than 80% coefficient of efficiency is commonplace. Those boilers are manually controlled and the only measurement device is a steam pressure manometer and it is used to control the boiler accordingly. As concern cold generation, compressor refrigerating systems not always correspond to compressor performance capability, as the summer air temperatures have grown and the refrigerating systems are worn out. This causes overconsumption of electricity, as the compressors work in the inefficient mode.

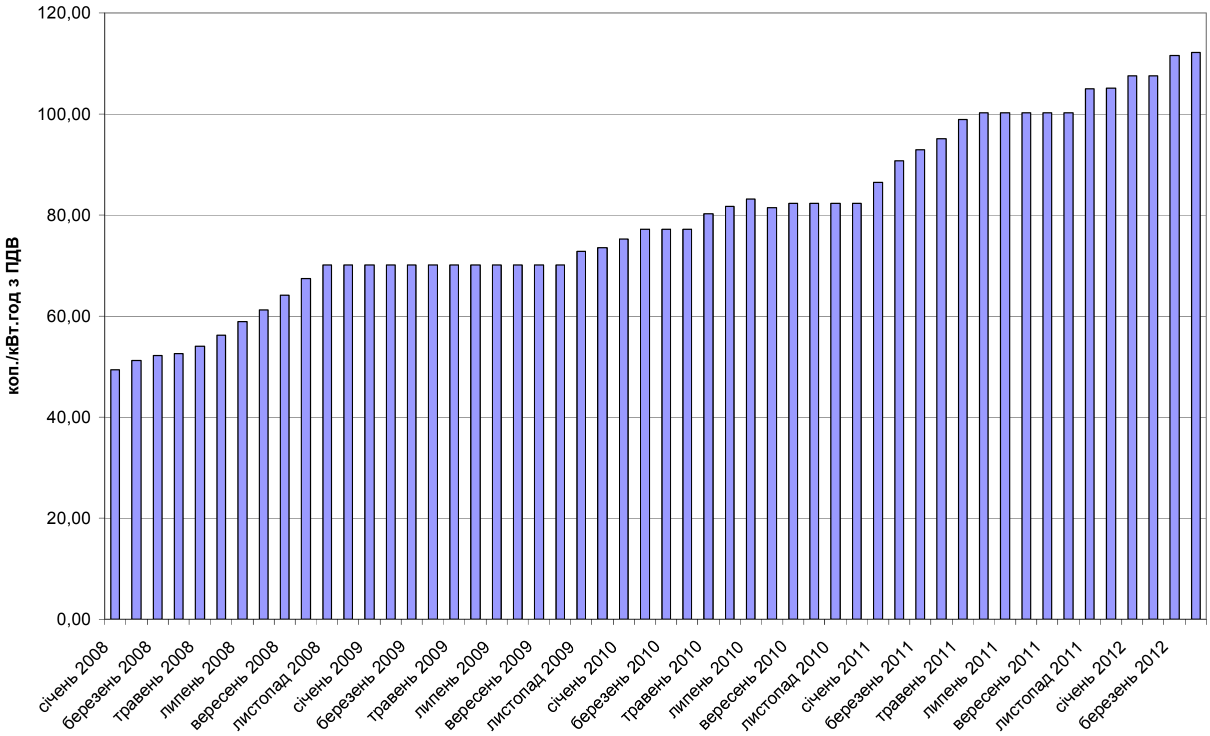

Diagram 2. Dynamics of electricity price increase

Energy efficiency benchmarking provides the opportunity to find out how effectively an enterprise uses energy resources as compared to its competitors and the best similar enterprises in the sector. It helps to identify the spots where energy is excessively consumed. For instance, what stage energy is wasted at: at generation, transportation or when consumed for product manufacturing?

However it is not essential to use only competitive or sectoral benchmarking. This method is flexible and it is possible to compare enterprises from different sectors, although not in full, but by their certain processes, workshops or sectors. For example, the following issues may be analyzed:

- How much more energy do we consume for heating office premises than others? Why? What is the least cost solution to this problem?
- Why do we consume more electricity to refrigerate products than other enterprises? What is the best solution to reduce this indicator value?
- What potential percentage reduction in electricity bills may we achieve through application of the three-zonal tariff? Why do some enterprises manage to reach higher savings than others?

- What secondary sources of heat energy do other enterprises use for hot water supply?

They are only several issues that benchmarking may help to address, however, an economic effect upon receipt of benchmarking findings and launching of best practices offers an enterprise significant energy saving opportunities.

Energy Efficiency Benchmarking Methodology

Energy efficiency benchmarking is based on comparing of energy spending in actual values per unit of output.

A model benchmarking curve reflects enterprise efficiency as a function of total product output at similar enterprises or as a function of total number of enterprises operating at this energy efficiency level or lower.

The most ineffective enterprises are portrayed in the left lower part of the curve with the most effective ones being represented in its upper right part. Benchmarking curve shapes will differ for various industries and regions. However, as a rule, several enterprises are most efficient while several enterprises are very inefficient. This situation is expressed in the form of steep region of the curve in the first and the last deciles, respectively. Between these two polar groups, the curve is usually depicted in the form of broad linear dependence between energy efficiency and cumulative output (number of enterprises). This relation could be used for approximate assessment of energy saving potential, which is defined as 50% of the difference between efficiency in the first and the last deciles.

The most efficient enterprise within the benchmark curve is taken to identify the Best Practicable Technology (BPT). Physical product output should be used, where possible, to identify an enterprise location by deciles. Where the data is lacking or unreliable, this approach may not be applied and deciles are formed on the basis of the number of enterprises.

Two other types of analysis could be applied to contribute to the enterprise-related data. They are based on average Specific Energy Consumption (SEC) per unit of output for the sector, region or country (1 type) and Energy Efficiency Index (EEI) developed by Phylipsen et al. (2002) and Neelis et al. (2007) in the Netherlands (II type).

SEC analysis employs an average current SEC value at the national or regional level depending on data availability. Where no data is available, statistics provide only the basis for evaluation of the energy efficiency. Statics enables analysis of the information on the use of energy resources at industry-specific (sector-specific) level including all production processes in a certain sector.

National EEI assessment j for sector x with production processes i is accomplished according to the following equation:

$$EEI_{j,x} = \frac{TFEU_{j,x}}{\sum_{i=1}^{n} P_{i,j} \times BPT_{i,x}} \qquad (1)$$

where TFEU – actual use of energy in sector *x*, according to the energy balance compiled by the International Energy Agency (IEA) (Petajoule (PJ) per year),

P – output of product *i* in country *j* (thousand tons (Mt) per year),

BPT – the best practicable technology for manufacturing product *i* (Gigajoule (GJ) per ton of products)

N – number of products to be pooled.

If the country's energy efficiency is the highest in the world, all processes for the sector (industry) would take BPT values. In this case, EEI of the country or region is equal to 1.

These approaches may be applied to identify energy efficiency potential for sector *x* in country or region *i* as follows:

$$Potential = 1 - \frac{International\ benchmark\left(BPT\ or\ SEC_{lowest,x}\right)}{SEC_{j,x}} \quad (2), \text{ or}$$

$$Potential = 1 - \frac{EEI_{lowest,x}}{EEI_{j,x}} \quad (3)$$

Therefore, benchmarking provides the capability to evaluate energy efficiency of an individual enterprise as compared to other enterprises and economic sector as a whole, and to identify energy saving potential.

BRIEF DESCRIPTION OF THE INDUSTRY AND ITS SPECIFIC FEATURES IN TERMS OF ENERGY SAVING

Vegetable oil industry in Ukraine is among the most important ones in the food sector considering its powerful export potential, and production output, and energy consumption volumes. 10% of the total food output falls onto it. The industry manufactures the following products: various types of raw and refined vegetable oils, hydrogenised fat, margarines, mayonnaises, soaps, glycerin. Biofuel production has been spreading at the industry's enterprises recently.

Sunflower prevails (over 90%) among multiple oil plants growing in Ukraine, while the outputs of rape oil, corn oil and other vegetable oils are far lower. Ukraine is among the leaders by oilseed output (8.5 million tons in goal weight) as well as sunflower oil (3.35 million tons). Ukraine also remains a permanent leader in sunflower oil exports – 2.7-2.8 million tons, or 54% of the world's sunflower oil exports. In 2011-2012 marketing year, total output of the main types of oil plants in Ukraine would be over 12 million tons subject to the domestic processing capacity of 11 million tons as of 1 September 2011 [1].

According to Ukroilprom Association, the oil production in Ukraine grows, with the basis of the produced oil being unrefined sunflower oil (see table 1).

Vegetable oil production and use, thousand tons (not considering oil factories)

	2011	2010	% of the previous year
Vegetable oil output,	3,244.0	3,011.0	107.7
Including sunflower oil	3,174.0	2,945.5	107.8
Refined oil	593.0	569,1	104.2
Bottled oil*	225.6	222,1	101.6
Sunflower oil exports	2,683.3	2,702.5	99.3
Sunflower exports	406.1	410.0	99.0

Over 90% of the total sunflower oil output is concentrated at 25 largest oil-and-fat manufacturers.

Oilseeds are stored in elevator silos – 10 to 40 meters high, 5 to 10 diameter cylindrical tanks, where seeds are stored in bulk. The heat is developed in silos due to biological processes (self-warming).

To prevent seeds damage, the developed heat is released by aeration from the silos using cool air at the temperature 1 to 2°C. The seeds are cooled down to 5 °C to extend their storage period.

Once sunflower seeds are delivered to production site, they are cleaned from impurities in a trommel – a drum consisting of two nets with different orifice sizes. This way both large (residual leaves) and small (sand) impurities are removed. To reduce excessive moisture and facilitate seeds cleaning, seeds are dried in tower driers or drum driers.

Unhusking of seeds with decorticating-fanning machines provides the capability to separate seed kernels that contain main portion of oil from husks where oil content is low. The husk is hulled and then fanned off the kernels.

Most factories incinerate husk (its mass accounts for 20-25% of the total seed mass) in solid fuel boilers, cyclone boilers or upon thermochemical conversion into gas with thermal power generation. This provides the opportunity for natural gas saving. Pellets (granules) are also formed of husk to further utilize them as biofuel. The problem with husk incineration is the large amount of gluey and abrasive ash and large content of hazardous compounds in flue gases.

Seed kernels are crushed at roller breakers to facilitate further processing and oil release. The received material (oil seed meal) passes two-stage thermomoist processing:

- Inactivation in a screw conveyor with hot water at 60 °C to inactivate oil seed meal ferment system;
- Cooking in oil seed cookers at 105°C to destroy cells and facilitate oil release.

Cookers consist of 6-8 vapor-filmed steaming vats and mixers. Oil seed meal is supplied to them from the upper vat and is cooked little by little while being poured down to the lower vats.

Cookers are main consumers of thermal power in pressure oil production.

Once cooked the generated mass (squash) immediately moves for pressing. The first pressing (forepressing) takes place at expellers. Received oil moves for refining. Forepressed cake contains approximately 20% oil. It is fed to second level presses – expellers. The second-stage pressure oil goes to refining, and forepressed cake (5-9% oil content) – for mixed feed production.

Extracting is used more often instead of expeller pressing. Forepressed cake is shaped into granules and fed to a column-type or belt-type extractor, where a pre-heated solvent at 30 to 40°C (gasoline, hexane, nefras, for aromatic oils – ethyl alcohol) is added. Solvent is heated with steam in a shell-and-tube or plate-type heater. Oil dissolves in a solvent, therefore its residues are extracted from cake. Oil solution in solvent (miscela) and defatted protein residues (protein meal) are obtained as a result of extracting.

The solvent is evaporated from miscela at triple-effect distillation vacuum evaporator. Each tube film distiller is heated with saturated steam, and solvent steam is fed out to vacuum condenser. To absorb residual solvent, superheated steam is supplied to a final distiller. Solvent steam is condensed, received solvent is used for repeated extraction. Oil, from which solvent has been evaporated (extracted oil), is used for manufacturing paints, oil varnishes, etc.

Protein meal also contains rather much solvent. To remove solvent, the protein meal is treated with heat in a toaster, which resembles a cooker by structure, bit consists of 10 vats, where saturated steam (to their vapor films) and superheated steam (directly to vats) is fed to absorb evaporated solvent. The solvent-free protein meal is used as livestock fodder additive.

The solvent is reused. To this end, the mixture of solvent vapors and water from distillers and toaster is condensed in vacuum condensers (part of them is cooled with coolant from refrigerating machines) and separated in precipitation tanks.

Distillers and a toaster are main consumers of thermal energy in oil extraction production.

Besides unrefined oil, oil-and-fat enterprises produce refined (bottled and bulk) oil. However, total heat and electricity spent to manufacture these products is significantly lower – this is attributable both to lower unit spending and smaller volumes of manufacturing (table 1).

See Diagram 1 for estimated breakdown of thermal energy for oil manufacturing and refining.

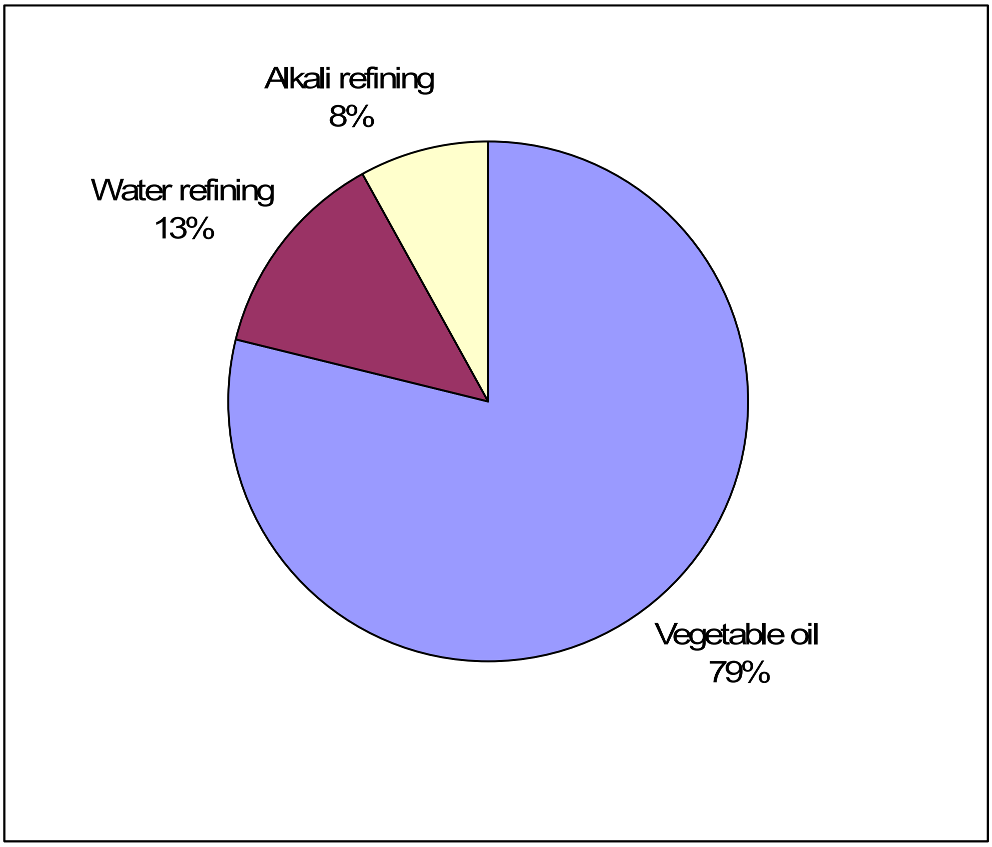

Diagram 3. Heat consumption breakdown by oil types

Therefore, the main portion of energy could be saved in unrefined oil production process, so this production process should be the primary benchmarking target.

Specifics of unrefined oil production in terms of energy consumption:

1) **seasonality of operations** – the plant works 270-330 days a year depending on the input seeds volume, the rest of time is a maintenance period;

2) **high heat and electricity demand** with relatively insignificant daily and monthly fluctuations during the period of oil extraction;

3) **various heat carriers** available in a factory heat supply scheme;

4) **explosive volatile compounds** present (solvent and its vapor)

5) **large number of reusable sources of energy** (evaporated steam, condensates, hot gases) that could be used;

6) **opportunity to use husk as the fuel** (however, some problems related to environment contamination arise).

ANALYSIS FINDINGS

Oil extraction factories and oil-and-fat plants containing sunflower oil manufacturing workshops have been selected for benchmarking.

The 2011 data on unit consumption of heat and electricity to produce unrefined vegetable oil have been received from 12 enterprises.

The analysis findings are represented in table 2.

Enterprise code*	Oil output in 2011, t	Unit energy consumption	
		heat, Mcal/t	electricity, kWt-hour/t
Vegoil-1	190,495	300.5	102.2
Vegoil-2	304,946	512.0	138.7
Vegoil-3	124,980	536.0	96.6
Vegoil-4	160,131	557.5	128.7
Vegoil-5	115,740	572.7	105.2
Vegoil-6	185,890	600.0	115.7
Vegoil-7	68,845	615.2	143.0
Vegoil-8	149,468	776.5	120.4
Vegoil-9	6,240	850.0	198.0
Vegoil-10	182,210	857.0	116.0
Vegoil-11	74,950	1,020.0	129.0
Vegoil-12	50,580	1,020.0	160.5

* names of enterprises are not disclosed in order to protect business information

Benchmarking curves have been built on the basis of the obtained information using the proved technique [2] (Diagrams 4, 5).

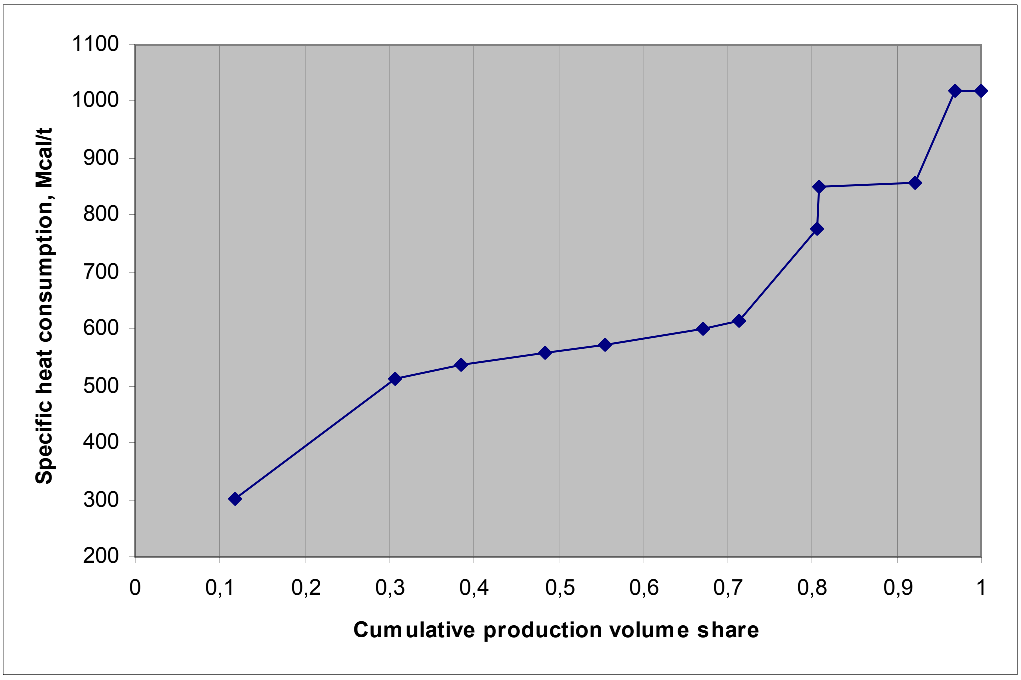

Diagram 4. Benchmarking curve of unit heat consumption by the manufacturers of unrefined sunflower oil.

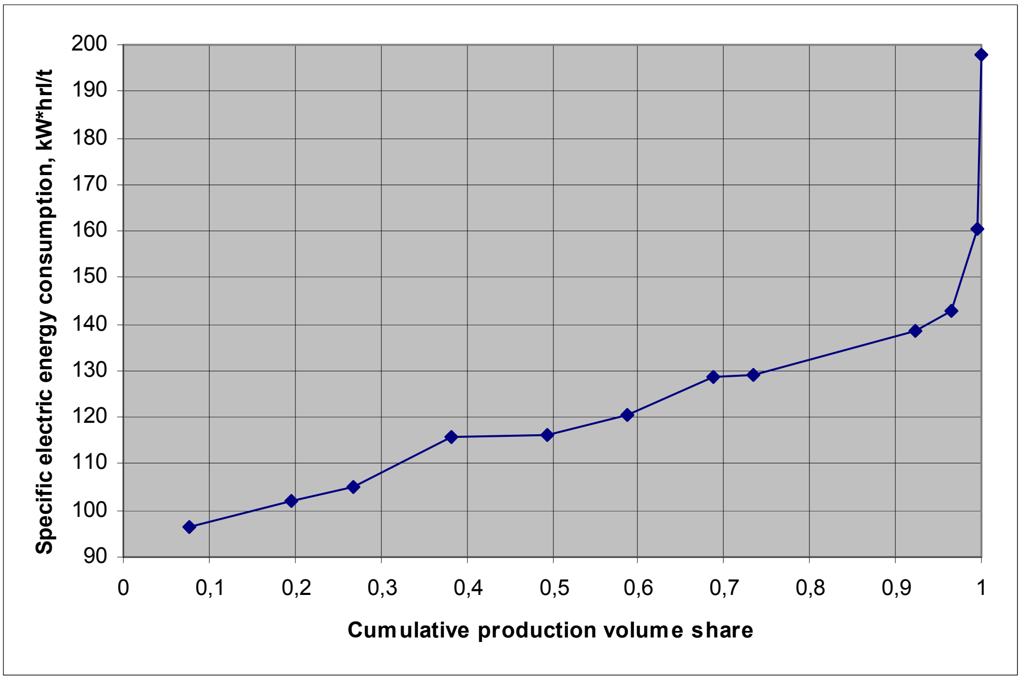

Diagram 5. Benchmarking curve of unit electricity consumption by the manufacturers of unrefined sunflower oil.

The curves are used to identify enterprises' efficiencies.

By heat consumption:
The most efficient enterprise – 300.5 Mcal/t
The least efficient enterprise – 1,020.0 Mcal/t

BAT = 300.5 Mcal/t
BPT = 517.0 Mcal/t

By electricity consumption:
The most efficient enterprise – 96,6 kWt-hour/t
The least efficient enterprise – 198 kWt-hour/t

BAT = 96,6 kWt-hour/t
BPT = 103.0 kWt-hour/t

CONCLUSIONS

1. Specific energy consumption by oil-and-fat industry enterprises varies in the range:
   - by thermal energy: from **300.5 Mcal/t** to **1,020.0 Mcal/t;**
   - by electricity: from **96.6 kWt-hour/t** to **198 kWt-hour/t.**

   This difference is due to:
   - the introduction of state-of-the-art energy efficient technologies and equipment at some enterprises, while most other enterprises operate obsolete equipment;
   - considerable losses of heat released to environment at small capacity enterprises;
   - significantly higher specific electricity spending at Vegoil-9 enterprise is due to its considerable underutilization of capacity – low volumes of input feedstock and low product output, respectively, thus resulting in non-optimum modes of its equipment operation.

2. The average specific heat consumption in the industry according to statistic data makes up **685 Mcal/t** for unrefined oil. **7** enterprises out of the selected enterprises are more effective than the average level in the industry that is **685 Mcal/t.**

3. The average specific electricity consumption in the industry according to statistic data makes up **130 kWt-hour/t** for unrefined oil. **8** enterprises out of the selected enterprises are more effective than the average level in the industry that is **130 kWt-hour/t.**

SOURCES

1. AGRONEWS - http://agronews.in.ua/node/2077

2. UKROILPROM Association portal - www.ukroilprom.kiev.ua

3. Global Industrial Energy Efficiency Benchmarking. An Energy Policy Tool.– Working Paper.– November 2010