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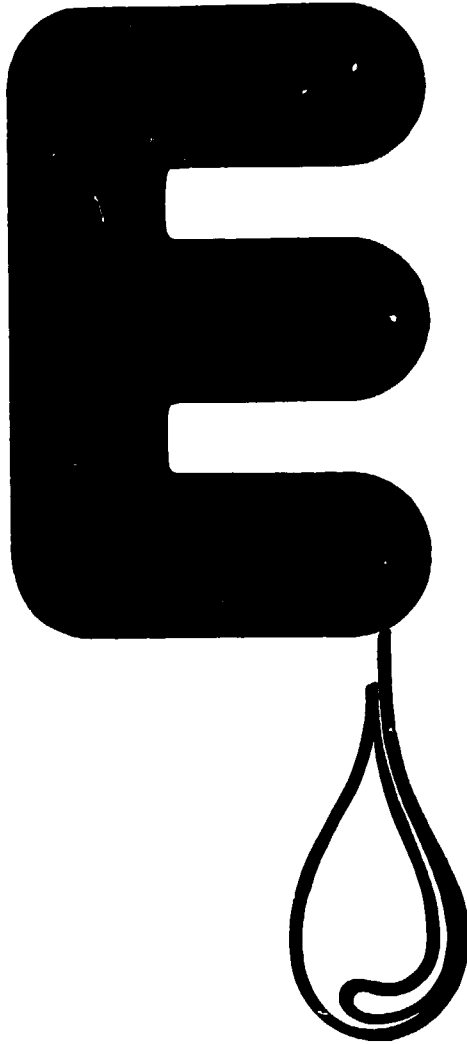
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**UNDP/UNIDO Project DP/RER/83/003:
Industrial Energy Conservation Network**



**ENERGY EFFICIENCY IN FOOD
PROCESSING INDUSTRY
East European Experience**

(1) 124p.
tables
graphs
diagrams
etc.

UNDP/UNIDO Project DP/RER/83/003
Field Document

ENERGY EFFICIENCY IN FOOD PROCESSING INDUSTRY
(EAST EUROPEAN EXPERIENCE)

Edited by
D. D. Gvozdenac

Novi Sad, October 1991

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PREFACE

This book is intended to represent a part of the activities performed within the UNDP/UNIDO Project DP/RER/83/003: *Industrial Energy Conservation Network*. The basic facts concerning this Project are given in Chapter 1. Actually, the main purpose of this book is to present some experiences in the field of energy conservation predominantly in the food processing industry. These experiences were accumulated during the six year period of activities in one of the seven subnetworks of this project: *Energy Conservation in Food Processing Industry*.

Let us explain in a few words how this subnetwork was operated and how these experiences were accumulated.

Distinguished experts and scientists from all member countries attended subnetwork meetings taking part in the exchange of experience and knowledge. They were engaged in two different ways. The first one was their active engagement in the preparation of national reports, i.e. their parts dealing with activities carried out in the field of energy efficiency in the food processing industry, which were presented mainly by the national coordinators. On the other hand, well-known experts and scientist also contributed to our Project by their presentations and reports on particular scientific and research results achieved in the subject field. Such cooperation resulted in more than 100 reports and a number of fruitful discussions during our subnetwork meetings.

In addition to this, several visits to a number of selected factories were also organized during each subnetwork meeting for the purpose of exchanging experience on particular applications. Another type of activities was carried out between the meetings and we consider it even more important. This type of activities included execution of the decisions taken at the subnetwork meetings, and further development of cooperation according to the specific interests of each participating country.

This book addresses these issues and presents technical consideration of energy efficiency.

Chapter 2 discusses a method that enables complete and uniform auditing of energy consumption and the state of relevant equipment in sugar refineries. It includes balance analysis of a complete sugar refinery and a diagram of energy flow distribution within the scope of its battery limits. Priority is given to the thermodynamical aspects of analysis.

Chapter 3 proposes an original, rigorous method of energy costing in the analysis of energy conservation options for bringing correct business decisions. It was shown how the application of this method would reject a very economical project. The case study was presented, too.

The subject of Chapter 4 is the operation of a complex system of industrial consumers having specific demands, and a power plant built in several phases and including a large number of boilers, turbines, pressure

reducing stations, steam coolers, and deaerators. The results of relevant analyses are based on the real working conditions and given for one calendar year. For that purpose, all of the working conditions had to be defined while the system operation had to be analyzed for each of these conditions separately. The most important energy losses have been located and their individual and total influence on the plant energy efficiency shown. Relevant measures have been proposed for the improvement of overall energy efficiency and economy within the scope of the subject power plant.

Chapter 5 gives the reader a very detailed analysis of the energy efficiency in dairy industry. This chapter starts with a brief state of the art review of the technology used in dairy industry. This review was used for recognizing the possibilities of energy conservation by introducing a new equipment and new technologies.

Chapter 6 deals with the analysis of the Hungarian food processing industry, and discusses the measures planned for economical and reasonable energy utilization as well as their expected results.

An analysis of energy efficiency in the Hungarian meat industry is given in Chapter 7.

The possibilities of energy conservation in the vegetable oil industry are given in Chapter 8.

Chapter 9 deals with the concept of a mobile Energy Diagnostic System developed at the Institute of Thermal Energy and Process Engineering, Novi Sad. A detailed description of equipment installed in the Energy Diagnostic System is also given because this equipment illustrates the real operation performances of the System in the best possible way.

Chapter 10 deals with the possibilities to reduce electric energy costs by using the ice accumulation plant. Energy audit was performed by using Energy Diagnostic System, and the real figures for technical and economical analysis were used.

Chapter 11 gives general analysis of energetics and environment. A lot of data are presented for proving the necessity of environment protection.

We do hope that this book could be interesting and useful for the energy experts of all profiles helping them to recognize energy situation in the East European Countries.

Editor



Prof. Dr. Dusan Gvozdenc

BASIC FACTS CONCERNING UNDP/UNIDO PROJECT:
INDUSTRIAL ENERGY CONSERVATION NETWORK

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UNDP/UNIDO Project DP/RER/83/003: *Industrial Energy Conservation Network* (former *Regional Cooperation in the Field of Industrial Energy Conservation*) is an organized support to all types of activities oriented to the industrial energy efficiency.

The Project was launched in 1985 during the implementation of the 3rd cycle of UNDP (United Nations Development Program) European Projects. Later on, it was included in the 4th cycle as well thanks to the significant results that had been attained in the previous cycle. This Project is one of the most important and largest projects included in the UNDP European Program. It will be completed by the end of 1991.

The Project is an international project including the governments of the following countries: Bulgaria, Czechoslovakia, Hungary, Poland, Portugal, Cyprus, Malta, Romania, and Yugoslavia.

The organizational structure of the Project is shown in Figure 1. Its Steering Committee is composed of the following members: the representatives of the participating countries governments, work coordinators from different Subnetworks and Training Centers, and UNDP (Project Financier), UNIDO (Executing Agency) and ECE (Assistant Executive Agency) representatives. In addition to this, the activities of the Steering Committee are constantly observed by the following observers: bank representatives and representatives from other countries, representatives of the consulting firms, etc.

The Project Secretariat was established in January 1989, with its registered office in Prague, Czechoslovakia. Since the date of its establishment, the Secretariat has been gradually taking on the role of the

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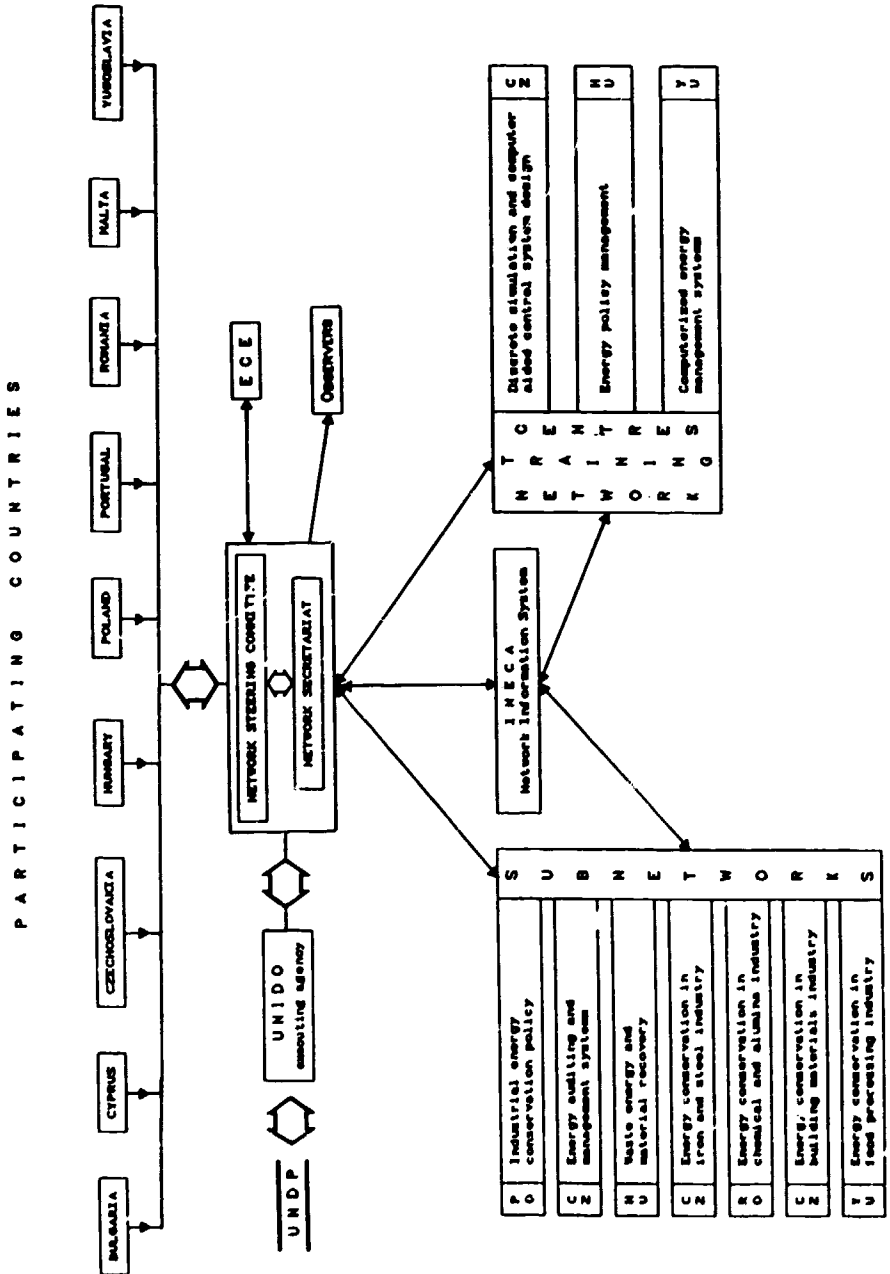


Figure 1. Organizational scheme of the Project

Project Executive Agency. The reason for this are the plans to prolong the Project activities after the date of its official completion (December 1991) without any further financial or professional support from UNDP.

For that purpose, a joint firm ENCCNET International has been already founded as well. It has its registered office in Zagreb, Yugoslavia, and is operated on the profitability basis. The firm is one of the most important Project outputs supported by a system of institutions included or established within the scope of this Project.

When analyzing the organizational scheme of the Project, it has to be emphasized that six Project Subnetworks (Food Processing Industry, Iron and Steel Industry, Chemical and Alumina Industry, Building Materials Industry, Waste Energy Recovery, and Energy Auditing and Management Systems) have been active from the very beginning while the seventh one (Energy Policy) has been launched in Phase II (started 1988). Namely, it has been noticed in Phase I that noneconomic factors have a strong influence on the creation of energy policies in the participating countries and that the influence of these noneconomic or nontechnical factors on the creation of energy policies has to be further analyzed in more details.

The formation of Training Centers is another important thing worth mentioning herein. The importance and position of these organizational forms are equal to those of the above specified seven Subnetworks. Their main task is to provide personnel training in the field of energy management both on global scale and within the scope of individual industrial plants. One of the characteristic features of the developing countries engineers employed in industry is their passive attitude toward existing and imported technologies. Their general tasks are to maintain processes within the existing limits of the technological conditions. Only few of them are capable to develop new processes or improve the existing ones by providing optimum conditions according to the following criteria: product quality, production cost, productivity, energy consumption, environment protection, etc. Our Training Centers have been designed to train personnel in a way making them capable to improve the existing technologies through their reconstruction and further development.

The role of INECA information system is especially important. It offers great possibilities regarding access to the vital information in the field of energy efficiency.

In order to attain energy efficiency and higher production levels in industry, the following direct tasks have been fulfilled either at the levels of certain countries or in individual factories:

1. *Development of a system of institutions in the field of energy efficiency;*
2. *Development of bilateral and multilateral cooperation among the participating countries;*
3. *Analysis of the existing technologies and their possible improvement;*
4. *Development of the measuring methods required to audit energy flows and process parameters;*
5. *Development of an information system designed for the energy efficiency purposes;*
6. *Personnel training;*
7. *Familiarization with technologies implemented in the developed countries (Study Tours);*

8. *Further development of the Project Secretariat activities and creation of the relevant conditions required to continue our activities in the period following the completion of this Project under the UNDP sponsorship;*
9. *Further development of the relevant legislative and economic compulsion measures.*

All above specified tasks are good indicators of the completed Project philosophy. However, it must be emphasized herein that the following conditions have to be provided for the execution of these direct tasks:

- a) *Simultaneous and well pondered actions within the scope of each direct task;*
- b) *Development of a system of institutions at the regional level as well as the level of each participating country and a network of factories relevant for the implementation of proposed and established energy efficiency programs;*
- c) *Provision of adequate financial support required for the Project implementation.*

Almost each of the above specified direct tasks has been fulfilled and a number of very important results obtained in the field of industrial energy efficiency. It is especially important that the organizational conditions have been provided for the relevant uninterrupted activities in the field of industrial energy efficiency planned for the period after the formal completion of this Project at the end of 1991.

AUDITING AND ANALYSIS OF ENERGY FLOWS IN SUGAR REFINERIES

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1 INTRODUCTION

As a rule, sugar refineries are large energy consumers and constant analyses of their energy flows are fully justified and necessary for the purpose of obtaining lower energy consumption per unit product. Such analyses are not urged only by the high level of fuel consumption but also by the fact that sugar refinery energy system usually includes considerable number and different types of energy transformer units. Thermal energy is used in technological processes in the form of steam generated in boilers. Electric power is usually generated in local plants inside the sugar refinery battery limits. All this indicates that there is a large number of activities that could be undertaken for the purpose of maintaining desirable levels of energy consumption per unit product. This means that all technological requirements shall be fulfilled at the level required and enabled by the applied technology in the field of sugar beet processing, i.e. in the field of sugar production.

Energy efficiency of a sugar refinery cannot be compared either with its own designed parameters or parameters found in available references or other sugar refineries if systematic auditing and analysis of relevant data on every and each sugar processing campaign carried out. A questionnaire has been prepared for that purpose and the final form of the analysis is attached as an annex to this paper. A uniform procedure shall be applied in data collecting and processing so as to enable direct comparisons (excluding correlation) of relevant data on different sugar refineries in a given country, region or larger areas.

For that purpose, one of the possible ways of data collecting is proposed and described in this paper including relevant description of the

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proposed method of analysis and definitions of output data on energy efficiencies characteristic for the operation of a given sugar refinery. In cases where information is prepared for a group of sugar refineries, the levels of their individual energy efficiencies as well as the proposals of possible future actions in each individual sugar refinery can be easily established on the basis of output data provided in that way.

This paper does not deal with possible technical solutions resulting in energy conservation. It enables only auditing of the existing state and preparation of a set of information required for comparison purposes establishing, thus, the necessity for a more detailed analysis of a particular case which would result in establishment of particular technical solutions providing energy conservation. All necessary data are resulting from usual measurements carried out in a given sugar refinery as well as continuous auditing of relevant parameters. As far as the particular conservation measures are concerned, analysis of the above-mentioned questionnaire and relevant output data give the first, but quite alarming signal that a team of properly trained and equipped experts shall be engaged to propose conservation measures on the basis of their own measurements.

2 REQUIRED INFORMATION

The first set of information includes general data on the refinery, the suppliers of installed equipment, and designed capacity of the refinery. These data will facilitate classification of sugar refineries and further comparisons of the refineries with similar operating, and technical and technological characteristics. The second set of information includes data on power units. On the basis of these data, the complete power system of a given sugar refinery could be recognized together with power sources, transformer units, the level of energy independence, possible connections with other power systems, and overall energy flows during a campaign of sugar beet processing.

The third set of information provides data on energy consumptions in particular, characteristic process units.

Such a concept of questionnaire provides possibilities to establish main characteristics of a complete sugar refinery and each of its power units and main consumers as well as to calculate specific energy consumptions for each type of energy, product, processed raw material, etc. These data are necessary and sufficient enough for comparison purposes as well as the establishment of required further analyses that will result in the economically justified consumption.

3 METHOD PROPOSED FOR THE MAINTENANCE OF DESIRABLE ENERGY EFFICIENCY LEVELS

This method of energy efficiency analysis in sugar refineries requires observation of a particular procedure. This analytical procedure is given in Figure 1. The solution of energy efficiency problems requires uninterrupted activities resulting in the continuous increase of energy efficiency in a given sugar refinery. In principle, this procedure is also applicable to other technologies because it defines only global actions. In other technologies, only data preparation and processing and output information are specific, i.e. different, and this procedure can be, therefore,

considered universal.

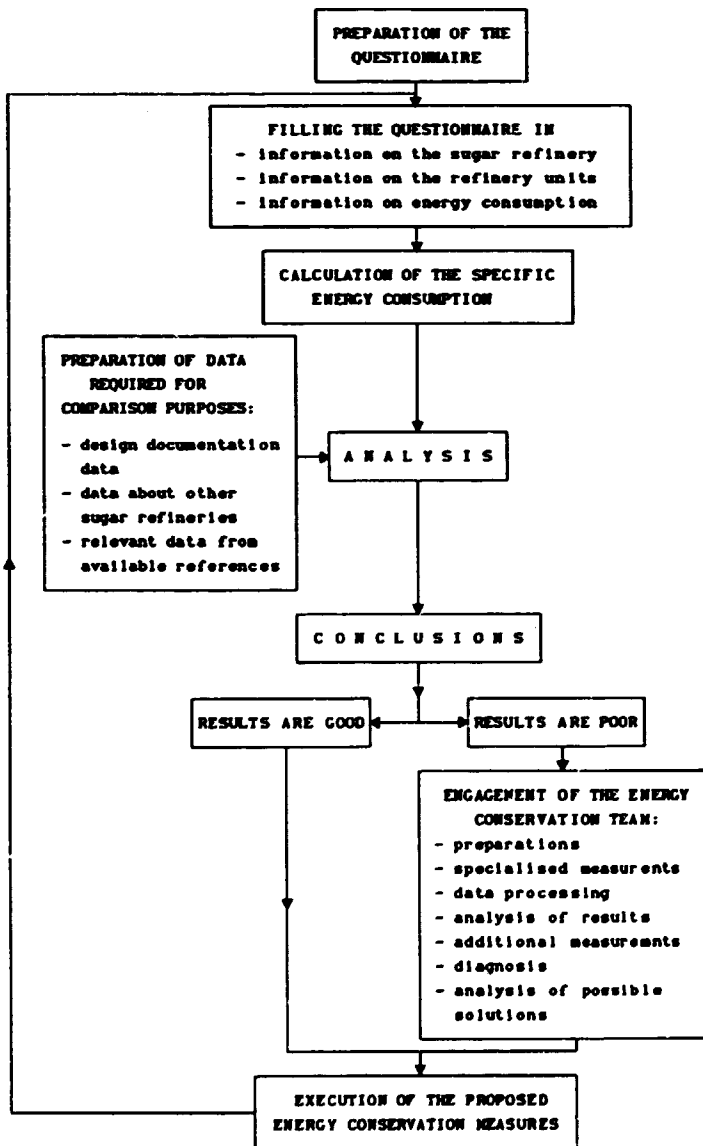


Figure 1. The procedure of auditing and maintaining the level of energy efficiency in a sugar refinery

4 CRITERIA APPLIED IN EVALUATION OF ENERGY EFFICIENCIES IN SUGAR REFINERIES

Uniform data must be defined for the purpose of comparing and evaluating energy efficiencies in sugar refineries and making final decisions on the necessities to take energy saving measures. Detailed analyses of the filled in questionnaire provides lots of information on a given sugar refinery but continuous global auditing of the sugar refinery operation requires the following data only:

- *Specific consumption of heat energy per unit product [kJ/t];*
- *Specific consumption of electric power per unit product [kWh/t].*

These two parameters are sufficient indicators of the necessity to take adequate energy conservation measures. However, when analyses of other questionnaire data are added, possible directions of future activities in this field can be also established quite accurately. In general case, the main ways in which possible energy savings can be achieved are as follows:

- *Saving measures applied within the scope of existing technology;*
- *Savings resulting from the alternation of technological procedures.*

Above actions can be successful only if experts in this field are engaged.

5 ANALYSIS OF ENERGY FLOWS IN THE SUGAR REFINERIES OF THE AUTONOMOUS PROVINCE OF VOJVODINA

The method proposed in this paper is a somewhat innovated procedure already applied in this field in the Autonomous Province of Vojvodina by the Institute of Thermal Energy and Process Engineering, Novi Sad, and the Provincial Committee for Energy, Novi Sad, during the period of several years. The fact that sugar refineries on the territory of Vojvodina consume approximately one third of the total oil fuel in Vojvodina is the best indicator of the necessity to take relevant energy conservation measures.

The consumption of liquid fuels in Denmark is 2.8 kg per 100 kg of the processed sugarbeet [1]. Our analyses show that, in the sugar refineries of Vojvodina, it ranges between 4.8 kg and 9.2 kg per 100 kg of the processed sugarbeet, so that the consumption is bigger than in Denmark by 171% to 329%.

For the purpose of more detailed analyses of energy flows in sugar refineries, it would be useful to establish a number of specific energy balance sections such as:

- *Power plant;*
- *Dryer for the sugarbeet cuttings;*
- *Lime producing unit;*
- *Sugarbeet processing unit.*

Technological process is the largest consumer of heat energy. 80% of the total quantity of steam used in a sugar refinery is consumed in the

sugarbeet processing.

Consumption for other purposes (heating of premises, local handling operations, delivery and shipping, sanitary facilities, etc.) shall be also added to the consumptions in the above-listed balance sections. A typical diagram of heat energy flows in the sugar refinery processes on the territory of Vojvodina is shown in Figure 2 [2].

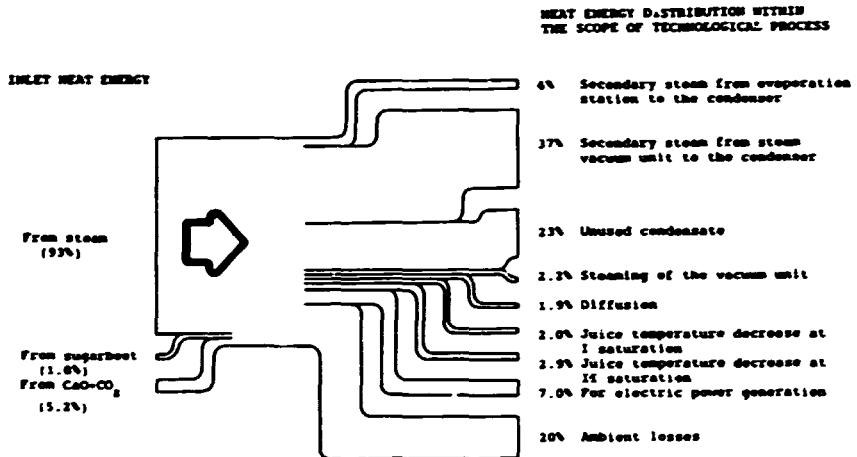


Figure 2. Schematic diagram of heat energy flows in a sugar refinery process

This diagram shows that the best possibilities for the use of waste energy are as follows:

- 1) Secondary steam from the steam vacuum unit to the condenser (waste heat amounts to 37%);
- 2) Unused heat of condensate (23%);
- 3) Ambient losses (20%).

According to [3], minimum energy required to separate the components of the sugar water solution amounts to 712 kJ/100 kg of the processed sugarbeet. The real quantity of energy consumed in separation is approximately 200,000 kJ/100 kg of the processed sugarbeet, i.e. it is 281 time larger than the minimum one [4].

Possible energy savings in the technological process are reduced to the following few types:

- Smaller quantities of water used for the extraction of sugar out of the sugarbeet;
- Lower operating parameters in the section of diffusion units as well as in steaming section;
- Rationalized energy flows.

In addition to comparisons with sugar refineries out of Vojvodina, it is also interesting to make comparisons of specific fuel consumptions in all 11 sugar refineries on the territory of Vojvodina. In the analyzed period (7 years) [4], a difference of about 50% (the difference between average consumptions in refineries with maximum consumption and refineries with minimum consumption) was noticed in the fuel consumption or steam consumption for process purposes. In the dryer for sugarbeet cuttings this difference in the fuel consumption is 32% while the difference in electric power consumption amounts to 86%. Above data need no comment. Maximum and minimum values of the average energy and fuel consumptions in the sugar refineries of Vojvodina are compared in Figure 3.

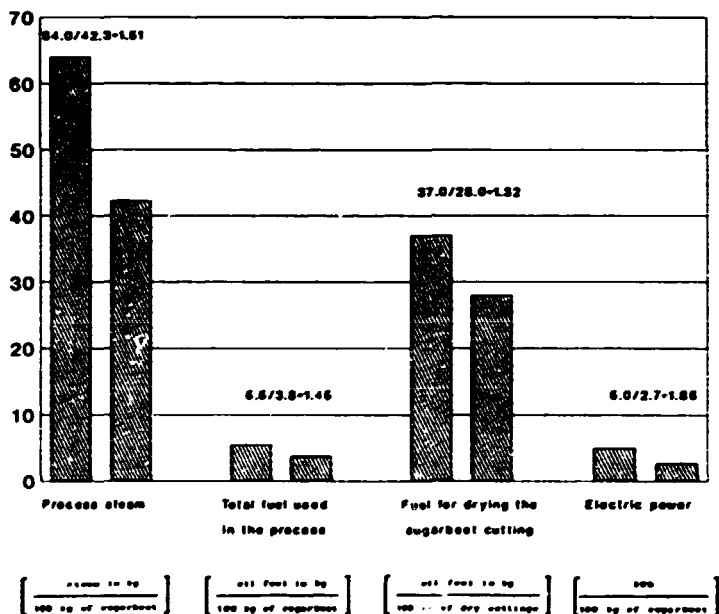


Figure 3. Maximum and minimum levels of energy and fuel consumptions in the sugar refineries of Vojvodina

Analyses of energy flows in the sugar refineries of Vojvodina, carried out in the period of the last seven years, show the following:

- Specific fuel consumption can be 71% to 229% lower but, even then, only current situation in some developed countries will be reached (Denmark is used as an example);
- Engagement in this field is also theoretically worth-while project because real energy consumption in our sugar refineries is 281 time higher than the theoretical one and these sugar refineries are, therefore, considered to be a very unfavorable type of plants;

- c) *Considerably lower energy consumption can be achieved in the technological process of water evaporation after dissolving sugar from the sugarbeet;*
- d) *Uneven energy consumption established in the sugar refineries of Vojvodina shall be eliminated without significant capital investments because their applied technologies are of the same type;*
- e) *As there are considerable amounts of waste heat in each sugar refinery, that are not feasible for use in the refinery process, an important form of energy conservation would be to connect potential "neighboring" consumers and develop regional energy systems.*

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ANNEX

DESCRIPTION		RESULTS OF ANALYSIS - DATA ON ENERGY CONSUMPTION IN SUGAR INDUSTRY		
		SUGAR [*]	DRY PULP	LIME
Number of refineries				
Total quantity of refined sugar-beet, [t/year]				
Total production, [t/year]				
Total fuel consumption, [GJ/year]				
Specific fuel consumption, [MJ/t]	average			
	the lowest			
	the highest			
Specific electric power consumption [kWh/t]	average			
	the lowest			
	the highest			
Possible energy conservation in existing technological process, [GJ/year]				
Possible energy conservation through application of different technological operations, [GJ/year]				
Notes:				
* Energy consumed in lime production is not included.				

Date and Place

Authorized Person

ENERGY CONSERVATION ECONOMICS (A PRACTICAL ENERGY COSTING METHOD)

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1 INTRODUCTION

Realistic energy costing is crucial for correct economic evaluation of any process involving transformation of energy. In most cases, the costing method should be adequate for reasonable allocation of investment cost between consumers of various energy forms.

In energy conservation projects, however, the situation is somewhat different. The units are already built and the primary goal is to minimize the total cost of running them, regardless of the distribution of these costs among various consumers.

The energy saving options are analyzed based on their economic effect. The engineers, however, express the benefits in terms of fuel saved, steam consumption reduction, energy saved in kJ/h or similar. To evaluate the money effect of the proposed projects, each energy carrier must be accompanied by its realistic value.

Since various energy streams can be involved in the conservation project (fuel, steam at different pressures, electricity, mechanical power), it is clear that enthalpy costing is not a valid concept. The pure Second law, or exergy costing, may be equally erroneous, because the higher exergy containing stream can be more valuable and worth saving only if its potential is used for power production. Saving high or low pressure steam has approximately the same effect if no power is produced by the reduction of the steam pressure, and quite different one if the opposite is true.

The method proposed here originates from the Second law analysis and it takes into account the quality of various energy forms. However it defers from pure exergy methods in the way the efficiency of fuel-to-power conversion and hence the steam cost are defined. The actual marginal

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mechanism and the cost of imported power are used for this, as will be further described.

A conservation project may cause a series of changes in the process and these changes are to be taken into consideration when evaluating the effects. For example, substituting a fired reboiler by low pressure steam reboiling means higher steam demand. The economic incentive is to be found in the higher efficiency of the steam boiler compared with the generally lower efficiency of the reboiler furnace. This incentive is considerably increased if the low pressure steam is obtained in a back-pressure turbine producing power, that is currently imported as the high price electricity. More steam consumed means more opportunity for producing cheap back-pressure power. The project is the more interesting, the higher is the price of the imported power.

This illustrates the importance of understanding the mechanism by which the whole process responds to some incremental changes in one of its parts. This will be referred to as the *marginal mechanism*.

Since an energy conservation study involves alternative projects, a comparison between various options has to be made. We found that a very convenient method is to convert all energy saving effects in one project into a single energy carrier - the *reference fuel* saving, and then compare these savings. Which fuel will this be is arbitrary, but a 9,600 Gcal/ton (40,182 kJ/kg) lower heating value fuel oil is a common solution. By assigning a dollar value to the reference fuel, all conservation options can be evaluated on the common bases.

How to convert the various energy streams into the reference fuel is the subject of the present paper.

2 EQUIVALENT ENERGY VALUE (EEV)

The equivalent energy value of an energy carrier is defined as the quantity of the reference fuel in mass or enthalpy units, equal in value with the given quantity of the energy carrier. In fact, it is the quantity obtained when a consumption, or saving, of an energy form is converted into the reference fuel.

2.1 EEV for Fuels

All fuels burnt in the process, or saved, are converted into the reference fuel on the basis of their LHV:

$$\text{in energy units: } EEV_{\text{fuel}} = LHV_{\text{fuel}} \quad (\text{kJ/kg}) \quad (1)$$

$$\text{in mass units: } EEV_{\text{fuel}} = \frac{LHV_{\text{fuel}}}{LHV_{\text{ref. fuel}}} \cdot G_f \quad (\text{kg/h}) \quad (2)$$

where G_f is the quantity or the flow rate of the actual fuel.

2.2 EEV for Electricity

The electrical power conservation projects most frequently aim at reducing the electricity import and substitution of this expensive power by cheaper own produced power in efficient cogeneration systems.

In order to produce their own power, the consumers will, of course, start to burn more fuel than before. It is obvious that the economic incentive is to be found in the trade-off between the additional fuel cost and the reduced electricity cost. A meaningful method to evaluate power saving projects is to convert power into fuel by applying a conversion efficiency index.

It is proposed here that as the conversion index, the Cost Equivalent Efficiency Index (CEEI) is used, defined as:

$$CEEI = \frac{\text{Cost of 1 kWh of fuel}}{\text{Cost of additional 1 kWh of electricity}} \quad (3)$$

The equivalent energy value of imported electricity is then $1/CEEI$, or for the 40,182 kJ/kg reference fuel:

$$EEV_{el} = \frac{1}{11.16 \cdot CEEI} \quad (\text{kg of reference fuel/kWh}) \quad (4)$$

The CEEI for imported electricity is the marginal cost of 1kWh delivered from the grid. If no electricity is imported, but all produced on the site, then the price at which 1 kWh of power can be sold to the grid is taken.

2.3 EEV for Steam

The steam can be obtained through one of the three possible marginal mechanisms:

- *burning fuel in boilers and producing steam for direct use,*
- *recovery of the waste heat in waste heat boilers,*
- *producing high pressure steam and producing power by reducing its pressure to the one required by the process.*

Evaluating steam in the first two cases is simple, since its is the only product. The value of the steam is directly determined from the cost of the fuel, taking into account the boiler efficiency.

If the process steam is obtained in a turbine, then the due credit must be given for thus produced power. For example, if some low pressure steam is saved somewhere in the process, then the money effect will be fuel saved *minus* the value of the power production loss. This loss is high if the turbine power substitutes the imported electricity, and low if it does not. The costing method must reflect this.

The following example will illustrate the steam costing procedure.

The steam turbine arrangement is shown in Figure 1. The fuel burnt in the boiler is:

$$G_{\text{fuel}} = \frac{h_1 - h_0}{\eta_b} \quad (5)$$

and this is in fact the *EEV* for high pressure steam.

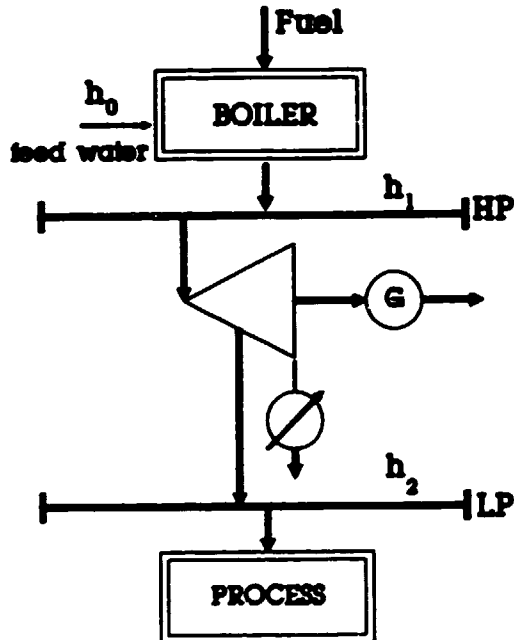


Figure 1. Simple steam system with power generation

The value of the power produced in the turbine is:

$$EEV_{\text{power}} = \frac{h_1 - h_2}{CEEI} \quad (6)$$

It is obvious that the value of the produced power increases as the cost of imported power increases (CEEI becomes smaller).

The value of the low pressure steam is the value of the high pressure steam minus the credit for produced power:

$$EEV_{LP} = EEV_{HP} - EEV_{power} = \frac{h_1 - h_0}{\eta_b} - \frac{h_1 - h_2}{CEEI} \quad (7)$$

We firmly believe that this costing procedure gives rigorous evaluation of the effect obtained by applying various energy saving measures. It further enables comparison of different forms of energy, notably imported electricity with steam consumption. Also, all mechanical work produced in small process turbines can be evaluated on the same basis since it reduces the electricity import. Closing a small process turbine and its substitution with an electric motor has two effects: (1) less steam needed, and (2) more electricity import. The proposed procedure is a basis for a straightforward trade-off calculation.

The low pressure steam has a low value if power is produced in turbines to substitute expensive electricity import. Saving this steam has small effect. In some cases, for some combination of parameters it may happen that the value of the low pressure steam becomes negative, meaning that it pays off to vent it and maintain the power production.

How the formula (7) reflects the realistic situations can be seen from the following analysis.

If the low pressure steam is obtained by throttling, then $h_1 = h_2$, and EEV for LP steam becomes equal to the EEV of the HP steam. Both are equally valuable in terms of saving.

If the isentropic efficiency of the turbine is increased, h_2 will be lower and $CEEI$ for LP steam is reduced. The more efficient the power production system is, the less attractive are savings in steam.

If the boiler is more efficient (higher η_b), $CEEI$ of the LP steam is reduced and steam savings are less attractive since less fuel will be saved.

If the HP steam pressure is reduced, the value of the LP steam increases since $\eta_b > CEEI$ and $(h_1 - h_2)/\eta_b$ is less reduced than $(h_1 - h_2)/CEEI$.

The EEV can be used also for condensing turbines. The outlet steam has no value since its heat content is wasted in the condenser. If, however, the calculation using Eq. (7) shows $EEV_{LP} > 0$, then it is cheaper to by power. If $EEV_{LP} < 0$, there is incentive for own power production, since the fuel expenditure $(h_1 - h_2)/\eta_b$ is smaller than the value of the power produced $(h_1 - h_2)/CEEI$.

The following example will show the application of the method and its advantages as the basis for bringing the correct business decisions.

3 EXAMPLE

A chemical process has a fired heater reboiler shown in Figure 2(a). The heat duty is 6.18 GJ/h, corresponding to the fired fuel of 7.5 GJ/h, since the furnace efficiency is 82%. The fuel cost is 85 USD/ton (2.12 USD/GJ or 7.6 USD/MWh).

A project is proposed to shut down the reboiler and use the stripping steam instead, as shown in Figure 2(b). The stripping can be accomplished by

using 1.8 t/h of the low pressure (LP) steam. The reboiler operates 8000 h/year. The investment required to replace the reboiler is estimated at 150,000 USD and the company policy is not to invest in energy conservation projects that pay back within more than 2 years.

Obviously, it is necessary to compare the cost of producing additional 1.8 t/h of steam with the fuel saved when the fired reboiler is shut down.

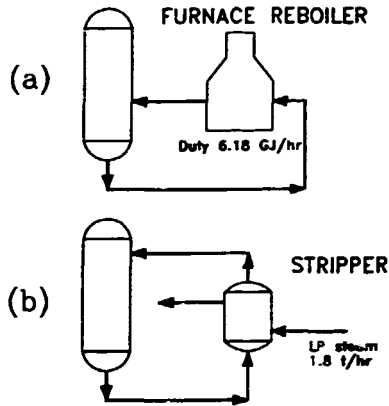


Figure 2. Replacement of furnace reboiler with steam stripper

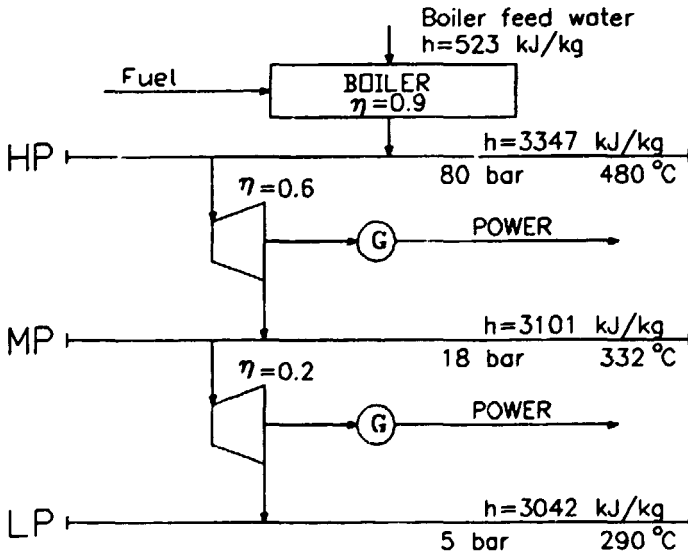


Figure 3. Example steam and power system

The site steam-power system is simplified and shown in Figure 3. The marginal mechanism to produce additional low pressure steam is as follows: The high pressure steam is produced in a 90% efficient boiler at 80 bar and 480 °C. Part of it passes through a back-pressure turbine with isentropic efficiency of 60% to produce electricity and substitute the part of the power imported from the grid at the cost of an additional MWh of USD 47.5 ($CEEI = 7.6/47.5 = 0.16$). The MP steam is obtained at the pressure of 18 bar and is passed through a small back-pressure turbine with isentropic efficiency of 20% to produce more power. The low pressure steam is obtained at 5 bar.

It is assumed that all condensate is returned to the boiler. Since there is a spare capacity in the boiler, additional steam can be produced, but this will require more fuel. This additional fuel has to be given the credit for producing more power and substitution of the expensive electricity from the grid. The project will be accepted or rejected depending on the cost of additional LP steam which, if not properly evaluated, can cause a wrong business decision to be made.

The evaluation will be performed rigorously, as proposed in the present paper, and compared with the results that would be obtained if enthalpy and exergy costing methods were used.

3.1 Rigorous Method

The fuel equivalent value of the high pressure steam is obtained from Eq.(5) as the enthalpy change across the boiler divided by the boiler efficiency:

$$EEV_{HP} = Q_f = (3347-523)/0.9 = 3138 \text{ kJ/kg}$$

The HP-MP turbine produced power value is obtained from Eq.(6):

$$EEV_{power} = (h_{HP} - h_{MP})/CEEI = (3347-3101)/0.16 = 1538 \text{ kJ/kg.}$$

The MP steam *EEV* is *EEV* for HP steam minus the value of the power produced:

$$EEV_{MP} = 3138 - 1538 = 1600 \text{ kJ/kg.}$$

In the same way, the power value from the MP-LP turbine is obtained as:

$$EEV_{power} = (h_{MP} - h_{LP})/CEEI = (3101-3042)/0.16 = 369 \text{ kJ/kg}$$

and the low pressure steam value as:

$$EEV_{LP} = 1600 - 369 = 1231 \text{ kJ/kg.}$$

Knowing the fuel cost of 85 USD/t (2.12 USD/GJ), the steam cost is obtained:

HP steam	$3138/40182 \cdot 85 = 6.64$ USD/t
MP steam	$1600/40182 \cdot 85 = 3.38$ USD/t
LP steam	$1231/40182 \cdot 85 = 2.60$ USD/t.

where 40,182 kJ/kg is the fuel LHV.

Note that the LP steam cost is only 40% of that of the HP steam, although its enthalpy is 90% of the HP steam enthalpy.

The annual saving is $(7.5 \cdot 2.125 - 1.8 \cdot 2.60) \cdot 8000 = 90,000$ USD/yr.

The pay-back period of the investment is 20 months and the project would be accepted for implementation.

3.2 Enthalpy Costing

If valued on the enthalpy basis, the LP steam would cost a fraction of the HP steam cost: $6.64 \cdot 3042/3347 = 6.0$ USD/t, the pay-back period would be 43 months and project would be rejected, missing an opportunity to save 90,000 USD per year.

The enthalpic values are obtained in direct proportion to the enthalpies at each header.

3.3 Exergy Costing

The exergetic values are obtained using the ratio of header exergies. The environment conditions are taken at 1 bar pressure and 20 °C boiler make-up water temperature.

If evaluated this way, the LP steam would cost 4.15 USD/t, with the corresponding pay-back period of 32 months and the project would also be rejected.

3.4 Sensitivity Analysis

The simple calculation is extended to include sensitivity analysis to the efficiency of the MP-LP turbine, and to the cost at which the power is imported.

If the MP-LP turbine efficiency is increased, more power would be produced from the same amount of steam. The proposed evaluation procedure takes this correctly into account by giving more credit to the MP steam and making the LP steam less valuable. Table 1 summarizes the results obtained for changing turbine efficiency.

Table 1. Rigorous costing

turbine efficiency, %	20	30	40	50	60	70
EEV _{LP} , kJ/kg	1231	1075	856	669	481	294
LP steam cost, USD/t	2.60	2.25	1.87	1.42	1.02	0.62

In Tables 2 and 3 the results of the same sensitivity analysis are shown, but applying the enthalpy and exergy costing methods.

Table 2. Enthalpy costing

turbine efficiency, %	20	30	40	50	60	70
EEV _{LP} , kJ/kg	3042	3017	2982	2952	2922	2892
LP steam cost, USD/t	6.06	6.01	5.94	5.88	5.82	5.76

Table 3. Exergy costing

turbine efficiency, %	20	30	40	50	60	70
EEV _{LP} , kJ/kg	872	858	852	835	816	807
LP steam cost, USD/t	4.15	4.09	4.06	3.98	3.89	3.84

Figure 4 illustrates the change of the project pay-back period with changing the turbine efficiency for all three costing methods.

Enthalpy costing proves to be completely inadequate since it much over-rates the low pressure steam and is not sensitive to the turbine efficiency change. The errors obtained by using the exergy costing are less dramatic, but again disqualify the method for the application in the energy saving projects evaluation. In both cases, a very economical project would be rejected due to the wrong evaluation procedure.

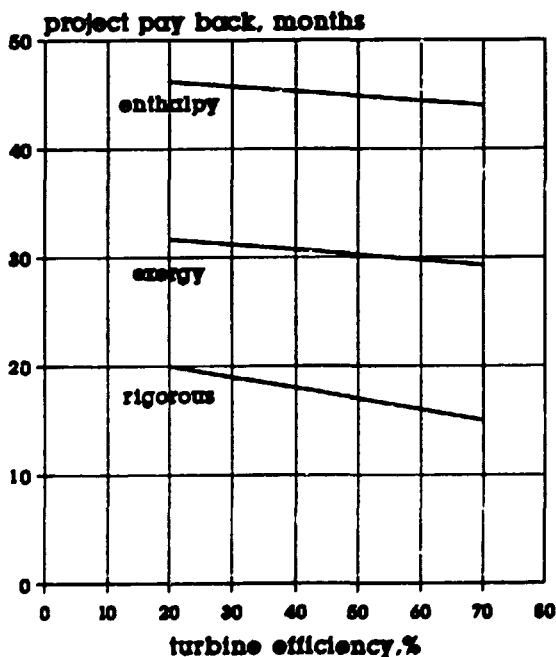


Figure 4. Project pay-back with different costing methods

The reason for the errors using the exergy method is in the fact that the exergy costing may be correct only if the high pressure steam potential to produce power is fully utilized. The method does not distinguish between the cases when this is true or not. Also, the method does not make difference if the expensive or cheap power is substituted as will be seen from the sensitivity analysis related to the cost of imported electricity.

If the cost of the imported power is changed, the value of the LP steam is also changed. The rigorous method takes this into account, while the enthalpy and exergy methods do not, giving a constant LP steam cost for all values of power.

The variation of the LP steam cost with the CEEI for imported power, as calculated by using the proposed method, is given in Table 4. A 20% turbine isentropic efficiency is assumed.

Table 4. Sensitivity to the CEEI change - rigorous method

CEEI	0.1	0.16	0.3	0.5	0.8
EEV _{LP}	88	1231	2121	2528	2756
LP steam cost, USD/t	0.19	2.62	4.51	5.37	5.86

The enthalpy method would give a constant steam cost of 6.06 USD/t and the exergy method of 4.15 USD/t.

The project pay-back period in function of imported power cost is illustrated in Figure 5 for all three costing methods. As before, only the proposed rigorous method reflects correctly the actual conditions.

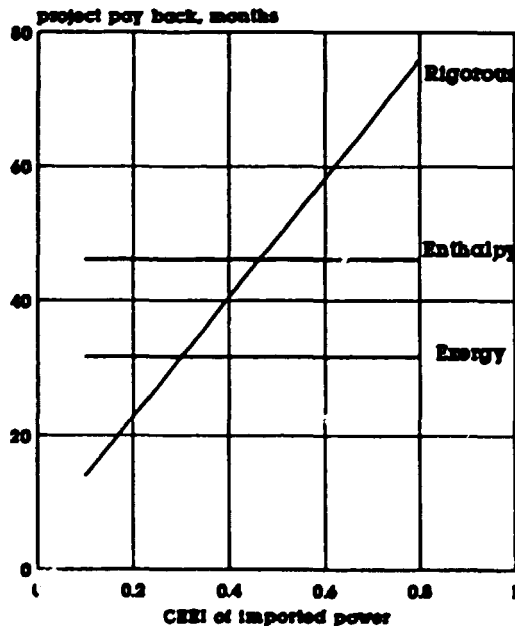


Figure 5. Project pay-back vs. imported power cost with different costing methods

This is a simple example, where the trade-off between additional steam cost and produced power is easy to analyze even without a specific methodology. In realistic situations, the problem will be more complex. For example, additional steam could be obtained from more than one source: a waste heat boiler, different marginal turbines, by improving the efficiency of a marginal turbine and save the steam, by elimination of an inefficient steam turbine and usage of electric motor, etc. A consistent methodology is needed to evaluate and compare all of these options on a common basis.

It is useful to review all parameters that are involved in the analysis even in the simple example presented. To see if it would be economical to replace the furnace reboiler with the stripping steam, the following had to be considered:

- *The site marginal fuel cost,*
- *Steam boiler efficiency,*
- *Configuration of the steam system,*
- *Power production strategy,*
- *Efficiency of the marginal steam turbines,*
- *Marginal cost of the imported power,*
- *Investment cost and policy.*

The number and diversity of the influencing parameters indicates how complicated is the answer to the simple question: How much does your LP steam cost?

4 CONCLUSION

The proposed rigorous method for energy costing in the analysis of energy conservation options is the basis for bringing correct business decisions. The alternative enthalpic and exergetic methods are inadequate for conservation projects. It was shown how the application of these methods would reject a very economical project. The rigorous method reflects the actual technical and economic environment and is sensitive to the changes in main operating parameters, notably the equipment efficiency and the cost of the imported power.

Nomenclature

<i>EEV</i>	Equivalent energy value, kg reference fuel/kg of actual fuel, or kg reference fuel/kg steam, or kg reference fuel/kJ, or kg reference fuel/kWh power
<i>LHV</i>	Lower heating value of fuel, kJ/kg
<i>CEEI</i>	Cost equivalent efficiency index of fuel-to-power conversion
<i>G</i>	Mass flow rate, kg/s
<i>h</i>	Steam enthalpy, kJ/kg
η_b	Steam boiler efficiency

ENERGY EFFICIENCY ANALYSIS IN AN INDUSTRIAL POWER PLANT PRODUCING BOTH HEAT AND ELECTRIC POWER

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1 INTRODUCTION

One of the possible ways resulting in the efficient use of the primary fuel energy is to link a larger number of energy consumers and form a local, town or regional energy supply system. Such a system includes a central plant designed for the fuel energy transformation, a main supply system, and energy consumers with their own distribution systems.

As a general rule, process steam, hot water for heating purposes, warm sanitary water, and electric power are produced simultaneously. The concept of the main supply system depends on the number and characteristics of the working fluids as well as the real disposition of the relevant energy consumers. Internal distribution systems and energy use conditions are defined by the nature and types of energy consumers.

The conditions of energy use are directed by the energy consumers. As far as the operation is concerned, these conditions are considered to be independent variables. The system is designed according to these variables and on the condition that all possible changes in the user's parameters are met. The influences mentioned hereinbefore are determined by the technological process procedure and weather conditions.

Strong links between all of the system parts result in possible occurrence of a large number of different effects to the total process economy, i.e. to energy transformation, distribution, and use. This requires optimization of the system working parameters in each of its possible operating conditions.

The position of energy users can be defined quite easily either through buying and selling contracts or by relevant agreements on the terms and conditions of energy use. In that way, the overall efficiency of the fuel

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energy use is indirectly effected as well. The transportation system effect to the economy changes in the fuel energy use is considerably smaller. However, this is not the case with the operating conditions of the energy transformation plants. As far as these plants are concerned, each condition and parameter dictated by overall optimal operation of all consumers can be observed and, nevertheless, the transformation processes as well as the preparation of the working fluid parameters can take place in quite different working conditions. That's why the efficient operation of an energy transformation plant gets all the characteristics of an independent variable, i.e. this is the reason of its independent influence on the complete system economy which can be drastically disturbed. This situation results in a kind of monopoly behavior toward energy users who may directly bear the total cost of any inefficiency in the operation of an energy transformation plant. To avoid this, the following constant measures shall be observed: technical self-discipline and control; implementation of all types of bonuses/fines; definition, control, and observation of all operating standards and parameters established beforehand for each of the changed working conditions. Energy efficiency of the entire system might be drastically disturbed disregarding the behavior of other parties involved in the system.

The above-mentioned problems have been partly solved through relevant analyses of such a system operation. The analyses have been made on the basis of an annual operation experience. Special attention has been paid to the effect of different operating conditions within the plant and necessary measures proposed for a higher energy efficiency of the complete system.

2 SYSTEM DESCRIPTION

This system has been formed in an industrial area of a city and it may represent a typical local industrial system.

Energy users are the local industrial consumers. The basic parameters of the working fluid at the energy transformation/power plant battery limits are shown in Table 1.

Table 1. Working fluid parameters at the power plant battery limits

Item No.	Type of User	PARAMETERS		
		t [°C]	p [Pa]	Consumption period [hr/year]
1	Process needs:	152	$5 \cdot 10^5$	7920
		200	$14 \cdot 10^5$	7920
		152	$5 \cdot 10^5$	2800
		250	$5 \cdot 10^5$	2800
2	Heating needs:	150	$5 \cdot 10^5$	3000
		250	$5 \cdot 10^5$	3000

The situation shown in Table 1 resulted from the method applied and conditions prevailing in different phases of the system formation. It partially resulted from the concept of the transportation subsystem as well. The optimization of these parameters is both necessary and possible but it has not been the subject of the analyses performed.

The transportation subsystem includes five steam lines with the following steam parameters [$^{\circ}\text{C}/\text{Pa}$]:

- $(152/5 \cdot 10^5) \times 3$
- $(200/14 \cdot 10^5) \times 1$
- $(250/5 \cdot 10^5) \times 1$

The power plant consists of the following units: five steam boilers producing an overall nominal quantity of steam in the amount of 290 t/h and three turbines with the nominal electric power amounting to 43.2 MW. The plant's design includes cross connections forming an entirety from the operational point of view so that each turbine can be cross-operated with any of the boilers. One of these turbines is of a back pressure type while the other two are condensation turbines with one and two steam takeoffs, respectively. There are six reducing stations and four steam coolers in the steam lines of either main or by-pass flows. These parts, together with five steam collectors, three heaters, two de-aerators and other parts of the auxiliary equipment, form the power plant consisting of the units made by different manufacturers and having different operational lives.

3 MAIN PRINCIPLES OF THE INDUSTRIAL POWER PLANT EFFICIENCY

As a rule, an industrial power plant is designed in full accordance with the relevant technological process and its capacity generally meets process requirements. The primary goal of such a plant is the production of thermal energy while the quantity of electric power produced only increases the overall energy efficiency of the complete system. This means that the turbine steam takeoffs are dimensioned in such a way that minimum preparations, i.e. corrections of the steam parameters, are needed according to the process requirements. At the same time, a set of a large number of different turbines requires the following conditions or sequences of their use: maximum loads of the back pressure turbines, full load of the back pressure turbine including a steam takeoff and, finally, the condensation turbine shall be put into operation at the full load of its steam takeoff and minimum flow to the condenser. This means that the condenser shall serve as an amortisseur of the complete system and operate at the lower values of the allowable flow rates.

The role of the reducing stations is also very important for the overall power plant efficiency. These stations are unavoidable in emergency conditions but their operation results in a pure energy loss. This fact requires special consideration in the phase of the power plant concept preparation. However, reducing stations are often operated in a way significantly exceeding both justified and economically acceptable needs.

This results in a more comfortable operation with negative effects shifted to the energy users.

The same applies to the steam coolers as well.

All these facts indicate that the way of the power plant management can be often considered the main generator of such a system inefficiency.

4 MANAGEMENT CRITERIA

Energy efficiency of a plant designed for the combined production of thermal energy and electric power depends to a large extent on its duty [1, 2, 3]. The crucial task is to establish its management criteria, i.e. to decide in which way the fuel cost shall be distributed among different types of energy produced. When saying this, we are having in mind that in the case of industrial power plants electric power is generally a by-product.

According to [3], the quantity of fuel used in the production of electric power can be considered a part of the overall fuel consumption in a power plant, i.e. in a combined heating plant/heating and power station. This dependence is given in Equation (1).

$$B_e = B_{H-EP} \left[1 - \frac{Q_c + Q_c^{hl}}{(Q_b^{gr} + Q_b^{fc}) \eta} \right] \frac{E_c}{E_c + E_{ep}} \quad [\text{kg/s}] \quad (1)$$

where:

- B_e fuel consumed in the production of electric power, kg/s;
- B_{H-EP} overall fuel consumption in a heating plant/heating and power station, kg/s;
- Q_c thermal power transmitted to the consumers, kJ/s;
- Q_c^{hl} heat lost in a heating plant/heating and power station in the process of Q_c production, kJ/s;
- Q_b^{gr} gross heat capacity of the boiler, kJ/s;
- Q_b^{fc} boiler fuel consumption, kJ/s;
- E_c generator load at the clamps, kW;
- E_{ep} electric power consumed to meet the local heat consumer's requirements, kW;
- η efficiency of heat transfer to the turbine units, including heat lost between the boiler and the turbine, -.

Specific fuel consumption per unit of the transmitted electric power (b_e^*) in the process of electric power generation is given in Equation (2).

$$b_e^* = \frac{B_e}{E_c} \quad [\text{kg/kWh}] \quad (2)$$

Fuel consumption per unit of the transferred thermal energy (B_t) in the process of thermal energy production is given in Equation (3).

$$B_t = \frac{Q_c + Q_c^{hl}}{\eta \eta_b H_d} + E_{sp} b_e^* \quad [\text{kg/s}] \quad (3)$$

where:

- η_b boiler efficiency, -;
- H_d low calorific value of the fuel, kJ/kg.

Specific fuel consumption per unit of the transferred thermal energy in the process of thermal energy production is given in Equation (4).

$$b_e^t = \frac{B_t}{E_c} \quad [\text{kg/kJ}] \quad (4)$$

The analysis of Equations (1) and (3) and Equations (2) and (4), respectively, show that specific heat consumptions in the given conditions of the transferred thermal energy production (Q_c) depend on the generated and transmitted electric power (E_c) as well as the locally consumed thermal energy/electric power.

This includes reduction of all internal energy losses with minimum necessities to operate:

- *reducing stations;*
- *reducing steam coolers.*

and is achievable through the reduction quantities of the labyrinth vapors, etc.

At the same time, the plant shall be operated in the conditions of the minimum condensation requirements which will result in lower losses to the surroundings.

5 RESULTS OF THE ANALYSIS

This type of analysis requires detailed survey of all operating conditions in the relevant energy consumers. For that purpose, an annual load diagram is to be prepared and a required number of the characteristic operating conditions together with their average durations registered. More detailed load diagrams will result in the more reliable results of the

analyses performed.

In order to prepare this study, only three characteristic conditions of the plant operation had to be recognized.

The main indicators of the power plant efficiency are shown in Table 2.

Table 2. Indicators of the power plant efficiency
($H_d = 29300$ kJ/kg)

Item No.	Parameter	Unit	Operating conditions		
			I	II	III
1.	Available fuel heat	kJ/s	204,000	199,000	260,000
2.	Transferred heat	kJ/s	82,000	82,000	126,000
3.	Electric load at the generator clamps	kW	27,500	27,700	32,000
4.	Gross efficiency of the power plant	%	53.55	55.14	60.79
5.	Fuel consumption:				
	-total	kJ/s	5.40	5.04	7.02
	-in the production of thermal energy	kJ/s	3.33	3.21	4.99
	-in the production of electric power	kJ/s	2.07	1.83	2.03

The most significant energy losses in different units of the power plant are given in Table 3.

Table 3. Energy losses in different power plant units

Item No.	Location of the registered loss	Unit	Operating conditions		
			I	II	III
1.	Reduction stations	%	3.65	3.42	3.64
2.	Steam coolers	%	3.91	4.15	4.76
3.	Labyrinths	%	1.15	1.71	1.31
4.	Total (1+2+3)	%	8.71	9.28	9.71

Table 3 shows that this power plant is energy inefficient in all periods of the year. The figures included in this Table do not require any additional comment. It is also quite obvious that a considerable number of different measures shall be taken because all data acquired on the power plant energy efficiency as well as the registered losses undoubtedly reveal an extreme comfort in the plant operation/management methods and significant technical defects in the entire power plant concept.

6 PROPOSED MEASURES

If it is assumed that the energy users have been operating within the frames of the established technological standards throughout the surveyed year, the overall efficiency of the fuel energy use shall be increased in the power plant itself. This implies execution of the following types of measures:

- a) *Technical measures;*
- b) *Organizational measures;*
- c) *Standardization measures;*
- d) *Bonuses/fines.*

According to their cost, all above measures can be divided in the following three groups:

Group 1

Group 1 measures include standardization/implementation of the personnel's technical and technological discipline and establishment of necessary bonuses/fines in order to raise the level and quality of the complete plant operation. These measures will bring the plant operation at any working condition as close to technically/ economically acceptable parameters as possible. It will be also relatively easy to implement them.

Group 2

These measures would require minor capital investments either to develop better conditions for a reliable control of the plant operation or to eliminate glaring technical errors (sealing, coating, and other activities in the field of regular maintenance).

Group 3

Group 3 includes major reconstructions, i.e. elimination of all dilapidated or energy inefficient and out of date solutions, and introduction of modern technologies designed for better control and management of the complete system.

The first two groups of the proposed measures are required to obtain the minimum quality in the plant operation and management from both technical and economic points of view. But these measures are also a basis for gaining necessary funds, practices, and technical discipline required to implement the rest of the proposed measures included in Group 3. All these requires united actions and preparation of a long-term program which shall regulate the rules of behavior as well as the consequences for not obeying them for each of the staff members whose actions might have any influence on the energy efficiency of the entire system. Full effects cannot be achieved through partial solutions only.

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ENERGY EFFICIENCY IN DAIRY INDUSTRY

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1 CHARACTERISTIC FEATURES OF TECHNOLOGY AND STRUCTURE OF ENERGY MANAGEMENT IN THE FIELD OF DAIRY INDUSTRY

Dairy industry, unlike food processing industries of campaign types, is characterized by stable, all the year round consumption of energy without seasonal variations. It belongs to big energy consumers e.g. in Czechoslovakia, it is the third in the ranking order of the biggest energy consumers, after sugar industry and breweries, with its proportion accounting for about 13% of the overall energy consumption of food processing industry as a whole.

Dairy industry can be characterized by step wise concentration of production and its specialization. In addition to consumer's dairies manufacturing products for immediate use, there are plants and factories producing long-life products such as condensed milk or dried milk products, production of butter, cheeses or ice-creams as single plants or in certain combinations.

The technological schemes of production in individual types of dairy plants largely differ, and the structures of energy management and running energy requirements are also different. The basic productional step common for all type of dairy productions is the basic treatment of milk, which is illustrated in Figure 1 together with the marks of energy inputs. The following schemes (Figures 2a and 2b) show, as an example of another type of dairy plants, technological schemes of butter and dried milk production.

The main part of energy consumption is bound to the processing step of production which is mostly carried out in heat consuming apparatuses. Certain amounts of energy are also consumed by various other production-related activities, such as handling of raw materials, semi-products and products, packaging and distribution, production of cold,

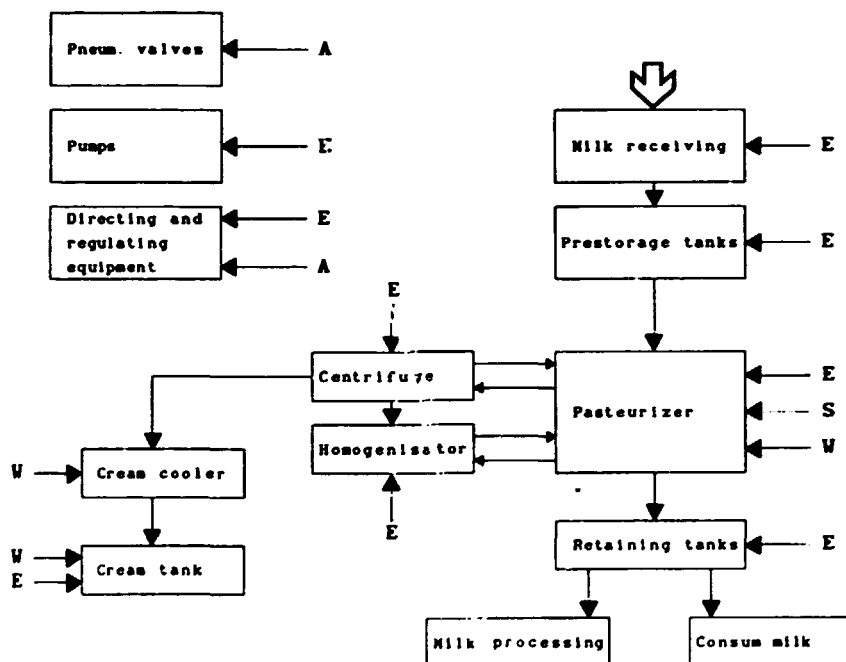
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steam and pressure air, sanitation, water management, etc.

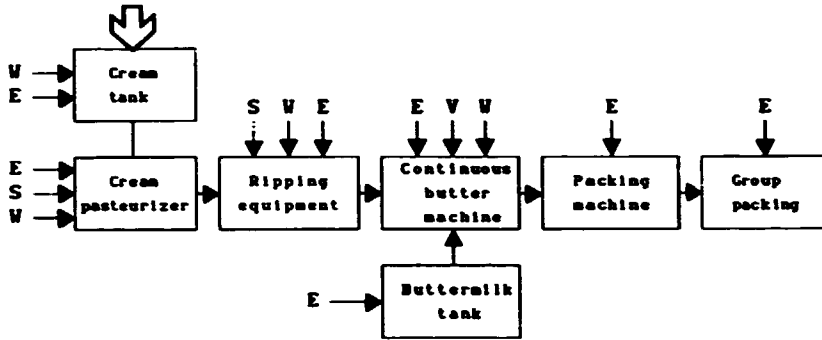
An example of energy distribution to the main technological purposes in a manufacturing plant is shown in Figure 3. The energy here is split to heat energy (steam) and mechanical energy (electrical power).

Dominating in dairy industry is the consumption of heat energy mainly produced in own boiler plants, but more economical way is to buy heat energy from outside sources. Consumption of electrical power, converted to heat equivalent, represents only a small proportion, e.g. in Czechoslovakia, in the period 1985-1988, it represented only 14.2% of overall energy consumption compared with 85.8% of heat energy. Increasing the proportion



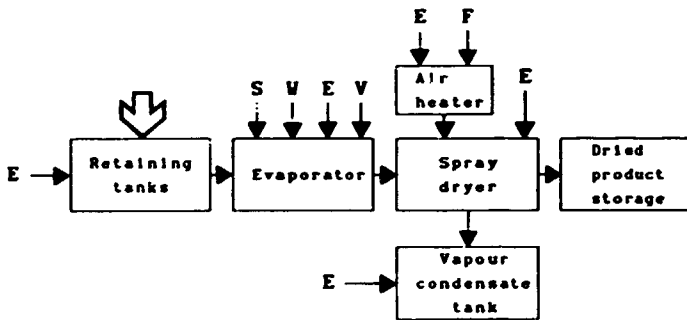
E - electricity; S - steam; W - water; A - pressure air

Figure 1. Scheme of basic milk treatment



E - electricity; S - steam; W - water; V - vacuum

Figure 2a. Technological scheme of butter production



E - electricity; S - steam; W - water; V - vacuum; F - fuel

Figure 2b. Technological scheme of dried milk production

of utilizing electrical power is a general trend in food industry as a whole and this also applies to dairy industry with its favorable impact on energy demand. Thus, for example, electric power consumption in the dairy industry of New Zealand has increased from 23% to 36% at a simultaneous reduction of the liquid fuel use from 77% to 64% which led to overall energy consumption decrease by 15% [1].

The proportion of individual kinds of energy as well as overall energy consumption are considerably influenced by the character of individual plant, produced assortment, used technologies and kinds and level of machine equipment.

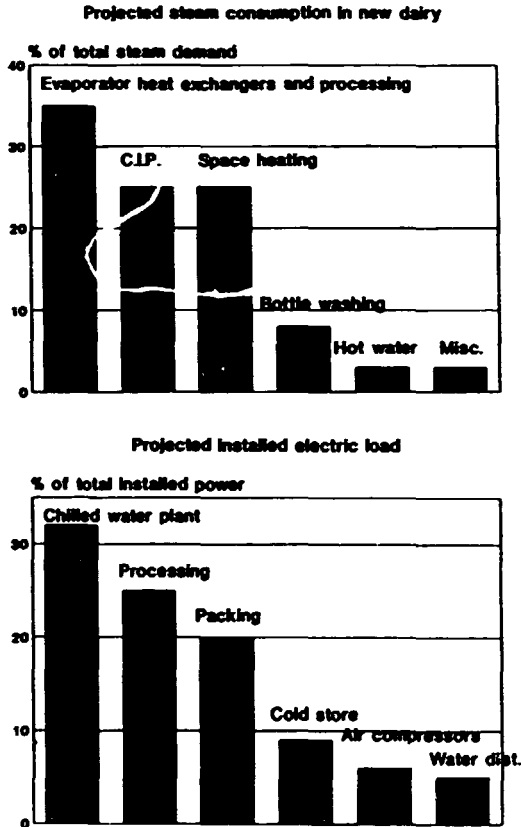


Figure 3. Energy distribution to main technological purposes of dairy plants [15]

Data concerning consumption of electrical power and heat energy in several Czechoslovak dairy industry plants and given hereinafter can be used as an example (Table 1).

The following tables characterize energy requirements of dairy industry as a whole and energy requirements for the production of individual types of products. The given values of specific energy consumption are related to a declared unit of production to allow mutual comparison.

Table 2 characterizes and compares specific energy consumption in dairy production plants of several countries in the world. (The values represent average state around 1980) [21].

Energy requirements for the production of various dairy products are offered in Table 3. The values are related to direct, technological energy consumption and to dairy production in Czechoslovakia [23].

Table 1. Survey of power and heat energy consumption in dairies of various kinds and capacity

Plant No	Processed milk t/24h	Kinds of production	Specific electric power consumption kWh/tons of processed milk	Specific heat consumption GJ/tons of processed milk	Specific energy consumption (total) GJ/tons of processed milk
1	100	Packed consum milk, Milk specialities, Creams, Butter, Curd, Soft and hard cheese	28.6	0.39	0.493
2	70	Packed consum milk, Milk specialities, Creams, Butter	29.9	0.54	0.647
3	240	Packed consum milk, Milk specialities, Creams, Butter, Curd, Curd cheese	49.0	0.76	0.936
4	110	Packed consum milk, Milk specialities, Creams	36.8	1.13	1.263
5	70	Dry milk	38.5	1.38	1.519
6	250	Dry milk, Dry buttermilk, Dry fodder mixes	39.3	1.93	2.072
7	250	Packed consum milk, Milk specialities, Creams, Ice-cream, Durable milk in boxes	127.5	2.36	2.819

The values of specific energy consumption given in Table 4 include moreover energy spent in collection of milk and its sanitation in a dairy plant. The table compares energy requirements for the production of four types of products in two European countries [21].

An interesting comparison is offered in Table 5 giving the values of specific energy consumption for certain dairy products of New Zealand [24].

A good imagination on the dependence of energy requirements in dairy production on the type and extent of a dairy plant production brings values also given in Table 1. The values are related to one of the productional areas in Czechoslovakia.

Table 2. Total energy demand related to processed milk
(International comparison)

Country	Specific consumption of energy (MJ/1000 kg of processed milk)
Czechoslovakia	1,400
East Germany	1,730
Austria	960
Great Britain	990
U.S.A.	1,150

Table 3. Energy demand for selected products
(Czechoslovakia)

Product	Specific consumption of energy (MJ/1000 kg of processed milk)		
	HEAT	EL. POWER	TOTAL
Milk 3.5% in 1 kg pouch	152	42	201
Yoghurt	1,906	264	2,170
Butter	609	248	938
Soft curd	2,635	360	2,995
Cheese in 100 pack.	2,555	718	3,273
Dried full-fat milk	11,072	654	11,726
Dried skim-milk	12,990	756	13,746

Table 4. Total energy demand for selected products in
Czechoslovakia and W. Germany

Product	Specific consumption of energy (MJ/1000 kg of processed milk)	
	Czechoslovakia	W. Germany
Milk 3.5% PE pouch	510	530
Butter Al film, 250 g	1,550	1,350
Curd 40% FDM, PVC cup	3,610	2,360
Fruit yoghurt, cup	2,730	2,690

Table 5. Energy demand for selected products - average,
(New Zealand)

Product	Specific consumption of energy (MJ/1000 kg of processed milk)		
	HEAT	EL. POWER	TOTAL
Full-fat milk in bottles	445	100	545
Cheeses (without specification)	3,270	190	3,460
Butter	1,920	150	2,070
Casein	11,820	660	12,480
Roller dried milk	9,430	450	9,880
Spray-dried milk	13,000	530	13,530

2 ENERGY SAVING ACHIEVED BY OPTIMIZATION OF RUNNING PARAMETERS IN EXISTING TECHNOLOGIES

This chapter deals with the main technological processes characterized by high energy requirements. It includes the choice of those particular possibilities which are not demanding from the investment costs viewpoint and do not need any complicated reconstruction of existing equipment.

2.1 Pasteurization

Pasteurization is a basic technological operation in the milk processing. Any milk coming into a dairy plant is for a short time heated to the pasteurization temperature (72°C, 30 s) and immediately cooled to the storage temperature (4-5 °C). This process, in its principle, represents double heat exchange (heating and cooling) and is currently carried out in plate heat exchangers. Decreasing of heat consumption in the pasteurization apparatuses is achieved by increasing the degree of heat recovery by utilization of heat contained in once heated milk. However, each increase in the degree of heat recovery requires considerable investment costs which, especially in the increase above 90% rise rapidly. Economical effectiveness advantage depends on the relation between running and capital costs (Figure 4).

According to optimum parameters of the pasteurization apparatus manufactured by the company ALFA-LAVAL and with regard to the prices of energy in Sweden, the values of heat recovery between 90-95% are considered economically optimal. The hitherto applied 66% of heat values exchange in milk pasteurization, using plate heat exchangers, can be no longer considered economical.

2.2 Homogenization

The homogenization process is, for its indisputable advantages, currently applied to consumer milk and consumer cream. However, electrical

power consumption in the drive of high-pressure homogenization pumps is rather high. It is expressed as a product of the milk volume flow rate through the homogenizer and the homogenization pressure. Energy savings can be achieved here particularly by decreasing the milk volume flow rate. A suitable solution here is the centrifugation of milk and homogenization of the obtained cream only which can be then mixed again with the centrifuged milk in a desired proportion. This solution allows to decrease the volume of the liquid passing through the homogenizer to one fourth.

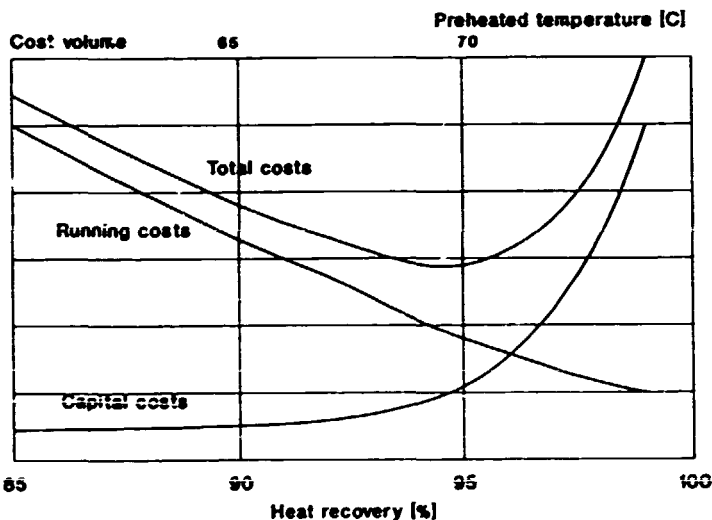


Figure 4. Cost curve showing optimal heat recovery equipment [1]

2.3 UHT treatment

In this process, hitherto prevailed a direct heating of milk by injecting steam under a pressure of about 1 MPa. Transition to indirect heating together with heat recovery from hot milk and utilization of this heat for pre-heating the cold milk, will bring considerable energy savings in production and possibility to leave out the purification of pressure steam intended for injection.

2.4 Evaporation

The evaporation process is used in production of certain milk-based beverages and condensed milk but mostly as the first step in the production of dried milk powder. Removal of water from milk is currently carried out mostly by means of evaporation at a decreased boiling temperature, i.e. under vacuum, which is the most advantageous method from the technological

viewpoint as well as from the product quality viewpoint.

However, from the energy consumption viewpoint this method is considerably demanding due to high evaporation heat necessary for the transition of liquid water to water vapors (e.g. at 60°C, 2400 kJ/kg of evaporated water).

Heat energy saving can be achieved by multiple utilization of vapor in consequent evaporation units, at step wise decreasing boiling temperatures. This method leads to multistage evaporators. Investment costs for multistage evaporators rise proportionally to the number of evaporation stages.

The optimum number of stages in an evaporation unit will be again a result of economical deliberation - reasonable comparison of expected energy savings and necessary costs (analogic relationship in Figure 4).

Another possibility to save heat for the milk evaporation is compressing the vapours to a higher pressure and correspondingly higher temperature, so that they could be used again for heating the same pressure stage of evaporator. Compressors available for this purpose are either steam jet compressors driven by superheated steam or mechanical blowers. Installation of a steam jet compressor to the existing evaporator does not require too high investment costs. On the other hand, reconstruction by means of mechanical recompression is far more complicated and more expensive.

2.5 Drying

There are several recommendations which should be mentioned from the energy conservation viewpoint in the current drying operation.

Above all, it is necessary to achieve as high degree of the milk evaporation as possible in the evaporator before it comes to the drying chamber. In the case of milk evaporation to 50% of the dry matter content, about 4/5 of the originally present water enters the drying chamber. At the same quantity of water, the single-stage drying chamber consumes roughly 7-times more energy than the three-stage evaporator.

Effects of various dehydration methods on specific energy consumption for this process are clearly illustrated by the diagram in Figure 5A. Real values of energy quantity in Figure 5 (x-axis) are not quoted. They depend mainly from the type of the used equipment and of the treated material.

For spray driers, which are for the reasons of product quality as well as operation economy the most widely spread driers currently used for milk drying, it is further necessary to achieve the following:

- *The highest possible input temperature of the fresh drying air coming into the heater, and its heating to the highest, technologically admissible value at the drying chamber input;*
- *Optimum distribution and flow of air in the drying space;*
- *The best possible utilization of the air drying capacity, i.e. its lowest possible output temperature;*
- *Pre-heating of evaporated milk before it enters the drying chamber.*

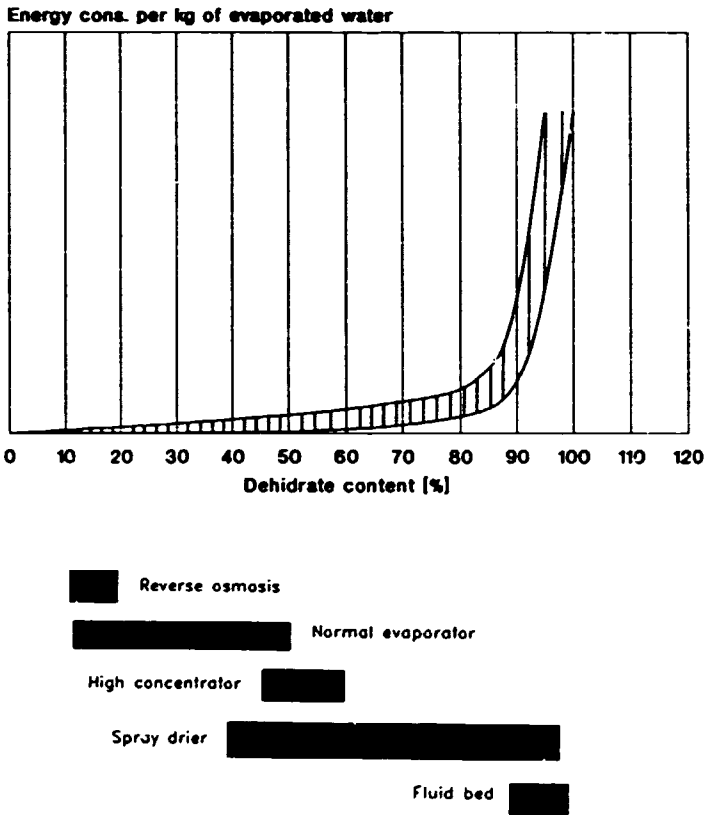


Figure 5. Area for various processes of water removing [17]

Most of the existing drying chambers operate at the air drying temperature of 190-210°C and the outlet air temperature of 95°C. Energy losses due to the high outlet temperatures of air are considerable.

However, in despite of numerous efforts of the foremost manufacturers of air-conditioning equipment, utilization of heat exchangers for heat recovery from the milk driers is rare. The reasons are mostly operational-clogging with flue dust, complicated and costly cleaning, possible bacterial contamination of fresh air, etc.

Effects of the basic process parameters of drying chambers on energy consumption are illustrated in the following diagrams (Figures 6-8).

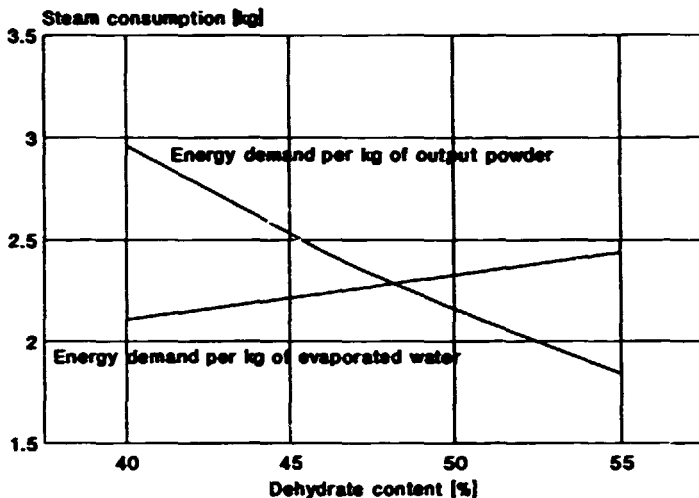


Figure 6. Influence of dehydrate content in concentrated milk on the spray drier energy consumption (inlet air temperature 200°C, output powder humidity 4%) [17]

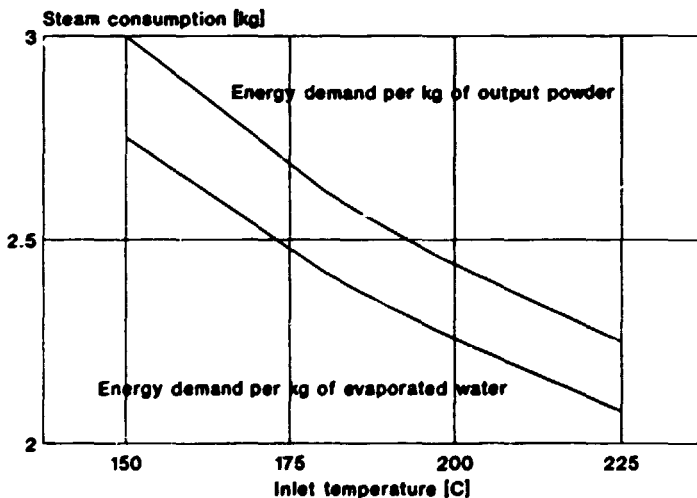


Figure 7. Influence of dry air inlet temperature on energy consumption during the spray drying (dehydrate content in vaporized milk 46%, output powder humidity 4%) [17]

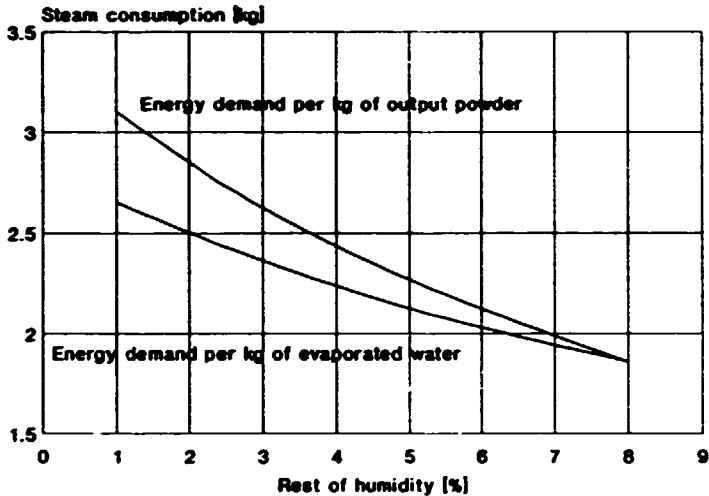


Figure 8. Influence of spray dried pulver rest humidity on energy consumption (inlet air temperature 200°C , dehydrate content in vaporized milk 46%) [17]

2.6 Water economy

The most realistic possibilities of energy savings in a dairy plant by means of heat recovery are offered by the production of hot water as a heat-carrying medium. It is, therefore, very important to have an integrated system of water economy in dairy plant, allowing sufficient variability in utilizing various heat levels of water, i.e. even waste water. Today, water is a very expensive raw material. Dairy plant with a water consumption equal to 2.5 - 3 -fold of the processed milk cannot operate effectively. A reasonable and admissible ratio is 1:1 or lower [15]. According to the same source, the dairy plant after reduction of this ratio from 2.5 to 1.0 decreased the running costs by a sum of money representing 10% of energy saving. The way how to decrease water consumption and thus energy consumption as well is in water persevering recirculation and multiple utilization. Especially suitable for this purpose are: *steam condensate, waste vapor condensate from multi effect evaporators, cooling water from cooling and air compressors, final rinse water from the CIP (cleaning in place) system and bottle washing machines.*

2.7 Pressure air

Pressure air is mainly used in rearrangement of the pneumatic valves, blowing off systems in sanitation, in production of ice-creams, in controlling and regulating devices, manufacture of certain packagings, and

in machine-manual manipulators. Pressure air production from the energy requirements viewpoint, is highly demanding (drive of compressors by individual electric motors) and it is, therefore, necessary to prevent its wasting. It is especially true for leakage in the leaky distribution pipelines operation of pneumatic devices of all types, especially elevating manipulators and units operating with manual control in intermittent intervals. For illustration, a Czech automatized dairy plant with large production of ice-creams consumes for the production of pressure air 26.6 kWh/1000 kg of the processed milk [6].

2.8 Refrigeration and freezing

Savings of energy (mostly of electrical power) in using the machine-produced cold, depend on the observation of the following principles:

- a) *Optimization of cooling parameters (e.g. condensation temperatures, vaporizer temperature, etc.);*
- b) *Distribution pipelines should be as short as possible and properly insulated to prevent losses of cold. Insulation must be constantly maintained in intact state. This is especially true for the piping of very low temperatures.*
- c) *Central production of cold for the remote appliances must be thoroughly considered from the economical viewpoint. In certain cases, it will be necessary to consider individual automatic units placed directly besides respective appliances and adjusted according to their needs;*
- d) *Utilization of all leaking heats with lower temperature levels and considering possibilities of their repumping.*

As practical illustration how selection of working parameters can influence energy requirements of cooling compressor stations, the plots in Figures 9-11 can be used. Energy savings utilization of waste heat from the compressor stations are conditioned by the installation of additional devices for waste heat recovery or repumping.

2.9 Sanitation and cleaning

Energy consumption in sanitation is, to a considerable extent, influenced by the applied system of cleaning. There are generally two automatized systems: central, and decentralized one. The formerly used method is the cleaning of entire dairy plant by one central cleaning station with tanks for cleaning solutions and water, heat exchangers, pumps, necessary automation elements, and programmable automatic devices for control and managing of the cleaning process.

Currently introduced method of cleaning is a decentralized cleaning system consisting of smaller sanitation units with mutual communication, which are linked to a central store of cleaning solutions. Sanitation units, consisting of tank, exchanger and a system of piping and valves, and controlled by a microprocessor, is located at each center. Such a distribution considerably simplifies piping, increases operability of the cleaning regimes, shortens the time required for cleaning, and decreases consumption of energy, water, and cleaning agents.

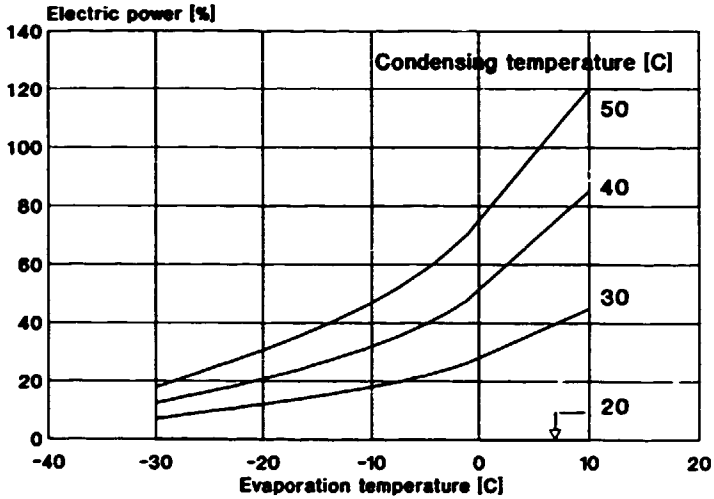


Figure 9. Increase in the electric power consumption when the condensing temperature is increased above 20°C, without considering the change in refrigeration capacity [1]

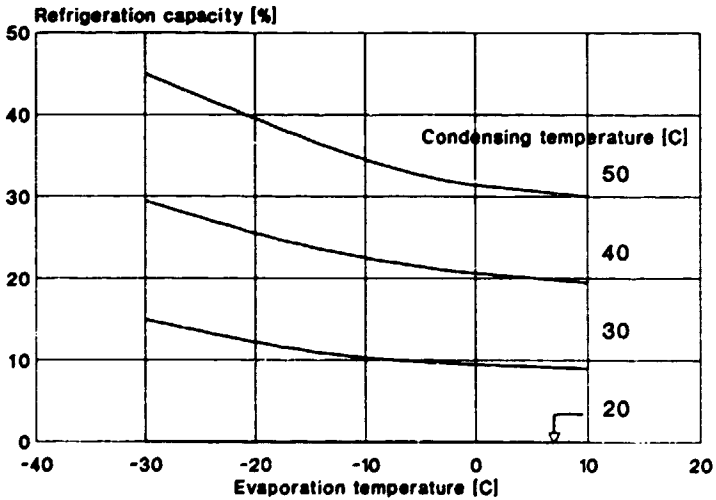


Figure 10. Decrease in the refrigeration capacity when the condensing temperature is increased above 20°C [1]

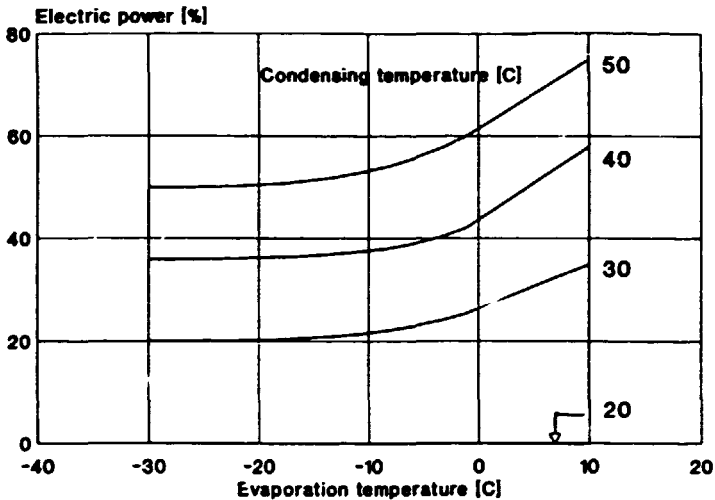


Figure 11. Total increase in the electric power consumption resulting from temperature increase, considering the change in refrigeration capacity [1]

Modern dairy plants usually have 50-70 cleaning circuits and, therefore, implementing of the decentralized cleaning is one of the very effective ways to savings which can account for 1/2 to 3/4 of the sanitation costs. Further possibilities to save water, and thus energy as well, include implementation of turbidity removing centrifuges continuously removing turbidity from the cleaning solutions. Multiple prolonging of cleaning solutions service life increases the economy of the working areas cleaning to such a degree that the centrifuge investment cost is paid back in several months.

2.10 Heat energy use and production in dairy plants

The main heat carrier in dairy plants is saturated or slightly superheated steam. For ecological reasons, the methods of steam obtaining can be arranged in the following ranking order:

1. Steam from remote steam pipe works or heating systems;
2. Night, off-peak electrical power at an economically advantageous price for the production of hot superpressure water in accumulation boilers, with its easy transfer to saturated steam;
3. Fuel gas from remote gas lines for the production of steam in own special generators (steam boilers);

4. *Liquid ash-free fuels for own production of steam and eventually for drying air heating;*
5. *Solid fuels, only after a considerate ecological treatment.*

Selection of steam generators (boilers) must be for its importance, considered very carefully which applies to the steam production in dairy plants generators as well (alternatives, see items 3, 4, and 5). Steam is a deciding element in energy consumption/energy saving possibilities. While ash-free, especially gaseous fuel burning boilers can work with the running efficiency of 93-95% and their regime is in full accordance with several hygienic requirements, solid fuels represent the most frequent source of serious difficulties in dairy plants which include especially:

- *Non-hygienic supply and storage of fuel;*
- *Variable consumption of fuel, and its efficiency varying in the mining site as well as in the process and dairy plant stores;*
- *Complicated treatment of fuel before its use and boiler feeding;*
- *Lower efficiency of the solid fuel burning boilers caused by an incomplete incineration, falling through, and ash and cinder removal from the furnaces;*
- *By-products of this incineration are health and ecologically hazardous flue gases (SO_2 , CO_2 , CO , NH_3 , and various hydrocarbons) and light ashes of fine particles;*
- *Removal and disposal of ash, cinder and unburnt residues represent further ecological damage to the landscape and environment, and an impaired hygiene in the vicinity of dairy plants.*

Thus solid fuels should be used only in utmost cases and, according to local circumstances and sources, heat energy and steam should be obtained by another, ecologically and economically more advantageous way.

This fact should be carefully considered especially in designing and localization of dairy plants at the sites where it is necessary to consider either existing or available sources of heat energy.

It should be especially reckoned with:

- *Dairy plant connection to remote sources of heat energy (steam piping, heat piping, gas pipelines);*
- *Use of pressure hot-water boilers (as accumulators of heat energy) heated by the resistance heat from the night, peak-off electrical power. This possibility is evident especially in connection with the existence of nuclear power plants with outputs which cannot be adequately decreased in the peak-off time;*
- *Use of another ash-free, particularly liquid and gaseous, fuel.*

3 POSSIBILITIES OF ENERGY SAVING BY INTRODUCING NEW EQUIPMENT AND NEW TECHNOLOGIES

The most pronounced changes in energy consumption in the manufacturing procedures can be achieved by junking inveterate, energetically inefficient machinery and equipment and replacing them with the new modern ones consuming less energy. Energy viewpoints should be considered in early stages, i.e. in designing new plants or proposing and projecting new

technological sections. A design preparation has to be preceded by elaborating detailed technological and power analysis. This analysis will allow to bring technological requirement into harmony with the requirements to minimize energy costs and to select the optimum solution. Before installing any new equipment or technology, it is always necessary to seek their optimum types meeting both the requirements of the product quality priority and the relevant requirements from the investment and running costs viewpoint.

3.1 Automation and microprocessor control

Full automation and microprocessor control is the most widely spread technical trend applied to all food industry technologies. Although, from the energy viewpoint, it represents a slight increase of power input required to drive control devices, measuring apparatuses and control centers introduction of these systems, on the whole represents considerable decrease of energy consumption by ensuring constantly optimal manufacturing conditions and parameters of a given technological procedure. The resulting decrease of energy consumption can be estimated to 5% from the total energy consumed according to the degree of all sections computerization. Besides the complete technological units, power systems are also equipped with their own self-contained computers evaluating all power parameters and regulating their optimum states in cooperation with the central computer and in dependence on the changes of process parameters. According to reference data, significant savings of energy are achieved by introducing computerization into the dairy freezing stores.

3.2 Drying line

Production of dried milk powder represents the highest consumption of energy in the existing dairy plants. In certain countries, this production is highly developed (France, Czechoslovakia, Austria) and represents a part of dairy plants, or is centralized and represents self-contained specialized plants for the production of dried milk powder (e.g. in Sweden). Rationalization of energy consumption in these plants is, therefore, a subject which attracts much attention of the respective technique manufacturers in the world. The possibilities of energy savings by means of the working parameter adjustments in devices and equipment have been already mentioned in the previous chapter. Now we shall mention new trends in the development of these devices, the effective ones from the energy consumption viewpoint. One of these trends is the optimal choice and selection of evaporators and driers for the so-called *drying lines*.

Specific energy requirements of the evaporation and drying processes, related to the amount of water evaporated from milk, is considerably variable. Specific consumption of heat energy in the entire out-of-date type of drying lines varies between 1.3-1.5 MJ per kg of the evaporated water. From this overall values, the values given for evaporators is 0.83 MJ/kg while the values given for driers range around 6 MJ/kg. The given values apply to usual drying lines consisting of a three-stage evaporator and a single stage spraying drier (processing about 12,000 l/h of the skimmed milk and evaporating 9,700 l of water/h in the evaporator and 1,130 l of water/h in the drying chamber).

The main possibility to decrease energy consumption in drying lines is replacing the few-effect evaporators by the multi-effect ones operating with heat-compression or by evaporators with mechanical vapor recompression (MVR). Drying chambers are replaced by multistage spray driers, including eventually equipment for the recovery of waste heat from the outlet air. In both of these devices replacement can be carried out in the form of complete reconstruction or they can be replaced by the new, more modern types.

Specific consumption of energy in a simple single-effect evaporator is about 2.65 MJ per kg of the evaporated water. In a modern evaporator with mechanical vapor recompression this consumption is up to 12 times lower, i.e. it is 0.2 MJ/kg. The multieffect evaporators with preconcentrators also reach similar specific heat demands as the evaporators with MVR. Another simple system of decreasing energy requirement in the complete drying line is based on the utilization of waste heat recovered from the vapor condensate. It is installed, for example, in a milk drying plant in Jindrichuv Hradec (Czechoslovakia) and represents a system of a four-effect evaporator with a steam jet heat compressor and a double-stage spray drier. This new device has brought a saving in the heat energy consumption amounting to 30% if compared to the energy consumption in the former drying unit (a single-stage drier, plate evaporator). The condensates of the evaporator waste vapor are led to the boiler plant, where they are filtrated and used as the pre-heated boiler feed water. This arrangement has brought further saving of about 5% of the consumed energy as well as a saving of the treated feed water.

One of the biggest manufacturers of evaporators and respective devices and equipment in the world is the company GEA Wiegand (Germany). It offers evaporators for various purposes with capacities ranging from 5 t (or less) of evaporated water per hour to 46 t/h, with various numbers of evaporating effects (up to 7), evaporators with thermocompressors and the latest technical top: single-effect multi-down take blow and double- or triple-effect evaporators with mechanical recompression of vapors (MVR). The drive of compressor blowers for MVR is mostly electrical. For liquid fuels, the combustion engine drive is also proposed. This engine is energetically solved as a highly effective one and ensures utilization of up to 83% of the supplied energy. The four-effect evaporators with thermocompressors are also manufactured by the firm Chepos-Chotebor in Czechoslovakia. These evaporators show a fairly good heat efficiency. In operation they consume 0.19 kg of steam (0.48 MJ/kg) per kg of the evaporated water. Other evaporator manufacturers well known in the world are Anhydro, Lagullare, Schaffer and others.

For the actual process of milk drying there are hitherto used two types of driers: drum and spray driers. Even when drum driers show lower specific consumption of heat energy in their operation, they are stepwise replaced by spray driers which achieve significantly better qualities of dried products and higher hourly outputs. Technically, they can be easily adjusted for the production of desired instant products and various other specialties as well.

The way to decreasing consumption of the energy in spray drying primarily leads to a more complete utilization of the drying air heat value as the drying air is used in this process in high amounts.

For example, a spray drier with a capacity of approximately 1300 kg of evaporated water per hour consumes about 33,000 kg of air. Therefore, the trends are to introduce a multistage process. One of this arrangements is the following:

Table 6. Energy consumption required to evaporate 1 kg of water in spray and drum drying

	Specific consumption of energy (MJ per kg of evaporated water)
DRUM DRIER	3.5 to 4.0
SPRAY DRIER	4.0 to 6.0

- 1st stage: *Drying air is heated to 200°C. During the drying process, it is in contact with a cloud of milk droplets cooled to a temperature of around 75°C. The milk powder obtained by this process is, however, dried only up to 6 or 7% of the final moisture content.*
- 2nd stage: *The incompletely dried milk powder has a tendency to be sticky. Therefore, the bottom cone of the drying chamber is replaced by a sieve bottom and small amounts hot air at a temperature of about 130°C are tangentially led under it.*
- 3rd stage: *The milk powder is led to vibrofluid trough the drier. It is dried there by air to the final desired 3.5% of the residual moisture at a temperature of about 110-130°C, in an approximate amount of only 2,250-3,000 kg/h. Conglomerated lumps (so-called instantized product) are simultaneously formed which are easily and quickly dissolved in reconstitution with water.*

The last auxiliary device in spray driers is the cooling vibrofluid through which powder is cooled to the storage temperature and practically dried to a desired final moisture as well.

The best known manufacturers of spraying driers in the world are the companies NIRO Atomizer (Denmark), Anhydro A. S., and other. Denmark and many other spray driers are also produced and exported by the Czechoslovak firm Vzduchotechnické Zavody Nove Mesto nad Vahom. A comparison of the specific energy consumptions in the three different types of drying lines is given in Table 7. Physical properties of the heated milk are equal in all cases, including the dry matter content in the condensate milk before it enters the drier.

3.3 Utilization of secondary energy sources

In dairy plant, there are many fluids (i.e. liquids and gases) which are heated and evaporated at one site and cooled or condensed at another one. From the energy point of view, it would be thus theoretically possible to propose a system which would be energetically so interconnected that it would need only minimum external source of energy for its stable operation. Apparently approaching to this case are certain already working dairy plants which, for their continuous duties, do not need any boiler plants producing

technological steam. Overall heat quantities required for technological purposes are obtained from the waste heat, e.g. from the stations of gas-burning motors, air-compressors or freezing units compressors. An example is a consumer dairy plant (without drier) in Malmo (Sweden). Its energy system has been proposed by the firm Energikonsult [8]. The temperature level of heat from the waste compressor and condenser cooling

Table 7. Comparison of specific energy consumptions in three types of drying lines

Type of drying line	A	B	C
Specific energy consumption per 1 kg of evaporated water	1.36	0.78	0.73
Specific energy consumption per 1 kg of produced powder	11.8	6.3	5.3

- A Conventional spray drier and three-effect evaporator (inlet air temperature 200°C)
 B Two-stage spray drier and evaporator with MVR (inlet air temperature 200°C)
 C Two-stage spray drier and evaporator with MVR (inlet air temperature 250°C)

water is, by means of a double-stage system of heat repumping, increased to the level of about 80°C in the first stage and to the level of about 105°C in the second stage. This solution, as briefly described above, has resulted in 60% lower energy consumption, and offers the possibility to leave the steam boiler out of the energy supply system.

3.4 Utilization of waste materials for energy generation purposes

In dairy plants it is particularly the case of whey. Until recently, whey has been considered a waste product, although it contains numerous biologically and nutritionally highly valuable substances. However, its optimum and complex utilization still remains a subject of many research efforts. From the energetical point of view, two systems of its utilization can be mentioned. Both systems have been developed by the company Food and Dairy Expo Manufactures (USA). One of them is based on the methane production from whey using the MARS system while the second one produces ethylalcohol [2].

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CHANGE IN THE ENERGY EFFICIENCY IN THE HUNGARIAN FOOD PROCESSING INDUSTRY

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1 INTRODUCTION

The energy crisis set in at the end of 1973 as well as its consequences brought about significant changes in the energetics of countries all over the world.

In Hungary, energy utilization was reevaluated in 1978 as a result of energy crisis.

Within the scope of energy consumption, both in respect of quantitative and structural features, this reevaluated energy utilization began to take effect from 1979 on. The principal trend of the new program was to achieve a significant decrease in the rate of fuel consumption in the national economy, compared to that of the recent decades (especially that of hydrocarbons and coke), thereby diminishing the energy intensity of our national economy.

2 DEVELOPMENT OF ENERGETICS IN THE FOOD INDUSTRY FROM 1981 TO 1985

Due to the reevaluated energy utilization, the trends developed at the end of the 70's remained effective. In the field of energy consumption, the former proportion of coal to hydrocarbon underwent a change:

- The reduction of coal consumption stopped;
- The consumption of natural gas increased;
- The consumption of oil and petroleum products diminished in

- accordance with the principles of energy saving;
- The electric power consumption increased.

The change in the proportion of different types of fuel in 1978, 1982 and 1985 is shown in Figure 1.

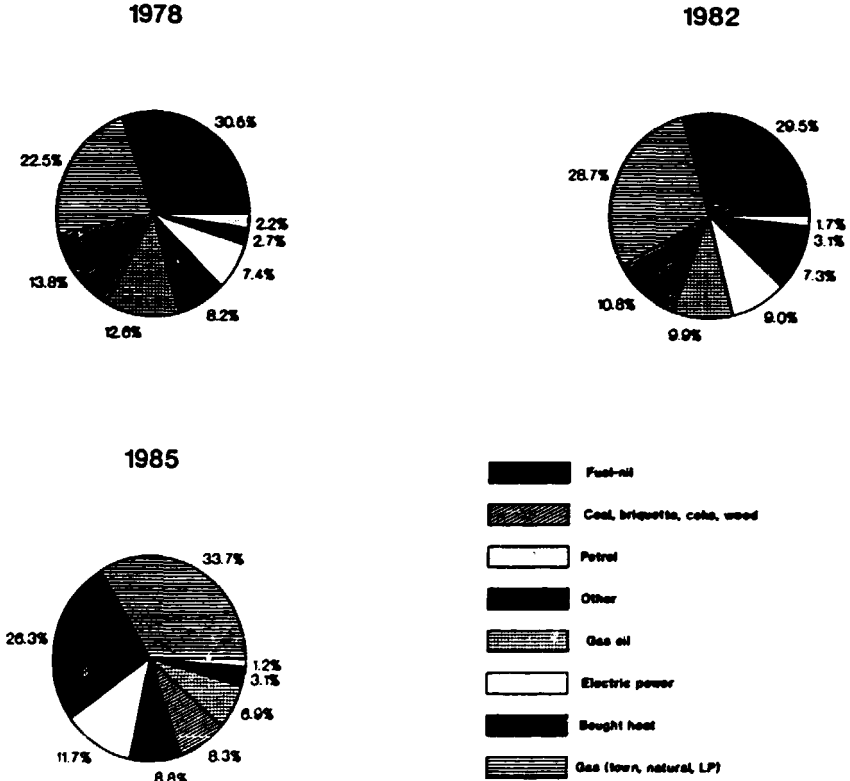


Figure 1. Percentage distribution of energy resources within the total energy use in the food industry

In addition to the favorable change in the structure of consumption, the specific consumption of fuel diminished as well, though the consumption in respect of expenses grew considerably, due to the several rises in fuel prices.

The total energy consumption expressed in heat value is shown in Figure 2. The development of energy costs and oil equivalent, respectively, falling on unit/million forint/production value is given in Figure 3.

The results achieved in the field of energy utilization were enabled by the considerable efforts made by the companies of the food industry in respect of organisatory actions in order to save energy. The companies utilized both their own resources and the credits and central subsidies granted for energy-saving purposes.

Due to the decrease in financial resources, the general repairs and reconstruction activities involving also the improvement and modernization of technical facilities came into the foreground, which also promoted, in most cases, the fulfillment of aspects for energy saving and improvement of cost efficiency in energy consumption.

The organisatory actions resulting in energy savings involve, among others, the following fields:

- *Achieving an optimum specific energy consumption by tightening the technological discipline and by increasing personal interestedness;*
- *Improving the energy efficiency by intensive maintenance of on-plant systems for supplying and utilizing energy;*
- *Extending the on-plant measuring and checking facilities;*
- *Achieving savings in fuel consumed by transport vehicles, as a result of economical utilization of transport facilities.*

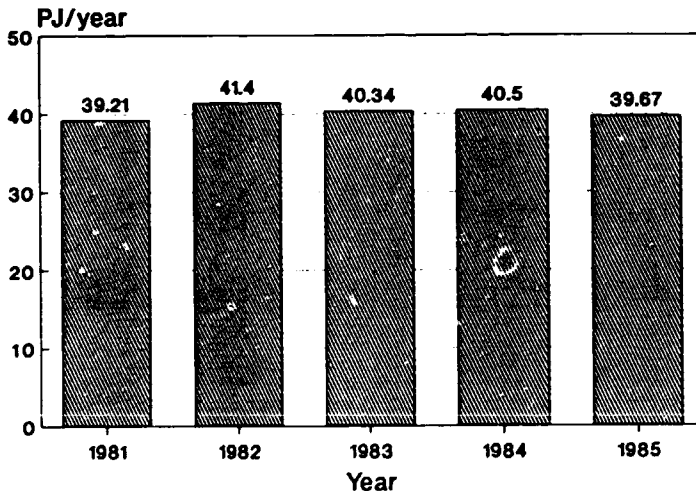


Figure 2. Total energy consumption in the food industry, (in heat value)

The action taken for improvement also comprised the modernization of systems for supplying and utilizing energy, as well as the improvement of the requisite instruments.

As a result of development, there was a decrease in energy losses, the utilization of waste heat could increase, the specific consumption parameters improved, the expensive fuel types were replaced by less expensive ones.

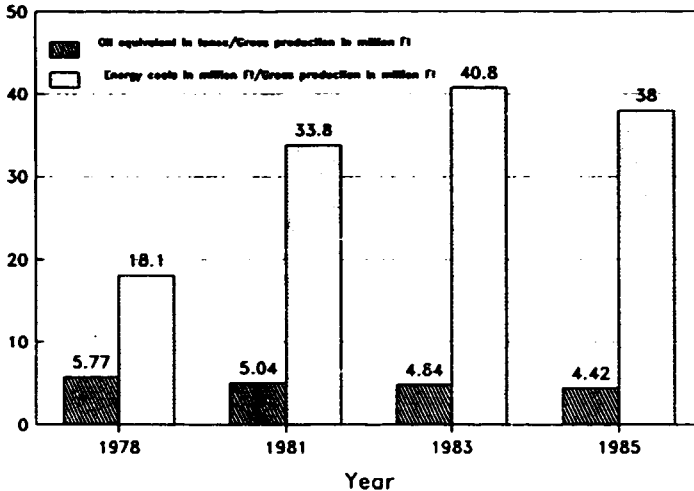


Figure 3. The variation in oil equivalent of total energy use versus gross production of the food industry and variation of the total energy costs versus gross production

Among the actions taken in this regard, the following fields are of primary importance:

- Modernization of milling technologies;
- Improvements of boiler plants in the factories of canning and sugar industries;
- Improvements on utilizing waste heat in the dairy and sugar industries;
- Increased utilization of by-products in the vegetable oil industry, by extending the capacities of boilers fueled by sunflower seed shell;
- Introduction and application of up-to-date processing and management systems as well as those of computer-aided energy management systems in the sugar and meat industries.

3 EQUIPMENT AND SYSTEMS OF PRIMARY IMPORTANCE, PROMOTING THE EFFICIENCY OF ENERGY UTILIZATION

The trend to reduce energy consumption and to increase the efficiency of energy utilization resulted, among others, in the accomplishment of many

successful improvement tasks, in the completion of new energy-saving facilities, processing lines, measuring, checking and processing systems for energy utilization.

Two such systems and equipment applied successfully would be mentioned. These are as follows:

3.1 Home-made boilers fueled by sunflower seed shell to utilize the cheap seed shell

The sunflower seed shell is one of the most important combustible by-products (wastes) arising in the food industry.

In Hungary, the vegetable oil industry, pertaining to the food industry, is a branch developing dynamically. By putting the Vegetable Oil Factory in Martfű into action, the oily seed processing capacity of our country had doubled by the beginning of the 1980's. This production level is expected to be considerably raised by the reconstruction of plants, i.e. process.

The proportion of oil grits always depends on the plant sorts grown and processed. If the oil contents of oily seed considerably increases, presuming an unchanged vegetable oil production, the demand on capacity will diminish since less grits will arise. The same can be told about the seed shells, i.e. the smaller the seeds are, the larger the proportion of shell is.

Due to the replacement of imported soya grits by the first class Hungarian sunflower seed grits, savings in hard currency could be achieved and this resulted in an excess shell quantity in the factories even specifically, compared to the quantities arisen previously.

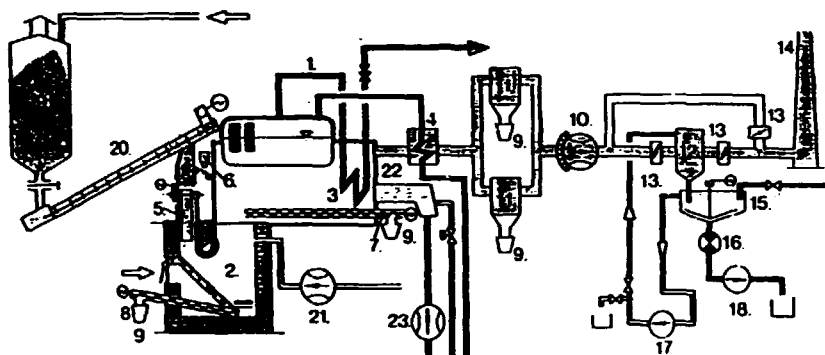
The existing boiler facilities in the individual factories did not allow firing of the arisen excess shell quantity. Therefore, the Hungarian Institute for Energetics, making use of the experience gained in respect to the boilers already in operation, supplied the boilers manufactured by the Bertsch Company which were started up in the recent years in the Vegetable Oil Factories in Rákospalota, Győr and Nyírbátor.

Technical data of the boilers:

Type:	NH-10	NH-15
Heat value of sunflower seed shell:	16,700 kJ/kg	16,700 kJ/kg
Rated steam production capacity:	10 tons/h	15 tons/h
Quantity of seed shell to be fired:	2,500 kg/h	3,500 kg/h
Temperature of produced steam:	240 °C	380 °C
Pressure of produced steam:	16 bar	28 bar
Feed water temperature:	100 °C	100 °C
Efficiency:	82%	86%

The technological flow sheet of sunflower seed shell firing is shown in Figure 4. The annual production of sunflower seed shells is given in Table 1. The sunflower seed shells make out about 15 to 18% of the produced raw material quantity. Hence, 62% was fired in 1982, 77% in 1984, and 87% in 1985. the heat value gained from firing the seed shells exceeded 1 million

GJ in 1985, which was equal to 39.3% of the heat value of the total fuel consumption in the vegetable oil industry. The achieved savings in energy costs resulted in 90 million forints in 1983, 103.3 million forints in 1985, and 121.1 million forints in 1985.



- | | |
|--------------------------------------|----------------------------------|
| 1. Sunflower seed shell fired boiler | 12. Wet scrubber |
| 2. Firing equipment | 13. Damper |
| 3. Superheater | 14. Stack |
| 4. Economizer | 15. Dorr settling device |
| 5. Swinging spout | 16. Rotating air-lock damper |
| 6. Safety damper | 17. Wash water circulation pump |
| 7. Fly ash transport | 18. Sludge pump or screw |
| 8. Slag screw transport | 19. Shell bin |
| 9. Fly ash container | 20. Scraper conveyor |
| 10. Induced draft fan | 21. Overfire air blower |
| 11. Fly ash cyclone | 22. Auxiliary natural gas burner |
| | 23. Forced draft fan |

Figure 4. The flow diagram of the sunflower seed shell firing

3.2 Measuring and regulating provided by a microprocessor-controlled power engineering system

In addition to the applied energy-saving machines and equipment and energy-saving technologies, the energy utilization systems providing up-to-date measuring, data processing and interfering possibilities are taking a part of over-increasing importance in intensifying the efficiency. In the food industry complexes in Hungary, the microprocessor-controlled energy utilization system type DATAWATT-P, manufactured by Hungarian Company for Development of Measuring Technics, is gaining ground, being suitable for measuring, processing and interfering in all fields (electricity, gas, steam, and compressed air).

The hardware and software structure of the system is of a module type, therefore this system is always designed and manufactured to perform the required task.

Table 1. Sunflower seed shell production and consumption in the Vegetable Oil and Detergent Production Company in 1983, 1984, and 1985

DERIVATION	Unit qty.	1983	1984	1985
Sunflower seed shell consumption	1,000 t	463	525	516
Produced sunflower oil	1,000 t	202	211	196
Sunflower seed shell	1,000 t	90	83	86
Fired quantity	1,000 t	56	64	75
Sold quantity	t	3	16	7
Seed shell grinding	1,000 t	2	1	4
Remaining quantity	1,000 t	29	2	-
Recoverable heat (fired qty*16.7 GJ/t)/ 1,000 t	GJ	935,200	1,068,800	1,252,500
SAVINGS				
Natural gas	1,000 m ³	19,562	21,950	25,770
Coal	t	5,964	6,816	7,670
Fuel oil	t	3,307	4,134	4,960
Heat qty obtained from firing	GJ	935,200	1,068,800	1,252,500
80% = equivalent to 1,000 m ³ of n. gas	GJ	748,160	855,040	1,002,000
Energy cost savings	1,000 Ft	90,000	103,300	121,100

TASK OF THE SYSTEM

- To receive and process the signals emitted by the measuring instruments (remote current transmitters, remote impulse transmitters, two-position signals) involved in the process;
- To store and evaluate the data obtained during the course of signal processing. To perform necessary interfering actions on the basis of the evaluated data;
- To register the measuring results;
- To register the events and interfering actions sensed by instruments of the system.

STRUCTURE OF THE MEASURING SYSTEM

The signals emitted by the measuring instruments of the process, in case of a simple system, will be received by a central data collecting and evaluating equipment while, in case of large systems, this will be performed by intermediate stations. These stations are meant to receive the two-position signals, too. The structure of the system can be seen in Figure 5.

The stations are designed for collecting the measuring data, data processing and for taking interfering actions. The results of measuring, processed by the stations, will proceed into a central data collector for further evaluation. The equipment for central data collection and evaluation will supply the stations with the data required for interfering in the process.

The central equipment and the local stations are connected in series by appropriate wires so as to allow data transmission.

Data transmission is performed in semi- or duplex duty by applying two or four wires, respectively.

Electric matching is provided by the low-speed "Modems" enabling a data transmission speed of 1,200 bytes/s. The central equipment and stations are based on the 8-byte microprocessors.

The energy savings in factories and plants reach even 20 to 30%. The designer of this system is the Hungarian Company for Development of Measuring Technics and it is manufactured by Ganz Factory for Kilowatt-hour Meters. The system has been applied for the first time in the Meat Complex in Szekszard and is still being developed.

4 TARGETS IN THE ENERGY UTILIZATION PROGRAM TILL 1990

4.1 Targets on national economy level

In respect of the economic development rate planned for the period of 1986 through 1990, an increment of not more than 1% per year, at an average, may be envisaged in the energy consumption, i.e. in 1990, the total energy consumption of our national economy may range from 1,375 to 1,390 PJ. The annual increase in electric power demand may not exceed 3 percent. Since the planned development in the national economy, at the present level of power economy, would require more than that, the energy utilization program comprises accomplishable tasks indicating what energy savings of approximate 50 to 55 PJ/year need to be reached in 1990, in relation to the present level. The program of energy utilization also comprises the main tasks to be accomplished with regard to the saving of materials, improvement of technology and utilization of wastes. A waste and by-product quantity equal to some 6.5 to 7.5 billion forints is planned to be utilized.

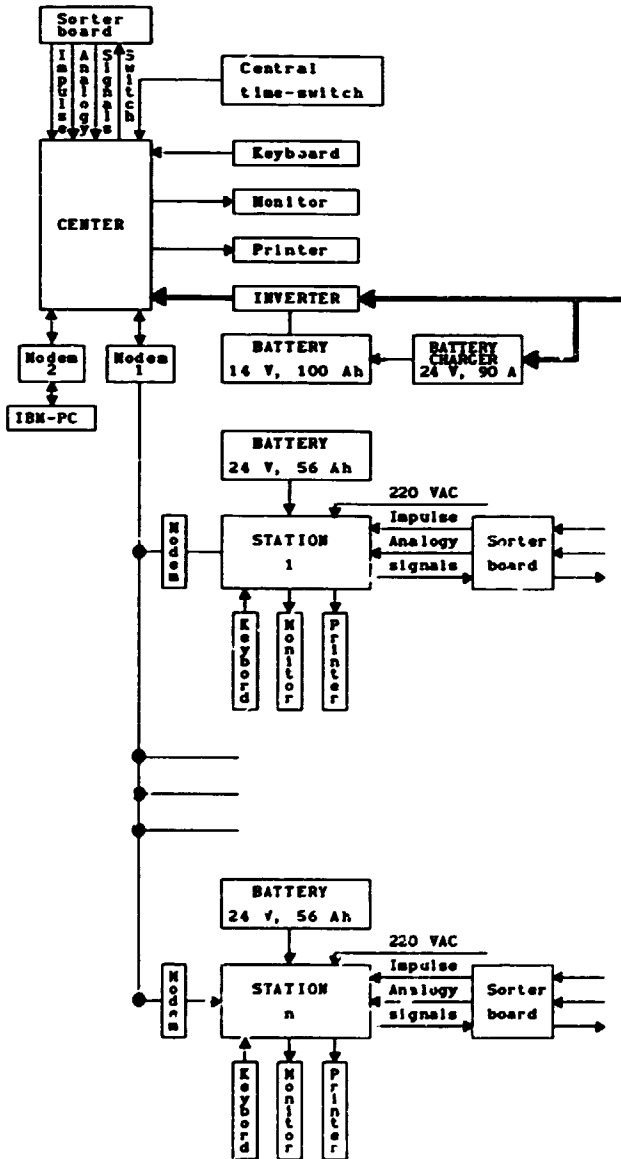


Figure 5. Structure diagram of the energy utilization system, DATAMATT-P type

4.2 Targets related to the food industry in respect of energy utilization

In accordance with the program of energy utilization, the increase in the energy consumption of the food industry may not exceed a rate of about 1.5 percent in the period of 1986 through 1990. The realization of this target presumes a decrease in the specific energy consumption of energy-intensive products of the food industry as follows:

PRODUCT	1980	1985	1990	Index $\frac{1985}{1990} \times$
White sugar, GJ/ton	15,664	17,789	13,754	93.0
Redistilled alcohol, GJ/hl	2,016	1,613	1,250	77.5
Brewed beer, GJ/hl	273	283	287	99.6

In respect of reaching these figures and as regards other activities in the food industry, the following economical actions need to be taken:

- Utilization of waste heat with the evaporators, in the crystallizers and in other equipment. Savings of 0.5 to 0.6 PJ/year can be reached by allocating an amount of 0.1 to 0.2 billion forints;
- Carrying out some minor changes in the technological processes of the dairy industry as regards sterilization, pasteurization and milk powder production aiming at savings of 0.25 to 0.28 PJ/year and utilizing an amount of 0.08 to 0.1 billion forints;
- Reconstruction of the existing equipment (extension of surface insulation, etc.) may result in additional savings of 0.35 to 0.4 PJ/year by allocating an amount of 0.15 to 0.2 billion forints.

4.3 Measures planned for economical and reasonable utilization of energy and their expected results

Considering the targets set out on the national economy level and in view of the plans outlined by the companies in this branch, a program was elaborated on the economical and reasonable utilization of energy in the food industry, involving the period of 1986 through 1990. The actions comprised by this program have been grouped as follows:

- I Energy savings foreseen to be reached by applying organisatory measures (related to overhead expenses);
- II Energy savings foreseen to be reached with the use of company owned resources, in respect of technical development;
- III Energy savings and replacement of the applied fuel to be obtained by investments foreseen to be established with the use of credits and central subsidies.

In the elaborated program, the planned action under the state control related to all companies and factories in the 12 branches of the food industry are involved. Due to a wide range and large number of data, a detailed information on the planned technical concepts would make no sense. However, some of the envisaged actions of general importance have to be underlined. These are as follows:

- *Setting up bio-gas plants;*
- *Purifying and recycling of condensate with the use of heat exchangers;*
- *Putting aseptic tomato processing lines into operation, with a decrease in energy by 33 percent;*
- *Establishment of ice-accumulating refrigeration systems;*
- *Application of automatic sugar cooking devices, type Siemens, on vacuum appliances;*
- *Introduction of gas-fuelled fork lifts and trolleys;*
- *Construction of thermal water fountains and establishment of hot water conduit systems;*
- *Application of microprocessor control (DAT/MATT-P) for energy consuming equipment items;*
- *Utilization of vapour in malt processing;*
- *Measuring of reactive electric power values, installation of capacitors for power factor corrections, replacement of existing electric motors;*
- *Utilization of waste heat from air compressors.*

The elaborated program foresees, for the period of 1986 through 1990, an energy saving value of about 5 million GJ equalling to an oil equivalent of 150 thousand tones, approximately. The savings will total to 2 to 3 percent per annum, in relation to the actual energy consumption. The specific investment costs for energy saving are lowest in Group I where savings of 1 GJ may be achieved by allocating 20.7 forints. In Group II, this amounts to 95.0 forints while in Group III, this runs to 223 forints. The rate of the planned savings, broken down to industrial branches, will be most significant in the sugar industry followed up by the meat, vegetable oil and canning industries.

The expected achievements of the actions planned for an economical and reasonable utilization of energy are shown in Table 2, as per industrial branches.

Table 2. Actions planned for an economical and reasonable utilization of energy in the period from 1986 through 1990 and their expected results

Table 2/1

BRANCH	Expected result I		
	In heat value GJ	In oil equivalent toe	Required costs million Ft
MEAT INDUSTRY	393,958	9,382	120.16
POULTRY AND EGG PROCESSING INDUSTRY	31,853	758	7.47
DAIRY INDUSTRY	48,570	1,181	47.33
CANNING INDUSTRY	114,649	2,699	26.93
MILLING INDUSTRY	66,600	6,660	30.30
SUGAR INDUSTRY	779,670	20,166	56.50
SWEETS INDUSTRY	29,146	718	10.55
VEGETABLE OIL INDUSTRY	60,750	1,440	14.70
ALCOHOL AND STARCH INDUSTRY	38,722	1,045	4.2
WINE INDUSTRY	12,910	230	11.43
BREWING INDUSTRY	21,545	94	5.30
TOBACCO INDUSTRY	127,110	3,150	22.50
FOOD INDUSTRY ALTOGETHER	1,725,783	47,523	357.37

Table 2/2

BRANCH	Expected result II		
	In heat value GJ	In oil equivalent tce	Required costs million Ft
MEAT INDUSTRY	265,624	6,331	144.00
POULTRY AND EGG PROCESSING INDUSTRY	144,746	3,447	142.33
DAIRY INDUSTRY	91,169	2,171	54.33
CANNING INDUSTRY	100,994	2,683	126.80
MILLING INDUSTRY	72,900	7,290	20.90
SUGAR INDUSTRY	241,428	6,089	363.90
SWEETS INDUSTRY	30,410	1,014	72.60
VEGETABLE OIL INDUSTRY	501,100	11,828	120.90
ALCOHOL AND STARCH INDUSTRY	88,802	2,115	34.14
WINE INDUSTRY	13,697	326	17.10
BREWING INDUSTRY	26,038	619	24.00
TOBACCO INDUSTRY	237,225	5,801	603.52
FOOD INDUSTRY ALTOGETHER	1,814,223	49,714	1,742.52

Table 2/3

BRANCH	Expected result III		
	In heat value GJ	In oil equivalent toe	Required costs million Ft
MEAT INDUSTRY	197,101	4,673	102.85
POULTRY AND EGG PROSESSING INDUSTRY	13,858	2,422	150.50
DAIRY INDUSTRY	74,577	12,003	209.50
CANNING INDUSTRY	265,062	5,982	339.54
MILLING INDUSTRY	1,500	150	0.8
SUGAR INDUSTRY	372,668	9,280	217.20
SWEETS INDUSTRY	54,376	1,308	25.10
VEGETABLE OIL INDUSTRY	-	-	-
ALCOCHOL AND STARCH INDUSTRY	105,258	6,127	102.00
WINE INDUSTRY	-	-	-
BREWING INDUSTRY	264,871	6,319	589.00
TOBACCO INDUSTRY	37,851	901	370.00
FOOD INDUSTRY ALTHOGETHER	1,387,122	49,165	3,106.49

ANALYSIS OF ENERGY EFFICIENCY IN THE HUNGARIAN MEAT INDUSTRY

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1 INTRODUCTION

Rational energy management is becoming increasingly important in influencing the cost/benefit aspects of production and evaluating the profitability of industrial subsectors within the total national economy and its agricultural sector.

The rationalization of production and the wide-scale application of material and energy efficient production technologies have become absolute necessities nowadays. The efficiency of energy utilization can be improved through better energy management at company levels (primarily through incentives directly affecting the users) and by quick implementation of the latest scientific achievements in practice (such as the direct and indirect utilization of byproducts and introduction of the new technologies).

2 ENERGY UTILIZATION IN THE HUNGARIAN FOOD INDUSTRY AND ITS POSITION WITHIN THE COUNTRY'S INDUSTRY

In 1989, the food industry production was 20.7% higher than a year before. Within this, relative directions and trends for the development of certain subsectors are rather different (Tables 1 and 2).

From the energy utilization aspect, changes were characterized by substantial production growths in the energy intensive subsectors such as sugar refineries (30.6%), breweries (19.8%), the spirits and starch subsector (12.5%) and the meat subsector (18.7%). Production in the energy less intensive sectors also rose more or less. The changes in production volumes were accompanied by the changes in energy utilization.

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In 1989, energy utilization fell substantially as a result of considerable reductions in industrial production, changes in the sectorial composition of production and climatic effects - to mention but a few of the major factors that affect energy utilization by industry. Of these, the greatest impact was exerted by the reduction in production, accounting for about 20 PJ with another 5 PJ produced by reduction in heating needs.

Table 1. The unaggregated energy utilization and energy needs of food industry sector under the supervision of the ministry of agriculture in 1988

Sector	Gross production (HUF bn)	Unaggrega. energy use (TJ)	Energy intensity (kJ/HUF)	Gross production rate (X)	Unaggrega. energy util. rate (X)
Meat	51.8	6,662.7	128.6	21.84	16.23
Poultry	21.1	1,821.1	86.3	8.90	4.43
Canning	27.9	5,829.4	208.9	11.76	14.20
Dairy	31.7	4,172.0	131.6	13.36	10.16
Milling	29.9	1,646.4	55.1	12.61	4.01
Sugar	11.1	8,357.9	753.0	4.68	20.35
Confectionery	17.8	899.7	50.5	7.5	2.19
Vegetable oil	12.6	2,900.5	230.2	5.31	7.06
Spirits and starch	9.6	4,017.6	418.3	4.05	9.78
Breweries	9.1	3,606.4	396.3	3.84	8.78
Wineries	7.3	662.7	90.8	3.08	1.61
Tobacco	7.3	487.0	66.7	3.08	1.19
TOTAL **	237.2	41,063.3	173.1	100.00	100.00

* at current prices

** w/o bakeries and pasta production, mineral water and carbonated water production

Conversely, increases in energy utilization came about as a result of the rising energy intensity of some of the industrial subsectors, increases in the production of certain energy intensive products which account for approximately 2 PJ of additional demand. As a result of the combined effect of these factors, overall industrial energy utilization fell by 15 PJ. Of this, metallurgy account for approximately 8 PJ with all the other sectors accounting for 1 to 2 PJ each.

On balance, most of the factors affecting energy utilization by industrial sector were indicative of decreases in energy consumption (Figure 1).

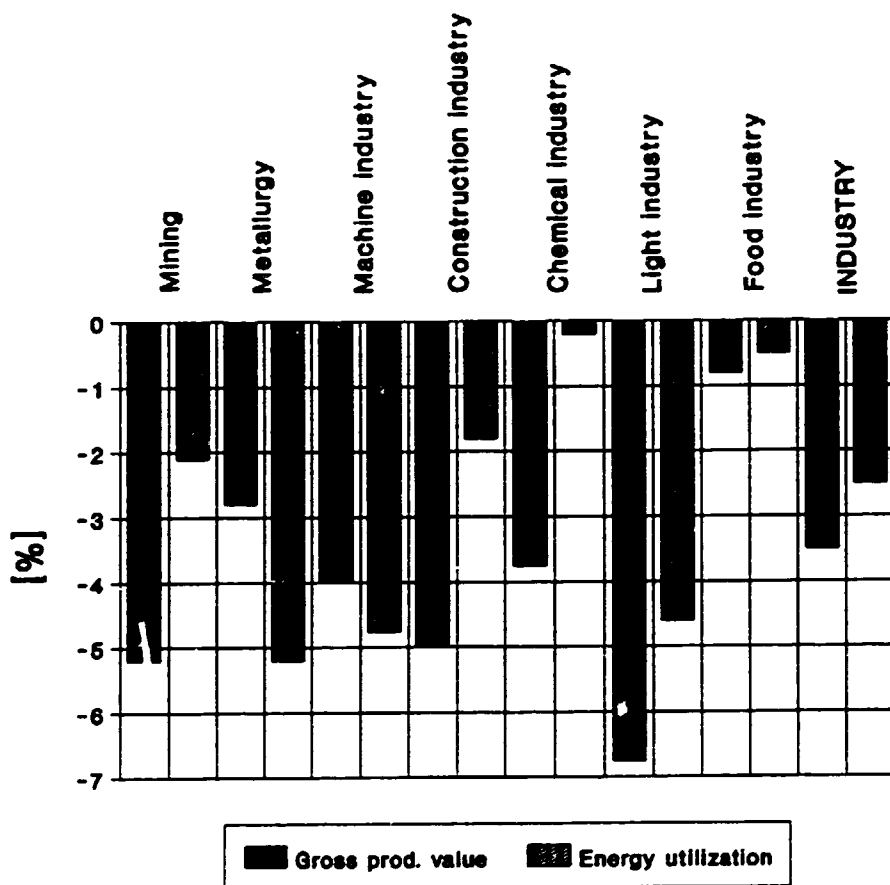


Figure 1. Changes in gross production values and energy utilization in industrial sector between 1988 and 1989

3 DEFINITION OF SPECIFIC ENERGY REQUIREMENTS FOR PRODUCT CATEGORIES IN MEAT INDUSTRY

The meat industry is one of the largest users of energy within the food processing sector. As the number of slaughtered animals and the quantity of processed meat increases, energy consumption also rises steeply. However, energy demand shows a more rapid increase than the actual number of

slaughtered animals and the capacity of the processing plants which may be attributed to higher mechanization levels of the technological processes and

Table 2. The unaggregated energy utilization and energy needs of food industry sector under the supervision of the Ministry of Agriculture in 1989

Sector	Gross production (RUF bn)	Unaggrega. energy use (TJ)	Energy intensity (kJ/RUF)	Gross production rate (X)	Unaggrega. energy util. rate (X)
Meat	61.5	6,545.9	106.4	21.48	15.85
Poultry	25.7	1,793.6	69.8	8.98	4.34
Canning	32.7	5,481.0	167.6	11.42	13.27
Dairy	41.3	4,100.5	99.3	14.43	9.93
Milling	37.5	1,635.8	43.6	13.10	3.96
Sugar	14.5	9,638.7	7664.7	5.06	23.33
Confectionery	18.4	896.2	48.7	6.43	2.17
Vegetable oil	15.7	2,710.8	176.0	5.38	6.56
Spirits and starch	10.8	3,879.0	359.2	3.77	9.38
Breweries	10.9	3,528.3	323.7	3.81	8.54
Wineries	8.7	660.1	75.9	3.04	1.60
Tobacco	8.9	441.8	49.6	3.11	1.07
TOTAL **	286.3	41,311.5	144.3	100.00	100.00

* at current prices

** w/o bakeries and pasta production, mineral water and carbonated water production

a conscious reduction of labor requirements. In addition, energy consumption in meat production depends on the sequence of technological processes, relative capacities and, last but not least, organizational and technical conditions.

Growing energy demand is moderated by several technical and organizational measures, some of which produce immediately identifiable results (e.g. better slaughtering performance reduces specific energy consumption while the processing of freshly slaughtered meat reduces the need for energy in cooling facilities). The results of certain other measures, however, can be identified only indirectly.

The most appropriate parameter to enable an objective determination of indirect results is specific energy consumption which is obtained by dividing the total energy consumed over a certain period of time by a unit of machinery or equipment or workshop with the volume of output produced over same period.

Although the parameter of specific energy consumption can be used to specify the profitability of product groups and technologies, the conditions for application are available only at a limited number of entities.

The most significant, but non existent conditions include the following:

- Most of the enterprises have no breakdowns by units operating as independent accounting centers, though they may be interrelated technologically or organizationally;
- Units already split up have no devices for measuring and evaluating their energy consumption which should be the basis of their accounting procedures. The energy consumption of two or more separate units are frequently measured by a single, common measuring system. In most cases, substantial engineering modifications would have to be made if separate measuring circles were to be installed as the so called "straight sections" required before and after the sensors take up long sections of the pipelines in which energy is flowing;
- The imported and locally manufactured meat processing machinery and equipment have not been qualified from the energy consumption aspects, consequently there is no basis for comparing their profitability. Often, the figures quoted in the user manuals carry but promotional values. When specific testing is effected, these values usually turn out to be lower than the original ones.
- Managers of units put up resistance and show incomprehension when individual energy meters are about to be introduced as they would allow for pinpointing their personal responsibility for excessive energy consumption;
- The absence of investment funds. Due to the idiosyncrasies of currently applicable meat processing technologies, they need various types of energy. For example, slaughtering technologies require electricity, cooling, steam, gas, compressed air and water with three different temperatures. The physical parameters of these types of energy fluctuate due to the frequent overloading of the networks over time and across a wide band. Consequently, compensation is required for the determination of the exact volume flows which calls for additional expenditure. If compensation is accepted, more expensive instruments need to be procured to facilitate evaluation.

Because of the absence of any one of the above major conditions, no specific norms of energy consumption have been developed either for product groups or technologies, embracing the entire range of production at a Hungarian meat processing company or corporation.

Following are the results of certain Hungarian and foreign reviews, attempting to determine specific energy demand.

4 HUNGARIAN REVIEWS

Up to now, the most comprehensive energy related review was conducted by the Baranya County Meat Industry Company, using a methodology by the Union of Creative Youth. Unfortunately, the extensive review was not accompanied by appropriate instrumentation therefore the results should be taken with a pinch of salt and used only for preparation of decisions.

The objective of the review was to evaluate the technological processes and the energy distribution systems of the company from the energy related aspects. Concurrently, material and cost indices were determined and their impact on energy consumption was analyzed. With the identification of the

interrelationships, information was provided for the company managers to assist them in decision making to modify unprofitable technologies, develop a more profitable product pattern and eliminate the errors from the energy distribution system.

The complex review was divided into three stages:

- *Collection and processing of information;*
- *Technical and economic analysis;*
- *Preparation for decision making.*

At the information collecting stage, data were taken from the energy meters concerning earlier and current periods, the internal energy consumption records of the company, follow up calculations and the fuel consumption records.

Figures 2/1, 2/2, and 2/3 indicate the aggregate energy consumption values by unit, the quantity of major products by unit and the calculated specific values.

The evaluation of the results produced some rather surprising conclusions. In accordance with the division of costs less raw materials, supplemented on the basis of an index currently applied in the meat industry, highly differentiated products bear much less overhead than fats. It is also unbelievable that overheads on smoked products are 50% higher than those on non smoked products.

It is impossible to justify the 28 GJ/t of specific energy demand for tripe processing despite the well known fact that net yield is only about 50% and the rest is lost as waste.

The results obtained through reviewing the energy distribution system were highly revealing, too. It was found that cooling accounts for half of all electricity consumption. The tests suggested that this was due to a badly designed evaporation system.

And last but not least, it was indicated that the method of the review could be improved by increasing the testing points, collecting measured data and feeding the recorded data into a computer.

Similar reviews are being conducted at some other companies to specify their specific parameters. In the course of the reviews, it was found that the Meat Processing Company of Szekszard had the best instrumentation.

5 FOREIGN REVIEWS

The July-August issue of V.P.C. of France published the results of a review carried out by a French food industry research institute in 1986 to determine the energy and the labour costs of technological operations on various slaughtering lines.

The most interesting elements of the results relate to attuning, skinning, evisceration, halving, cleaning and veterinary control, carried on during pig, cattle, calf and sheep slaughtering:

Cattle slaughtering

Skinning is the most labour intensive operation, according for 34% of labour on average. Evisceration is the second most labor intensive with 18%. The labour intensity of stunning is in the range of 8 - 11% and depends on the actual methods used. Mechanized skinning accounts for 40% of the total

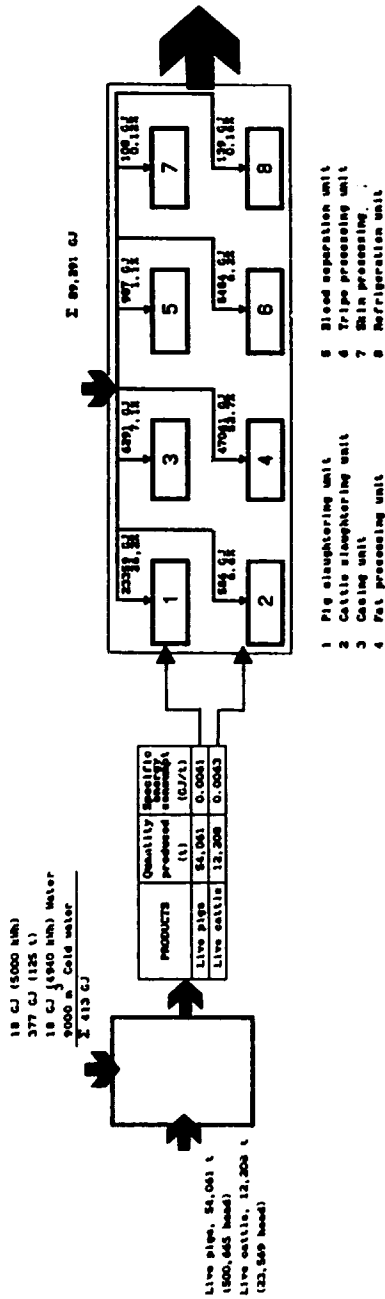


Figure 1/1. Process flow sheet for meat industry

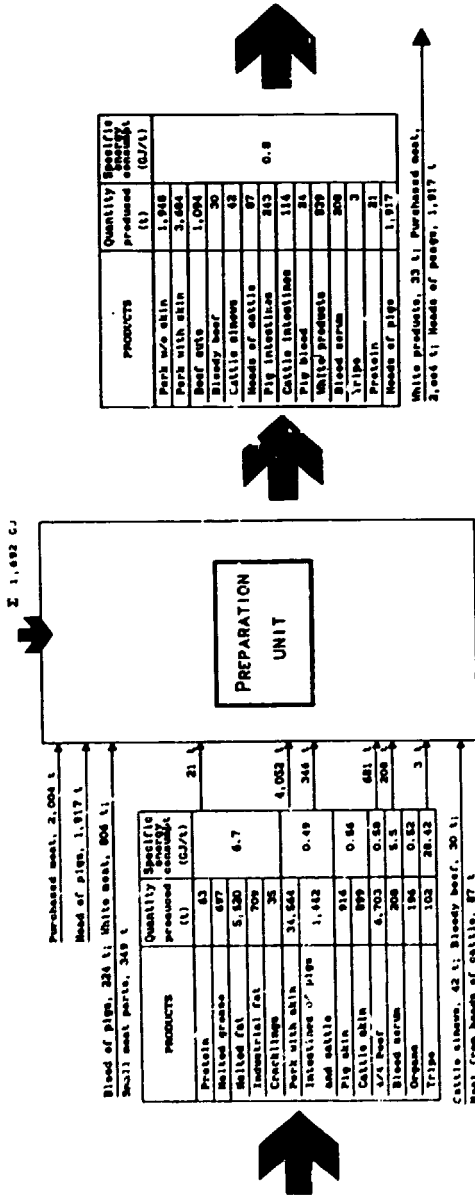


Figure 1/2. Process flow sheet for meat industry

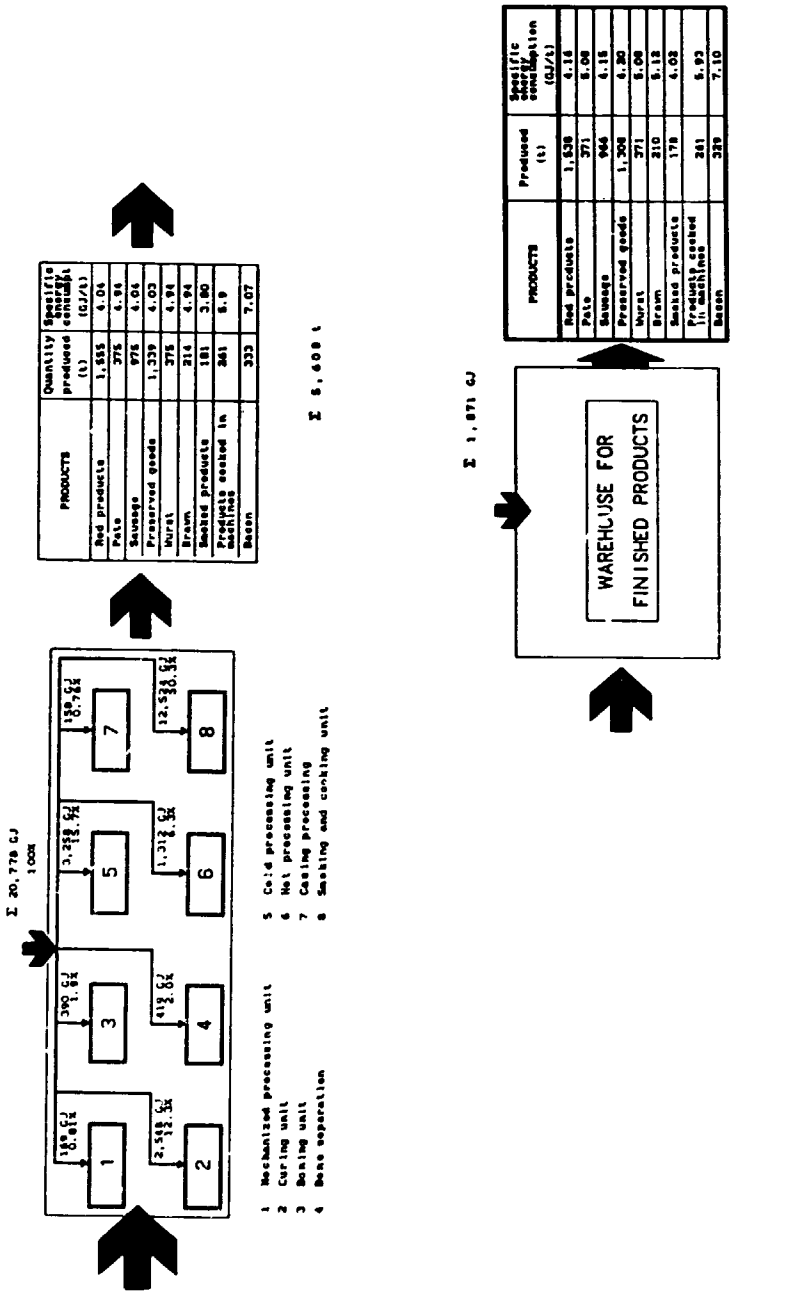


Figure 1/3. Process flow sheet for meat industry

energy consumption. Surprisingly enough, veterinary control was found to be the second most energy intensive operation due to the high demand for light intensity, as specified by the standards.

Pig slaughtering

As indicated by the findings, the specific labour requirement of heavy duty slaughtering lines (400 - 500 animals per hour) is only one-third of that of lower capacity slaughtering lines (70 animals per hour). Evisceration, cleaning and scrubbing are the most labour intensive operations which account for 40. - 45% of the total labour demand. Skin dressing (mechanical cleaning, scalding, singeing, washing, etc.) accounts for 80 - 85% of the total energy consumption.

When comparing the cost of operating heavy duty and lower capacity slaughtering lines, it is found that the energy costs per one kilogram of product are approximately the same while specific labour costs are four times higher on the lower capacity lines.

6 POSSIBILITIES FOR SPECIFYING SPECIFIC ENERGY PARAMETERS BASED ON THE TESTS OF MEAT INDUSTRY TECHNOLOGICAL PROCESSES AND THE EVALUATION OF THE FINDINGS

The objective of the energy related testing of technological processes is to detect all points of the processes which are critical from energy related aspects and to sort out the products and technologies that require disproportionately high volumes of energy. Using cost accounting methods in business entities, profit and loss centers can be identified. Following a careful consideration of the findings, decision can be made about the modification of the operations, replacement of technological equipment and substitution of labor with machinery.

Review should be extended to embrace studies of the energy distribution systems and their component parts since losses through energy distribution systems with erroneous design and defective utilization, lacking meters and control instruments and without proper maintenance and overall structure, would make any gain from technological changes to remain immaterial.

One of the key assignments is to review energy inputs; based on the finding of such reviews, contracts with energy suppliers may be amended.

The energy related review of independent accounting units (blocks) should be supplemented by an analysis of raw material flows entering the unit and those of semi-finished and finished products leaving the unit, while specifying all the cost items that are related to production and processing.

The current system of prime costing, as effected today in the meat industry, hinders the recognition of true costs because -due to their high cost proportions- only raw material costs are split among the products, and all other costs, such as labor, energy, indirect material and storage costs, are merely added on a supplementary basis in proportion to the relative production costs.

Although specified on the basis of prime costing and supplementary costing, specific energy consumption values should be used for the purposes of economic and technical analysis in enterprises; they can be extremely useful in determining profit and loss centers. Decision made on the basis of

the findings of such analysis should, in the longer term, lead to increases in corporate profitability.

Due to substantial requirements in financial investments and capital goods, the reviews should be conducted in two phases.

In the first phase, the total energy consumption of the technologies should be determined unit by unit, together with material and labour costs. Once this figure is established, an approximated specific energy index can be calculated in proportion to output that would reflect reality more closely as compared to methods hitherto used and could be used for decision making about economic and technological issues.

The energy distribution systems should also be reviewed in the first phase, to be followed by amendments to the system subject to the findings and the contracts concluded with the energy suppliers.

In the second phase of the review, specific indices should be established for the technological machinery and equipment and processing lines within each unit or block, while analyzing technological operations. Once the precise results of the review are available, the profit and loss centers of the technologies can be specified and operative changes can be made.

7 THE METHODS OF ENERGY RELATED REVIEWS OF TECHNOLOGICAL PROCESSES

7.1 Steps in preparation for the review

- *Identification of units (blocks) that are technologically or organizationally connected and found suitable for independent accounting;*
- *Production of material, energy and cost flow diagrams for interrelated blocks;*
- *definition of types of energy, required for the operation of the technological equipment in the units and an estimate about consumption;*
- *Metering energy and selection and installation of the metering sections and nodes;*
- *Selection, procurement or rental of sensors, data recording devices and data analyzers with appropriate accuracy, measuring principles and measuring ranges;*
- *Production of appropriate work sheets for unit review.*

8 E N T E R V, A COMPUTER BASED DESIGN PROGRAM TO SUPPORT ENERGY MANAGEMENT

The objective of the program is to improve energy cost projections in an uncertainty range of $\pm 5 - 10\%$. Constant increases in energy costs call for a systematic approach to cost projections that use the advances of mathematical - statistical procedures. As indicated by practical experiences, current methods and procedures can produce an approximate accuracy of 20%.

In order to achieve this objective, currently available data should be properly organized and CFNSUS II method used to produce a factor by factor

projection using the pre-processed data at the first stage. Key target figures can be obtained with the REGAL Expert System, which can accommodate and model the relationship and links among the various factors.

8.1 Data base

The efficient use of the model calls for a detailed and accurate data base about historic changes in costs and factors that affect them. These data are easily handled and separated by data base manager programs. The SENZOR data base manager system is well proven in this field (see Annex 1).

To provide a clearer picture about prevalent tendencies, data should be collected in a monthly breakdown which, in turn, can be prepared for further processing.

8.2 Projections by factors and data processing for contracting with the CENSUS II method

Further analysis is best done with one of the methods listed in the technical literature as the most efficient, i.e. CENSUS II (see Annex 2). The method can identify the fundamental tendencies inherent in the phenomena at issue, i.e. in energy costs and the factors that affect them; it can sort out and quantify single and random effects (such as extreme weather conditions, etc.) and provides efficient projections. Next year's energy costs and volumes often need to be projected as early as in August-September. In this way, demands for the next year's energy generation capacities (electricity, gas, and steam) can be approximated much more efficiently than otherwise. It can be used to finalize data in kW, kg/h or Nm³, for the contracts with the suppliers.

If contracts are made on the basis of sound data, considerable amounts can be saved in costs.

8.3 Cost projections considering relationships among factors - The REGAL Expert System

There is a set of relationships among costs and the factors that affect them which can be modeled. If information is available about the changes in the factors that affect energy costs, which can be obtained from CENSUS II, sound and quantifiable projections can be provided about the envisaged changes in energy costs.

The expert system can answer the questions (see Annex 2) about the order of importance of the various factors and the changes in costs triggered by the unit change in any factor.

As production figures are regularly available by the beginning of the year, energy cost plans can be developed in monthly or quarterly breakdown, following the identification of the set of factors which constitute a part of the business entity's comprehensive annual cost plan. This offers an opportunity for updating the key elements of the roll-over plans.

Various production factors, the indicators of energy utilization expressed in physical terms and quantified with CENSUS II, and possible weather factors (as justifying variables) affect energy costs (as a dependent variable).

It is possible to draft several types of models about energy costs. The comparison of the results received can help ultimately to select the appropriate scenario on the basis of the viability analysis of the models

and the quality of user's skills.

8.4 Practical utility of ENTERV

The practical utility of ENTERV lies in the fact that it can automatically report energy costs in a monthly breakdown for the next year as well as the projected volumes in physical quantities. To achieve this, it provides a preliminary estimate. However, adjustments by qualified and experienced professionals are still necessary. Projections are based on a historic data base. In czse historic inflation at 15-20% changes, the appropriate corrections can be made irrespective of the method used, once the basic figures are available. Of course, the rate of inflation can be incorporated in the model by using REGAL.

Additional advantages:

- *Continuous cost projections can be quickly updated;*
- *Changes in externalities and changes in prices, markets and other impact can be incorporated into the model quickly and without difficulty;*
- *There is no need to have sophisticated knowledge about information technology to be able to use the program. It is a set of User-friendly software.*

8.5 Advice on software application

When starting to use the program, the samples should first be reviewed to practice operation irrespective of the fact whether initial training was provided or not. While using the program, the user will get continuous assistance to solve problems in application and methodology. In addition to the detailed software description, the Help function in REGAL is also useful.

8.6 Application at the Szekszard Meat Processing Company

Computer based energy management has been used at the company by its Energy Management Team since 1984. Due to price rises, energy costs always increase by 10-15% per annum. Therefore, a systemic approach to cost management had to be developed. Data collection and processing is done with the SENZOR data base manager program.

Quantifiable factors are analyzed with the CENSUS II method (see Annex 2), and the contracts with the suppliers were made on the basis of the findings. The results thus obtained provide the basis for the application of the REGAL Expert system (see Annex 2). The REGAL expert system was used in two versions:

- a) *Dependant variable (y) represents the total energy costs in HUF^o '000;*
The justifying variables (x_i) include:

^oHUF = Hungarian Forint

- cattle slaughtered (head),
 - ham production (tons),
 - electricity (HUF '000),
 - steam (HUF '000).
- b) Dependent variable (y) represents the total energy costs in HUF '000;
- The justifying variables (x_j) include:
- electricity (HUF '000);
 - steam (HUF '000),
 - electricity (MWh),
 - total steam (MWh) (gas, oil, petrol, wood, coal, gas oil, etc. in MWh).

Following the comparison of the results from the two models, annual plans based on monthly energy cost projections are finalized in accordance with the output plans. The precise figures in the roll-over plan were finalized with the ENTERV.

Using these two methods, the Szekszard Meat Processing Company could achieve significant savings in energy costs.

9 REFERENCES

1. MOLNAR, I., Determination and Elaboration of Specific Energy Demand Values of Product Groups and Technologies in the Meat Industry,
2. MARTON, F., HERMAN, S., Kiss, T., ENTERV Computer Based Design Program to Support Energy Management,

ANNEX 1

Energy management data 1984-85-85-87-88-89
 Records
 Energy table 1984-85-85-87-88-89

30.09.1989 064

Item	Month	Total	Total	Total	Other	Other	Other	Steam
		Ft '000	CJ	MWh	Ft '000	CJ	MWh	Ft '000
68f	08	10647.00	22271.97	6186.66	1615	2484.00	690	4837

Steam	Steam	Steam	Electr.	Electr.	Electr.
MWh	CJ	Tons	Ft '000	MWh	CJ
3853.66	13873.21	5874	4195	1643	5914.80

Sheet 1

Energy management data 1984-85-85-87-88-89
 Records
 Specific data 1984-85-85-87-88-89

30.09.1989 064

Item	Specif. 1	Specif. 2	Specif. 3	Specif. 4	Specif. 5	Specif. 6
	GJ/ton	Ft'000/t	MWh/t	stemGJ/t	Ft '000/ MWh	Ft '000/ MWh Steam
68f	3.45	1.65	0.25	2.15	2.55	1.25

Specif. 7	Specif. 8	Specif. 9	Specif. 10	Specif. 11	Specif. 12	Specif. 13
Ft '000/ t steam	Electr. CJ %	Electr. Ft'000 %	Steam CJ %	Steam Ft '000 %	Other CJ %	Other Ft '000
0.82	26.55	39.40	62.29	45.43	11.15	15.16

Sheet 1

Energy management data 1984-85-85-87-88-89

Records

Specific data, Table II

30.09.1989

064

Item	Specif. 1 GJ/ton	Specif. 2 Ft '000/t	Specif. 3 MWh/t	Specif. 4 steamGJ/t	Specif. 5 Ft '000/ MWh	Specif. 6 Ft '000/ MWh Steam
68f	3.45	1.65	0.25	2.15	2.55	1.25

Specif. 7 Ft '000/ t steam	Specif. 14 Ft '000/ MWh Steam	Specif. 15 KWh/'000 m3	Specif. 16 '000 m3	Specif. 17 Water m3 /ton	Production tons	Total GJ
0.82	198.8	79.54	0.08	7.05	6439	22271.97

Sheet :

Energy management data 1984-85-85-87-88-89

Records

Specific data, Table II

30.09.1989

064

Item	month	pigs head	cattle head	pigs tons	cattle tons	white fat tons
68f	08	28311	2612	2977	1385	615

lard tons	ham tons	foil- packed tons	canned tons	processed tons	meatmeal tons	Total produced tons
84	201	25	402	630	120	6439

ANNEX 2

CENSUS II
Electricity plan, 1990

30.09.1989
14:21:01

Final, adjusted data, trend, projection, average for h[i,j]

Month	1990	1990	
January	1641.2	1742.5	1.00488
February	1640.7	1133.1	0.99988
March	1640.2	1604.6	0.99561
April	1639.7	1379.3	0.99467
May	1639.2	1429.1	0.99414
June	1638.7	1789.8	0.99705
July	1638.2	1879.4	1.00057
August	1637.8	1825.2	1.00162
September	1637.3	1676.3	1.00210
October	1636.8	1880.7	1.00248
November	1636.3	1639.0	1.00250
December	1635.8	1681.6	1.00229

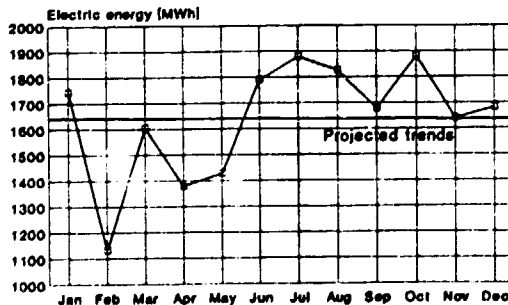
trend projection h[j] ave.

H[i,j] ave. 0.000000

Can we go on?

CENSUS II
Electricity plan, 1990

30.09.1989
14:22:32



ANNEX 3

REGRESSION ANALYSIS
VARIABLE DESIGNATION AND TRANSFORMATION

No. of variables in the initial matrix: 15 No. of cases: 48

Variables included in the analysis:

Y() Maximum variables: Others to be included:
Recommended maximum: 3

Possible transformations:

a=a a=exp(a) a=ln(a) a=1/a a=a(-k) a=a(+k)
a=a+k a=a^k a=a*k a=a/k a=a+b a=a-b a=a*b

No. of justifying variables (p): 14
Initial item No. of the analysis: 1
Item No. (recommended: 210) (n): 48
Final item No. of the analysis: 48
Do you want to make corrections (y/n): ?

REGRESSION ANALYSIS

00:38:37
STATISTICS

80:01:01

Param.	Value	Stat. error	t. st.	Param.	Value
Stat. error					
Consts.	638.6	621.5	1.027		
Electr. MWh	0.5239	0.2523	2.077		
Steam MWh electr.	-0.0166	0.0393	-0.42		
HUF '000 steam	0.9069	0.1184	7.660		
HUF '000	1.0159	0.0462	22.0		

p=5 n=48 t.st.rate: 43 table value: 2.01700
regr. stst. error: 278.2893355 normality test:>

R^2 0.96350182 F atat. *4, 43(>283.7852 (0.0000000) = >

Multikollinea: bad

Chi²: 33.94526

Autocorrelation: ???

D-W: 1.58148

Homoskedasyt.: O. K.

h: 2.28225

???

O. K.

ENERGY CONSERVATION POSSIBILITIES IN EDIBLE OIL INDUSTRY

J. Turkulov*, Dj. Karlovic*, V. Radenkovic*,
Novi Sad, Yugoslavia

1 INTRODUCTION

The sudden increase of energy price, as well as its higher ratio in the price of the finished products, is a big challenge for the engineers. This very serious and complex problem can be solved by the joint work of engineers of different profiles (technologists, energy experts, constructors, etc.).

In the scope of the food technologies, the edible oil industry is a big consumer of different forms of energy. So, even the smallest saving per ton of the processed raw material will result in big savings at the end of the process, as the capacities are relatively big (the capacities of the factories in Yugoslavia are 350 to 1000 t/day).

2 ENERGY CONSERVATION POSSIBILITIES

In our opinion the rationalization of energy consumption can be achieved in several ways:

1. *By better organization of work;*
2. *By modification of the existing technology and equipment;*
3. *By new technological solutions.*

Ad. 1. *THE BETTER ORGANIZATION* should ensure continuous work (four shifts without breaks on Sundays and holidays). In this way the cooling of equipment will be avoided after stopping, as well as the heating when the work begins. In most of the Yugoslav factories the up-to-day equipment ensures the continuous work. This is provided by building in appropriate buffer tanks for the semi products. The oxidation can be prevented by

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cooling the edible oil either before entering the tank, or in the tank itself (due to the heat radiation).

With better organization, the need for these tanks will decrease to a minimum and, at the same time, the heat losses will be negligible. The systematic and constant control of condense post would result in significant energy savings.

Ad. 2. THE MODIFICATION OF THE EXISTING TECHNOLOGY AND EQUIPMENT would induce investment which should be quickly paid back during operation.

A heat bleaching process has been developed at our Department. As the traditional method with bleaching earth is omitted, the energy saving is very big. Heat bleaching is used in two of our oil processing factories. On this process, more details will be given when discussing the block scheme of edible oil refining.

In the section for edible oil obtaining and processing, heat exchangers should be installed where economical.

In the part about better organization, the so-called "buffer tanks" have been mentioned. It is rather difficult to achieve a completely continuous processing, so these tanks should be insulated and airtight. In that case, an inert gas (N_2 or CO_2) can be introduced in the tanks. These conditions ensure good preservation of oil, practically without temperature change, and at the same time without heat loss.

In the industry, a part of the condensed water is returned to the boiler room. But, mostly, it is discharged for safety reasons, as it may get polluted with hexane in the extraction process. This is a big loss in the oil industry. The installation of appropriate devices for hexane identification, as well as the multi-stage control, would ensure recycling of this water. This would result in considerable energy saving, too.

One of the most important oil seeds in Yugoslavia is sunflower. The seed itself contains 20-26% of hull. In the hull of the elder sorts, the lipid content was below 1%. These values are higher today - approx. 5% or even more. The main components of these lipids are waxes and solid triglycerides. The hull also contains crude fiber, K, Mg, etc. It can be added to feed so as to balance the protein content.

1 kg of the sunflower seed hull contains about 17,000 kJ/kg. So it can be also used as a highly valuable fuel which is practiced in our industry.

This year, approx. 200,000 [ha] will be under sunflower in Vojvodina. With the average yield of 2 t/ha, it gives 400,000 t of sunflower. During dehulling, some 16% of hull is removed from the sunflower seed (about 9% remains in the material being processed further) and this gives the total quantity of 64,000 t of the sunflower seed hull. Using it as a fuel, some 27,000 t of liquid fuel could be saved.

Very often, steam pipelines and some other oil processing devices are not insulated correctly. Heat radiation takes place during the process inducing higher losses.

Ad. 3. NEW TECHNOLOGICAL SOLUTIONS. The price of energy influences the choice of technology more and more.

The edible oil industry often obtains raw materials with very high moisture contents. To ensure its safe storage, the raw material has to be dried below the so-called "critical moisture". The dessication of the plants - for example sunflower sprinkling with Mg-chlorate solution - decreases the moisture content in the raw material by 10% and facilitates its further drying.

When planning an edible oil factory, the way of oil obtaining should be discussed, i.e. whether to obtain oil in the traditional way: pressing-extraction, to extract the seed directly or to apply "cold pressing" and extraction which is a completely "new" technology. Also, the refining has to undergo certain changes. It is questionable whether to perform the traditional neutralization, bleaching and deodorization or to make certain changes. The biggest steam consumer is the vacuum system, consisting of 3 to 4 steam jet ejectors (thermoccompression) connected with the barometric condensers. This system is a subject of the constant interest of experts and its rationalization will probably soon take place. More about this when discussing the block scheme of edible oil obtaining and processing.

Process water from the refining and hydrogenation section has a high heat content. It could be used for heating the hot houses. For the refining, water is needed in the quantity of some 200 m³/h (the capacity of the factory being 150 t/day). The biggest quantity of water is used for cooling the barometric condensers. The outlet temperature of the water is 30-35 °C.

Using this water for oil heating approximately 5·10⁶ kJ/h would be obtained.

The schemes of oil obtaining (sunflower, and other oil seeds) are given in Figures 1 and 2.

The edible oil industry of Yugoslavia works about 280 days/year. In order to provide raw material for the whole period, it has to be dried below the critical moisture and after that, it can be stored. The driers of oil seed and other agricultural products are big steam consumers. These driers are mostly the chamber - types ones, where drying is performed indirectly by heater air. Up to 10% of moisture calculated on the weight of the material is removed here. This value depends on the climate conditions. The hot air (120-150 °C) is cooled during the drying process, saturated and discharged by the ventilators or cyclones into the atmosphere. The outlet temperature can be higher than 80 °C.

By installing appropriate exchangers, the hot outlet air could be used for heating the seeds that are going to be dried.

The possibility to use the solar energy should be also discussed.

Significant energy could be saved if the seeds were dried to the moisture content that is 3-4% higher than the critical moisture. In that case, the seed could be safely stored in the cells under inert gas (CO₂, N₂), but the cells should be completely airtight.

The seed can be also stored with a higher moisture content if it is cooled to 8 °C and stored at this temperature. It has to be discussed what is more economical: the traditional storage or the seed preserving at lower temperatures.

Before pressing, the oil seeds are cleaned and dehulled. The hull content in the dehulled sunflower should be 7-10%.

A smaller energy saving is achieved if dehullers are adjusted so that the non-dehulled seed content, that has to go back to dehuller, is as low as possible. The aspiration has to be adjusted too in such a way that a bigger amount of hull is removed by it.

The traditional processing includes breaking of the material, conditioning at 90-110 °C and pressing.

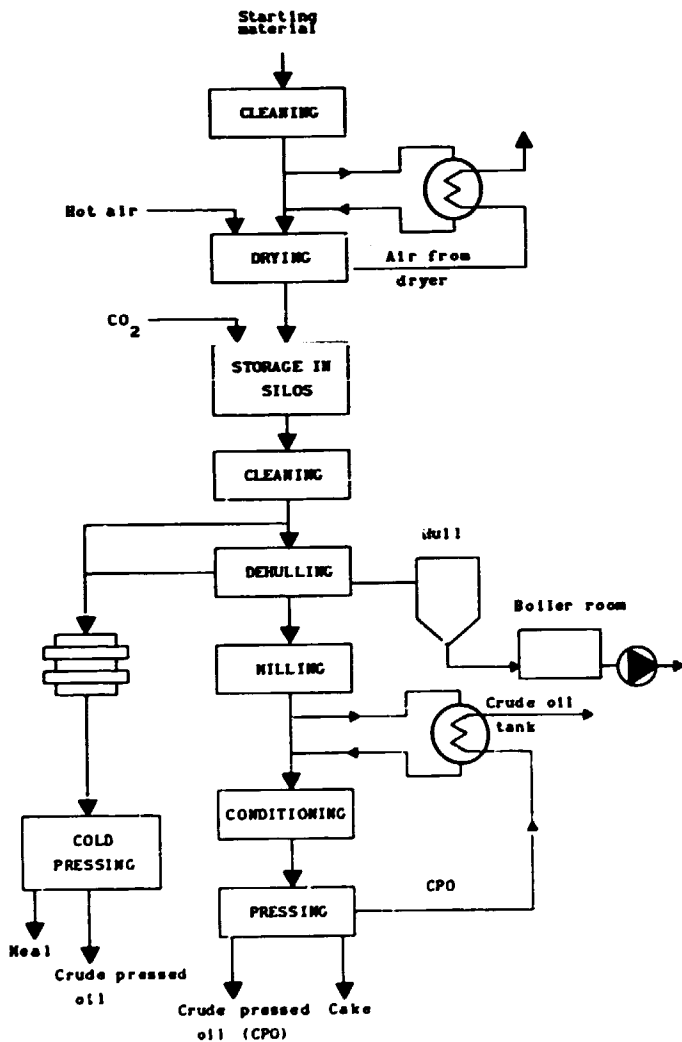


Figure 1. Block scheme of crude pressed oil obtaining

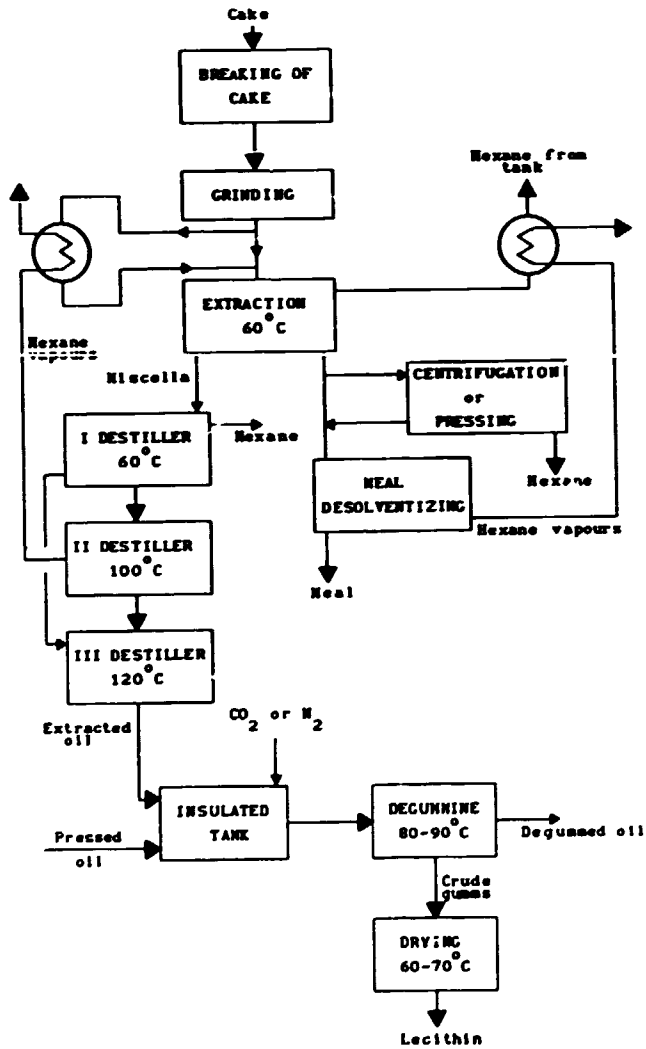


Figure 2. Block scheme of extraction and obtaining of degunned oil and lecithin

During conditioning, the material is partially dried and the hot and damp air is being evacuated. It cannot be reliably claimed that the use of this energy would be economical for preheating the material entering the cookers.

Continuous screw presses are used for pressing this material. The temperature of the pressed oil can be even 120 °C. The pressed oil is, up-to-now, cooled and filtered though it could be used for heating the material entering the cooker. This could be performed very simply, by installing some duplicators into the screw conveyors.

This is a newer technology where the material from the mills, before pressing, is undergoing extraction. It provides energy saving, but the technology has not yet been completely developed for different oil seeds.

The newest processing procedures, including considerable energy saving, propose the "cold" pressing (of dehulled material) without grinding.

The obtained cake or material that has not been pressed is flaked and solvent extracted. The solution of oil in the solvent - miscella, is distilled mostly in three stage distillers. The vapors from the second distiller could be used for the hexane heating. That means that a heat exchanger should be installed. The obtained crude extracted oil should be transferred to an insulated tank with inert gas preventing oxidation. The degumming of both the crude extracted oil and the pressed one should follow immediately. The meal leaving the extractor contains mechanically captured hexane. It enters the desolventizer-toaster, i.e. a device designed to evaporate hexane from the meal. This device is also a big steam consumer. The energy use could be decreased if a bigger amount of solvent was removed from the meal by centrifugation-decantation. After such pre-treatment, the meal would be toasted.

The moisture content of the meal is usually increased from 7 or 8 to 12% after toasting. The moisted meal is then transported to the feed factory. Without meal moistening, the quantity of energy consumed for transportation would be approximately 5% larger. The block scheme of the vegetable oil refining and hydrogenation is given in Figure 3.

During refining, all undesirable components are removed from the oil. The process consists of several phases. The free fatty acids are removed during the alkaline neutralization at 80-90 °C. A part of the formed soap is removed by centrifugal separation. The remaining soap content is removed by water washing and separation. The traditional refining process includes bleaching and deodorization. Between the devices where these procedures take place, there are tanks for the temporary storage of oil. The oil is cooled in these tanks and then heated to the desired temperature. To avoid the cooling-heating of the oil, these tanks should be insulated and the oil kept under inert atmosphere.

In the process of oil bleaching, active bleaching earths are used. Steam and electric energy are needed. The bleaching oil is deodorized under vacuum (500 Pa). The deodorizer and the vacuum system are the biggest steam consumers. The temperature of the deodorized oil is 200-220 °C (sometimes even higher) and it can be used for preheating the oil entering the deodorizer. To use as much energy as possible the counter current exchangers with big surfaces should be installed. After that, the deodorized oil is cooled with water and cooling agent to temperatures below 14 °C. At this temperature, waxes crystallize and can be separated by filtration (winterization).

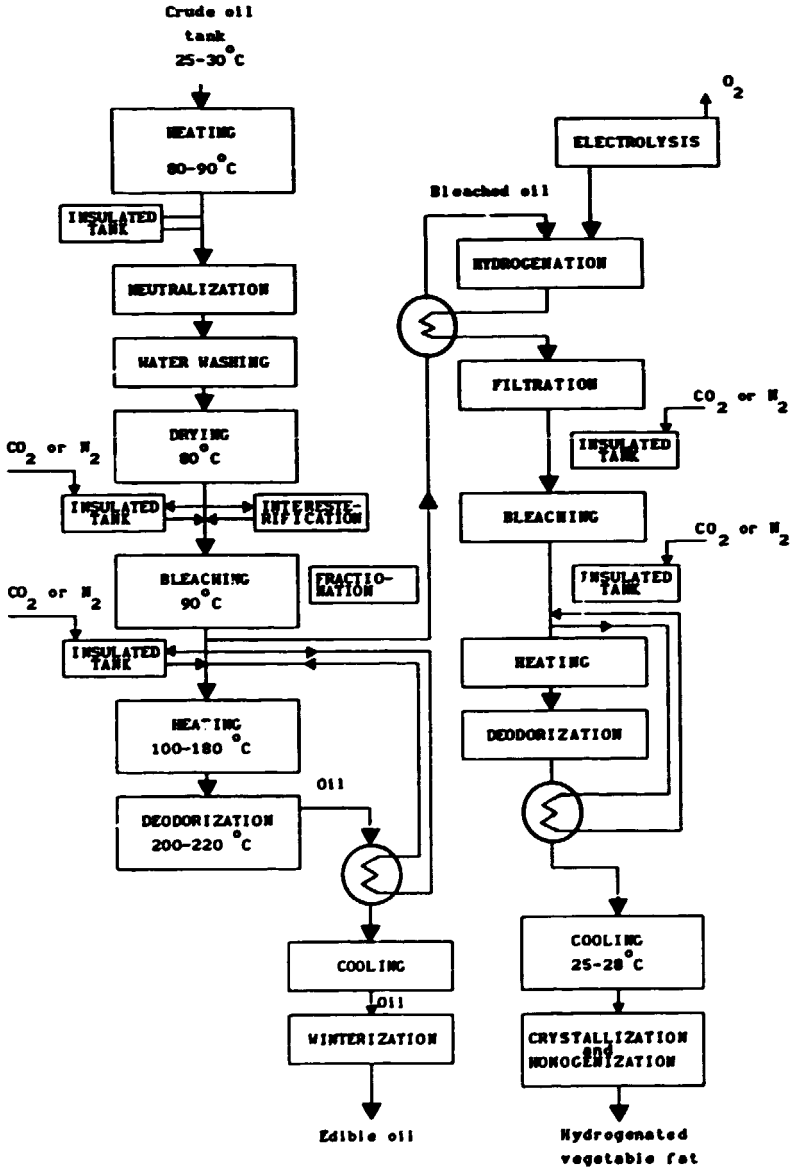


Figure 3. Block scheme of edible oil refining and hydrogenation

The winterized oil can be used in an exchanger to cool the oil that is going to be winterized.

Very often, winterization follows bleaching. This is, in a way, technologically approved. If deodorization is performed correctly, winterization can follow this refining step.

Bleaching can be performed, as it has already been mentioned, in the deodorizer. In that way, considerable amounts of energy can be saved.

Hydrogenation is a process in which the oils, in the presence of hydrogen and catalyzer, are transformed into solid fats. It is an exothermic reaction taking place at 160-200 °C.

Before hydrogenation, oil is neutralized and bleached. In our opinion, active earth bleaching can be avoided. Heat exchangers are used here, too. Before hydrogenation, oil is heated there by the hydrogenated fat. The catalyzer is filtrated from the hydrogenated fat which has to be bleached and deodorized in the way mentioned in oil refining. The deodorized fat, quickly subcooled to 20-28 °C, is crystalized and then homogenized and packed.

The hydrogen used for hydrogenation is obtained by water electrolysis. The need for energy is very big, approximately 5 kW/m³ of H₂. It is obvious that the electrolyser is the biggest electric energy consumer (500-800 kW/h). However, hydrogen can be obtained from natural gas, too. In that case, less energy is needed but, the procedure is feasible only if the capacities are bigger than 400 m³ of H₂/h. The natural gas processing in Vojvodina would be profitable and it would satisfy the existing capacities of the vegetable fat factories.

The operation in the plants producing margarine and interesterified fats or the fractionation plants are similar to the previously mentioned ones, so it won't be discussed in details. However, it has to be pointed out that interesterification and fractionation very often result in fats having the same or even better quality than the vegetable fats obtained by hydrogenation. Having this in mind and knowing that the production of H₂ demands electrical energy, the conclusion can be made that interesterification and fractionation - the technological processes designed for the modification of fats - would have an important place in the field of energy saving.

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ENERGY DIAGNOSTIC SYSTEM (CONCEPT AND CAPABILITIES)

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1 INTRODUCTION

The concept of energy conservation includes a number of activities or procedures taken for the purpose of transforming certain existing conditions into the new ones with lower specific consumptions of energy. But, at the same time, all current technical, economic, environment requirements shall be also met through the introduction of relevant measures. Energy audit, an unavoidable component of any conservation program, includes complex analysis of each particular process for the following purposes:

- i) to establish how and where is the energy used or converted;
- ii) to identify possibility for a lower energy consumption;
- iii) to find economic and technical solutions which will result in a lower energy consumption;
- iv) to determine priorities among the proposed process improvements having in mind energy saving as the final goal.

Of course, each particular action in the field of energy conservation must be based on the following specific conditions: specific aspects of a given technology, personnel training, national energy policy, economic and technical conditions required for the execution of a given action, specific national standards, regulations, and recommendations, etc. It is obvious that, in each particular conservation program, effective results can be expected only if we are familiar with all above-listed components, either on a national or the regional level, and if relevant actions in each and every established task are simultaneous and well pondered.

Energy Diagnostic System designed to audit industrial energy flows and process parameters was developed by the Institute of Thermal Energy and

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Process Engineering, Novi Sad, in 1988. System development was preceded by detailed analyses of the real industrial needs as well as the establishment of initial conditions required for its construction. All that will be described in the following chapter with much more details.

2 ASSUMPTIONS AND CONCEPTS INVOLVED IN THE DEVELOPMENT OF ENERGY DIAGNOSTIC SYSTEM

Let us first discuss some basic assumptions involved in the development of Energy Diagnostic System. They are as follows:

- a. *The aim of measurements must be to establish real energy flows and process parameters for the purpose of decreasing energy consumption and improving the quality of products;*
- b. *If economic and technical levels of the Yugoslav industry are taken into account, all parts of equipment installed in Energy Diagnostic System must have multipurpose features so as to enable establishment of the real energy balance according to the preliminary determined control limits of the plant;*
- c. *Energy Diagnostic System is just one of the conditions required to execute the complete energy conservation program and it is obviously not sufficient;*
- d. *In contrast to the "western" type of mobile energy auditing systems, our version must include relevant software required to process all available data on a given energy consumption as well as the capability for much more detailed in situ measurements.*

Let us now explain all above-listed assumptions with more details.

- Ad. a. Energy consumption measurements in each separate field of the processing industries have decisive roles in all energy conservation programs. They are bases on which conclusions are made about energy efficiency in a given plant, about possible savings within the scope of a particular process and potential technological changes for the purpose of decreasing energy consumption keeping the same quality of products or even improving it. Existing measuring equipment, installed in the Yugoslav industrial plants, is often insufficient or unreliable, i.e. it is not the type of equipment enabling correct conclusions about possible energy conservation. Moreover, technical staff employed in industry is more interested in the quality and quantity of products than in the problems of energy consumption. All these facts resulted in the necessity of primary orientation to complex measurements of the parameters required to prepare relevant energy balances.
- Ad. b. Multipurpose equipment results from the multipurpose Energy Diagnostic System designed for all industrial fields, i.e. for both small and large boilers, either hot water or steam types, for different types of driers, tunnel kilns, heat exchangers, etc. Such a purpose required wide ranges in measurements of either parameters or conditions which, unavoidably, resulted in lower accuracy of instrumentation. Nevertheless, required accuracy must

be provided in all industrial measurements. In addition to this and because of necessary on-line measurements, System must be equipped with measuring equipment having analog electric outputs adapted to the uniform system of data acquisition. This cannot be always provided (for example, in cases where gas flow rates are to be measured in the large diameter channels) but, nevertheless, an efficient data processing software can be developed for all off-line measurements. And finally, necessary equipment was selected in accordance with relevant orientation of the Institute and its predominant specialization in the field of measurements referable to thermal energy flows. Electric power flows are of the secondary interest for us and, therefore, this System shall be equipped only for the basic electric power measurements.

Ad. c. Any measurement is senseless if it has no function in process operation or is not used for the purpose of decreasing energy costs, improving the quality of products, protecting environment, establishing relevant parameters required to analyze and improve existing technologies, etc. Having that in mind, we initiated an intensive activity in order to affirm all elementary goals included in the energy conservation program. The scope of all other executed tasks will influence further development of Energy Diagnostic System as one of the basic components included in energy auditing and energy conservation.

Ad. d. "Western" concept of Energy Auditing System is predominantly based on the analysis of available energy consumption data, usually registered in relevant documentation of each industrial plant, as well as the preparation of general types of energy conservation programs with necessary economic analysis. Decisions about concrete actions are made on the basis of such general programs and analyses. In our case, available data on energy consumption are not reliable, installed instruments are either out of order or inaccurate, factory personnel is not interested in auditing or lower energy consumption, there are no systems of economic force or stimulation developed either for individual employees or for the complete factory and, therefore, our concept must be based mainly on the necessity of energy consumption auditing. In addition to this, simultaneous measurements and regulations are also required due to the lack of proper plant regulation. As measuring capabilities are still limited, necessary analysis of the complete plant can be performed only unit after unit. This requires considerably longer time periods in comparison to the analysis of "existing" information. In other words, our concept is capable "to give technology careful consideration" for the purpose of establishing optimum operating conditions and such approach is also required because of the circumstances prevailing in our industry. In several cases, our experiences proved that considerable energy savings resulted from elimination of glaring and constant errors made in process operation.

On the basis of assumptions formulated as above, a concept of Energy Diagnostic System was developed in a way meeting the following requirements.

- to be mobile and compact;
- to be multipurpose;
- to guarantee accurate measurements;
- to enable quick analysis;
- to be comfortable.

All above assumptions and requirements shall be considered having in mind twenty five years of experience acquired in measurements by the Institute of Thermal Energy and Process Engineering. It should be noticed that these measurements include energy flows and process parameters in the field of processing industries.

3 TECHNICAL CHARACTERISTICS OF ENERGY DIAGNOSTIC SYSTEM

Measuring equipment of this Energy Diagnostic System is installed in the adapted space of ADRIA house trailer (type 430-TD) with the effective floor area of 8.6 m^2 (see Figure 1). The interior part of the trailer is adapted so as to be suitable for measuring equipment installation and

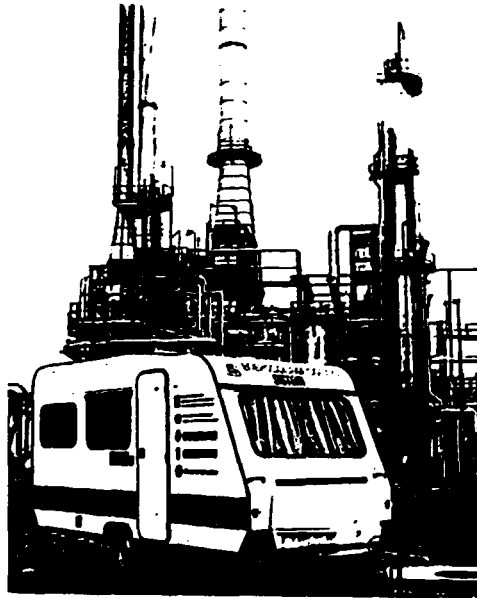


Figure 1. Energy Diagnostic System

operation. A system voltage stabilizer (SMN 10/20 kVA) has also been installed to satisfy requirements of the power supply to computing and other types of equipment. Due to the installed air-conditioner, all necessary activities can be performed in optimum temperature conditions throughout the year.

A list of equipment currently installed in the Energy Diagnostic System including main characteristics of all its parts is given in Table 1. Our

orientation in the field of energy auditing and current capabilities of Energy Diagnostic System are shown in this list in the best possible way.

We ourselves developed complete software required for the execution of any type of measurements.

4 PHASES IN ENERGY DIAGNOSTIC SYSTEM ANALYSIS

In selecting the method of analysis that should be applied in a particular plant, we had in mind our earlier experiences, experience acquired in Energy Diagnostic System operation, and current conditions prevailing in our industry. The method includes the following phases:

- i) *Analysis of engineering documentation and energy costs. Establishment of control limits and preparation of relevant scenario that shall be applied during the measurement of energy flows and process parameters;*
- ii) *Measurement of energy flows and process parameters;*
- iii) *Processing of measurement results;*
- iv) *Analysis of the processed results and their comparison with the design parameters, local norms, standards, etc.*
- v) *Making decision about the following:*
 - *Process regulation and repetition of Phase ii) through iv),*
 - *Preparation of relevant conservation program including technical and economic analysis;*
- vi) *Execution of the adopted conservation program;*
- vii) *Establishment of effects resulting from the executed program by repeating Phase ii) through iv).*

The above-described procedure is of a general type and it can be easily noticed that measuring itself makes only a part of the complete procedure. Simultaneous actions of different types of experts are also required to provide completely successful execution of a conservation program. It should be noticed that no conservation program can be successfully executed before all other necessary conditions - economic, technical and organizational - have been provided, too.

5 CONCLUDING REMARKS

The concept and capabilities of Energy Diagnostic System, as developed by the Institute of Thermal Energy and Process Engineering, Novi Sad, in 1988, have been described in this paper.

It shall be specially emphasized that the problem of measurement is only one condition required for the execution of a particular energy conservation program. A number of other requirements - organizational, technical and economic - shall be also well pondered actions in all essential parts of a conservation program lead to a sure success.

Table 1. - A list of equipment currently installed in the Energy Diagnostic System

No	Type of Equipment or Instrument	Producer	Notes
1	Data Acquisition/Control Unit HP-3054DL - Personal Computer HP-85B (64 KB) - Voltmeter/Schanner HP-3497B (120 Channels) - Matrix Printer HP-22358B - Plotter HP-7475A - Floppy Disk HP-9127AB	Hewlett-Packard (USA)	Main system for data collection and analysis. With real time clock.
2	Data Acquisition/Control Unit - Controller HP-98155 - Voltmeter HP-3455A - Scanner HP-3495A (40 Channels)	Hewlett-Packard (USA)	Auxiliary system for data collection and analysis. Without real time clock. Compatible with the main system.
3	Liquid-In Glass Thermometer	Various	Range from - 50 to 300 °C.
4	Thermocouple - Iron-constantan - Chromel-alumel - Copper-constantan - Platinum 13X rhodium - platinum and adequate compensation cables (~2000m)	Omega (USA) and Omega (W.C.) or hand made	Range from - 200 to 1400 °C. Diameters of wire are ranging from 0.1 to 0.7 mm.
5	Monochromatic - Brightness Radiation Thermometer (Optical Pyrometers)	Siemens-Hallike (W.C.)	For temperatures from 700 to 3000 °C.
6	U - tube manometer	Various and hand made	Working pressure up to 10 bar and maximum high up to 1200 mm. Manometers are filled with mercury, water or alcohol.
7	Inclined manometer	Various and hand made	Only for small pressure differences.
8	Capacitive differential-pressure transmitter and deadweight gage for calibration	ATK (YU)	For pressures up to 70 bar with standard electric output.
9	Burdon pressure gauge	Various	For pressure up to 600 Bar.
10	Hot-wire anemometer	Schilt-knecht (CH) and Airtherm (USA)	-
11	Pitot-static tube	Schilt-knecht (CH) and hand made	Various lengths from 200 to 3000 mm and diameters from Ø3 to 20 mm, respectively.
12	Revolving-vane anemometers	Airflow (W.C.) and Schilt-knecht (CH)	With or without electric output.
13	Turbine flowmeter	ISTA (W.C.)	For flow measurement of liquids. With or without electric output.
14	Variable-pressure drop flowmeter	Various	Mostly orifice flowmeters. For flow measurement of gases, liquids and steams. With or without electric output.
15	Constant-pressure drop flowmeter (Rotameter)	Various	For flow measurement of gases and liquids
16	Combustion gas composition measurement (Orsat analyzer and single - element flue gas analyzer - Bacharach)	Various	For CO ₂ and CO in a sample.
17	Gas analysis computer	CENTER (A)	For O ₂ , SO ₂ , NO _x , CO and CO ₂ , and differential pressure measurement from -10 to +10 Pa. Combustion efficiency measurement as well.
18	Dry and wet-bulb thermometers measurement unit (Aspirated psychrometer)	Various	For temperatures up to 70 °C. With or without electric output.
19	Condensation method for very hot and wet gases humidity measurement	Hand made	Temperature range from 70 to 200 °C.
20	Other: Ammeter, Voltmeter, Wattmeter, Equipment for sound and vibration measurement, Tachometers, etc.	-	-

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REDUCTION OF ELECTRIC ENERGY COSTS
IN A DAIRY
RESULTING FROM THE INSTALLATION
OF A COLD WATER ACCUMULATION PLANT

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1 INTRODUCTION

Just after milking, the temperature of milk is approximately 35 °C. Milk can be spoiled at this temperature in a few hours. In order to preserve its quality, milk shall be cooled after milking as soon as possible. The cooling time shall not exceed two hours. The required cooling temperature is about +4 °C. At this temperature, milk can be preserved for a couple of days. It is cooled indirectly by cold water. The water is supplied by use of traditional cooling systems.

Milking takes place two times a day - in the morning and in the evening. This causes two distinct peaks in the electric power consumption. If a cooling system has been built at the milking place or at a local milk collection point, there are usually no significant electric devices whose switching-off could result in (at least) partial decrease of the above-mentioned peak loads. The engaged capacity can be controlled to a certain level only in case where the cooling system makes an integral part of a dairy. This is done through coordination of the working times in the rest of the existing electric facilities. However, the two peak loads have considerable influence on an uneven daily consumption of electric power, even in this case.

Such a situation is most directly reflected in the total cost of electric power, a considerable part of which is the capacity engaged. The

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cooling system is the most significant power consumer. Assuming that the possible load alterations have already been considered in the phase of process engineering, the peak electric load can be reduced through accumulation of the cooling energy. This means that the possibility to prepare a part of the cooling energy at the time of the cheaper electric power shall be taken into consideration. The cooling energy obtained in this way can be accumulated and used for cooling purposes in the periods of the peak electric loads.

An analysis of the feasibility of introducing the cold water accumulation has been prepared for a concrete case and based on the concrete data obtained from the Pivnice Dairy, Yugoslavia.

2 AN ANALYSIS OF THE DAILY COOLING WATER REQUIREMENTS

According to the data submitted by the Pivnice Dairy, the required cold water is prepared, maintained and used in the period between 6 a.m. and 10 p.m.. The use of their cooling system for other purposes is extremely small, so it has not been taken into account in order to explain, more clearly, the idea of the possible ways of the cold water use.

Daily requirements of the cooling energy in the form of cold water are 9,400 MJ. The time schedule of this energy engagement is shown in Figure 1.

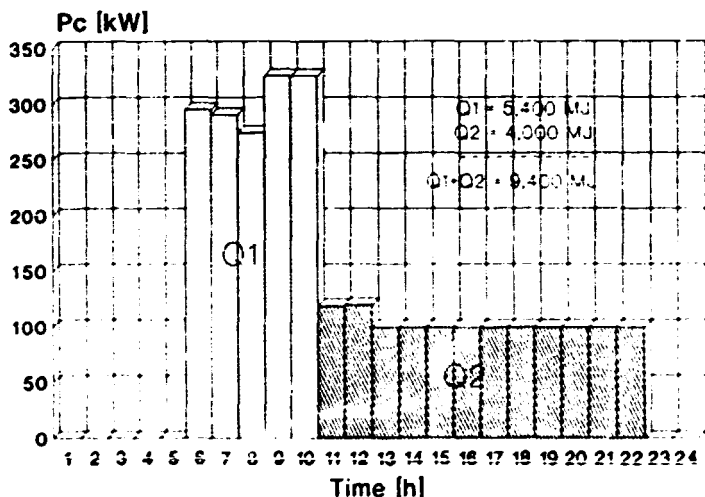


Figure 1. The time schedule of the cooling energy use

The period of an intensive use of the installed capacity is marked as a dotted area (Q1). In this period, the cooling capacity is engaged in the range between 275 and 325 kW. During the rest of the time (Q2), the cooling

capacity is engaged in the range between 100 and 120 kW.

According to the existing system of rates in the Autonomous Province of Vojvodina, this type of cold water preparation causes the highest electric power expenses for the following reasons:

- The cooling system operates at its full capacity at the time of the most expensive electric power, and
- The maximum quantity of electric power is engaged by the cooling system at the hours when all other electric facilities within the Dairy battery limits are operated, too.

The main idea is to change these relationship so that the system will be in full operation in the period of the cheapest electricity while the maximum engagement of the power capacity will decrease. This can be done if Q1 energy from Figure 1 is prepared during the night (the period of the cheaper electricity) and the power capacity engaged according to maxigraph reduced to minimum.

The system for the cold water preparation in the Pivnice Dairy has been reconstructed. A pool has been constructed to accumulate 5,400 MJ of the cooling energy. 16,250 kg of ice are required for that purpose and they can be produced in 7 days. Thus the total Q1 quantity of the cooling energy from Figure 1 is provided. More exactly, daily cooling requirements can be partially satisfied by energy prepared during the night (Q3) and accumulated up to the moment of its use. The time schedule of the cooling energy preparation, in case of its indirect use in the form of cold water, is shown in Figure 2.

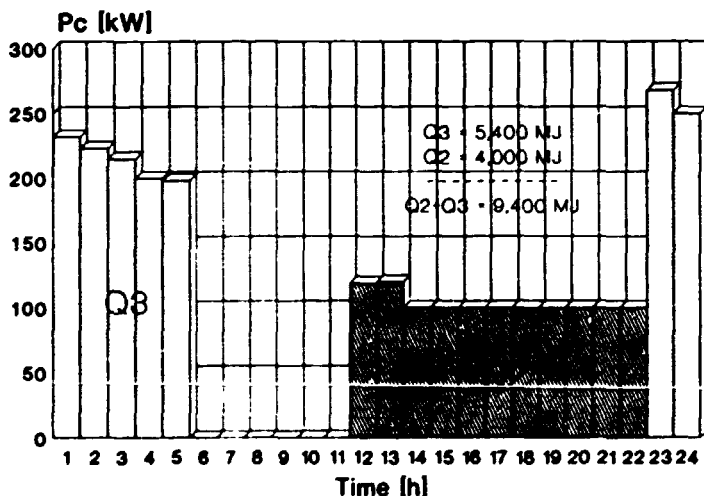


Figure 2. Time schedule of the cooling energy preparation

This does not affect either the way or the time of the cooling energy use because (Q3) energy prepared in advance (Figure 2) will be used as (Q1) energy (Figure 1).

3 PLANT DESCRIPTION

In the case that cold water is prepared in a system excluding cooling energy accumulation, capacities are designed according to the current needs. Then the cooling capacity of the compressor is established according to the diagram of the cooling requirements.

Another possibility is to prepare cold water in a system including accumulation of the cooling energy either in the form of cold water or in the form of generated ice. In that case, the size of the cooling system is determined in accordance with the required quantity of the cooling energy as well as the accumulation time available.

In both cases, the system consists of the same components. The only difference between these two types of the cooling system are the capacities of certain elements. In the systems excluding accumulation, the capacities of compressors, electric motors, condensers, collectors, and accessory components are somewhat larger while the systems including accumulation of the cooling energy have considerably larger vaporizers and pools designed for the preparation and storage of ice and cold water. When these two accumulation possibilities are compared, it becomes obvious that the system designed for ice accumulation is more convenient because the unit volume of ice can accumulate approximately 80 times larger quantity of the cooling energy than the same volume of water does [1].

The main advantage of the system excluding accumulation is the lower total investment resulting from the following fact: *The cost of larger vaporizer and additional accumulation pool exceeds the difference in price caused by somewhat larger capacities of other parts of the required equipment.*

However, the system including accumulation is cheaper in operation. The main advantages of this system are as follows:

- *The installed power capacity of the cooling system is lower (this results in the lower power capacity of the complete power supply system installed in the Dairy as well as the lower taxes due to the Power Distribution Authorities at the time of construction),*
- *The lower total power capacity decreases the maximum possible engagement of the power capacity according to maxigraph,*
- *The system including accumulation provides far better control possibilities in regard to the capacity engagement in the periods when electricity is cheaper.*

Being aware of the advantages offered by the cooling energy accumulation system, the Pivnice Dairy has reconstructed its existing cooling system. A new system including ice accumulation was constructed at the time when the capacities of the old cooling system excluding accumulation had to be extended by 50%. A schematic drawing of the new system is shown in Figure 3.

In order to produce 16,250 kg of ice in 7 hours, a pool of the following size has been constructed: 7,500 mm × 3,500 mm × 2,200 mm. The

pool consists of 12 ice accumulation sections made of ϕ 42.4 mm x 2.6 mm pipes. The total pipe length is 1,611 m. The ice generation rate is such that the cooling system operates at the average evaporation temperature of -5°C during the first hour. The temperature is gradually decreased to reach -11°C in the seventh hour. This is achieved thanks to the two parallel compressors (45 kW, 980 min^{-1} , $\cos \phi = 0.86$; 30 kW, 730 min^{-1} , $\cos \phi = 0.84$) operating at the following power capacity engagements: from 66 kW during the first hour down to 59 kW in the seventh hour, i.e. 415 kWh on the whole.

The same cooling effect can be achieved in a system excluding accumulation provided that the evaporation temperature is -6°C and assuming the range of the power capacity engagement of 75 - 83 kW or 385 kWh on the whole.

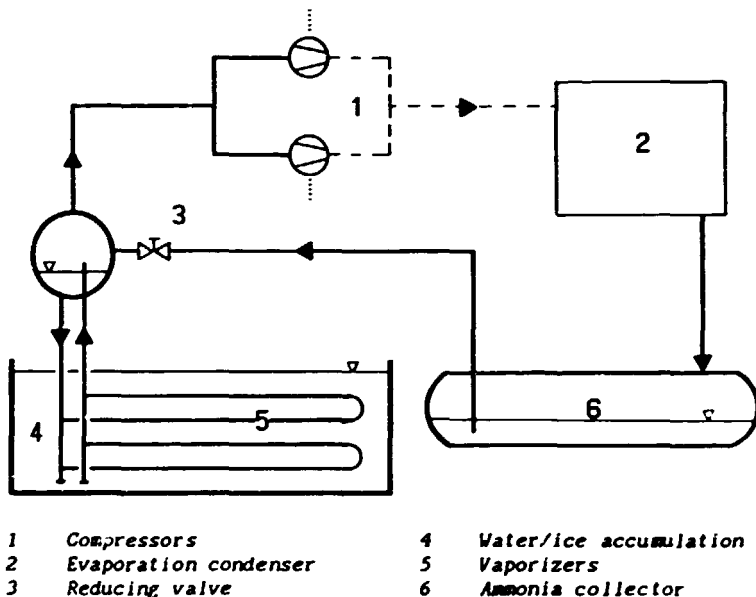


Figure 3. A scheme of the system designed for the cold water preparation

In each of the two above-mentioned cases, cooling requirements are in full accordance with the real Dairy needs. In the system including accumulation, the plant operates at night preparing (Q3) cooling energy (Figure 2) while in the system excluding accumulation, the plant would operate at the same time when the cold water is being used, preparing (Q1) cooling energy (Figure 1).

The rate of ice formation and other technical and energy aspects regarding the operation of the ice accumulation system in the Pivnice Dairy

have been studied on the basis of measurements carried out by the Institute of Thermal Energy and Process Engineering, Novi Sad, on april 12/13, 1990 [1]. The experiments have been done using the Energy Diagnostic System, i.e. a computer aided system designed for industrial energy measurements under the real operating conditions.

4 ECONOMIC ANALYSIS

The system including accumulation, as installed in the Pivnice Dairy, would be approximately 27,000 USD more expensive than the similar system without accumulation.

The cost of electric power and engaged capacity according to the current Schedule of Rates in the Autonomous Province of Vojvodina can be calculated by use of Equation 1.

$$C = C_P + C_A + C_R \quad (1)$$

- C_P The price for the maximum engaged power capacity according to maxigraph;
- C_A The price for the active electric power;
- C_R The price for the reactive electric power.

In this analysis, only operation of the system designed to prepare the cold water required for cooling purposes (Q1) has been taken into account because (Q2) (Figure 1) is identical in both relevant cases. In the system excluding accumulation, cold water is prepared at the time of its use and the cost of electric power and engaged capacity can be calculated according to Equation 2. In the system including accumulation, cold water is prepared during the night (Q3) (Figure 2) and Equation 3 is applicable.

$$C_1 = C_{P1} + C_{A1} + C_{R1} \quad (2)$$

$$C_2 = C_{P2} + C_{A2} + C_{R2} \quad (3)$$

where subscripts 1 and 2 denote the two different solutions.

The difference in price is given in Equation 4.

$$\Delta C = C_1 - C_2 \quad (4)$$

In order to enable extrapolation of the results obtained in this analysis to a longer period of time, further analysis will be prepared according to the current prices from September 1991. This will be done by applying the average season price of electric power and engaged capacity and the exchange rate of 42 YU Dinars for 1 USD as well as by observing the ratio of the set higher and lower daily rates.

The result of this, is the final form used to calculate differences in the monthly costs of electric power and engaged capacity according to maxigraph. It is given in Equation 5.

$$\Delta C = 11.117 \cdot (P_1 - P_2) + (0.039 \cdot A_1 - 0.0191 \cdot A_2) \cdot 30 \quad (5)$$

where:

AC [USD/month]	Monthly difference in price;
P [kW]	Engaged capacity according to maxigraph;
A [kWh/day]	Active electric power consumed in a day;
1, 2	Subscripts: 1 - system excluding accumulation, 2 - system including accumulation.

For $P_1 = 83$ kW, $P_2 = 66$ kW, $A_1 = 385$ kWh/day, and $A_2 = 415$ kWh/day, monthly difference reads as follows:

$$AC = 456 \text{ USD}$$

The above sum shows how much a monthly operation of the system including cooling energy accumulation is cheaper than that offered by the system excluding accumulation. In this way, the difference in the investment cost would be paid back in 59 months.

It is assumed that the pay-back period could be even shorter because only the most evident influence has been analyzed. The first reason why this assumption could be realistic is the fact that all neglects and simplifications have been made for the purpose of ensuring higher reliabilities of the final results.

The following two facts have neither been taken into account: 1) the influence of the maximum engaged capacity in the cooling system designed for the cold water preparation on the overall maximum engaged capacity of the Dairy, and 2) effect of shifting the operation of the most significant electric capacities installed in the Dairy from morning to night hours.

5 CONCLUSIONS

The following most important conclusions can be made on the basis of analyses carried out under the real operating conditions in the Pivnice Dairy:

1. As far as the investment cost is concerned, the implementation of the systems designed to prepare and accumulate cooling energy in the form of ice and cold water is more expensive than the implementation of similar systems excluding accumulation.
2. However, these systems are cheaper in operation. Their pay-back periods depend on the real conditions. In this particular case, the pay-back period is less than five years.
3. The installation and operation of these systems provide better prerequisites for a more efficient control of the Dairy Power Supply System.

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ENERGETICS AND ENVIRONMENT

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1 ENERGY MANAGEMENT IN THE LIGHT OF ENVIRONMENT PROTECTION

The scientific-technical revolution has brought on one hand the enormous profits for mankind while on the other hand and in result of the initial ignorance and later disrespect of the environment problems, it has led to the environment pollution on the scale not known before.

The energy management has been and still is of great importance in the environment pollution.

Broadly speaking, the energy management includes all activities bound with:

- *The exploitation of the energetistic raw materials and their conversion into the electric energy or into other kinds of the energy carriers,*
- *The utilization of the obtained energy to the productive services aims.*

The civilization development jump of the mankind in the XIX and XX century was possible thanks to great energy resources on the Earth. About the role of the energy management in the life of the nations as well as the individuals, testifies the fact that somewhere round the year 1980 almost 86% of the world energy consumption took place between 30 and 60 degree of the north latitude, with 29% of the Earth population, while the rest of the population, that is to say 71%, consumed 16% of the released energy on the Earth [2].

On one hand, the modern energy management has caused the economic and civilizing development of one part of the mankind but, on the other hand, the too quick development has been and still is dangerous for the mankind

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because:

- *The non renewable resources of the energetics raw materials are quickly diminishing, which causes increasing of their winning costs,*
- *The growing environment pollution in connection with the winning of the raw materials as well as that obtained from the energy utilization.*

From there arises energy management rationalization necessity in the food industry enterprises.

The rationalization should include the activities streaming to:

- *The energy wasting reduction,*
- *Neutralization or minimization of the energy management damaging results for the environment,*
- *Application of the nonconventional energy carriers, which are not dangerous for the environment.*

2 PARTICIPATION OF THE FOOD PROCESSING INDUSTRY ENERGETICS IN THE NATURAL ENVIRONMENT POLLUTION

The height and the quality of environment pollution are activities derivative from many different pollution sources. Food processing industry plants are among them, too.

In this situation, it is difficult to say precisely in what measure they cause this pollution. Only the indirect estimations are possible e.g. basing on the quantitative data of the consumed energy carriers.

Though the food processing industry occupies a leading place among the different industry branches, it does not belong to the greatest energy users. In the year 1987, the Polish socialized food processing industry held the first place among 23 industry branches according to the value of the global production and the number of the production enterprises. But in relation to the electric energy consumption, it occupied the seventh place. The electric energy consumption in the food processing industry in Poland in the year 1987 was only 4.1% of the overall socialized industry consumption while in this year, the production value of the socialized food processing industry is 15.4% of the total Polish socialized industry. The direct consumption of fuels and energy from 121.7 PJ in the year 1987 has made 6.4% of this consumption in the whole Polish socialized industry in this year [1]. From these data, one can see that the Polish food industry does not belong to the energy absorbing industries.

In Netherlands, where agriculture and food processing industry play also a great role as in Poland, in the year 1985 the fuels and energy consumption was 9.4% of the overall Dutch industry consumption. From this, it can be indirectly concluded that the food processing industry in a state scale, even in these states where the agriculture and food processing industry play a great role, does not belong to the group of industry branches which is decisive for the environment pollution.

But it does not mean that there are no energy absorbing plants in the food industry as e.g. sugar factories, breweries, dairies, potato plants, meat factories, which locally play a great role in the environment

pollution. Taking into consideration that the damages done in the environment by the energy management have to be respected in the costs of production, it becomes evident that properly counted costs of the energy management would be often higher than their level fixed up to now.

Though the fuels and energy consumption in the food industry is not large, these costs expressed according to the values in global formulation present, nevertheless, already large amounts.

An example for this, may be again the Polish food processing industry. The Polish food processing industry e.g. in the year 1984 consumed 1.8% of the electric energy produced in the state, but this consumption is in this year equivalent to 4,301 thousand tons of the conventional fuel or to the sum of 334 million USD.

Respecting this fact as a result of the energy management rationalization, it is possible to diminish the energy consumption for about 15% which, in this concrete case, means that it is possible to reduce the dues for the energy consumption in the amount of about 50 million USD and it also means an abatement of the environment pollution from the food processing industry in the height of 15%.

The fact that the participation of the food processing industry plants bound with the environment pollution through their energy management activities is comparatively small, does not relieve these plants from the duty of the pollution minimization.

3 THE REDUCTION OF THE ENERGY WASTE, A DIMINISHING FACTOR OF THE NATURAL ENVIRONMENT POLLUTION

As it was already said, the energy waste diminishing in result of the rationalization automatically causes the diminishing of the energy management effects negative for the environment. The data about the energy management in Netherlands speak of the problem importance and of the protection possibilities in the environment.

Netherlands consume energy in the equivalence of 35 billion guilders a year. The value of the wasted energy is equal to 5 billion guilders. The production of this wasted energy is an additional ballast for the already contaminated environment.

With the diminishing of the energy waste to zero, it is possible to diminish the environment ballast by 20% which is already a considerable value [15].

The structure of the energy consumption in Netherlands is shown in Figure 1.

It is known, on the ground of many years experience of SVEN (Stichting Voorlichting Energiebesparing Neaderland), that even in the plants with a conscious energy utilization, it is possible to reduce the bills amounts for the energy for about 15%. It is to say, that the energy consumption rationalization has and can have a great influence on the environment pollution diminishing.

Therefore, it is a necessity to consider the energy management problems in the same context with the environment protection.

The problems of the energy management and the environment protection must be considered in a mindful manner, respecting the priority of the environment protection.

The special importance is to acknowledge to the organizational instruments of the energy management rationalization, because their application leads to the diminishing of the absorbing energy production without expensive investments.

The organizational management rationalization is the cheapest form of its improvement.

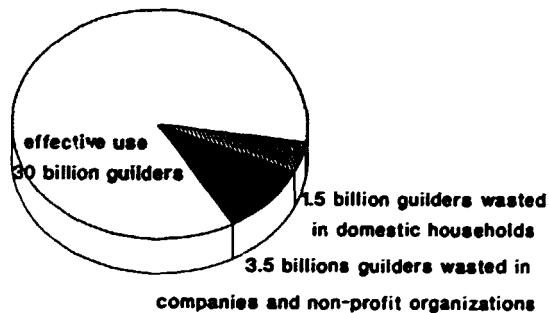


Figure 1: Structure of Energy Consumption in Netherlands [15]

4 DIMINISHING OF THE NEGATIVE ENERGY MANAGEMENT INFLUENCE ON ENVIRONMENT

4.1 Environment Pollution through the Food Processing Industry Plants

Although all the plants have not got their own boiler rooms and power stations, all of them use electric motors and internal combustion engines having often highly developed their own motor-car transportation. They also use electric power supplied by the high voltage lines.

The food processing industry plants are generating:

- Air contamination through SO_2 , SO_3 , CO , NO_2 , and other gases,
- Thermic contamination of the air and water,
- Electromagnetic fields,
- Dust emission to the air,
- Ashes and cinder tips accumulations,
- Acid rains and acid waters.

4.2 Air Contamination through Gases and Dust

Especially dangerous are the contaminations of the air and water because they play a very important role in the ecological chain, as shown in Figure 2.

Figure 2 is a conceptional scheme including the most important connections and illustrating the energy management influence on the ecological chain. The most important feed-backs connected with the energy management biosphere pollution are also presented in this Figure. Without air, men can live only few minutes. Human health requires non contaminated air. Air is a mixture of different gases composing the atmosphere. Air is composed as follows: 78% of nitrogen, 21% of oxygen, carbon dioxide, and small quantities of other gases and steam. Up to the height of 20 km above the sea level, the dry air composition without steam is constant.

The plain air, that means in a natural composition, is necessary for the life of plants, animals and people.

About 100 substances contaminate the air. These substances are

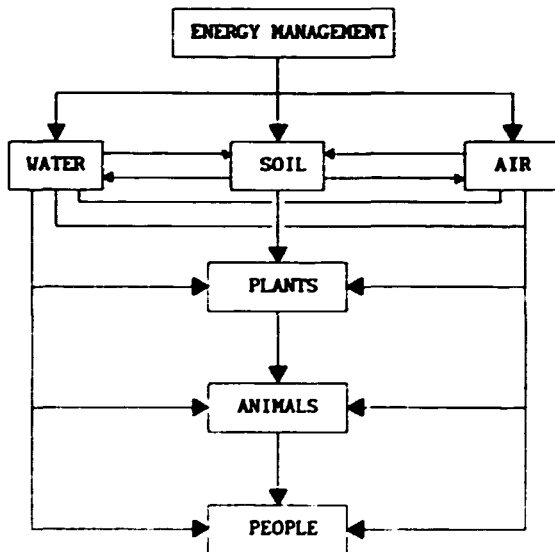


Figure 2: The influence of the energy management on the ecological chain

dangerous for the human health.

The most frequent pollutants are: carbon monoxide (CO), sulphur oxides (SO₂ and SO₃), ammonia (NH₃), hydrogen fluoride (HF), nitrogen oxides (NO₂), arsenic disulphide (As₂S₂) and others.

It was estimated that before the year 1990, the quantity of CO₂ in the Earth atmosphere had increased by 20% in relation to the normal quantity.

The increase of CO_2 in the air leads to the greenhouse effect. CO_2 is heavier than the air. The CO_2 influence is similar to the influence of glass in a greenhouse. Consistently, the thawing of the pack and mountain ice follows.

The diminishing of the vegetable life on the Earth limits the reduction of CO_2 in the air in the photosynthesis processes.

Sulphur oxide (SO_2) is another dangerous air pollutant. For the industry purposes, the worst sorts of coal are generally combusted, their sulphur contents ranging from 0.5 to 4.0%. Petroleum also contains considerable quantities of sulphur. In the result of the combustion processes of these fuels, these quantities are emitted into the atmosphere. The combustion of these fuels causes not only the air pollution but indirectly the acid rains and acid water as well, which are very destructive for the environment.

The production plants contaminate the air with different types of dust as well.

In connection with the building of very tall factory chimneys, dust and the gases are transported from the emission places, where they caused the environment pollution. The greatest dust pollution of 1km^2 of the land was in 1985. In Czechoslovakia it amounted to 10.9 t/km^2 , in Poland 5.9 t/km^2 . In 1984, it was 2.7 t/km^2 in GFR and 5.3 t/km^2 in Hungary.

4.3 Thermic Contamination of Air and Water

The other negative effect connected with the production activities are the thermic contaminations of the environment. At the actual technical level of the energy raw materials conversion to the electric power, the efficiency of the motors is 35 - 40%. In the year 1976, the quantity of the energy losses in relation to the overall energy used in the USA was 49% [2].

As no measures had been taken, this energy was transmitted to the environment causing its thermic contamination [2]. This resulted in the permanent eagerness of engineers to design more and more effective motors.

In the conditions of bad technical solutions and badly organized energy management, warm water or even hot water is discharged into the streams, rivers, ponds or lakes which is not indifferent for the biological life.

4.4 Generation of Electromagnetic Fields

Around the high voltage transmission lines reaching the production plants as well as around the power units, electromagnetic fields are formed.

The phenomena of their influence on the environment, especially people and animals, have not been studied enough. There are such lines and this type of equipment in the food industry, too. According to the Environment Protection Agency, 35 million electromagnetic installations were operated in the USA food and wood industries in 1977. The pervasion of the installation of these production plants has been increasing from year to year causing the higher strength of these fields influence.

4.5 Ashes, Dumps and Cinder Tips

In result of the solid fuels combustion, considerable quantities of ashes and cinders are accumulated in the vicinity of the large industrial

plants. They often need considerable areas which are practically eliminated from the ecosystem, being also the emission source of different substances destructive for the soil.

It is possible to transform ashes and cinders, e.g. into the building materials, to utilize them in winter to the roads and highways strewing and the like, which allows to diminish the areas occupied by dumps and tips.

4.6 Generation of Acid Rains and Acid Water

Besides air, water is the second basal factor which decides about the life on the Earth. The water content in a healthy human system is equal to 60-65% of the overall body mass. The water content in the bodies of animals oscillates between 60-97%. The plants vegetation is impossible without water. Water is the principle and the best dissolvent indispensable in vital processes. For these reasons, the proper quality of water is of the first rank.

The human civilization development, a badly noted sense of the technical progress which should play a service role to the man and his environment, cause the pollution of the inland and see waters.

The energy management also participates in this contamination but only when solid fuels are used, e.g. coal and mineral oil. They contain 3.0 - 4.5% of sulphur, which is oxidized during the combustion processes. Besides sulphur dioxide, other compounds are generated but the most dangerous is SO_2 .

SO_2 gets into the atmosphere with smoke where it binds itself with the water molecules and in result of this binding, sulphur acid is made. It is contained in rain and fog or it settles on the soil in the form of dry molecules as the so-called *acid rain*. The acid rains are the plague of the industrial areas as well as the distant territories where they are brought by the air currents.

In the states of the middle Europe, the emission of sulphur to the atmosphere is appraised to around 27 million tons in a year. 80% of this emission comes from the following five states: Great Britain, Germany, France, Czechoslovakia, and Poland [8].

Acid rainfalls lead to the rupture of the plants vital functions and the result of this is the deterioration of the meadows, the contamination of the soils under cultivation and the quick devastation of the forest regions. There are technical possibilities to achieve important limitations of the SO_2 emissions but they require very large expenses which are practically an economic barrier not allowing or hindering the limitation of SO_2 emission in a short time. Therefore, the cheap desulphurizing methods of the combustion gases are worthy of the interest.

4.7 Environment Protection is also in the Sphere of Energy Management

Besides the traditional energy management problems which have already been mentioned herein, another problem has to be considered in the field of energy management. It's the problem of the environment contamination decrease through the energy management measures.

The business boards of the enterprises are the managers of their energy services as well. As the executives of these services, they must be aware how dangerous the energy management of enterprises and plants might be in the field of the environment protection, to what degree precisely they cause the contamination of the air, water and soil, the devastation of the fauna and flora and, in the final consequence, the growth of the people morbidity through the lack of their right decisions or activities.

In fact, they contribute to the life level debasement on a social scale through their destructive environment activities.

The reduction of this negative energy management influence is not possible only by decreasing energy consumption through the utilization of the technical instruments neutralizing it but also through the application of the unconventional energy carriers on a large scale.

5 UNCONVENTIONAL ENERGY CARRIERS AND ENVIRONMENT POLLUTION

From the environmental protection point of view, one ought to acknowledge those energy carriers which do not create pollutions and perturbations in the environment.

More and more frequently, men write and speak about the utilization of the renewable energy sources or the utilization of the unconventional energy carriers. These two ideas partially cover each other.

A common feature of the wanted new energy sources is their environment harmlessness and cheapness, today and in the future.

These kinds of energy include:

- *Solar energy,*
- *Wind energy,*
- *Waterfall energy,*
- *Geothermal energy,*
- *Inflow and outflow energy,*
- *Biogas energy.*

5.1 Solar Energy

Sun is the reachest energy source, which permanently provides the Earth. In 36 hours, the Earth receives as much energy from the Sun as the mankind has consumed in the form of coal and petroleum from the beginning of its civilization.

In Middle Europe, the solar radiation gives the area of 1 m^2 50% of its energy received by 1 m^2 in the desert of Sahara. These two quantities attest that the states from the moderate climate region also have a colossal possibility of the solar energy utilization.

The fundamental problem of the solar energy utilization is its storage. A decisive moment in the solar energy practical utilization has been the construction of the unique type of the photo voltaic cell. The efficiency of this cell is around 40%. The weakness of the solar power plants are the great areas of the Earth occupied by them. These areas are 100 times larger than the areas occupied by the coal-fired power plants of the same capacity.

In 1988, the building of the first solar power-plant began at the desert of Karakorum. This plant will have the power of 300 MW.

In Netherlands, on the island of Terschelling, studies are prepared on

the parallel utilization of the solar and wind energies in the same energy system.

5.2 Wind Energy

Wind is the second inexhaustible source of energy. About 6 thousand years ago, man began to utilize the wind energy. Through the centuries, people have been using the wind to do their work easier.

It is worth mentioning that there were about 100,000 windmills at the North Sea coast, between Netherlands and Denmark at the beginning of the 20th century. These windmills supplied mechanical energy to the flourmills, oil presses, sawmills and beater mills [9].

Later on, with the appearance of such energy carriers as coal and mineral oil, the windmills utilization was limited.

Finally, the energy recession in the year 1973 took the wind energy into consideration once again. The wind energy can be utilized as a mechanical energy in the small food industry plants, for example in flour mills, oil presses, etc.

More and more frequently, the wind energy is transformed into electric energy.

In the year 1988, there were about 16,000 wind electric units in the world with the total capacity of 1,000 MW.

In Netherlands, it has been projected that the electricity received from the windmills will be equal to 1,000 MW in the year 2000.

There are lands with strong winds and they could receive 10-25% of the necessary electric energy from this source [8]. A good example is California where the utilization of the 4,000 MW wind turbines has been anticipated [8].

With the technical progress, the electric energy received from the wind energy will be cheaper than the electric energy from the conventional sources.

5.3 Energy of Waterfalls

Long ago, the utilization of the waterfalls was already known. 20% of the world electric energy production results from the utilization of the waterfalls. Most water-power plants are located in South America. The West Europe draws 21% of its electric energy from the hydroelectric stations.

In Switzerland, about 90% of the waterfall potential is utilized for the electric energy production. This level should be acknowledged as the level achievable in other countries. In the past, the waterfall energy was transformed into the mechanical energy of the flour mills, sawmills, presses and so on. Today it is rarely the case. The come-back of this type of energy utilization in the small food processing industry plants is motivated by both economic and environment protection reasons.

5.4 Inflow and Outflow Energy

The inflow and outflow in the great water reservoirs, such as oceans and large seas, cause the big inflow and outflow waves. The energy of these waves may be transformed to the electric energy. Some states have good conditions to utilize the inflow and outflow waves energy and, therefore, they build or intend to build proper power stations.

5.5 Geothermal Energy

The sources of the geothermal energy are:

- *natural reservoirs of dry steam under the surface of the earth,*
- *hot waters from the earth,*
- *ledges of dry rocks with very high temperatures.*

The heat inside the Earth is the result of high pressures, the radioactive elements disintegration and the heating of the deep Earth ledges by magma.

The geothermal energy is also an energy source without limits for mankind.

It is estimated that the external 16 km thick Earth stratum stores more than 2,000 times larger quantity of heat than that which could be received from the combustion of all coal stocks on the Earth.

The high economic efficiency of geothermal energy is proved, among other things, by the fact that the cost of rooms heating with geothermal water makes only 25% of their heating with the mineral oil.

10% of the Earth surface is characterized by very large and relatively accessible stocks of geothermal energy.

In the year 1983, ten to twenty states were already running 130 geothermal power plants, their capacities being over 3,000 kW [11].

The *Geyers* in California was the largest geothermal power plant in the year 1983 with its capacity of 1,000 kW. It is anticipated that a chain of geothermal power plants will be organized in California by the year 2000. Its capacity will amount to 4,500 MW. From the hot sources in Hungary, about 1,600 MW is received in a year.

It appears that the former opinion, according to which some countries are poor in the geothermal energy sources, has been wrong. Poland is also one of these states. Today it is estimated that the energy equivalent of 8 billion tons of conventional fuel can be obtained in Poland in this way.

5.6 Biogas Energy

The biogas production becomes more and more interesting from the environmental protection point of view. Biogas is a product of the organic matter anaerobic fermentation. Biogas contains 50% of methane.

It is produced:

- *Of especially prepared biomass, plants offals and animal excrements or;*
- *Plants offals in the food industry enterprises if they have no better form of their utilization.*

It is believed that biogas will play a significant role in the energy balances of many states.

In Great Britain 8-13% of the yearly energy demand will be covered by the biogas production.

The great hopes with biogas production are common in France. The quantity of biogas produced in the year 2000 will be equivalent to 10 million tons of the mineral oil [12].

In Belgium, the biogas production from biomass is compared with the great energetics.

It is anticipated that the Polish biogas production will be equal to 1 billion m^3 in the year 2000.

An important producer and exporter of the biogas installations is Sweden.

The possibilities to utilize biomass as an energy source are proved to be great, i.e. the energetic value of the biomass produced yearly on the Earth is seven times higher than the yearly energy demand of the mankind.

6 ENVIRONMENT POLLUTION INFLUENCE ON HUMAN HEALTH

A high increase of population, the scientific and technological revolution which is not always and finally oriented to the welfare of man and his environment, the development of the social systems oriented to the maximization of production without paying attention to the social cost of this maximization, are carriers of the growing morbidity, civilization sickness and environment pollution.

It can be already spoken about the ecological catastrophe areas, where practically there are no conditions for the normal life.

For example, there are 27 ecological catastrophe areas in Poland. These areas occupy 35,220 km^2 or 11.3% of the total territory of Poland. In the year 1982, 13 million inhabitants or 35.5% of the overall population of Poland lived in these areas.

Energetics has an important role in the environment pollution but it has already been said that the food processing industry participation in the environment pollution is not important though it may be quite noticeable locally.

The consequence of the environment pollution in relation to population is the increase of its morbidity.

In the combustion processes of coal and petroleum used as fuels in the food industry plants, SO_2 , CO, NO_2 , and other components are emitted. The respiration of the air with even small SO_2 content during a longer time period may lead to visible health changes for the worse in persons suffering from bronchitis or heart/circulatory system diseases.

A high concentration of SO_2 can cause a strong mucous membrane vexation or bronchial muscles cramp. Anyhow, in the centers of the strong gas and dust actions (as for example in Krakow), a real progress of the respiratory system diseases in the result of this contamination has been proved.

Inordinate quantities of the emitted CO_2 are of a degenerative influence on the senses and human constitution [7].

Nitrogen contained in NO_2 , as a result of its chemical transformations in the environment, appears in the form of the nitrates, which are transported to human bodies through their feeding systems. Nitrates have a very strong cancer influence.

There is a suspicion that, under the influence of the nitrogen sulphate ions coming into the human bodies dissolved in water, DNA can be transformed to another compound [10].

They are neither indifferent to the electromagnetic fields generated round the power units or along the high voltage transmission lines.

These fields cause the nervous excitability and conduce to the

development of cancer. Comparatively low levels of this radiation can cause headaches, excitement, loss of appetite or memory.

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