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Industrial Energy Efficiency - Ukraine
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REPORT
ON ENERGY AUDIT
AT *KHARKIV FAT PROCESSING COMPLEX*
City of Kharkiv, UKRAINE

Prepared by Mr Mikhail Tarnovsky
Mr Yury Bykov
Mrs Nelly Smirnova

Prepared for United States Agency for International Development
Washington, D C 20523-1415

Burns and Roe Enterprises, Inc
1400 K Street, NW, Suite 1050 Washington, D C 20005
Telephone 202-408-6831 Facsimile 202-408-6835

Table of contents

1 0 EXECUTIVE SUMMARY **3**

1 1 INTRODUCTION 3
1 2 PRINCIPAL FINDINGS 4
1 3 RECOMMENDATIONS 4

2 0 GENERAL BACKGROUND **8**

2 1 ENTERPRISE HISTORY 8
2 2 NUMBER OF SIMILAR ENTERPRISES IN UKRAINE 8
2 3 SIGNIFICANCE OF THIS SECTOR FOR THE NATIONAL ECONOMY 9

3 0 CURRENT STATUS OF PRODUCTION **10**

3 1 PRODUCTION OUTPUT IN NOVEMBER 1997 10
3 2 PRODUCTIVITY OF LABOR IN 1997 VS 1996 10
3 3 PROSPECTS OF DEVELOPMENT 10
3 4 EXPORTS VS DOMESTIC SALES 10

4 0 FINANCIAL STATUS OF THE ENTERPRISE **11**

4 1 CURRENCY VS BARTER 11
4 2 VIABILITY OF ENTERPRISE 11

5 0 ANNUAL ENERGY CONSUMPTION AND ENERGY COSTS **12**

5 1 ANNUAL ENERGY CONSUMPTION IN 1997 12
5 2 CURRENT ENERGY AND FUEL PRICES 13
5 3 ENERGY USE PROFILE 14

6 0 PREVIOUS ENERGY IMPROVEMENTS **21**

7 0 ENERGY AUDIT **22**

8 0 ENVIRONMENTAL IMPACT OF RECOMMENDATIONS **25**

APPENDICES

A ENERGY CONSERVATION OPORTUNITIES (ECOs)
B PHOTOGRAPHS OF THE PLANT
C CONVERSION FACTORS
D ABBREVIATIONS

1 0 EXECUTIVE SUMMARY

1 1 Introduction

This energy audit has been conducted under a program sponsored by the US Agency for International Development This project, referred to as Delivery Order #30, consisted of performing twenty four audits throughout Ukraine The purpose of the project was to develop Ukrainian energy service company (ESCO) capabilities To accomplish this task, Burns and Roe Enterprises, Inc (the primary contractor) hired Ukrainian engineers These engineers were trained in U S techniques of conducting energy audits and in ESCO concepts The industrial energy audits were conducted to facilitate the ESCO training

Since these industries are very large, a one week site visit is not sufficient to adequately audit the entire facility The site visit was restricted to one week due to other project considerations However, the engineering staff were trained to identify improvements that would be representative of the entire plant In many cases it was necessary to focus the auditing efforts on one system or only on a portion of the plant Therefore, this audit is based on what could be accomplished during the one week allocated While this audit contains numerous recommendations for the plant management, the plant management is encouraged to perform a complete audit of the entire facility Hopefully, the plant management will consider hiring the engineers trained under this project to continue this work, which will result in a complete understanding of energy usage within the plant, as well as a complete listing of all potential energy improvement projects

The current report describes the findings of the energy efficiency audit performed by Burns and Roe at the JSC Kharkiv fat processing complex The Kharkiv fat processing complex is the one of the largest producers of margarine, mayonnaise and vegetable fat in Ukraine The plant is equipped with conveyor lines though unfortunately production capacities are used only by 35%

The plant products are in demand at the domestic market and make up 33 2% of total production in Ukraine They meet the highest quality standards The total output in 1995-1997 amounted to 144,900,000 Hrivnas, The share of energy in the production cost was 18%

The objectives of the energy efficiency audits were as follows

- to conduct informal training in the energy management practices
- to create an institutional awareness of energy management
- to recommend specific steps for improvement of energy efficiency, including management cost-free actions and equipment to be procured with USAID funds
- to recommend medium cost and capital investments actions, reflecting large energy conservation opportunities

A team of energy auditors consisting of three Ukrainian specialists performed an energy audit during March 23 - 29, 1998 Having fulfilled its objectives, the project team prepared the following draft report

1 2 Principal Findings

The Kharkiv fat processing complex is a fairly energy intensive enterprise The consumption of fuel and energy in 1997 was as follows

- electricity - 16,600 thousand kWh,
- thermal energy - 64,680 Gcal,
- natural gas - 10,800 thousand m^3,
- chemically treated water - 630 thousand m^3
-

The energy audit team has discovered many attractive opportunities of improving energy efficiency at the current energy and fuel prices Presently the energy efficiency improvement is cost effective though difficult to implement due to high interest rate of the bank credit and general economic difficulties

Closed-type JSC "Kharkiv fat production complex" is considered fairly successful by Ukrainian standards and is capable of energy conservation implementation

The plant staff approved procurement of portable combustion analyzers and other measuring instruments included in the audit team equipment

Energy consumption efficiency can be improved by proper arrangement of energy use in technological production processes

The proposal envisages further implementation of suggested long-term measures by the plant itself together with private Ukrainian energy servicing companies One of the objectives of ESCO is acquisition of long-term (2-3 years) financing to implement energy conservation projects

One of the team members - Mr M Tarnovsky can render substantial assistance in reduction of energy use by instituting energy management service at the enterprise outside the USAID project under an individual contract

Implementation of the ECOs will reduce energy consumption by 30% and, accordingly, its costs, will improve working conditions as the temperature in several rooms reaches 40°C

The time limits of the present Project do not permit to monitor the operation of the equipment intended for space heating season

1 3 Recommendations

Recommendations listed below will improve energy efficiency of the plant, reduce the costs and consolidate competitiveness of the enterprise

To encourage the facility to implement energy efficiency and energy conservation, USAID is contributing energy auditing equipment to the plant This equipment consists of standard energy auditing instrumentation and meters that will enable them to implement an energy saving activity
For example, ECO #1 "Energy management institution" will set up systematic energy conservation activities by establishment of an energy management section responsible for the control and analysis of the energy consumption at the plant and development of recommendations for renovation and improvement of any energy saving systems

Generally the energy management section should consist as a minimum of three persons technical supervisor, electrical and thermal engineers The supervisor should be a part of the plant management and report directly to the plant general manager It is essential as energy consumption and energy costs acquire a special importance and a plant manager should be aware of energy conservation potential

The major part of the proposed measures can be implemented with minor adjustments at other industrial plants i e to be the standard solution of a common problem

If implemented the measures proposed by the auditors will ensure an opportunity to reduce energy consumption annually

- electric power by - 10,370,000 kWh (64%)
- natural gas by - 2,694,000 m^3 (25%)
- chemically treated water - by 100,000 m^3 (16%)

and will result additionally in reduction of pollutant emissions

1 Solid particles - 45 6 tons/year
2 Sulfur dioxide - 102 7 tons/year
3 Carbon oxide - 28 2 tons/year
4 Nitrogen oxide - 30 8 tons/year

The recommendations listed in Table 1 will improve energy efficiency of the plant, cut down costs and consolidate the competitiveness of the plant The Table lists several energy conservation opportunities with short payback periods

Capital investments of $716,800 into the improvement of energy efficiency (ECO #1 through ECO #6) will result in annual savings of $737,300 later

List of Energy Conservation Opportunities (ECO)

ECO priority #	Description	Electricity, 1,000 kWh	Natural gas, 1,000 m^3	Chemically treated water, 1,000 m^3	Annual savings, US$	Project cost, US$	Payback, years
1	**Institution of energy management** This ECO will ensure energy use management and reduce energy costs by 10%	1600	1080		162'400	81'200	0 5
2	**Optimization of thermal and hydraulic parameters of thermal supply networks** This ECO will monitor on-line energy consumption, prevent excessive energy use and improve energy efficiency at the enterprise	10	150		14'500	10'000	0 7
3	**Thermal energy and electric power co-generation** This ECO will improve combustion efficiency	8760			333'000	500'000	1 5

4	**Recovery of condensate** This ECO will reduce thermal energy and chemically treated water losses		1300	100'000	212'000	115'000	0 6
5	**Thermal insulation of piping and equipment** This ECO will reduce heat losses		56		5'300	3'600	0 7
6	**Gas and air mixture saving opportunity in production process** This ECO will enable instantaneous control of combustion saving natural gas		108		10'100	7'000	0 7
	TOTAL	10'370	2'694	100'000	737'300	716'800	1

2 0 GENERAL BACKGROUND

Director Alexander N Vasilenko
Chief power manager Vladimir P Kalashnik
Phone (0572) 76-21-28
Fax (0572) 76-38-29
120 Ilyich pr Kharkiv 310019

2 1 Enterprise history

The Kharkiv fat processing complex was founded in 1932

Presently the enterprise has been converted into a closed-type joint-stock company (CJSC)

The complex comprises four primary production units
- margarine unit
- mayonnaise unit
- refining unit
- purification unit

The most energy intensive facility is the refining unit where vegetable oil is refined at the upgraded Alpha Laval separation line using additionally with the Westphalia equipment with overall capacity of 150-180 tons daily Alongside the vegetable oil the refining unit produces vegetable fat which is the basis of margarine The margarine unit is equipped with two Johnson lines - new and old, one Shroeder line and one Roberts line The complex extensively uses conveyor lines though unfortunately production capacities are used only by 35%

The CJSC "Kharkiv fat processing complex" is a specialized producer of margarine, mayonnaise and vegetable fat

The total workforce is 821

2 2 Number of similar enterprises in Ukraine

Currently there are six similar enterprises in Ukraine listed below

1 Donetsk Margarine Plant
2 Uzhgorod Margarine Plant
3 Lviv Fat Processing Combined Facility
4 Zaporizhzha Fat Processing Combined Facility
5 Odessa Fat Processing Combined Facility
6 Kyiv Margarine Plant

2 3 Significance of this sector for the national economy

The products of the Kharkiv fat processing complex are in demand at the domestic market and constitute 33 2% of the total output in Ukraine They meet the highest quality standards

3 0 CURRENT STATUS OF PRODUCTION

3 1 Production output in November 1997

#	Description	Unit of measure	Production output
1	Margarine products	tons	3 102
2	Vegetable fat	tons	2,350
3	Mayonnaise	tons	260
	TOTAL	tons	5,712

3 2 Productivity of labor in 1997 vs 1996

Productivity of labor in 1997 grew as compared to 1996 by 30%

3 3 Prospects of development

The present economic situation is characterized by the production slump It is connected with appearance at the market of foreign low-quality products The enterprise has developed a plan of technical renovation aimed at quality upgrading by additional refining of vegetable oil (winterizing, bleaching), expanding the range of products and growth of production output

The enterprise produces its own output and processes externally owned raw materials There are permanent suppliers and customers

3 4 Exports vs Domestic sales

In 1997 product exports amounted to 3% of the total production output After completion of renovation products meeting world standards will be produced

4 0 FINANCIAL STATUS OF THE ENTERPRISE

4 1 Currency vs Barter

Bartering made up 42% of total sales in 1997

4 2 Viability of enterprise

Production output of the fat processing complex in 1996-1997

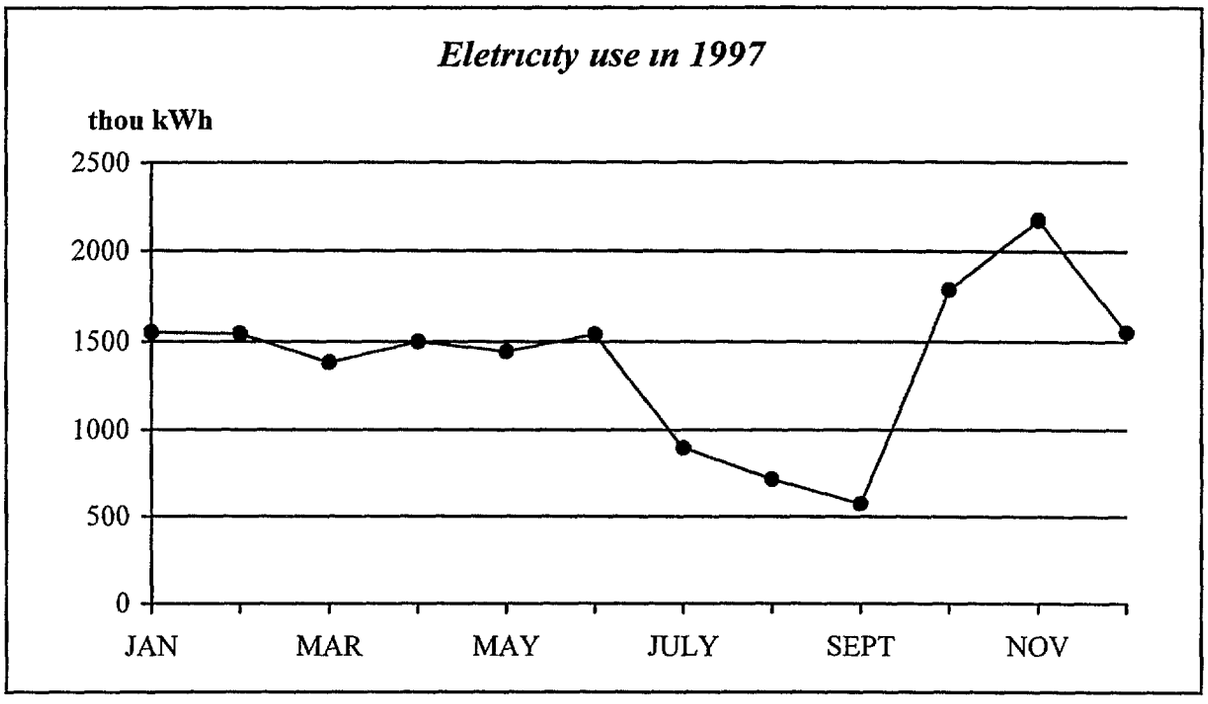
##	Name of product	Unit of measure	1996	1997
1	Margarine	ton	20,768	26,223
2	Mayonnaise	ton	8,212	3,156
3	Vegetable fat	ton	12,739	16,472
4	Refined and deodorized oil	ton	24,639	25,507
	TOTAL	ton	66,358	71,358

The analysis showed that in 1997 production output grew by 7% as compared to 1996

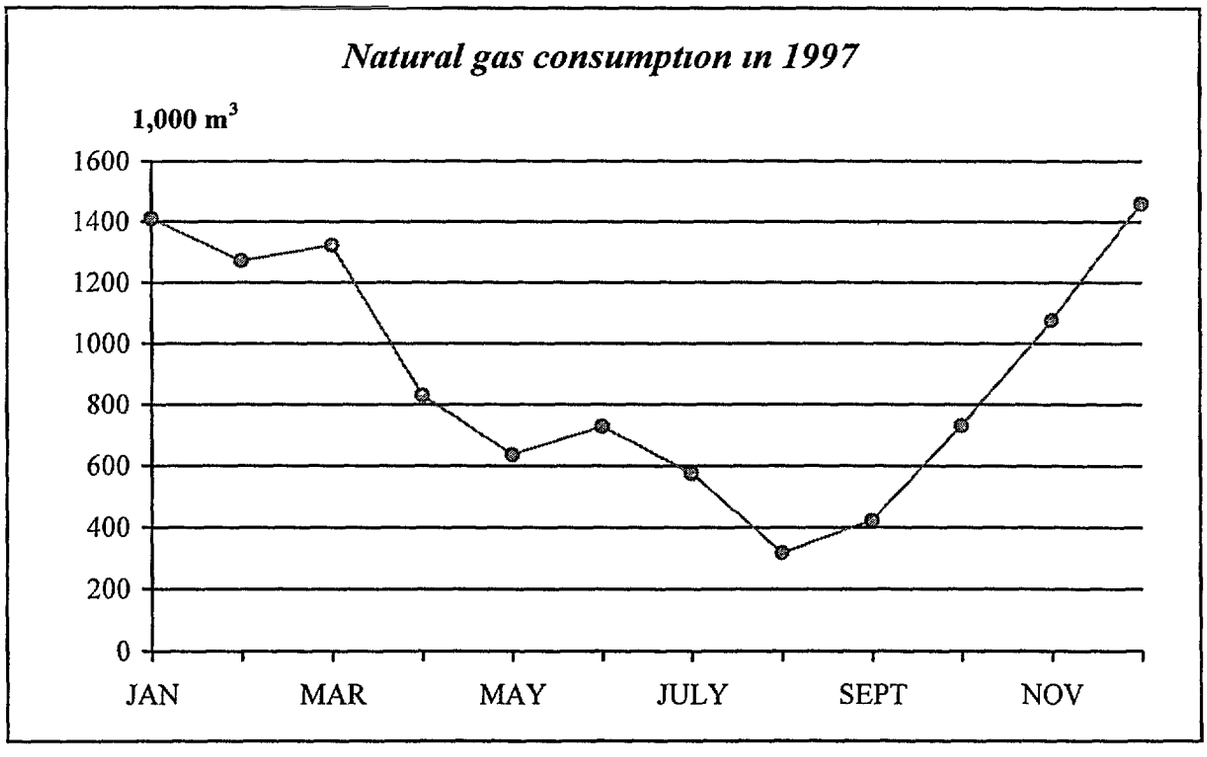
Profitability in 1997 was 22%
Total production output in 1995-1997 was 144 9 million hrivnas
The share of fuel and energy in the production cost is 18%

5 0 ANNUAL ENERGY CONSUMPTION AND ENERGY COSTS

5 1 Annual energy consumption in 1997



As seen from the charts the plant operation during the year was unstable The minimum electric power consumption in July, August and September was due to necessary overhaul during the summer season, maximum consumption in October and November was caused by the oversupply of raw materials (sunflower oil)



Natural gas consumption chart shows that thermal energy losses not directly connected with production and necessary use for the winter season space heating reach 30% indicating considerable gas saving potential

5 2 Current energy and fuel prices

Electricity

The works pay its electricity bills by two-part tariffs
1 Negotiated demand
2 Amount of consumed electricity by electric meter readings

Electric power bills are paid at the following rates

• 1 kW of negotiated demand	3 6$
• 1 kWh of consumed electricity	0 031$
Negotiated demand	3,000 kW
Payment for negotiated demand	3,000 × 3 6 = 10,800 ($)
Average monthly electricity consumption	1,390,000 kWh
Payment for actual electricity consumption	1,390,000 × 0 031 = 43,090 ($)
Total payments	10,800 + 43,090 = 53,890 ($)
Actual price for 1 kWh	53,890 / 1,390,000 = 0 038 ($)

Fuel

The sole type of fuel used by the enterprise is natural gas
The cost of 1000 m^3 is $94 06

Water

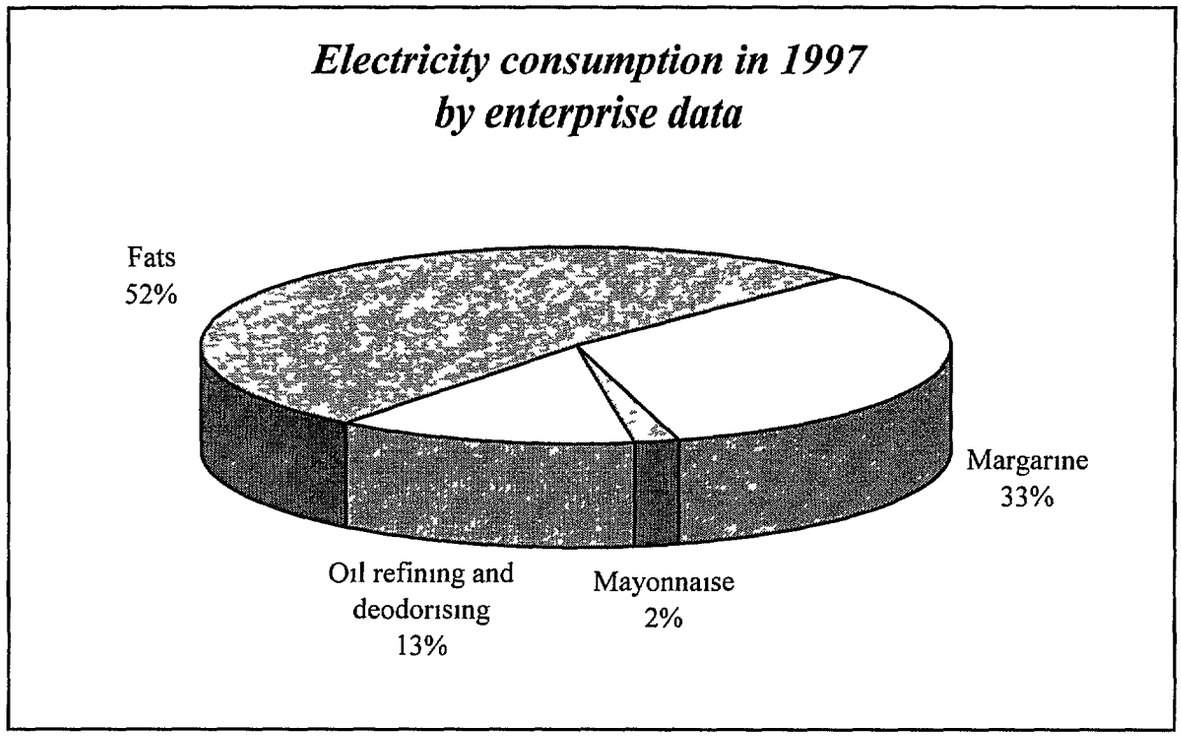
The complex purchases for production purposes 1,480 m^3 of water a day from the city utility network
The cost of 1 m^3 is $0 95

Average annual energy consumption and costs in 1995-1997

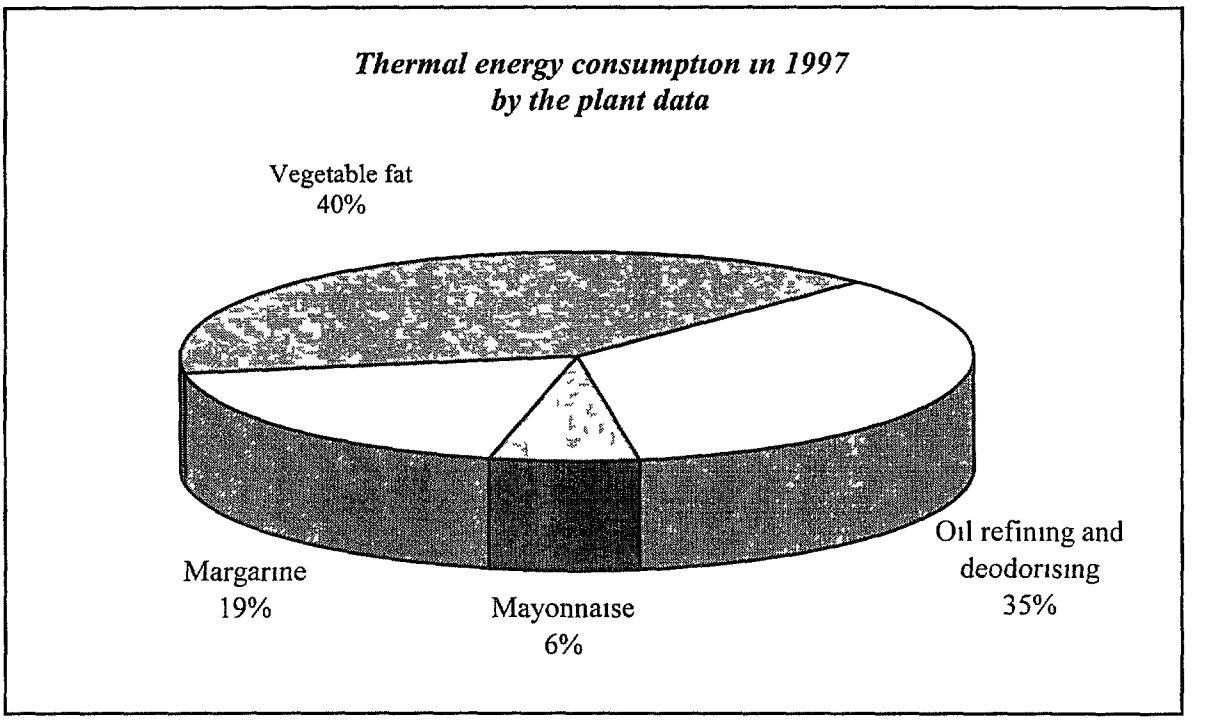
Energy consumption	Electricity, 1,000 kWh	Natural gas, 1000m^3	Chemically treated water, m^3	TOTAL
1995	13668	8850	615000	
1996	15469	10300	623400	
1997	16658	10775	630000	
Energy costs	$	$	$	$
1995	410040	708000	584000	1702040
1996	464070	844600	592200	1900870
1997	499740	883550	598500	1981790

5 3 Energy use profile

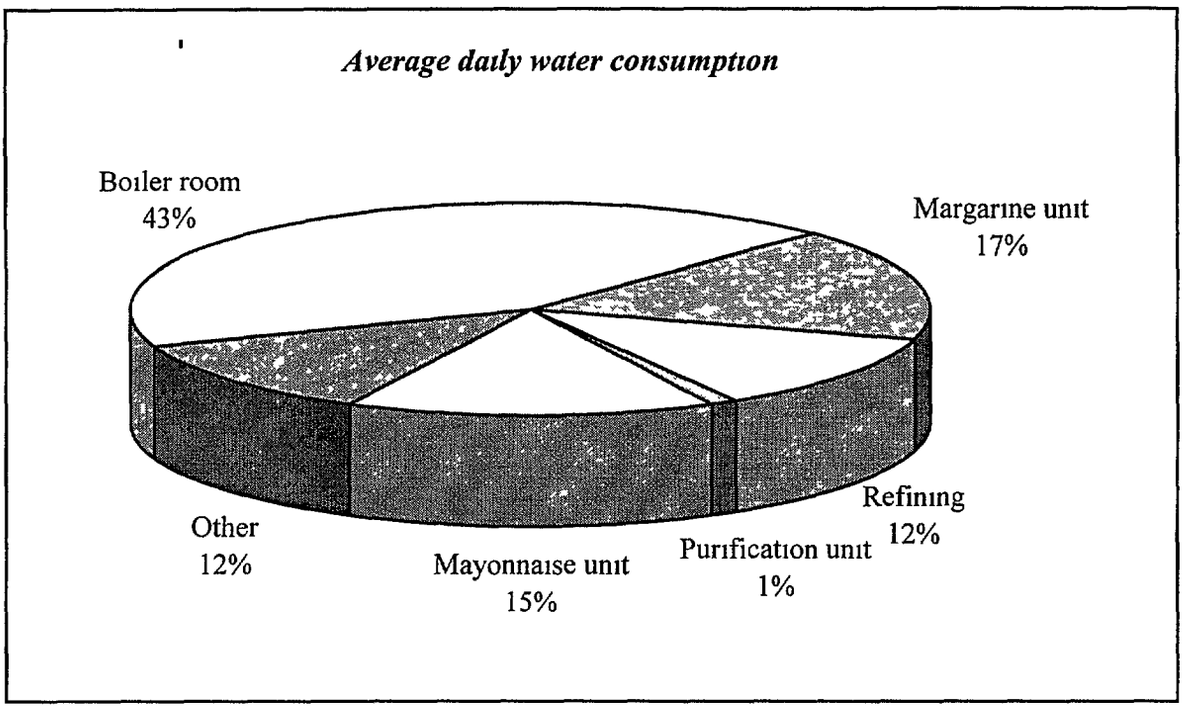
Average hour electricity consumption is 2,800 kWh



Product name	Electricity use, thousand kWh	%
Margarine	4,993	33
Mayonnaise	243	2
Vegetable fat	8,005	52
Oil refining and deodorizing	1,987	13
TOTAL	15,228	100

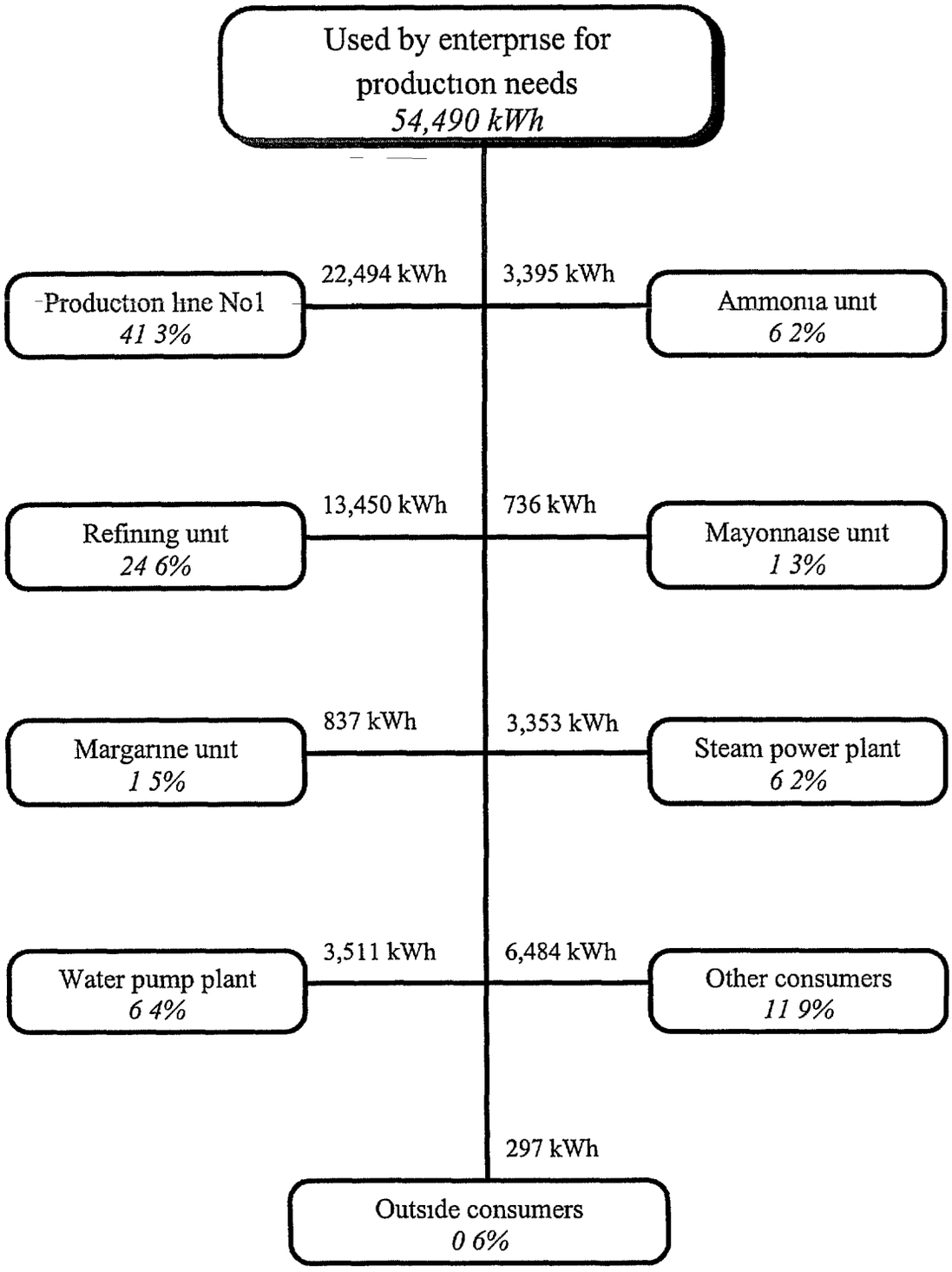


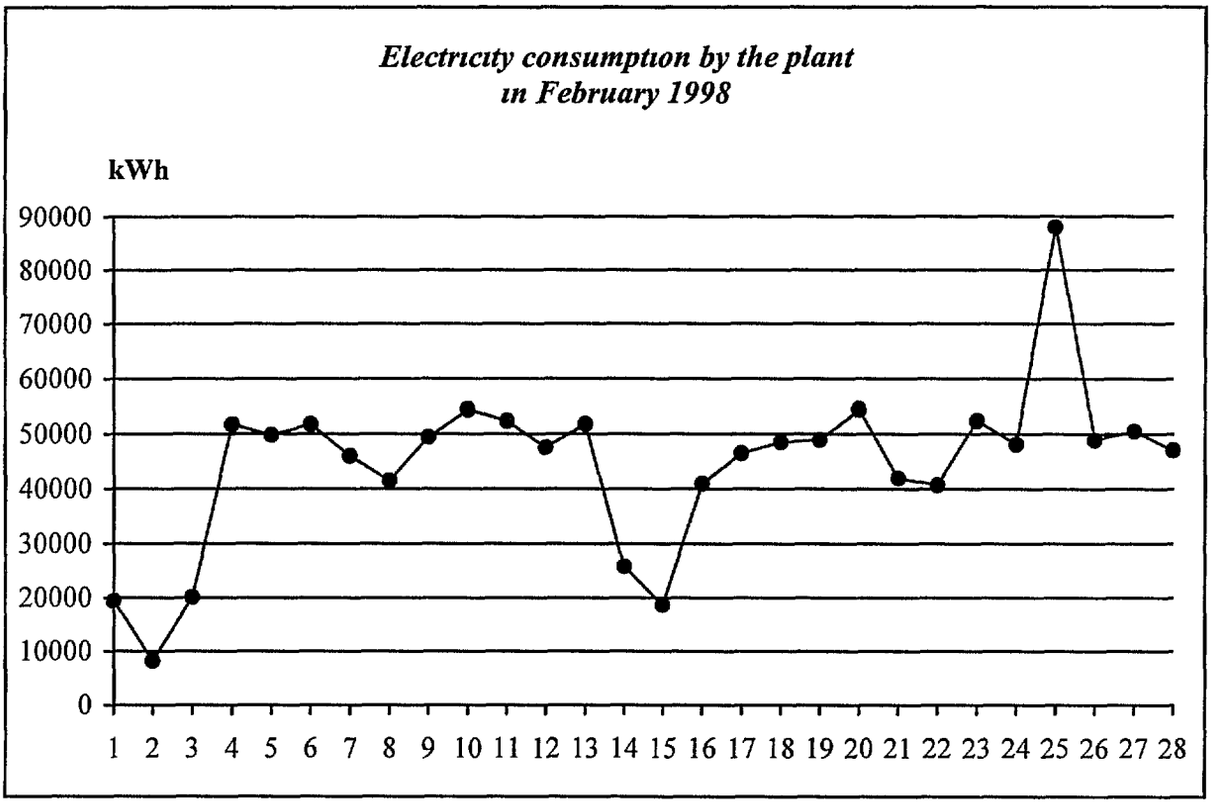
Product name	Thermal energy use, Gcal	%
Margarine	12,063	19
Mayonnaise	3,982	6
Vegetable fat	26,190	40
Oil refining and deodorizing	22,446	35
TOTAL	64,681	100

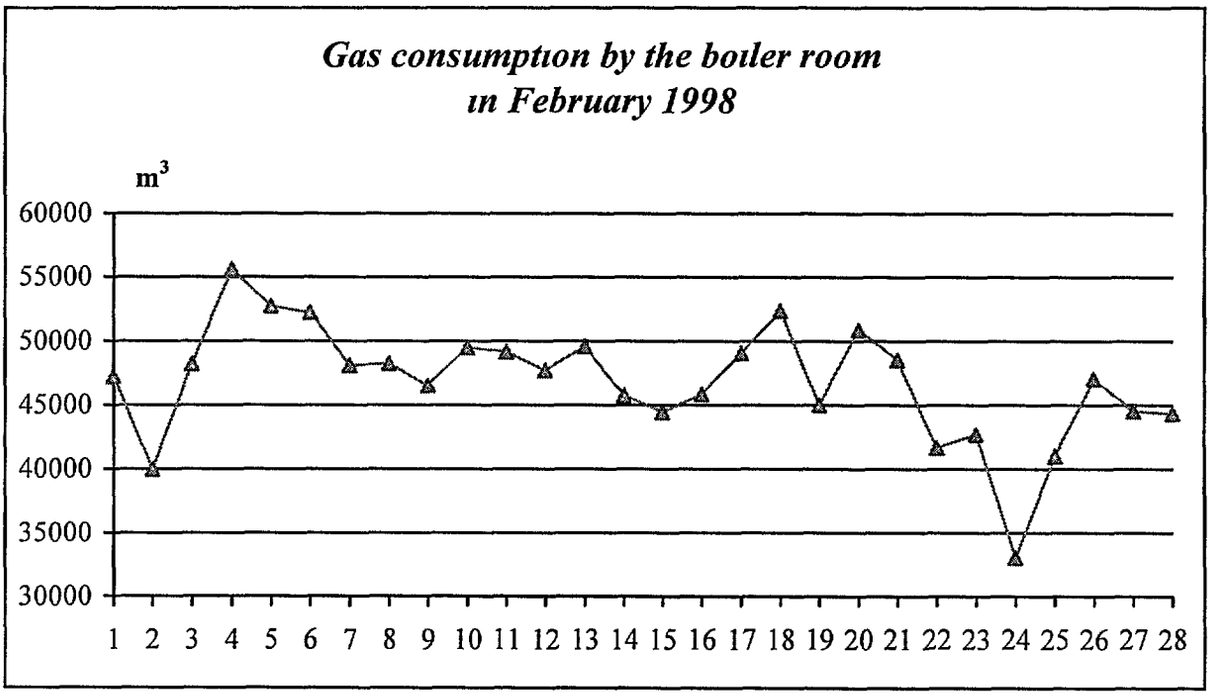


Consumer	Water use, m^3/day	%
Refining unit	245	12
Purification unit	21	1
Margarine unit	336	17
Mayonnaise unit	300	15
Boiler house	850	43
Other	348	12
TOTAL use	2,100	100
from city utilities	150	7
from deep wells	1,950	93

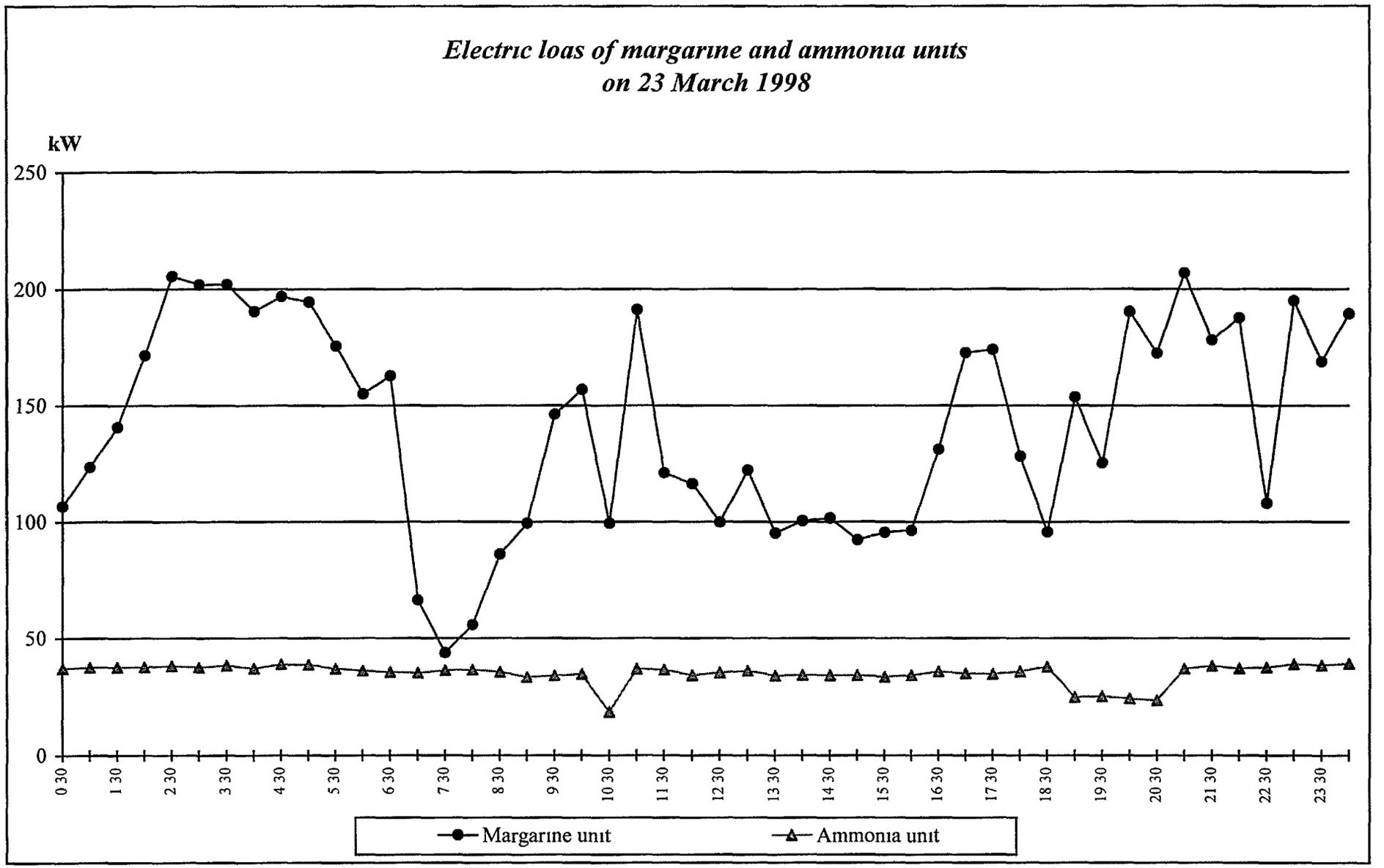
Electricity use balance on 24 March 1998







Electric power and natural gas consumption generally corresponds the degree of the production capacity use However on 24 and 25 February there is a discord between of electric and thermal loads This requires an accurate analysis and an answer to the question why the electric power use was higher by 30 MWh than usual? Which production line allowed excessive power costs of US$1,000 during the day? This confirms the necessity for institution of energy management described in Appendix A (ECO #1)


Electric loas of margarine and ammonia units
on 23 March 1998
kW
250
200
150
100
50
0
0 30
1 30
2 30
3 30
4 30
5 30
6 30
7 30
8 30
9 30
10 30
11 30
12 30
13 30
14 30
15 30
16 30
17 30
18 30
19 30
20 30
21 30
22 30
23 30
Margarine unit
Ammonia unit

The electric use charts of the margarine and ammonia production units show the relation of refrigeration machinery operation to the workload of the margarine production unit but it is characterized by time lag The ammonia unit does not have feedback from the margarine production unit It can be seen at the chart in the time intervals from 0^{30} am to 7^{30} am, from 1^{30} pm to 4^{00} pm, from 6^{30} pm to 11^{30} pm Average hourly consumption of electric power by the ammonia unit was approximately 150 kW Introduction of automatic close technological links between the margarine production unit and refrigeration plant will reduce average hourly consumption by up to 20% and electricity costs by US$5,000 annually

6 0 PREVIOUS ENERGY IMPROVEMENTS

Energy conservation measures implemented by the Kharkiv fat processing complex in 1997 are listed below

1 Installation of deep-well water reagent-free iron oxidizing and dissolved iron purification equipment
2 Operation of the DKVR-10/24-370 boiler with automatic burner control instead of the No3 Babcock Wilcox boiler
3 Operation of the magnetic water treatment plant to reduce carbonate sediment in heat exchangers
4 Installation in the boiler house of a Transonic heat exchanger of mixer type (HX) for space heating instead of steam-to-water heaters
5 Repairs of insulation of steam and hot-water piping and equipment
6 Sealing of leaks in the fixtures and flanges of pipelines
7 Removal of 15-kW pumps from the space heating system due to installation of the mixer-type HX
8 Replacement of 75-kW pump with 55-kW pump in the water pumping unit

Recommended measures reflect existing potential for energy conservation The complex carries out various organizational and technical measures in order to reduce energy use dictated by the desire to lower production costs The HX installation was completed but the unit turned to be unfit for operation in the space heating system Certain issues were no addressed due to the lack of acceptable technical solutions and funds

Unfortunately the energy conservation program lacks implementation data and economic results

7 0 ENERGY AUDIT

As the result of the energy audit at the OJSC Kharkiv fat processing complex the audit team recommended several proposals for improvement of energy efficiency at the plant The majority of the problems are typical for Ukrainian enterprises so the solutions of these problems can be replicated for enterprises with similar systems of energy use

Introduction of the recommended measures will reduce annual energy consumption

1	Electricity	by 10,370,000 kWh (64%)
2	Natural gas	by 2,694,000 m^3 (25%)
3	Chemically treated water	by 100,000m^3

The results of technical and economic calculations of energy conservation opportunities

ECO #1 - Institution of energy management

Energy management is the main avenue by which energy usage reduction and increase in consumption efficiency can be achieved Energy management is a management system based on standard measurements and checks providing for such operation of the plant that ensures only absolutely necessary consumption of energy for production purposes

In order to implement continuous supervision and analysis of energy use we recommend to institute energy management system and provide necessary measuring equipment

Implementation of this project will reduce fuel and energy costs by 162,400 $/year
Payback period will be 0 5 year
See details of this proposal in Appendix A, ECO #1

ECO #2 - Optimization of thermal and hydraulic parameters of thermal supply networks

Presently the space heating at the plant is furnished by the boiler house of the plant via thermal supply network from steam-to-water heaters and, partially, approximately 40%, steam space heating is used via steam piping from processing equipment in the main building Design thermal load for heating the entire complex Q = 1 6 Gcal/hour, connected heating capacity is 80% of the design capacity
The lack of hydraulic and thermal adjustment of thermal networks and space heating systems causes 20-30% waste of heat and 20-30% of electric power for heat medium pumping

In order to reduce heat consumption for space heating down to the standardized values and decrease of electric power consumption for network water pumping it is necessary to determine using the installed instruments the actually connected heat load, to

calculate hydraulic parameters of hot water networks, after the hydraulic calculations controlling draining diaphragms should be installed at each consumption site before each space heating system

Implementation of this project will reduce fuel and energy costs by 14,500 $/year
Payback period will be 0 7 year
See details of this proposal in Appendix A, ECO #2

ECO #3 - Thermal energy and electric power co-generation

The plant boiler house is equipped with two DKVR boilers The energy auditors recommend to install steam turbines in the plant boiler house It will result in an opportunity to optimize the DKVR boiler operation and generate additional electric power without damage to the production process This will reduce the volume of purchased power and lower energy costs

Implementation of this project will reduce fuel and energy costs by 333,000 $/year
Payback period will be 1 5 years
See details of this proposal in Appendix A, ECO #3

ECO #4 - Recovery of condensate

Currently the plant boiler house uses approximately 10,000 thousand cubic meters of natural gas for steam generation Steam generation meters are absent 100,000 tons of condensate a year are lost irretrievably This causes the loss of 10-15% of generated thermal energy and 95% of chemically purified boiler water

The energy auditors consider it necessary to study the system of steam consumption, develop and introduce a condensate recovery system

The condensate recovery system will arrange thermal flows within the production processes and permit their automation further on

Implementation of this project will reduce fuel and energy costs by 212,000 $/year
Payback period will be 0 6 years
See details of this proposal in Appendix A, ECO #4

ECO #5 - Thermal insulation of piping and equipment surfaces with temperatures of over 60^{0}C

The analysis of the steam distribution system resulted in the finding that some of the pipelines and equipment units are not thermally insulated The energy losses due to the lack of insulation at pipelines and at the surfaces of steam consuming equipment are formidable The temperature inside the equipment rooms reaches 40^{0}C with the ambient temperature of 2^{0}C This impairs the working conditions considerably

We recommend that the steam piping should be fully insulated The thickness of insulation should be selected dependent on the piping diameter and its purpose

Implementation of this project will reduce fuel and energy costs by 5,300 $/year
Payback period will be 0 7 year
See details of this proposal in Appendix A5, ECO #5

ECO #6 Gas and air mixture savings opportunity in the production process

For thermal energy supply two DE-10/14, two DKVR-10/39 and DKVR-10/23 boilers are used (one is standby) To run these boilers the operation charts have been worked out but automatic control of fuel-to-air ratio in conformity with the load is nonexistent The air consumption value is controlled periodically by the supply air pressure and gas consumption by the pressure before the burners which under the conditions of uncontrolled air infiltration does not allow one to substantiate the idea of optimal combustion processes

We recommend to equip the operation personnel of the boiler unit with the ENERAC-2000 combustion analyzer and to include in the operational responsibilities of the operator periodical check of combustion processes which would ensure savings in natural gas There is a realistic possibility to reduce gas consumption in case of implementation of this measure by 2-2 5%

Implementation of this project will reduce fuel and energy costs by 10,100 $/year
Payback period will be 0 7 year
See details of this proposal in Appendix A, ECO #6

8 0 ENVIRONMENTAL IMPACT OF RECOMMENDATIONS

The most efficient way of reduction of hazardous emissions into the atmosphere is decrease of fuel and electric power use Energy conservation and efficiency are extremely urgent from the ecological standpoint

The proposed project contains energy conservation measures aimed at saving fuel and electric power The main fuel used at the JSC Kharkiv fat processing complex is natural gas The harmful substance that forms in significant quantity during combustion of this fuel is nitrogen oxide (NO_X) The nitrogen oxides are harmful to the human health and can cause severe respiratory problems
Since combustion of natural gas results in the least emissions of the carbon dioxide CO_2 (that is the main gas responsible for setting "the green house effect"), saving natural gas will contribute to weakening of "the green house effect" Carbon monoxide (CO) is emitted after an incomplete combustion of fuel, it reacts with other substances and has various detrimental impacts Sulfur dioxide resulting from combustion destroys materials

Annual energy resource savings due to implementation of energy management will be as shown in the Table1

1 Electricity saving - 10,370,000 kWh
2 Natural gas saving - 2,694,000 m^3

According to the data from the Ministry of Energy, in 1996 1 kW h of the electric power meant emitting into the atmosphere of 17 g of contaminating substances, including the following

sulfur dioxide SO_2	9 9 g
carbon oxide CO	0 5 g
nitrogen oxides NO_x	2 2 g
solid particles	4 4 g

Reducing electric consumption results in decreasing the amount of the emitted harmful substances that can be determined by the formula

$$h = h_n \quad E_{ps},$$

where

h_n - the specific content of emissions, g/kW h
$E_{p.}$ - electric power saving, kW h

Amounts of pollutants formed during generation of 6,720,000 kWh

1) sulfur dioxide SO_2	h_1 = 9 9 x 10,370,000= 102,700,000 (g/year)
2) carbon oxide CO	h_2 = 0 5 x 10 370 000= 5,200,000 (g/year)
3) nitrogen oxides NO_x	h_3 = 2 2 x 10,370,000= 22,800,000 (g/year)
4) solid particles	h_4 = 4 4 x 10,370,000= 45,600,000 (g/year)

Calculation of the carbon oxide that forms after combustion of coke-oven gas is made by the formula

$$M_{CO} = 0\ 001 \quad B \quad K_{CO} \quad Q_r\ (1 - q/100),$$

where

B - consumption of oil-well gas, m^3/yr,

K_{CO} = 0 25 kg/GJ - the quantity of carbon oxide that is produced per heat unit released after combustion of oil-well gas,

Q_r = 35 MJ/m^3 - the lowest calorific value of natural fuel,

q = 0 5 % - heat losses resulting from an incomplete gas combustion,

M_{CO} = 0 001 2,694,000 0 25 35 (1 - 0 5/100) = 23,000 (kg/yr),

or

M_{CO} = 23 t/yr

Calculation of the nitrogen oxides per time unit (t/yr) shall be done by the formula

M_{NOx} = 0 001 B K_{NOx} Q_r (1 - b),

where

K_{NOx} = 0 1 kg/GJ - a parameter characterizing the amount of the nitrogen oxides forming per 1 GJ of heat, kg/GJ,

b = 0 15 - a coefficient for taking into account the degree of decreasing the level of emissions of nitrogen oxides resulting from implementation of technological measures

M_{NOx} = 0 001 2,694,000 0 1 35 (1 - 0 15) = 8,000 (kg/yr),

or

M_{NOx} = 8 t/yr

Implementation at the fat processing complex of energy conservation measures will decrease the energy resource consumption, and in its turn lower the quantity of harmful emissions into the atmosphere

TABLE OF POLLUTANT EMISSION REDUCTION

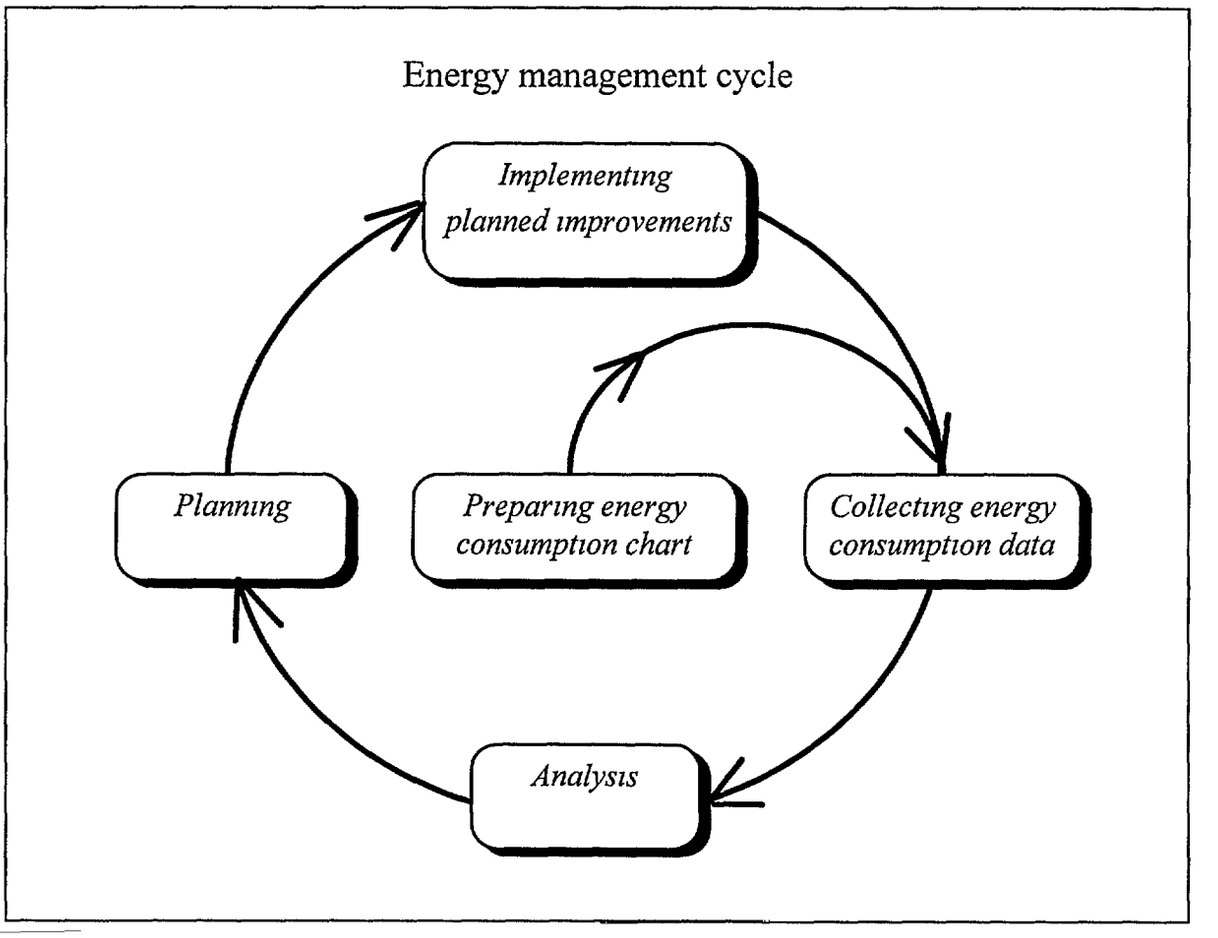
	Reduction in emissions as result of the energy savings, t/yr		
Emissions	**Electric power**	**Natural gas**	**TOTAL**
Hard particles	45 6	-	45 6
Sulfur dioxide	102 7	-	102 7
Carbon oxide	5 2	23	28 2
Nitrogen oxides	22 8	8	30,8
Total emission reduction			207,3

APPENDIX A ENERGY CONSERVATION OPPORTUNITIES (ECOs)

ECO # 1 Institution of energy management

ECO description

Energy management is the main avenue by which energy usage reduction and increase in consumption efficiency can be achieved This management strategy is based on conventional measurements and documentation and provides operating conditions that facilitate minimal energy consumption needed for the technology This is also a management tool which comprises a continuous research allowing precise knowledge on facility's energy distribution and consumption, as well as on best energy utilization for production, district heat and other non-productive purposes



Implementation of energy management program will result in having more detailed energy consumption records Such system will allow comparison of the energy usage to that of other enterprises for precise evaluation of energy saving projects that are considered by the facility

Implementing an energy management activity typically would involve establishing a separate section of employees to deal only with energy efficiency At a minimum an energy management section should consist of three people technical supervise, an electric engineer and a thermal engineer

The main duties of an energy management section include

- Preparing facility's energy consumption chart (probably in collaboration with an outside consultant, energy auditor),
- Collecting fuel and energy consumption data using measuring and testing equipment,
- Preparing a plan for implementing additional measuring and testing equipment,
- Collecting data on raw materials and energy consumption and on production output,
- Making key calculations on improving energy efficiency - for overall facility as well as specific production lines,
- Implementing new technologies on existing and new energy systems to improve energy efficiency of operation,
- Encouraging the personnel to indicate potential energy conservation opportunities
- Keeping informed on current energy policy trends and neighboring issues, (e g , such as new tax legislation, existing consumption restrictions, subsidies, environmental aspects etc)

In order to implement permanent energy consumption monitoring and analysis we recommend to institute energy management system at the plant and to provide required measuring equipment The set of equipment that will be useful for the plant should include

- three phase energy analyzer,
- tachometer,
- hot-wire anemometer,
- combustion analyzer,
- non-contact thermometer,
- ultrasonic leak detector,
- digital contact thermometer,
- light meter,
- power factor meter,
- portable temperature/humidity/ dew point meter,
- computer with printer

Annual energy savings

Currently the works use annually on average 16,600,000 kWh of electric power, 10,800,000 m^3 of natural gas

Typically, combustion efficiency improves by 2 5% from utilizing the combustion analyzer Electric power use efficiency can be linked to a wide range of factors 1 g power factor correction, improvement of equipment load control (shutting off idling equipment), optimization of motor loads, optimization of pump operation, improvement of compressor load control On average improvement of electric power use can ensure from 3 to 10% savings of total electric power consumption

The global experience and practice show that in case of institution of full-time energy management ensures 10% of fuel and energy consumption savings Energy savings will amount to

1) Electric power - 16,600,000 x 0 1 = 1,660,000 (kWh)
2) Natural gas - 10,800,000 x 0 1 = 1,080,000 (m^3)

Annual cost saving estimate

1 At the price of $0 038 per 1 kWh of electric power the cost savings will be 1,660,000 x 0 038 ~ $60,800
2 At the price of $94 06 per 1,000 m^3 of natural gas the cost savings will be 1,080,100 x 94 06 ~ $101,600

Total energy cost savings will be
60,800 + 101,600 ~ $162,400

Implementation Costs

According to the world practice, expenses on implementing energy management constitute 50% of estimated energy savings, i e

162,400 x 0 05 ~ $81,200

Simple payback

Implementation costs - $81,200
Annual cost savings - $162,400
Simple payback period will be
81,200/162,400 ~ 0 5 (year)

ECO # 2 Optimization of thermal and hydraulic parameters of thermal supply networks

ECO description

Presently the space heating at the plant is furnished by the boiler house of the plant via thermal supply network from steam-to-water heaters and, partially, approximately 40%, steam space heating is used via steam piping from processing equipment in the main building Design thermal load for heating the entire complex Q = 1 6 Gcal/hour, connected heating capacity is 80% of the design capacity

$$Q_u = 1\ 6 \times 0\ 8 \sim 1\ 28 \text{ (Gcal/hour)}$$

At the ambient temperature $t_a = +3^0C$ thermal energy use for space heating should be

$$Q = Q_u \times (t_{in} - t_a)/(t_{in} - t_a^c) = 1\ 28\ (18\text{-}3)/(18\text{-}[\text{-}23]) = 0\ 47 \text{ Gcal},$$

where t_{in} - temperature inside heated room,
t_a^c - calculated minimum temperature of ambient air

The actual registered thermal energy use is as follows

$$Q = 45 \times (74\text{-}55) = 0\ 86 \text{ (Gcal)},$$

where 45 is water supply to the thermal network,
74-55 is the temperature difference in the input and output piping

Overheating of buildings is as follows

$$0\ 84 - 0\ 47 = 0\ 39 \text{ (Gcal) or}$$
$$0\ 39/0\ 86 = 0\ 45, \text{ i e } 45\%$$

In order to reduce heat consumption for space heating down to the standardized values and decrease of electric power consumption for network water pumping it is necessary to implement the following measures

- to determine using the installed instruments the actually connected heat load,
- to calculate hydraulic parameters of hot water networks,
- after the hydraulic calculations controlling draining diaphragms should be installed at each consumption site before each space heating system In this case the entire space heating system will be hydraulically stable,
  it is required that the resistance of the internal systems before which the controlling diaphragms must be placed should be not higher than h ≤ 1 mm water column Otherwise, the internal systems will have the coolant flow rate 1 5 to 2 times higher than the designed one,
- after installation of the controlling draining diaphragms a thermal testing of the system and checking of correspondence of the actual flow rates to the designed ones are required In case of any variations in any direction, one shall correct the diameters of the controlling draining diaphragms

The above mentioned measures after their implementation shall give the following results

- decrease of the electric power consumption for the heat medium transportation,
- decreased heat losses due to overheating of buildings

Annual energy savings estimate

The lack of hydraulic and thermal adjustment of Thelma networks and space heating systems causes 20-30% waste of heat and 20-30% of electric power for heating medium pumping

If we assume that the heat load in the heating season of 1998 will be
Q = 1 6 Gcal = 1 6 Gcal then the heat use per 1 degree-day will equal

$$1\ 6 \times 24/41 = 0\ 94\ \text{(Gcal)},$$

1 7

where 41 is the number of degree-days per year in the city of Kharkiv during the coldest days

Given that the number of degree-days for Kharkiv is equal to ~ 3,500 the use of heat for space heating will be

$$Q = 0\ 94 \times 3{,}500 = 3{,}290\ \text{(Gcal)}$$

Overheating will be additional 30%

$$3{,}290 \times 0\ 3 \sim 1{,}000\ \text{(Gcal)}$$

With the specific use of natural gas of 150 m^3/Gcal the natural gas savings will be

$$1{,}000 \times 150 \sim 150{,}000\ (m^3)$$

Electric power consumption by the network pump for the heat medium circulation is

$$7\ 5 \times 24 \times 189 = 34{,}020\ \text{(kWh)},$$

where 7 5 - motor capacity (kW),

24 x 89 - motor operation hours during heating season

Electric power savings will be

$$34{,}020 \times 0\ 3 = 10{,}000\ \text{(kWh)}$$

Annual energy cost savings estimate

1 At the price of $0 038 per 1 kWh of electric power the cost savings will be
10,000 x 0 038 ~ $380
2 At the price of $94 06 per 1,000 m^3 of natural gas the cost savings will be
150 x 94 06 ~ $14,110

Total energy cost savings will be

$$380 + 14{,}110 \sim \$14{,}500$$

Implementation Costs

1 The design costs

- determination of actual heat loads,
- development of a new thermal lines system,
- hydraulic calculation of the thermal lines

The approximate cost is $5,000

2 Fulfillment of measures resulting from the study and calculations - $1,000

3 Thermal and hydraulic tests of thermal networks, adjustment of controlling draining diaphragms - $2,000

4 Overhead costs at 30% will be $2,000

Total costs will be 10,000 ($)

Simple Payback

Commissioning costs - $10,000
Annual cost saving - $14,500
Simple payback period

$$10{,}000/14{,}500 = 0\ 7\ (yr)$$

As the duration of the heating season is 6 months per year, the actual payback since commissioning will be

$$6 \times 0\ 7 \sim 4\ 0\ (months)$$

ECO # 3 Thermal energy and electric power co-generation

ECO description

The plant boiler house is equipped with two DKVR boilers generating steam with the following parameters

- DKVR 10/24 pressure - 24 kg/cm^2, temperature - 350^{0}C,
- DKVR 10/39 pressure - 39 kg/cm^2, temperature - 440^{0}C

The energy auditors recommend to install steam turbines in the plant boiler house It will result in an opportunity to optimize the DKVR boiler operation and generate additional electric power without damage to the production process This may result in utilization of potential energy of superheated steam that can generate up to 1 5 MW of electric power in wintertime and up to 0 75 MW in summertime using steam turbines The energy auditors see it expedient to use steam turbines in the works boiler house of 1 5 MW total capacity This will reduce the volume of purchased power and lower energy costs Average annual capacity of the steam turbine will be 1 MW

Annual energy savings estimate

Electric power generated by in-plant facilities will amount to

1,000 x 24 x 365 = 8,760,000 (kWh)

Annual cost savings estimate

Cost savings by reduction of externally purchased power at the price of $0 038 per 1 kWh will be

8,760,000 x 0 038 = $333,000

Implementation costs

Design - $50,000

Equipment - $250,000

Turnkey installation - $100,000

Overheads and contingencies at 25% - $100,000

Total costs - $500,000

Simple payback

Commissioning costs - $500,000
Annual cost savings - $333,000
Simple payback period will be

500,000/333,000 ~ 1 5 years

ECO # 4 Recovery of condensate

ECO description

Currently the plant boiler house uses approximately 10,000 thousand cubic meters of natural gas for steam generation

Since steam generation meters in the boiler house are lacking we may assume that the amount of natural gas corresponds to thermal energy generation (at the standard of 130 m^3/Gcal) of the following quantity

10,000,000/130 ~ 76,900 (Gcal),

that is equal to the steam (with heat content of o 73 Gcal/ton) of the following quantity

76,900/0 73 ~ 105,000 (tons/year)

The condensate is not returned to the boiler house except the condensate from space heating heat exchangers to the amount of 1 ton/hour or 5,000 tons/year 100,000 tons of condensate a year are lost irretrievably This causes the loss of 10-15% of generated thermal energy and 95% of chemically purified boiler water

The energy auditors consider it necessary to study the system of steam consumption, develop and introduce a condensate recovery system

The condensate recovery system will arrange thermal flows within the production processes and permit their automation further on

Annual energy saving estimate

Thermal energy savings will be

100,000 x (0 1 - 0 02) ~ 9,800 (Gcal),

where 0 1 - heat content of condensate,
0 02 - average annual heat content of input water

This corresponds to natural gas savings

9,800 x 130 ~ 130,000 (m^3/year)

and savings of chemically purified water - 100,000 tons/year

Annual cost savings estimate

1 At the price of $94 06 per 1,000 m^3 of natural gas the cost savings will be 1,300 x 94 06 ~ $122,000
2 At cautious expert estimate we may assume that the price of chemically purified water is $0 95 per 1 m^3, then the cost savings will be
100,000 x 0 95 ~ $90,000

Total fuel cost savings will be

122,000 + 90,000 ~ $212,000

Implementation cost

At cautious expert estimate the costs will be

• inspection of steam supply system and condensate turnkey recovery system development on	$5,000
• equipment price	$70,000
• additional fixtures (15%)	$10,000
• installation cost (30%)	$20,000
• correction of design drawings, contract supervision, adjustment (10%)	$10,000
TOTAL costs	$115,000

Simple payback

Implementation costs - $115,000
Annual cost savings - $212,000
Simple payback period will be

115,000/212,000 ~ 0 6 (year)

ECO # 5 Thermal insulation of piping and equipment surfaces with temperatures of over 60°C

ECO description

The steam generated at the boiler house is used extensively for production needs of the complex , laundry, motor transport unit and for space heating There are branchlines to various production buildings from the trunk steam pipelines The refining unit is one of the principal consumers of steam Equipment installed here uses from 3 to 5 tons of steam per hour at 6-10 kg/cm^2 pressure

The analysis of the steam distribution system resulted in the finding that some of the pipelines and equipment units are not thermally insulated The energy losses due to the lack of insulation at pipelines and at the surfaces of steam consuming equipment are formidable The temperature inside the equipment rooms reaches 40°C with the ambient temperature of 2°C This impairs the working conditions considerably

Particulars of non-insulated piping are given in the table below

#	Purpose of piping	Location	Length, L m	Diameter, D mm	Number of valves	t, °C
1	Steam	Main production unit	10	219	3	110
2	Steam	Refining unit	8	102	2	105
3	Steam	Refining unit	5	102	3	153
4	Steam	Refining unit	9	76	1	140
5	Steam	Refining unit	7	50	1	110
6	Steam	Water purification unit	5	89	1	160
7	Steam	Pipeline section	5	40	-	170
8	Steam	Pipeline section	10	30	-	108

The gives the results of measurement of external surface temperatures

Annually the steam is consumed 300 days on average

We recommend that the steam piping should be fully insulated The thickness of insulation should be selected dependent on the piping diameter and its purpose

	Purpose	Diameter, mm	Insulation thickness, mm
1	Steam	102 - 219	100
2	Steam	50 - 89	80
3	Steam	30 - 50	40

Annual energy savings estimate

We should determine thermal energy waste for insulated and non-insulated pipes according to the methodology below [Methodological instructions for determination of losses of fuel and energy resources RD5 EDIV 015-008094 Minmashprom, Kiev, 1994]

Thermal energy waste in non-insulated pipelines (kcal/hour) is determined by the following formula

$$Q_{nin} = g_{nin} \times L_0 \times k,$$

where g_{nin} - specific losses of non-insulated piping (kcal/meter x hour),

k - correction factor depending on the outside temperature and difference between pipe outer wall and outside temperatures,

L_0 - given length of piping, m

$L_0 = L + (1m \times n) = 10 + (1m \times 3) = 13$ (m)

n - number of valves within the section

For the pipeline #1 from the Table we have

$$Q_{nin1} = 560 \times 13 \times 0\ 91 = 6{,}620 \text{ (kcal/hour)}$$

Further calculations were carried out similarly and are summarized in the Table below

Thermal energy waste of insulated (Kcal/hour) pipelines is calculated by the formula

$$Q_{in} = g_{in} \times (t_1 - t_2) \times a \times b \times L_0$$

where g_{in} - specific loss over 1 meter of piping with the difference $(t_1 - t_2) = 1^0C$ depending on the thickness of insulation, kcal/m x hour ,

t_1 - temperature of pipe walls assumed as equal to temperature of heat carrier, °C,

t_2 - temperature of air, °C,

a - correction factor depending on the thickness of insulation, thermal conductivity if insulation material and temperature difference between heat carrier and air With insulation thickness up to 100 mm and temperature difference up to 200 °C $a = 1$,

b - wind correction factor (with wind velocity of 5 m/sec)

Presently it is realistic to cut down waste in the thermal networks by using modern efficient types of thermal insulation materials with thermal conductivity of 0 03 - 0 05 kcal/ (m x hr x °C) We assume the use of these piping insulation materials

For pipeline #1 from the Table

$$Q_{in1} = 0\ 364 \times (110 - 2) \times 1 \times 1\ 04 \times 13 = 530 \text{ kcal/hr}$$

Similar calculations were carried out for all pipelines and are shown in the Table below The savings are received taking into account the length of a pipeline

Pipeline No	Given length L_o, m	Thermal waste without insulation Q_{nin}, kcal/hr	Thermal waste with insulation Q_{in}, kcal/hr	Savings S_N, kcal/hr
1	13	6,620	530	6,090
2	10	2,730	250	2,480
3	8	4,370	290	4,080
4	10	3,730	280	3,450
5	8	1,470	140	1,330
6	6	3,280	230	3,050
7	5	1,700	210	1,490
8	10	1,370	230	1,140
TOTAL				23,1103

Thus annual loss of heat
$Q_{tr} = Q_{tr\ n} \times 300 \times 24 \times 10^6 = 23{,}000 \times 300 \times 24 \times 10^6 = 166$ Gcal,

220°C steam is supplied to three oil heaters in the refining unit via the pipeline at 25 kg/cm^2 pressure Large heat waste is determined by non-insulated surfaces and measurements taken with the help of infra-red remote thermometer ($T_1 = 122°C$, $T_2 = 123°C$, $T_3 = 120°C$)

Total external surface area is $F = 80$ m^2

Total area of non-insulated surfaces is $F = 80$ m^2 The loss of heat into the environment is calculated by the formula

$$Q_{loss} = K \times F \times \Delta t \times 10^6 \text{ (Gcal/hour)},$$

where

$K = 4\ 5$ kcal/m^2 x hour x °C - thermal conductivity coefficient of structures
$F = 80$ m^2 - area of heat exchange
$\Delta t = (t_{sur} - t_{amb})$ - temperature difference
t_{sur} = surface temperature
t_{amb} = ambient temperature
$n = 300$ - number of days

Heat losses at $t_{sur} = 120°C$, $t_{amb} = 40°C$ are calculated independently

$$Q_{loss} = K \times F \times ((t_{sur} - t_{amb}) \times 24 \times n \times 10^6 =$$

$$= 4\ 5 \times 80 \times (120-40) \times 24 \times 300 \times 10^{6} = 210\ (\text{Gcal})$$

Specific consumption of gas is b = 150m^3/Gcal

Thus annual gas savings will amount to

$$Q = (Q_{tr} + Q_{loss}) \times b = (166 + 100) \times 150 = 56{,}400\ (\text{m}^3/\text{year})$$

Annual cost savings estimate

Cost savings at the natural gas price of US$94 06 per 1,000 m^3 will be

$$56\ 4 \times 94\ 06 = 5{,}300\ (\$/\text{year})$$

Implementation cost

Total cost of necessary insulation for 80 m^2 at the price of US$20 per 1 m^2 will be

$$C_1 = 80 \times 20 = \text{US\$}1{,}600$$

Insulation costs for steam piping is calculated by the formula

$$C_2 = L \times C,$$

where

L is total given length of steam piping, m,

C equals US $20/m - the cost of 1 m of piping insulation,

$$C_2 = 59 \times 20 = 1{,}180\ (\text{US\$/year})$$

Total estimated costs of insulation to be installed at the enterprise will be US$2,780,

Overheads 30% - US$820

TOTAL - US$3,600

Simple payback estimate

Annual savings US$5,300

Implementation costs US$3,600

Simple payback

$$3{,}600/5{,}300 = 0\ 7\ (\text{year})$$

ECO #6 GAS AND AIR MIXTURE SAVINGS OPPORTUNITY IN PRODUCTION PROCESS

ECO description

For thermal energy supply two DE-10/14, two DKVR-10/39 and DKVR-10/23 boilers are used (one is standby) To run these boilers the operation charts have been worked out but automatic control of fuel-to-air ratio in conformity with the load is nonexistent The air consumption value is controlled periodically by the supply air pressure and gas consumption by the pressure before the burners which under the conditions of uncontrolled air infiltration does not allow one to substantiate the idea of optimal combustion processes

We recommend to equip the operation personnel of the boiler unit with the ENERAC-2000 combustion analyzer and to include in the operational responsibilities of the operator periodical check of combustion processes which would ensure savings in natural gas There is a realistic possibility to reduce gas consumption in case of implementation of this measure by 2-2 5%

Annual energy savings estimate

According to the plant data on the use of fuel in 1997 total consumption of natural gas was 10,775 thousand m^3
At a cautious estimate of gas use reduction by 1% the annual savings will be

10,775 x 0 01 ~ 108 (thousand m^3/year)

Annual cost savings estimate

At the price of fuel of $94 06 per 1,000 m^3 the fuel cost is
94 06 x 108 ~ US$10,100

Implementation cost

Equipment cost

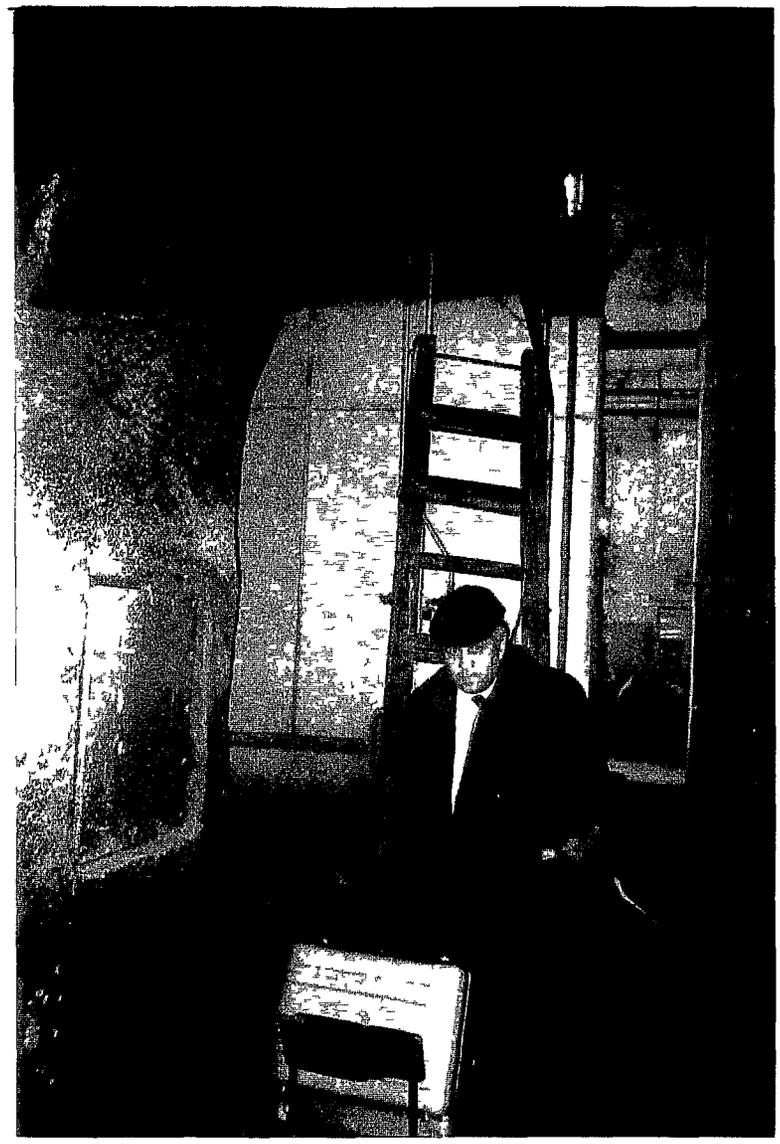
Combustion analyzer	US$5,000
Computer	US$1,000
Calibration gas set	US$500
Shipment	US$500
TOTAL equipment cost	US$7,000

Simple payback

Implementation cost	US$7,000
Annual cost savings	US$10,140

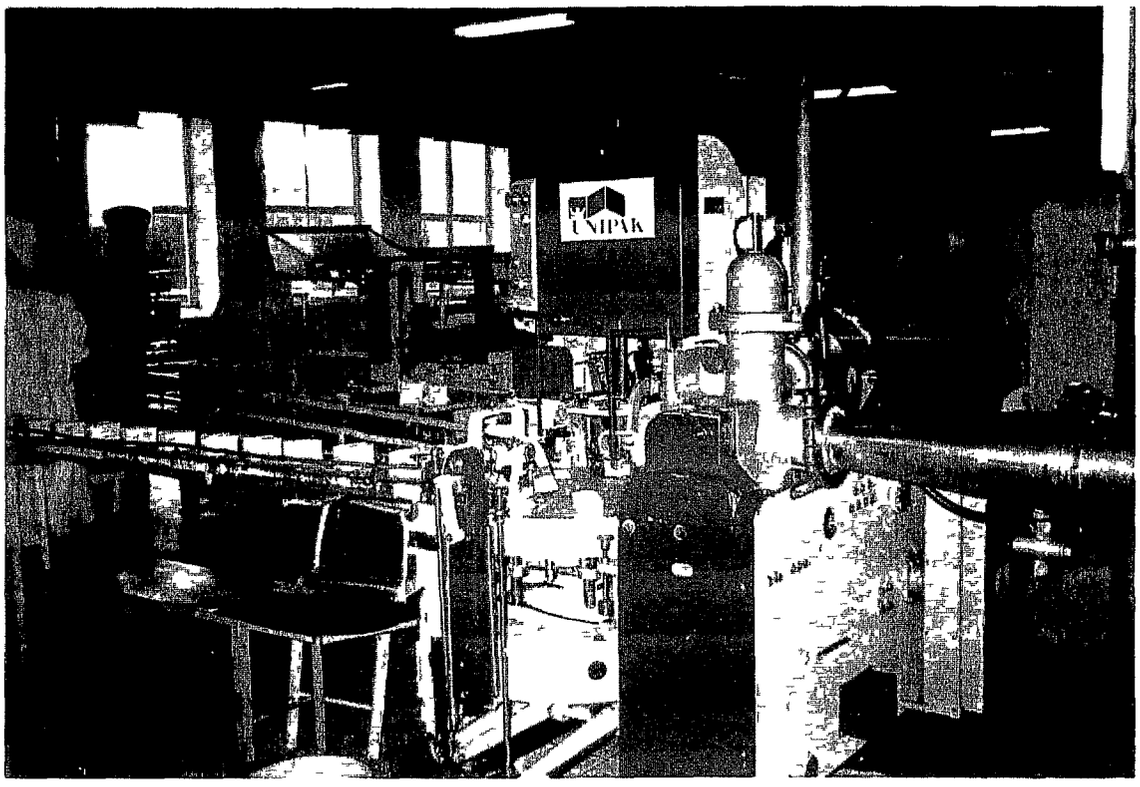
Simple payback will be
7,000/10,140 = 0 7 year or 8 4 months,

APPENDIX B PHOTOGRAPHS OF THE PLANT

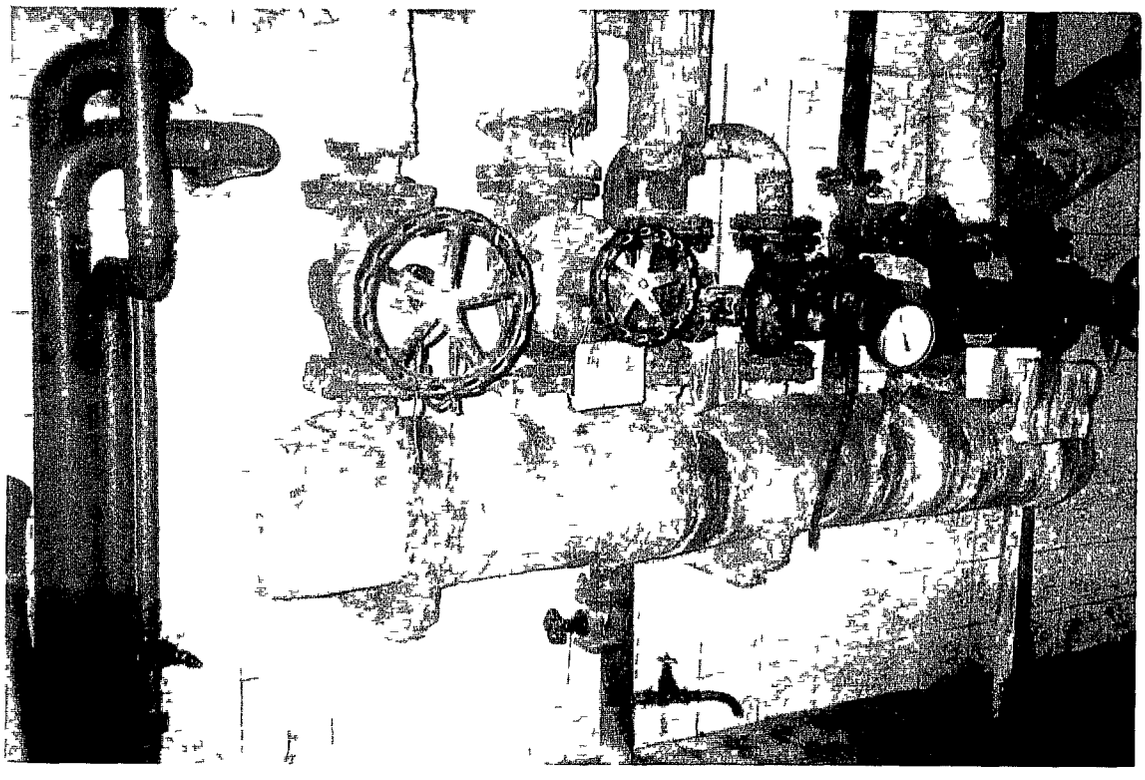


Производство измерений газоанализатором “ENERAC-2000”
состава уходящих газов за котлом ДЕ-16-14

Measurements of the exaust gases content after DE-16-14 Boiler
with ENERAC-2000 combustion analyzer



Цех производства маргарина
Workshop for Margarine Production



Паровой коллектор Главного корпуса
Steam manifold in the Main Building

Неизолированные паропроводы Главного корпуса

Non-insulated steam lines in the Main Building

APPENDIX C CONVERSION FACTORS

Currency rates of exchange

1 hrivnia - local currency unit
1hrivnia = US$0 54 as of December 1997

Conversion factors

Heat

1 cal = 4 187 J
1 kcal = 4 187 kJ = 3 968 BTU
1 Gcal = 4 187 x 10^3 = 4 187 GJ
1 BTU = 1055 J = 1 055 kJ = 1 055 x 10^3 MJ
1 tce (tonne of coal equivalent) = 7,000 kcal x 3 968 BTU = 27,78 x 10^6 BTU = 27,78 MBTU

Power

1 W = 3 6 x 10^3 J = 3 6 kJ
1 kW = 3 6 x 10^3 kJ = 3 6 MJ = 860 Kcal
1 MW = 3 6 x 10^3 MJ = 860 Kcal
1 kcal = 1 163 x 10^3
1 Gcal = 1163 kW = 1 163 MW
1 kW = 1 36 HP
1 kW = 1 34 hp

Pressure

1 kg/cm^2 = 1 atm
1 atm = 101 325 kPa = 0 1 MPa
1 bar = 10^5 Pa = 100kPa = 0 1 MPa

Length

1 mm =0 03937 in = 0 00328 ft
1 cm = 0 3937 in = 0 0328 ft
1 m = 3 937 in = 3 281 ft

Weight

1 gram = 2 2046 x 10^3 lb
1 kg = 2,2046 lb
1 t = 1000kg = 2 2046 x 10^3 ft

Area

1 cm^2 = 0 155 square in = 1 076 x 10^3 square ft
1 m^2 = 1 55 x 10^3 square in = 10 76 square ft

Volume

1 m^3 = 35 31 cu ft = 1000 l
1l = 35 31 x 10^3 cu ft
1l = 0 264 US gal

Heat content

1 kJ/kg = 0 43 BTU/lb
1 kJ/m^3 = 26 84 x 10^3 BTU/cu ft
1 MJ/m^3 = 26 84 BTU/cu ft
1 kcal/m^3 = 4,187 kJ/m^3 = 0 112 BTU/cu ft

Temperature

^{0}C = 0 56 (^{0}F-32)

APPENDIX D ABBREVIATIONS

ABBREVIATIONS

CIS - Commonwealth of Independent States
ECO - energy conservation opportunity
ESCO - energy service company
etc - et cetera
Hr - hrivnia
i d - id est
JSC - joint-stock company
mln - million
TACIS - Technical Assistance to CIS countries
tel - telephone
thou - thousand
US - United States
USAID - United States Agency of International Development

BTU - British thermal unit
^{0}C - degrees Celsius
cm^2 - centimeter squared
^{0}F - degrees Fahrenheit
g - gram
Gcal - gigacalory
GJ - gigajoule
h - hour
kcal - kilocalory
kg - kilogram
kgf - kilogram-force
kV - kilovolt
kV-A - kilovolt-ampere
kW - kilowatt
kW h - kilowatt hour
Lm - lumen
m - meter
m^2 - meter squared
m^3 - meter cubed
min - minute
MJ - megajoule
mm H_2O - millimeters of the water column
MW - megawatt
t - tonne
tce - tonne of coal equivalent
t/h - tonnes per hour
W - watt