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ENERGY EFFICIENCY AUDIT REPORT
SERDIKA MILK PLANT

Sofia, Bulgaria

PREPARED BY:

INTERNATIONAL RESOURCES GROUP, LTD.
Washington, DC

and

ECOTECHPRODUCT, LTD.
Sofia, Bulgaria

U.S. EMERGENCY ENERGY PROGRAM FOR EASTERN & CENTRAL EUROPE

U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT
BUREAU FOR EUROPE
WASHINGTON, DC 20523

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List of Acronyms/Abbreviations (in alpha order)

A.I.D.	U.S. Agency for International Development
bbl	barrel
BTU	British thermal unit
°C	degrees Celsius (or Centigrade)
HHV	high heating value
IRG	International Resources Group, Ltd.
kCal	kilocalories
kg	kilogram
kVa	kilovar
kWh	kilowatt hours
LHV	low heating value
lv	leva; Bulgarian unit of currency which, at the time of audit, 15 lv = U.S. $1.
PPM	parts per million
ROI	return on investment
t	metric tons
T.O.D.	time of day tariffs
USD	U.S. Dollar
V	volts

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The Energy Conservation Audit Team of the International Resources Group, Ltd. (IRG) wishes to acknowledge assistance provided by the Ministry of Industry, the Committee on Energy, and its Inspectorate for Energy Utilization in arranging visits to participating facilities. IRG also would like to thank the U.S. Agency for International Development, European Development Resources Section, Office of Energy and Infrastructure for coordinating the entire project.

Work under the A.I.D.-funded Emergency Energy Program at the Serdika Milk Plant, Sofia, was conducted through a cooperative effort by the factory management and staff; Committee on Energy; Ecotechproduct -- a private sector energy conservation consulting firm; and IRG.

It is IRG's hope that the exchange established through this initiative is maintained and expanded in the future.

PREFACE

In the wake of the political and economic collapse of the Soviet Union, the nations of Central and Eastern Europe confront an energy situation for which there is no historical precedent. Overnight long-standing supply agreements for oil, natural gas and electricity supplies from the Soviet Union have been curtailed or discarded with attendant dramatic increases in the prices of these commodities. In addition, as the veil of secrecy has been lifted in these nations, the devastating legacy of years of neglect of coal and other fossil fuel pollution and an aging, largely unsafe, and unregulated nuclear power industry are vital issues that need to be addressed in light of the fundamental structural reform of these Central and Eastern European economies. Democracy for these countries means change amidst great political and economic uncertainly.

For Bulgaria, the general atmosphere of crisis in the regional energy sector is compounded by the fact that all of its natural gas and coke and most of its petroleum is imported. Moreover starting in April 1991, the electric power supply imported from the Soviet Union, which previously accounted for a significant amount of Bulgaria's electricity supply, was cut off. Furthermore, domestic electricity production from nuclear power, previously a major source of energy, has been decreasing since the autumn of 1991, as the Kozloduy nuclear power station was taken off-line due to safety concerns. Given these concerns, energy efficiency must play a vital role in transformation of the energy and industrial sectors in Bulgaria.

To support the transition from Soviet-based dependence to democracy, based on free market principles, the United States, in 1989, instituted a program to assist the countries of Central and Eastern Europe with humanitarian aid, technical assistance and direct economic aid. The U.S. focused initially on Poland and Hungary, where this transition was in its most advanced stages. Since that initial commitment to Poland and Hungary, the U.S. has expanded its focus to include Czechoslovakia, Bulgaria, Romania and Yugoslavia as technical assistance recipients in Eastern and Central Europe. In the future, large scale assistance is likely to be given to the Baltic States, Estonia, Latvia and Lithuania, as well as the republics of the forrner Soviet Union -- and possibly Albania.

Grants and other assistance to Central and Eastern Europe already account for a U.S. commitment of $1.5 billion since 1989. In Fiscal Year 1991, alone, grant assistance to the region totaled about $450 million. Many of these special assistance grants were funded through the U.S. Agency for International Development, with implementation assistance by various U.S. agencies and private sector organizations.

One important initiative under the U.S. technical assistance program was the U.S. Agency for International Development Emergency Energy Program for Eastern and Central Europe, Component #1: Industrial Energy Efficiency Improvement. This program was designed to address regional energy sector problems on a short-term basis and to identify and implement energy efficiency initiatives. This effort combined in-plant, on-the-job training with identification and implementation of energy management practices and low-cost measures to be implemented during the period of the contract work. This report outlines the activities of the Industrial Energy Efficiency Improvement project in one plant in Bulgaria.

The purpose of the Industrial Energy Efficiency work was to improve in the short-term the efficiency of energy use by industry. Specific objectives included:

1) fostering improved management of energy use in industrial plants by identifying and implementing immediately cost-effective "low cost/no cost" energy efficiency improvements;

2) transferring energy auditing and management techniques including financial and economic analysis techniques; and

3) providing equipment to implement low-cost options, to improve monitoring and energy management, and to identify additional energy efficiency opportunities.

To accomplish these objectives the following actions were undertaken:

1) Eight industrial facilities were selected as target plants for audits. The plants were selected on the basis of:

   - potential for significant energy savings;
   - the likelihood that the plants will continue operating in the new economic climate;
   - applicability of results to similar plants in Bulgaria to which the energy conservation measures developed in this program could be applied.

2) Two Audit Teams went to Bulgaria on two separate occasions, each Team visiting four or five plants to perform energy audits and conduct training.

3) The Teams identified, specified, and procured energy efficiency equipment to be used by the plants to implement short-term energy efficiency improvements.

4) Representatives of the Audit Teams returned to the plants in January 1992 to assist in implementation of the audit recommendations, and to monitor the energy improvements actually achieved.

5) The Teams presented a wrap-up workshop for plant managers and technical staff of the participant plants and other similar plants throughout the country. The seminar was held in Sofia January 27-29, 1992.

The Bulgaria Light and Heavy Industry Audit Teams each audited four plants:

<u>Light Industry</u>
Serdika Dairy Processing Plant - Sofia
Pharmacia Pharmaceutical Company - Stanke Dimitrov
Parvi Mai Cotton Textile Processing Plant - Varna
Dobritch Poultry Processing Plant - Tolbuhin

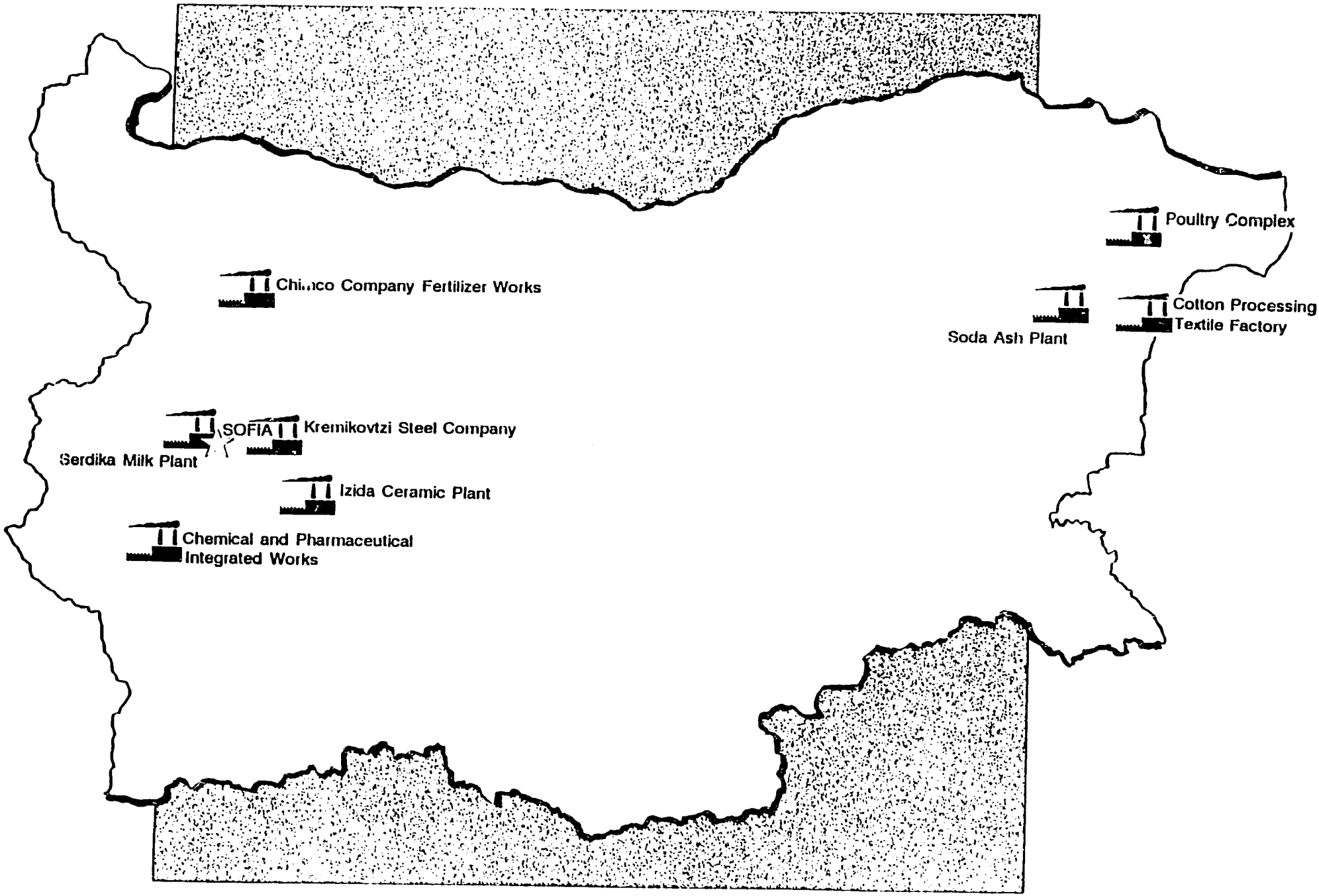


Figure 1. Location of eight industrial plants audited by the IRG team.

Factory

Heavy Industry
Izida Ceramic Facility - Elin Pelin
Kremikovtzi Steel Plant - Sofia
Chimco Ammonia and Urea Facility - Vratza
Sodi Soda Ash Plant - Devnia

The Audit Teams collected data at every plant on the costs of producing steam and electricity, primarily using plant records, audit measurements, and interviews with plant officials. In some cases, the Audit Teams counselled the plants in the establishment of systems for cost accounting in the plant, particularly where it related to energy costs per unit of output. The Industrial Energy Efficiency activities had tremendous success and generated letters of support from several plant managers.

Program Rationale

While this program was clearly a logical starting point for improved energy use patterns, it is only a beginning. Although all activities under the Industrial Energy Efficiency project were conducted using a relatively small budget for equipment purchases, the energy savings results were significant. Thus, the program demonstrated the tremendous potential for energy savings through low cost and no cost mechanisms. Moreover, these programs represented important energy savings initiatives that were implemented on a timely basis, within a matter of months.

These initiatives should serve as a cornerstone for a new way of approaching energy savings in Bulgaria. They represent the lowest cost and most readily implemented energy savings initiatives available. Furthermore, the energy savings techniques/measures identified and implemented in this Emergency Energy Program should be applicable to other similar facilities and process units throughout Bulgaria. As a result, these low cost techniques for improving energy efficiency, and thereby improving economic efficiency in industrial facilities, should serve as a model for restructuring energy use in the Bulgarian industrial sector.

The project also highlighted a number of issues that fundamentally affect the ability of industrial entities to solve energy problems. Basic issues such as industrial energy pricing, environmental regulation, legal reforms, corporate organization and management structure, personnel training, and the overall economic environment all affect the ability of industrial concerns to implement energy savings opportunities. Thus, the Industrial Energy Efficiency Improvement project attempted to address issues of micro-level plant organization and management, training, and economic evaluation at each of the plants. In addition, the IRG Team has outlined key macro-level issues which must be addressed by the Government of Bulgaria before comprehensive energy efficiency initiatives are enacted. These issues are addressed in this report as well as in Industrial Profile Report and the Policy and Institutional Analysis Report for Bulgaria, both prepared as part of the Industrial Energy Efficiency Improvement project.

Ultimately, the IRG Team is convinced that the overwhelming potential for energy and cost savings in the Bulgarian industrial sector will provide sufficient incentive for plant managers and industrial executives to actively promote the need for reforms that encourage energy conservation and improved economic efficiency.

1. EXECUTIVE SUMMARY

The Serdika Milk Plant is one of forty-two major dairy facilities in Bulgaria; it was originally constructed in 1950, and has had several expansions and renovations in the ensuing years. The most recent expansion occurred in 1974 - 1975 when the capacity was increased from 100 tons of milk per day to its current production of 500 to 600 tons per day. The average peak production last year, by contrast, was 350 tons. The milk supply available to the plant has decreased this year, as has market demand for products. Over-capacity and wasteful energy practices have made the facility an inefficient energy user.

Annual energy consumption at Serdika for fuel oil averages 7,580 tons per year. Since 1989, the price of fuel oil has increased from approximately 158 lv/ton to 2,250 lv/ton. Lighting and refrigeration are two major electricity consumers in the plant.

The International Resources Group Energy Conservation Audit Team recommends rebuilding the condensate system, intensifying steam-leak repair programs, replacing missing steam and refrigeration line insulation, and shifting production schedules to off-peak electrical periods. These are all low-cost, rapid return strategies for improving energy efficiency. Capital-intensive projects, such as replacement of the refrigeration systems, are not recommended until the real market for facility inputs and products are more clearly defined. When the market is better defined, the entire plant and process should be evaluated and compared to the economics of constructing a new facility.

Team members also addressed the issue of motivating staff to such a level that no- and low-cost conservation opportunities are implemented routinely.

In an effort to address staff motivation, Team members recommended a portion of the condensate recovery system be rebuilt using some U.S. manufactured equipment with the expectation this could dispel the claim that condensate pumps and steam traps are faulty. Of course, equipment supplied from any source must be maintained. Thus, part of this recommendation is that such maintenance be monitored. Finally by involving the plant staff in the actual installation of equipment, the Team hoped to generate further staff interest in saving energy.

Results of the Emergency Energy Program, Industrial Energy Efficiency

Some new equipment and instruments were purchased under the Emergency Energy Program. Items include:

- Portable Infrared Thermometer
- Oxygen Analyzer
- Fluorescent Light Fixtures (various)
- Industrial Stethoscope
- Steam Traps (various)
- Pipe Fittings (various)
- Electric Power Monitor

More capital intensive recommendations have been outlined for the longer term, and are summarized in **Table 1**.

Table 1: Summary of Opportunities for Energy Savings - Serdika Milk Processing Plant

I. No Cost/Low Cost Measures Evaluated	Investment (lv)	Energy Savings (kWh/year)	Cost Savings (lv/year)	Payback (years)	Recom's
Adopt energy management program	-	3,448,300	1,000,000	0.3	yes
Install stack gas analyzer (or O2 and T sensors)	30,000	258,600	75,000	0.6	yes
Repair steam leaks	15,000	1,551,700	450,000	0.1	yes
Replace installation on steam and condensate lines	5,000	120,700	35,000	0.2	yes
Restore condensate system	80,000	862,100	250,000	0.4	yes
Replace fluorescent lamps or disconnect ballasts	45,000	344,800	100,000	0.5	yes
II. Capital Intensive Measures Evaluated					
Install heat exchangers on finishing machine dryers	560,000	2,672,400	775,000	0.9	yes
Heat recovery from waste water	-	-	-	-	NEI
Replace air conditioning units	-	-	-	-	NEI
TOTAL	735,000	9,258,600	2,685,000		

NEI - Not enough information available about key investment parameters, including management payback requirements, etc. at the time of audit to recommend implementation of the project. The Team does not suggest that these investments are not sound, but stresses a more comprehensive analysis of the return on these investments is necessary before investment funds are allocated.

NOTE - Where necessary for currency conversions, an exchange rate of 15 lv = US$1 has been used in this report, since it was the exchange rate in effect at the time the audit work was conducted. In January 1992, the exchange rate value was closer to 25 lv = US$1.

2. PLANT BACKGROUND

Serdika Milk Plant in Sofia is a processor of milk collected from different producers. End products at the plant include pasteurized milk, Mladost brand yogurt, ordinary yogurt, ice-cream, unpacked cream, sour cream, butter, curds, and yogurt- and milk-based desserts. **Table 2** outlines plant production, and **Table 3** presents the total annual liquid-fuel consumption in Serdika, in accordance with October 1989-September 1990 accounting data.

Table 2. Production of dairy products at Serdika, October 1989-September 1990 (tons)

Month Year	Milk & Mladost yogurt	Ordinary yogurt	Ice cream	Cream (unpacked)	Sour cream	Butter	Curds	Desserts	Total
10/89	4,742	5,646	220	71	97	77	60	5	10,918
11/89	4,668	5,415	240	59	85	68	48	4	10,787
12/89	5,030	5,274	203	63	94	86	57	9	10,816
1/90	4,934	5,322	183	53	62	108	46	13	10,722
2/90	4,716	5,376	245	53	107	67	50	9	10,624
3/90	4,824	6,101	416	69	78	82	50	8	11,629
4/90	4,738	6,253	210	57	82	10	50	5	11,505
5/90	4,823	6,266	350	35	80	112	59	8	11,733
6/90	4,100	5,949	445	53	44	71	32	12	10,706
7/90	3,675	6,567	678	41	21	66	29	8	11,085
8/90	3,567	5,696	625	35	23	70	28	6	10,050
9/90	3,706	5,176	378	42	21	57	21	1	9,402
	53,726	69,041	4,193	631	794	974	530	88	129,977

The total amount of dairy products produced in the period 1989-1990 was 129,977 tons, of which 41.3% was pasteurized milk and Mladost brand yogurt, and 53.1% was production of ordinary yogurt. Total milk and yogurt production accounts for 94.4% of the overall output; these two production lines, together with ice-cream (which accounts for another 3.2% of production), have therefore been selected for analysis because they consume most of the energy.

Table 3. Fuel Oil Consumption, October 1989-September 1990

Month	tons/month	Unit consumption ton fuel/ton output
10/89	750	0.0687
11/89	730	0.0677
12/89	450	0.0416
1/90	790	0.0737
2/90	750	0.0706
3/90	700	0.0602
4/90	650	0.0565
5/90	550	0.0469
6/90	750	0.0700
7/90	380	0.0343
8/90	450	0.0448
9/90	634.5	0.0674
TOTAL	7584.5	0.0583

Average monthly consumption = 632 tons fuel oil
Average daily consumption = 21 tons fuel oil
Average hourly consumption = 0.88 tons fuel oil

Notes:

1. The boiler room operates 24 hours per day, 365 days per year.
2. In September 1990, the price of fuel oil was increased to 300 leva (lv) from 158 lv.
3. Typically, steam production is 12 tons/hour at 6.5-7 atmospheres (atm.) of pressure with the heat content of 650 kilocalories (KCal) kilogram (kg).
4. Heat content growth without condensed water recycling is 650 kCal/kg (580 kCal/kg, if recycled).

At 300 lv/ton of fuel oil (as of September 1990), the annual cost of fuel was 2.275 million lv per year. Given a world price of fuel oil of $150 per ton (in 1991), annual fuel costs were $1,138,000 in 1991, at which the market rate of dollar exchange (15 lv = US$1) is equivalent to 17,070,000 lv per year. Thus, the transition to hard currency settlements, which began in 1991, result in an increase of 14,800,000 lv in fuel expenditures alone. Given annual product output of 130,000 tons, these additional expenses will result in an average increase in production costs of approximately 113.8 lv per ton.

2.1 Boiler Operation

The Team observed that one boiler, with a capacity of 12 tons/hour of steam, was operating during the plant audit. The fuel oil was heated to approximately 90 - 110°C. Boiler inspections suggested good maintenance; no apparent air leaks, oil leaks, or cracks or breaks in the refractory were observed.

Stack, air, and fuel oil (mazut) temperatures were measured with portable equipment, and flue gases were analyzed. Measured stack-gas temperature was 323°F/162°C with 5.5% excess oxygen, and reasonably satisfactory operating conditions. (refer to **Appendix I** for other details). There was no instrumentation equipment available on any of the boilers other than drum-level gauges. Similarly, there was no combustion air or feed water preheating, and only 5 to 10% of the condensate was returned. (See **Section 2.2** below).

However, the Team found that it was possible to close the manual draft damper progressively to provide 3.2% excess oxygen, at which level stack-gas temperature decreased to 150°C; this resulted in a savings of about 6,600 lv when annualized.

2.2 Condensate System and Steam Traps

The condensate system is in poor condition and the only condensate recovery attempted prior to the April audit was in the central water heating area. This returned an estimated 5 to 10% of the system's total condensate produced. The Energy Conservation Audit Team estimated substantially more condensate could be returned in this plant, yielding significant energy-cost savings. Thus, the Team recommended that the management design and install condensate return facilities from one heat station in the Serdika milk plant. Costs to rebuild and maintain the condensate system would be approximately 65,000 lv, but would ultimately result in savings of up to 700,000 lv/year.

2.3 Electrical Distribution

Serdika has two main feeders from the electric utility at 10 kV, which are stepped down to 400 V through substations. Transformer equipment appeared to be in good condition, but was of a relatively high energy-loss design. Much of the distribution system and the switching gear is old and has had repairs made on an *ad hoc* basis, with no attempt to focus on more "systemic" and permanent repair solutions.

During February 1991, Serdika received a penalty of 11,046 lv for low power factor, and in March 1991 a penalty of 44,601 lv. Capacitors were installed in the spring of 1991 to bring the power factor up to about 0.93, within the "no-penalty" range.

There was also a demand meter with a printer available; however it had not been used since 1990, demonstrating a lack of concern for potential electricity savings.

At the time of audit, electrical power loads had not been controlled; however, considering the time-of-day (T.O.D.) pricing in effect, this opportunity to save money was discussed in the Energy Management Seminar given at the plant. The T.O.D. tariff is as follows:

8 to 10 AM & 6 to 10 PM	- 0.56 lv/kWh (4 cents/kWh)
6 to 8 AM & 10 AM to 6 PM	- 0.28 lv/kWh (2 cents/kWh)
10 PM to 6 AM	- 0.12 lv/kWh (8.6 mills/kWh)

These rates were below new load incremental costs, and the off-peak rate was below decremental costs. It was also noted that maximum demands had been set and a penalty of five times the above rates was established as a goal for the plant, although these criteria are not always observed.

2.4 Lighting

Lighting standards in Central Europe are substantially below those found in other parts of the world; lighting in the Serdika plant, however, was even below many Central European levels. Many of the interior fixtures and lamps were in terrible repair and were of poor quality design. Others were burned out or broken and had not been replaced, despite the fact that these fixtures and lamps increased energy used in the plant, based on units of illumination.

Consequently, the Energy Conservation Audit Team recommended replacing some of the burned out lamps with efficient, U.S.-manufactured fluorescent bulbs. In addition, the Team recommended burned-out lamps either be replaced or the ballasts disconnected, so future electricity losses could be curbed.

It is important to note that relatively efficient incandescent and fluorescent fixtures and lamps are manufactured in Bulgaria, as well as the most efficient luminaries, high-pressure sodium equipment. However, the quality and efficiency of these Bulgarian-made models may have practical limitations, such as durability. Some exterior lights and major city street lights in Bulgaria are already equipped with high-pressure sodium fixtures and lamps.

2.5 Heat Balances - Steam

Since data regarding fuel volume was only available through examination of plant invoices, rather than actual measurements, and generated steam was not measured, it was only possible to make a rough approximation of the steam heat balance. The most significant factor highlighted by the calculation of this balance was the unrecovered condensate, determined to be 70 kCal per pound of condensate, representing a loss of 770,000 kCal/hour (3.06 million Btu/hour). This amount was equivalent to a fuel oil loss of 0.53 barrels/hr .

At 80% boiler efficiency, this loss is equivalent to:

1,108,000	lv/year	@1200 lv/Ton
$79,000	/year	@$13.64/bbl
1,625,000	lv/year	@1760 lv/Ton
$116,000	/year	@$70.00/bbl

Additional losses were incurred as a result of the extra expenses of water and treatment chemicals.

2.6 Heat Balances - Refrigeration

The lower temperatures necessary for milk processing at the plant are generated in two refrigerating stations; one station is located in a separate cooling department, while the other was part of the yogurt-production line. In practice, the two refrigerating installations were interconnected, and the processed cold was supplied by the main refrigerating station.

There were 14 refrigerating compressors in the main refrigeration stations as follows:

1.	BBC refrigerating compressor	315 kW	1 unit
2.	BBC refrigerating compressor	450 kW	2 units
3.	ATLAS refrigerating compressor (3 disassembled)	75 kW	9 units
4.	USSR refrigerating compressors	28 kW	2 units

Installed refrigerating capacity considerably exceeds requirements, and for this reason, the actual compressors in operation included 2 high-pressure compressors, with the effective electrical demand of 315 kW and 450 kW, and 2 low-pressure compressors with electrical demand of 28 kW.

High-pressure compressors served the equipment functioning with evaporation temperatures of -20°C, and the low pressure compressors served the machinery with evaporation temperatures of -35°C and -45°C.

Main cooling loads included:

Item	Energy use
Chilled water for milk, yogurt and ice-cream	1,000,000 kCal/hour
Stores for yogurt	300,000 kCal/hour
Installation for ice water for milk production	1,300,000 kCal/hour
Condensing aggregate	16 units 4,000,000 kCal/hour
Ice-cream store -20°C	1,000 m^2 chilling surface.
Ice-cream store -20°C	800 m^2 chilling surface.
Eskimo generator	185,000 kCal/hour
Freezers	6 units x 20,000 kCal/hour
Ice-cream store	30,000 kCal/hour
Cooling capacity of fan coolers	4,000,000 kCal/hour.

From the high-pressure compressor, ammonia vapor was fed into sprinkling condensers. The condensed ammonia then went into a linear receiver where it was distributed to the chilled water plant, milk and yogurt stores, and the intermediate tank used as a low-pressure condenser.

Evaporation temperature in the high-temperature range was -20°C. To arrive at -35°C ammonia evaporation, part of the ammonia was subcooled via high pressure evaporation at -20°C. From the intermediate tank, the subcooled ammonia was then fed for evaporation into the ice-cream store and freezers.

The evaporated low-pressure ammonia was drawn in to the circulation receiver from low-pressure compressors and pumped into the intermediate tank where it was condensed. The evaporated high-pressure ammonia from the chilled water plant and milk and yogurt stores was drawn in by high pressure compressors, going into high-pressure sprinkling condensers.

Cooling and condensing of ammonia vapor in the high-pressure sprinkling condensers was accomplished with chilled water, which after heating in the condensers was cooled in fan coolers (16 units) with an electric capacity of 9 kW each.

Project-related studies and analyses indicated that average cooling load of the Serdika Plant was between 2,000,000 and 2,600,000 kCal/hour.

Overall, refrigeration equipment was old and almost worn out. Frequent repair work has been performed on the bearings of the compressors' electrical motors. Moreover, since the oil separating system of the refrigerating installation was inadequate, annual oil costs were approximately 8,000 - 9,000 lv for this process subcomponent. There was no load automatic control system for the refrigeration system, nor was there the necessary measurement instrumentation.

The refrigerating and freezing storages for fresh milk, yogurt, and ice-cream products were comparatively new, with good foam/polyurethane heat insulation. However, insulation of the refrigerating equipment and distributing pipelines was poor. A rough estimate of additional electric energy costs due to poor insulation was 15 to 30%.

The Energy Conservation Audit Team recommended that since the existing refrigeration installation is worn and in need of replacement, it would not be reasonable to outfit this system with a control and monitoring system. Instead, the plant should investigate options for replacing the refrigeration system, using more energy efficient equipment.

3. ENERGY MANAGEMENT

3.1 Energy Management Structure

Prior to the April 1991 audit, the Serdika management staff had hired a private energy-service company (Ecotechproduct) to assist them in developing a strategy for energy management. However, the plant did not have a formal Energy Management Program, nor did it have any procedures for identifying and implementing energy saving measures or other investment projects. Personnel, including maintenance staff, had no incentives to focus on energy management or conservation issues. Moreover, owing to the lack of measurement instruments, little energy-consumption data had ever been collected. Similarly, management had no standardized system for using economic criteria to evaluate investment projects. However, the management's cooperation with the Emergency Energy Program and local energy consultants demonstrated a clear concern for energy management issues. Consequently, establishment of an energy management program and completion of appropriate personnel training to facilitate implementation of the Program should be high management priorities.

3.2 Energy Management Seminar

Recognizing the importance of energy management in determining the overall efficiency of industrial energy use, the Energy Conservation Audit Team presented a seminar at the Serdika Plant in April 1991, addressing a number of energy-management issues. Recommendations presented in the seminar were designed to provide an overall framework for improved energy management and training related to energy efficiency.

Issues crucial to any discussion of energy management include:

- Economic Principles - it is important in any energy management regime to view energy costs as production input costs. In addition, concepts related to the benefits and costs of energy efficiency investments and return on investment must be analyzed. The in-plant seminar attempted to define the economic benefits and costs of conservation opportunities. This was coupled with an introduction, explanation, and determination of the Return on Investment (ROI) along with the pay-out time of individual opportunities as tools for ranking and prioritizing projects;

- Energy Management Programs - specific programs which could help foster an energy ethic within a plant should be encouraged. These programs could include incentive/disincentive, "turn out the lights" campaigns, etc. A comprehensive energy management program also should incorporate an effective mechanism for energy cost accounting. Such a mechanism might require the purchase of and training in the use of computer accounting software, etc.

- Energy Monitoring - successful improvement in energy utilization in an industrial facility is contingent upon continued monitoring of energy use. Increased energy prices in Bulgaria have forced new emphasis on this issue. As such, energy

efficiency training must encompass economic justifications for the selection of instruments to monitor energy use; and

- Energy Surveys - energy surveys and audits similar to the one conducted under the Emergency Energy Program should be part of an overall energy management framework. In particular, energy surveys should attempt to regularly evaluate such important areas as:

  - steam leaks
  - condensate leaks
  - insulation opportunities (water, steam, refrigeration)
  - electrical opportunities
  - lighting
  - water leaks
  - air leaks
  - boiler operations
  - refrigeration
  - air conditioning

Issues addressed at the April seminar were dealt with in more detail at the January 1992 Energy Management Workshop in Sofia, at which a representative of the Serdika plant made a presentation. The outline of a presentation on Energy Management Practices, given at the January seminar, is included in **Appendix VII**.

3.3 Training Requirements

Training requirements for this plant vary by personnel area. However, at a minimum, all plant personnel should receive basic training in energy awareness. Technical and managerial personnel should receive more extensive training in economic and technical areas through seminars, training retreats, and where feasible, outside training courses at technical institutes.

As outlined in the energy management seminar, training in energy awareness, economics, and energy cost accounting are crucial elements in improving plant energy efficiency. At almost every level, improved training in economics, data collection, and low cost energy management techniques would yield significant energy savings.

It is particularly important that divisions responsible for overseeing energy utilization and energy efficiency activities receive training in such key areas as:

- energy cost accounting - this type of training would be particularly useful if it involved practical skills training related to use of energy cost accounting software packages. Even if it is not possible to purchase and utilize more sophisticated computer accounting programs, plant personnel can learn the basic tools used to maintain solid cost accounting standards within the plant.

- energy efficiency investment planning - again, training in investment planning would be extremely useful if it included familiarization with the tools used in some energy investment planning programs such as the "Envest" program.

Refresher courses and subsequent programs for all plant personnel should focus on: specifics of the plant's energy management program; key energy waste areas; identification of solutions to energy conservation problems; energy conservation monitoring and incentive schemes. In addition, training initiatives for managers should address economic issues (with varying degrees of specificity depending on job requirements) including investment evaluation tools, plant profitability, export benefits and principles, and employment issues. Finally, programs for department heads, engineers and technical specialists should address a variety of technical issues including thermodynamics (as applied to both steam and refrigeration systems), engineering economics, and detailed energy management techniques.

4. ENVIRONMENTAL CONSIDERATIONS

The Serdika Milk Plant is located in a densely populated area of Sofia, with a multi-story apartment complex situated within a few hundred feet of the boiler house. Periodically boiler stacks emit black smoke, especially when the boilers are initially started and/or when the air/fuel ratio is poor. Consequently, air quality in the neighborhood is directly affected. Boiler stacks are a minimal height to serve the draft needs. Thus, sulfur dioxide (SO_x) and nitrogen oxide (NO_x) emissions resulting from inefficient combustion may also be an unseen issue.

At the time of audit, plant management staff were contemplating the use of bottled gas to start the boilers. The Energy Conservation Audit Team recommended that A.I.D. provide equipment to measure stack gas analysis and assist in developing and implementing boiler regimes to minimize the carbon and SO_x or NO_x emissions. Depending on future changes in Bulgarian environmental standards, this and other environmental issues may become problematic.

Plant wastewater was disposed of through the municipal system. Team members were advised that the wastewater met government regulations; however, the Team did not conduct water tests to confirm this.

5. ENERGY EFFICIENCY IMPROVEMENT OPTIONS

Listed below are options for improving energy efficiency use within the plant. Clearly, all these practices and projects will help conserve energy in the facility. However, given the reality of scarce resources for implementing these projects, the IRG Energy Conservation Audit Team recommended some options be given priority. This prioritization is included in **Section 6**. Nevertheless, this section outlines the wide variety of options available for energy efficiency improvement. Ultimate decisions regarding implementation of alternative options will depend upon criteria set by plant management -- including acceptable payback periods, and upon the overall corporate strategy.

5.1 No- or Low-Cost Options

For the purposes of this paper, "no-cost" items refer to projects to be initiated at the expense of the plant, in cases where expenditures are involved. Although few of these recommendations are literal "no-cost" propositions, they should all be possible to implement within the existing framework of plant expenditures (i.e. leva purchases, improved maintenance, and housekeeping). Local investment and installation labor for low-cost initiatives will be provided by the plant. Hard currency for some of the low-cost items will be available under the A.I.D. Emergency Energy Program. In addition, justifications and specifications for these items are included in **Appendix V**.

1. **Adopt an energy management program.** This "no-cost" project has potential savings of more than 1,000,000 lv/year with ROI's in excess of 100%, and a payback period of less than three months.

2. **Install stack-gas analysis equipment.** This investment will help minimize emissions and effect the most efficient air/fuel mixtures; it has an estimated capital cost of 30,000 lv. The value of fuel savings from this investment would be 180,000 lv/year, with a ROI of at least 100%, and a payback period of 0.3 years. The U.S. Agency for International Development would help finance this project.

3. **Rebuild and maintain the condensate system.** This project has an estimated capital cost of 65,000 lv, and a potential fuel savings valued at 700,000 lv/year. The ROI would be more than 100%. with a payback period of 0.2 years.

4. **Repair steam leaks.** This project has an estimated capital cost of 10,000 lv, and would yield fuel savings valued at 600,000 lv/year, with a ROI of 100% and a payback period of 0.1 years. The U.S. Agency for International Development will also assist in financing this project.

5. **Replace inculation on steam lines.** The estimated capital cost for this project is 10,000 lv, and energy savings would be 180,000 lv/year. The ROI would be 100%, and the payback period 0.1 years.

6. **Replace insulation on refrigeration lines.** The cost of this project is 35,000 lv, yielding energy savings of 400,000 lv/year, with a ROI of more than 100%, and a payback period of 0.2 years.

7. **Repair air leaks**. This project would cost 4,000 lv, yield 40,000 lv/year in energy savings, have an ROI of more than 100%, and a payback period of 0.2 years.

8. **Lighting Improvements**

   - **Install energy efficiency fluorescent (or metal helide) lighting luminaries**. This project would cost 210,000 lv, and yield estimated annual energy savings of nearly 30,000 levs/year[1]

   - **Clean fixtures and relamp fluorescent lights every six months**. If lighting levels are deemed too high, disconnect the ballasts of unwanted fluorescent fixtures. This project would cost 14,000 lv, and result in 20,000 lv/year in energy savings[2], with a ROI of 100%, and a payout in 0.7 years.

9. **Refrigeration Improvements**

   - **Purge non-condensables periodically to maintain low condensate pressure**. To repair existing purge point and install an additional one to improve removal of non-condensables from refrigeration system would cost 8,800 lv, and result in savings of 167,000 lv/yr. This is a ROI of 100%, with payout in one month.

   - **"No Cost" Refrigeration Process Improvements**. In addition to the projects outlined above, the Audit Team recommended a number of maintenance and operation changes pertinent to refrigeration energy conservation opportunities.

     - **Optimize Defrost Cycle**. Set the defrost cycle based on seasonal, humidity, and load requirements.

     - **Properly Sequence Compressors**. Manage compressors so that each operates at or near full capacity.

     - **Reduce Condensing Pressure**. Operate the refrigeration system at the lowest condensing pressure possible with existing condenser capacity.

     - **Maintain Cooling Tower and related equipment, and treat cooling tower water**.

---

[1] The estimate of cost savings resulting from this investment includes only energy savings, thereby excluding savings derived from increased personnel productivity, which are estimated to be substantial enough to justify this investment.

[2] Plus a probable significant increase in productivity and a decrease in mistakes.

- **Load Management.** Manage both supplementary and product loads.

5.2 Capital Intensive Options

The following four capital intensive energy efficiency options were discussed with plant management, and initial comments were made concerning each. However, since requisite data, including plant payback period requirements, were not available for these options, and feasibility studies had not been conducted, Team members were not able to make a definitive recommendation about these options. The IRG Energy Conservation Audit Team recommends a comprehensive evaluation be made of both the technical and economic aspects of all four investments prior to the commitment of any investment funds.

1. **Replace outdoor and storage area lighting with high efficiency HPS (High Pressure Sodium) fixtures.** Costs are estimated to be in the 50,000 to 100,000 lv range.

2. **Reinstall the electricity demand controller in an operating area.**

3. **Replace refrigeration equipment at such time as product demand and interest rates stabilize.**

4. **Review process improvement opportunities in light of state-of-the art in step with labor cost expectations.**

6. RECOMMENDATIONS & CONCLUSIONS

The following recommendations and conclusions represent those areas which the Energy Conservation Audit Team believes should be priorities for the Serdika Milk Plant.

6.1 Improved Energy Management Practices

Priority areas for corporate energy management at Serdika should be the establishment of training initiatives designed to improve energy efficiency awareness, data collection techniques, energy cost accounting, and energy investment planning capabilities as well as the establishment of a comprehensive energy management program, including an energy management committee.

In conjunction with improved training, management should establish energy management criteria, including minimum acceptable investment payback criteria and incentive/disincentive schemes for encouraging energy savings. In addition, management should attempt to conduct a comprehensive evaluation of all investment options, both low cost and capital intensive to determine cost and payback periods for the required investments (in terms of energy saved, losses avoided, or production increases), to categorically prioritize investment opportunities.

6.2 Improved Operating Practices and Operational Changes

The following recommendations reflect changes in operating practices, housekeeping and maintenance which can yield significant energy savings with minimal investment cost. These recommendations include focusing attention on energy management, condensate and steam systems, lighting, instrumentation and dryers, in addition to changes in the operation of the boilers.

1.	**Energy Management.**	The Team recommends the Plant establish an energy management program to ensure awareness of energy issues is established at Serdika, and appropriate mechanisms exist for monitoring energy use and encouraging energy savings.
2.	**Condensate**	Repair and restore the condensate system, and design and install condensate-return facilities from one heat station. Provide a limited amount of equipment (pumps, fittings and traps) to demonstrate a workable system, and replace insulation on steam lines.
3.	**Instrumentation**	Prioritize the purchase, installation, and use of energy meters and portable instruments to identify energy waste areas, monitor improvements, and provide data for evaluating energy- efficiency investments. Priority items should include condensate pump, oxygen analyzers, and temperature monitors for stack gas.

4.	**Steam Systems**	Repair steam leaks, replace insulation on steam lines, and replace steam traps.
5.	**Lighting**	Change to new high-efficiency fixtures and replace burned out lamps and fluorescent lamps, and disconnect ballasts.
6.	**Refrigeration**	Replace insulation on refrigeration lines. Purge non-condensables periodically to maintain low pressure of condensate, and work to optimize the defrost cycle. Properly sequence compressors. Reduce condensing pressure. Maintain cooling tower and related equipment, and treat cooling tower water. Institute load management programs.
7.	**Air**	Repair air leaks.

6.3 Recommended Capital Investments

Equipment Purchased Under the Emergency Energy Program

1.	**IR Thermometer**	The portable infrared thermometer will be used to identify damaged insulation or heat losses from other sources throughout the plant. The cost of the item was $437; estimated savings from this instrument are expected to be $1,200 per year.
2.	**Oxygen Analyzer**	This item will be used to monitor excess air in the combustion process. The cost of this item was $476 and the savings from the item are estimated $2600 per year.
3.	**Fluorescent Lights**	More efficient fluorescent lights will replace some burned-out fixtures within the plant, achieving a higher level of light at a lower energy-consumption rate. The cost for these fixtures was $14,250, with savings estimated to be approximately $2,000. However, additional economic savings will be achieved through productivity increases, bringing the payback period for this item to approximately two years.
4.	**Industrial Stethoscope**	The industrial stethoscope will be used to check for steam trap leakages. The cost of this item was $451, and the resulting energy savings are valued at $4,200 per year.

5. **Steam Traps** — The high quality US-made steam traps will improve steam utilization within the plant and avoid large energy losses associated with steam leaks and faulty steam traps. This investment cost $8435, and its resulting energy savings are valued at nearly $52,000.

6. **Pipe Fittings** — The pipe fittings will be used along with the steam traps to improve the steam utilization within the plant. This investment cost $5148 and will save an estimated $30,000 worth of energy per year.

7. **Power Monitor** — The electric power monitor, which cost $5870, will be used to monitor electric energy use throughout the plant, where in-situ meters are not available. The monitor will help energy managers to identify energy waste areas, monitor improvements, and provide data for evaluation of energy efficiency investments.

Details on the specifications and justifications for this equipment are included in **Appendix V**.

Other Recommended Capital Projects

Since the Agency for International Development is not in a position to finance all of the opportunities available for energy efficiency improvements, the IRG Energy Conservation Audit Team recommends a number of other investment projects for the plant to implement on its own. These recommendations include:

1. **Insulation** — The plant management should purchase insulation for condensate, steam lines and refrigeration systems as part of comprehensive condensate, steam and refrigeration system improvement initiatives.

2. **Instruments** — To the extent that the U.S. Agency for International Development is unable to fund all necessary instrument purchases, the plant should purchase measuring and metering devices for temperature, pressure, oxygen, and electricity, at a minimum. A condensate pump should also be a purchase priority.

In addition, the Team recommends that the plant management continue to investigate the costs and benefits associated with some of the capital-intensive projects listed in **Section 5**.

REFERENCES

Methven, Norbert E., "Innovative Rate Making for Utility Services", American Paper Institute, Engineering conference, Boston. (1984)

Spassov, Christian & Simeonov K., "Long-Term Research into Waste Heat Recycling and Improving the Energy Balance Structure of the Serdika Enterprise - Sofia. (1990)

Methven, Norbert E., "An Energy Conservation and Management Program", American Paper Institute, Atlanta. (1979)

APPENDIX I

Stack Gas Analysis

Serdika Milk Plant

BOILER #2

Position		1	2			
Date	4-6-91					
Time		13:27	13:28	13:41	13:49	13:52
Combustion Eff.	%	76.3	74.6	85.3	85.6	85.4
Ambient Temp	°F/C	71/22	71/22	76/24	/26	/27
Stack Temp	°F/C	323/162	316/155	304/151	304/151	302/150
Oxygen	%	5.5	5.8	4.5	3.3	3.2
Carbon Monoxide	PPM	10	15	34	108	115
Carbon Dioxide	%	11.5	11.3	12.3	13.2	13.3
Combustible Gases	%	0.91	1.0	0.26	0.27	0.33
Excess Air	%	35	37	26	18	17
Oxides of N	PPM	285	280	289	284	2283
Sulfur Dioxide	PPM	1000	1101	998	1219	1251

1. Closed damper to position 1 from 10 positions (1 is fully opened and 10 is fully closed).

2. Closed damper to position 2 from 10 positions.

3. Fuel in computer was 19,360 BTU/lb versus approximately 16,500 to 17,000 as estimated for Mazut. Therefore efficiency, carbon dioxide, and excess air will be in error.

APPENDIX II

Energy Efficiency of Equipment

Serdika Milk Plant

Transformer Department	Power	Consumption	
		Maximal	Average
	kVA	kW	kW
1 TP1 - Milk	630	317	220
2 TP2 - Refrig.	1000	776	504
3 TP3 - Yogurt	630	149	69
4 TP4 - Refrig. (Italian)	630	336	167

Opportunities to increase energy efficiency:

A. Optimal loading of transformers. A local energy ring seems to be a good proposal to reach this goal. It will save approximately 21,000 lv per year.

B. Install the automatic system for measurement and control of power consumption (EKP-80). Expenditures will be 10,000 lv and the efficiency, due to the reduction of peak energy consumption, will be about 6,000 lv/year.

APPENDIX III

Steam Leaks

Serdika Milk Plant

The main steam lines are new and in good condition, the distributing stations, however, have leaks from flanges and glands of valves.

The condensate system is in poor condition; there is a return of condensate to the boilers from only the steam water heat exchangers, of approximately 8%.

Condensate from the distributing stations have not been returned at all due to missing or broken pumps and steam traps. There is no automatic system for controlling the condensate level in the banks.

APPENDIX IV

MEETING PARTICIPANTS

Meeting
April 3 and 4, 1991 (Wednesday and Thursday)

Name	Position	Affiliation
Norbert Methven	Engineer	International Resources Group
Christian Spassov	President	Ecotechproduct
Ivan Nickolov	Computers & Heating	Ecotechproduct
Petya Stoyanova	Interpreter & Computers	Ecotechproduct
Lyubomir Kaloferov	Director in Energy Department	Energy Department
Danail Danailov	Chief of Section	Energy Department
Svelta Razmova	Inspector of Energy Consumpt.	Energy Department
Emil Razmova	Inspector of Energy Consumpt.	Energy Department
Veselin Lishkov	Inspector of Energy Consumpt.	Energy Department
Valery Krastev	Inspector of Energy Consumpt.	Energy Department

Meeting
April 5, 1991 (Friday)

Name	Position	Affiliations
Norbert Methven	Engineer	International Resources Group
Christian Spassov	President	Ecotechproduct
Ivan Nicolov	Computers & Heating	Ecotechproduct
Petya Stoyanova	Interpreter & Computers	Ecotechproduct
Svelta Razmova	Inspector of Energy Consumpt.	Energy Department
Emil Nikolov	Inspector of Energy Consumpt.	Energy Department
Vaselin Lishkov	Inspector of Energy Consumpt.	Energy Department
Nedeltcho Nedeltchev	Chief Insp., Energy Consumpt./Sofia District	Energy Department
Ivan Kostov	Inspector	Serdika Milk Plant
Cyril Oklev	Deputy Director	Serdika Milk Plant
Jossif Penev	Mechanic	Serdika Milk Plant
	Chief Mechanic	

Meeting
April 6, 1991 (Saturday)

Name	Position	Affiliation
Norbert Methven	Engineer	International Resources Group
Christian Spassov	President	Ecotechproduct
Ivan Nickolov	Computers & Heating	Ecotechproduct
Petya Stoyanova	Interpreter & Computers	Ecotechproduct
Svetla Razmova	Inspector, Energy Cons.	Energy Department
Emil Nikolov	Inspector, Energy Cons.	Energy Department
Vaselin Lishkov	Inspector, Energy Cons.	Energy Department
Nedeltcho Nedeltchev	Chief Ins., Energy Cons./Sofia Dist. Inspector	Energy Department
Jossif Penev	Chief Mechanic	Serdika Milk Plant
Dimiter Nikolov	Mechanic, Boiler Room	Serdika Milk Plant

Meeting
April 8 and 9, 1991 (Monday and Tuesday)

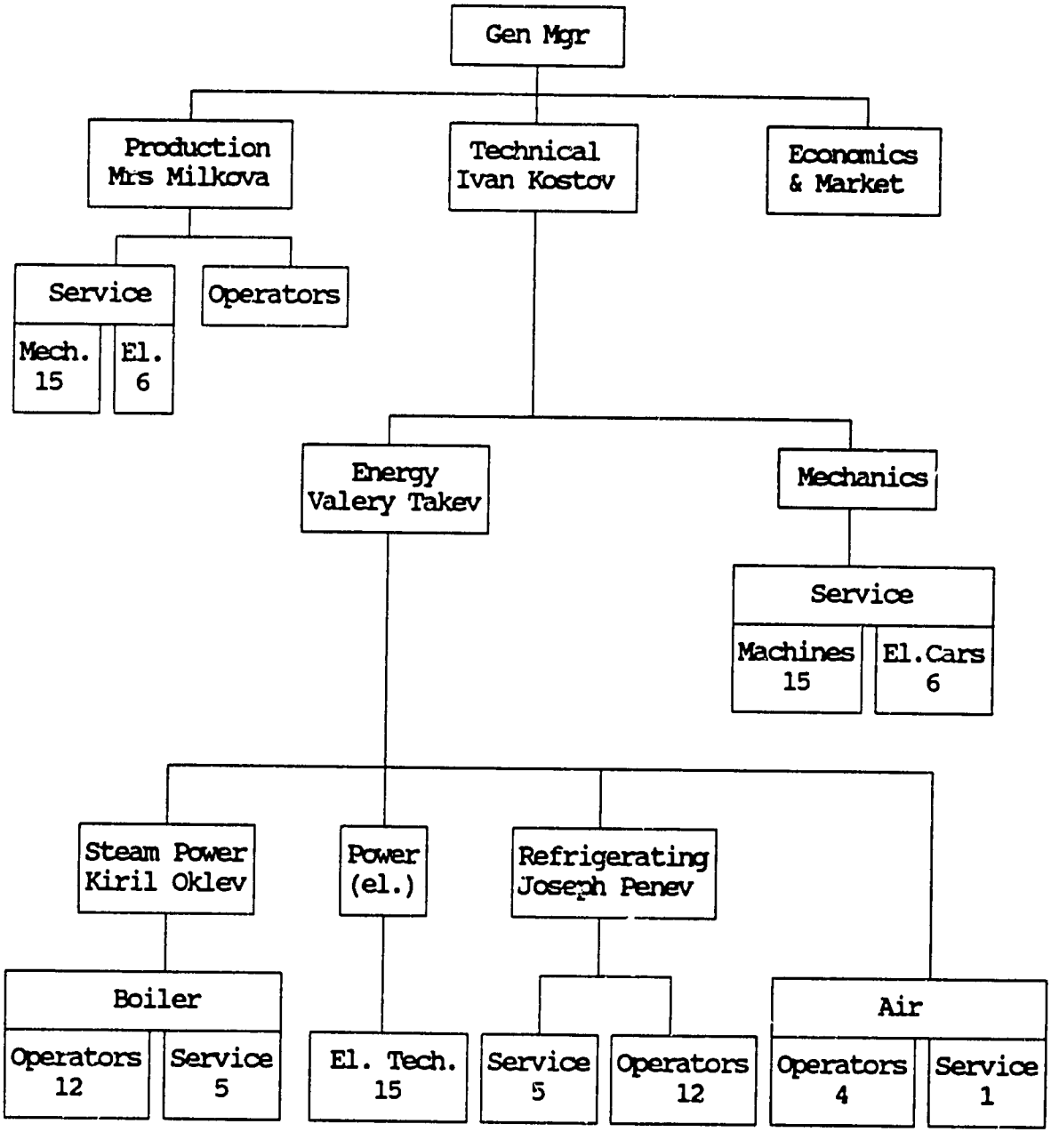
Name	Position	Affiliation
Norbert Methven	Engineer	International Resources Group
Christian Spassov	President	Ecotechproduct
Ivan Nikolov	Computers & Heating	Ecotechproduct
Petya Stoyanova	Interpreter, Energy Cons.	Ecotechproduct
Svetla Razmova	Inspector, Energy Cons.	Energy Department
Emil Nikolov	Inspector, Energy Cons.	Energy Department
Vaselin Lishkov	Inspector, Energy Cons.	Energy Department
Nedeltcho Nedeltchev	Chief Insp., Energy Cons./Sofia District Inspector	Energy Department
Ivan Kostov	Deputy Director	Serdika Milk Plant
Jossif Penev	Chief Mechanic	Serdika Milk Plant
Cyril Oklev	Mechanic	Serdika Milk Plant
Dimiter Nikolov	Chief, Boiler Room	Serdika Milk Plant

Meeting
April 11, 1991 (Thursday)

Name	Position	Affiliation
Norbert Methven	Engineer	International Resources Group
Christian Spassov	President	Ecotechproduct
Ivan Nickolov	Computers & Heating	Ecotechproduct
Mariana Strugarova	Interpreter & Computers	Ecotechproduct
Svetla Razmova	Inspector, Energy Cons.	Energy Department
Emil Nikolov	Inspector, Energy Cons.	Energy Department
Vaselin Lishkov	Inspector, Energy Cons.	Energy Department
Nedeltcho Nedeltchev	Chief Inspector, Energy Cons./Sofia District Inspector	Energy Department
Pelagia Milkova	Acting Director	Serdika Milk Plant
Ivan Kostov	Deputy Director	Serdika Milk Plant
Jossif Penev	Chief Mechanic	Serdika Milk Plant
Cyril Oklev	Mechanic	Serdiak Milk Plant

SERDIKA MILK PLANT

ORGANIZATION CHART



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APPENDIX V

EQUIPMENT SPECIFICATIONS AND JUSTIFICATIONS FOR PURCHASE OF EQUIPMENT

SERDIKA MILK PLANT, SOFIA

All consumable items and critical spare parts must be provided for two years usage. Two sets of operating and maintenance manuals are required, and equipment must be durable and proven for the service desired. Metric units are to be used unless otherwise specified. 220 V, 50 hertz power is available. Units should be complete and ready for installation with all required equipment, and quotations should provide complete installation sketch and description of all equipment to be supplied.

1. **Portable Infrared Temperature Measuring Instrument** -- to be used in conjunction with the flue gas analyzer and oxygen analyzer to assess and help minimize stack emissions, affecting the most efficient air/fuel mixtures. The infrared temperature measuring device will also be able to provide the necessary measurements associated with rebuilding and maintaining the condensate system and repairing steam leaks. Dickson Company model IR-550 or equivalent is recommended.

2. **Oxygen Analyzer** -- to be used in conjunction with the infrared temperature device and flue gas/emissions analyzer to analyze stack gas emissions, help and minimize emissions and affecting efficient air/fuel mixtures. Davis Instruments Model BC 108101 or Universal Enterprises Model C5A or equivalent is recommended.

3. **Replacement Oxygen Sensors** -- to provide replacement sensors for the oxygen analyzer, ensuring the effective operation of this instrument in the future; this would also facilitate analysis of stack emissions. David Model BC 108927 or Universal Enterprises Model AO51 or equivalent are recommended.

   For items 1-3:

Estimated annual energy savings:	620,690 KWh/year
Estimated cost savings:	180,000 levs/year ($12,000)
Estimated cost:	30,000 levs ($2,000)
Estimated Payback:	0.3 years

4. **Energy Efficiency Fluorescent (or Metal Helide) Lighting Luminaries** -- to be designed for the Yogurt factory with 100 Footcandles 4' above the floor. 220 volts, 50 hertz. To include 50 Fixtures, 100 spare tubes (lamps), and 20 spare ballasts or electronics. Fluorescent lighting designed for this factory would greatly improve energy efficiency, contribute to a probable increase in productivity, and decrease mistakes within the facility.

Estimated annual energy savings:	68,966 KWh/year
Estimated cost savings:	20,000 levs/year ($1,333)
Estimated Cost:	14,000 levs ($933)
Estimated Payback:	0.8 years.

5. **Industrial Stethoscopes** -- to be used with other appropriate equipment in support of work to rebuild and maintain the condensate system and to repair steam leaks, resulting in an overall increase in energy efficiency. Davis Instruments or equivalent vendor.

6. **Thermostatic Steam Traps** -- to be used to replace faulty steam traps as part of an overall strategy to rebuild and maintain the condensate system and repair steam leaks; recovery of condensate will yield significant energy savings. 1" 152 NPT, 1" 152 Internal Kit and 1" 152H Internal Kit in Stainless Steel where available. Yarway Models or Armstrong or equivalent recommended.

7. **Unibody Disc Traps with Strainer** -- to replace traps as part of an overall strategy to rebuild and maintain the condensate system and repair steam leaks. 3/4" 721 NPT, 3/4" 721 Internal Kit, 3/4" 721 Blowdown kit, 1" 721 NPT, 1" 721 Internal Kit, 1" 721 Blowdown Kit. Yarway or Armstrong Models or equivalent recommended.

8. **Unibody Variable Orifice** -- to be used as part of an overall strategy to rebuild and maintain the condensate system and repair steam leaks. 3/4" 741L NPT, 3/4" 741A internal Kit, 3/4" 741B Internal Kit, 3/4" 741C Internal Kit, 3/4" 741D Internal Kit, 3/4" 741 Blowdown Kit, 1" 741L NPT, 1" 741A Internal Kit, 1" 741B Internal Kit, 1" 741C Internal Kit, 1" 741D Internal Kit, 1" 741 Blowdown Kit. Yarway or Armstrong Models or equivalent recommended.

9. **Pipe Fittings** -- to be used as part of a strategy to rebuild and maintain the condensate system and to repair steam leaks. 3/4" Unions, 1" Unions, 3/4" x 6" nipples, 1" dia x 12" Nipples, 3/4" NPT Dies, 1" NPT Dies, Die Wrench/hande, 3/4" Strainer Y-type w/stainless steel woven strainer, 1" Strainer y-type w/ stainless steel woven strainer, 3/4" tees, 1" tees, 3/4" gate valves, 1" gate valves, 3/4" swing check valves, 1" swing check valves. American Building Supply is a recommended vendor.

<u>To rebuild and maintain condensate system</u>:

Estimated annual energy savings:	2,413,793 KWh/year
Estimated cost savings:	700,000 levs/year ($46,666)
Estimated cost:	65,000 levs ($4,333)
Estimated payback:	0.2 years

To repair steam leaks:

Estimated annual energy savings:	2,068,966 KWh/year
Estimated cost savings:	600,000 levs/year ($40,000)
Estimated cost:	10,000 levs ($667)
Estimated payback:	0.1 years

1. **Video tapes** -- videos on Principles of Operating Steam Traps, Trouble Shooting Steam Traps, Steam Trap Repairs, The Air in Steam, Guidelines for Steam Efficiency, Solving Water Hammer Puzzle, and A Matter of Principle - Comparison of Disc vs. Bucket Steam Traps. These videos, available through Armstrong Machine Works would be used with video equipment as teaching tools designed to complement efforts to rebuild and maintain condensate systems and repair steam leaks.

2. **Overhead Projector** -- to be used by the Committee on Energy as a teaching device in support of work to rebuild and maintain the condensate system and repair steam leaks, thereby contributing to the overall energy efficiency of the plant. Overhead projector with high intensity position and three spare lamps. 220 volts, 50 hertz. Lanier Presentation Systems (808-423-9657) or equivalent recommended.

3. **Transparency Film** -- to be used with the overhead projector as part of a teaching strategy designed to support the rebuilding and maintenance of the condensate system and the repair of steam leaks. Transparency Film 8 1/2 x 11" for use with plain paper copiers. 3M Model PP2200 or equivalent is recommended.

4. **Projection Screen with Retractable Floor Stand** -- to be used by the Committee on Energy as a teaching tool to complement activities designed to rebuild and maintain the condensate system and repair steam leaks. Approximately 42" x 42" screen.

Items 1-4:

Estimated energy savings	see above
Estimated cost	$2,800

APPENDIX VI

ADDITIONAL CHARTS

Refrig. & Heating

INSULATION OPPORTUNITIES

Date 04.06.91
Area Serdika Milk Plant

Location (Be Specific)	Comments *	Tag No.	Length **	Wid. **	Dia. **	Repair Costs $	Savings $/Yr	RC %
Refrigeration equipment and pipe line								
Near to Milk Shop	tank; t_s=0°C	1	12	5				
— " — " — " —	tank; t_s=0°C	2	7		1.7			
— " — " — " —	pipe; t_s=-5°C	3	9		0.08			
Refriger. station	tank; t_s=-5°C	4	12	6				
— " — " — " — 70%w.i.	tank; t_s=-5°C	5	5.5		1.2			
— " — " — " —	tank; t_s=-5°C	6	3		0.8			
— " — " — " —	tank; t_s=-5°C	7	3		0.8			
— " — " — 20%w.i.	tank; t_s=-15°C	8	2		1.0			
— " — " — "	tank; t_s=-12°C	9	3		0.6			
— " — " — " —	pipe; t_s=-10	10	60		0.219			
— " — " — " —	pipe; t_s=-5	11	10		0.159			
— " — " — " —	pipe; t_s=-10	12	30		0.05			
Heating pipe line & cond. tanks								
Heating station yoghurt milk	pipe; t_s=160°C	13	6		0.05			
— " — " — " —	tank; t_s=90°C	14	3	3	1			
Heating st. fr. milk	— " — ; t_s=80°C	15	2.5	2.5	1			
Steam boiler st	pipe; t_s=60°C	16	10.0		0.133			
— " — " —	pipe; t_s=35°C	17	27.0		0.075			
— " — " —	pipe; t_s=140°C	18	30.0		0.159			
— " — " —	pipe; t_s=140	19	30.0		0.08			

* Indicate what it is: tank, pipe, duct, etc.
** Show all dimensions in feet, except show pipe diameter in inches.

For pipe, annual cost (multiply by 2 for outside items).
For flat surfaces, annual cost (multiply by 2 for outside items).

Formulated by:
1. eng. Joseph Penev
2. eng. Ch. Spassov

CONDENSATE LEAKS

Date 06.04.91
Area Yerka dairy plant

	Location (Be Specific)	Comments	Tag No.	* GPM	Repair Costs $	Savings $/Yr	P.C %
1	Steam boiler st - two leaks from flanges at the steam lines						
2	Yoghurt shop (heating st) There are mount. cond. tank's (two) without insulation and cond. pumps						
3	Fr. milk shop (dist. heating st) It is the same situation. There aren't cond. pumps. Some of the cond. lines from the consumators to the cond. tanks are broken out						
4	Ice-cream shop (dist. heating st) There are two cond. tanks one cond. pump but the cond. goes in the channel.						
5	Proposition: 1.						
					?	+	
					65,000	500,000	

* all condensate returned at 55 psig values.

For 12 months leaks, 1 GPM = .

See over

Savings 65,000 60,000

cpw/0212/c25-5
2C 02/12/86

ELECTRICAL OPPORTUNITIES

Date april 04. 91.
Area (LW) [БР] Seadika MP

Location (Be Specific)	Comments *	Tag No.	Type **	Watt / HP	No.	Repair Costs $	Savings $/Yr***	RC %
C. Обвиване на осветителните тела с светлоотразително фолио								
Wrapping lighting equipments with reflecting foil								
1. Цех кисело мляко Yogurt milk dept.	Външно inner		FL	19000	185	9250	8700	
2. Цех кисело мляко Yogurt milk dept.	Външно inner		FL	40000	380	19000	18400	
3. Цех сладоледа Ice cream Dept	Външно inner		FL	18000	180	9000	4200	
					2	40,00		
		2	1 lamp; @	12Lm				
D. Подмяна на осветителните тела с по-ефективни								
Replacement of lighting equipment with more efficient ones								
1. Цех прясно мляко Milk dept	Външни in door		FL	19000	185	46250		
2. Цех кисело мляко Yogurt milk dept	Външни in door		FL	40000	380	95000		
3. Цех сладоледа Ice cream dept	Външно in door		FL	18000	180	45000		
F. Подмяна на дроселите на лампите с по-ефективни								
Replacement of ballasts of lamps with more efficient ones								
1. Цех прясно мляко Milk dept.	Външно in door		FL	19000	185	5550		
2. Цех кисело мляко Yogurt milk dept.	Външно in door		FL	40000	380	11400		
3. Цех сладоледа Ice cream dept.	Външно in door		FL	18000	180	5400		

* Indicate whether it is inside or outdoor lighting.
** For type show MV = mercury vapor, HPS = high pressure sodium, INC = incandescent, and MH = metal halide. FL
*** Unless actual HP is known, multiply nameplate HP rating by 1 HP costs.

Formulated by:
eng. E. Nicolov

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ELECTRICAL OPPORTUNITIES

Date april 04, 91
Area "Serdika" MP

Location (Be Specific)	Comments •	Tag No.	Type ••	Watt / HP	(Бр) Nc.	Repair Costs $	Savings $/Yr•••	RC %
A. Почистване на лампите и осветителните тела								
Cleaning of lamps and lighting equipments								
1. Цех прясно мляко	Вътрешно		FL	19000	185	2100		
Fresh milk shop	indoor		INC	9000	150	150		
2. Цех кисело мляко	Вътрешно		FL	40000	380	5320		
Yoghurt shop	indoor		INC	4800	80	80		
3 Цех сладолед	Вътрешно		FL	18000	180	2520		
Ice-cream shop	indoor		INC	3600	60	60		
	300 кВар							
4 Складове и гаражи	Вътрешно		FL	7200	60	840		
Storages and garages	indoor		INC	9000	150	150		
5. Двор	Външно		HPS	15000	60	1200		
Yard light	outdoor							
B. Подмяна на лампите с по-ефективни (INC → FL)								
Replacement of lamps with more efficient								
1. Цех прясно мляко	Вътрешно		INC	9000	150	15000	3700	
Fresh milk shop	indoor							
2 Цех кисело мляко	Вътрешно		INC	4800	80	8000	1800	
Yoghurt shop	indoor							
3. Цех сладолед	Вътрешно		INC	3600	60	6000	1320	
Ice-cream shop	indoor							
4. Складове и гаражи	Вътрешно		INC	9000	150	15000	3400	
Storages and garages	indoor							

• Indicate whether it is inside or outdoor lighting.
•• For type show MV = mercury vapor, HPS = high pressure sodium, INC = incandescent, and MH = metal halide. FL
••• Unless actual HP is known, multiply nameplate HP rating by 1 HP costs.

Formulated by:
eng. E. Nikolov

STEAM LEAKS

Date 04.06.91
Area Lendica milk plant

Location (Be Specific)	Comments	Tag No.	* Size	Repair Costs $	Savings $/Yr
1 Boiler station - main steam collector	gland of valve	W	14 un	@70	$ 140,000
		M	1 un	46 @6,000	30,000
2 Distribute station for fresh milk shop	gland of valve	W	3 un	560	30,000
	flange	M	3 un	8098	240,000
3. Distribute station for office use building	there is a steam is hole space				
4. Distribute station for yoghurt shop	gland of valve	W	2 un	230	20,000
5 Distribute heating station for ice-cream shop	gland of valve	W	5 un	811,5	50
6. Auto wash basin - steam collector	the drain valve doesn't work well	M	1 un	61,5	30,
	gland of valve	W	2 un	241,5	20,
				740310	
			Sav.	10,000	610,000

Note: The costs above are in a case of changing the wrong valves to achieve highest reliability.
The repairing can be cheaper - average about 30lv per valve - 31un x 30lv = 930lv

* Can use the following code for leak size: W = wisp, M = moderate, S = severe.

(610,)

For 12 months leaks, wisp = , moderate = , severe = .

cpw/0212/c25-4
2C 02/12/86

AIR LEAKS

Date April 6 1991
Area Serdika

Location (Be Specific)	Comments	Tag No.	* Size	Repair Costs $	Savings $/Yr	KO: %
(1) Pasteurization Department; Distribution box; middle	weak whisp			200	Low / 800	
(2) Packing yogurt Dept. — Hamba 4	severe			"	8000	
(3) Packing yogurt Dept - Hamba 3	average			"	1600	
(4) Packing yogurt Dept - Aman 1	weak			"	800	
(5) Packing yogurt Dept - Aman 2	average			"	1600	
(6) Packing yogurt Dept - condensate separator	severe			"	8000	
(7) Compressor Dept Second receiver (air) manometer	average			"	1600	
(8) Condensate Dept. - manometer	weak			"	800	
(9) Old compressor; cooler	severe			"	8000	
(10) Packing milk dept - machine No. 6	severe			"	8000	
(11) Packing milk dept - machine No. 5 (two leaks)	average			"	1600	
(12) Packing milk dept - machine No. 4 (two leaks)	average			"	1600	
(13) Packing milk dept - tube passing air to mech. No. 5 and 6 - next room	average				1600	

* Use following hole sizes (inches): 3/64, 1/16, 1/8, 3/16, 1/4, 3/8, 1/2.

For 12 months leaks, 3/64 = 0.3 KW, 1/16 = 0.4, 1/8 = 3.1, 3/16 = 8.3, 1/4 = , 3/8 = , 1/2 = .

X 5760 = KWH/yr	2625	5250	27,000	22000	~40,000
@ 0.3 $/KWH	800	1600	8,100		
	Wisp	Avg	8-19 Severe	Sug 4000	

epw/0212/e25-3
2C 02/12/86

APPENDIX VII

"ENERGY MANAGEMENT PRACTICES"

PRESENTATION OF MR. BARRY TUNNAH AT THE ENERGY MANAGEMENT WORKSHOP

SOFIA, BULGARIA

JANUARY 1992

ENERGY MANAGEMENT PRACTICES: A BRIEF REVIEW

I. INTRODUCTION

Why is energy conservation important? The simplest answer is that it makes a firm more profitable. By practicing good energy management techniques through a well structured and organized company plan, management and employees become more aware of how energy is being used, of the actual costs of energy, and of the methods and equipment that can be used to control and reduce energy waste.

Energy management is a disciplined activity, organized for the more efficient use of energy without reducing production levels or lowering product quality, safety, or environmental standards. The underlying principle is cost effectiveness. Energy management therefore requires both technical and financial evaluations. A systematic and structured approach to energy management is required to identify and to realize full potential savings.

It is apparent that many companies and plants have not identified even simple energy conservation measures with short payback periods, and many who have identified such opportunities fail to implement them. Many studies show that the main barriers to action on energy conservation are:

* lack of knowledge of what is technically possible
* inappropriate financial analysis methods
* management attitudes towards energy efficiency

The greatest successes generally occur at companies where management visibly supports an integrated energy management program.

At the plant level, benefits include:

* lower production costs and higher profits
* better competitive position

* improved ability to withstand future energy cost increases
* improvements in productivity in general
* environmental benefits

The potential benefits of solid energy management are entirely dependent on the nature of the plant concerned. However, savings for a plant which is starting an energy management program are often 20 to 30 percent of present energy consumption, and even more in many cases. For most firms, energy conservation makes very good business sense.

II. THE ENERGY MANAGEMENT APPROACH

2.1 Where To Start

How does a company begin to address the problem of controlling energy consumption and costs? The answer will depend to a great extent on the company concerned -- its current organization and management philosophy. Two points are particularly important.

* top management must be fully committed to controlling energy costs
* the appropriate organization must be set up to implement, and be accountable for, the energy management program

2.2 Top Management Commitment

The decision of company management to control energy costs is a vital first step. This must be clearly stated and understood by all within the company. An important part of top management commitment is to set up the responsible organization for implementing the energy management program. This is commonly at two levels, the Energy Manager and the Energy Committee.

2.3 The Plant Energy Committee

Because energy concerns different departments within a firm, an effective energy management program will involve many people. In some companies, a committee is formed to include representatives of important departments. While unnecessary bureaucracy must be avoided, there are advantages to having an active Energy Committee at the plant:

* it can encourage communications and the sharing of ideas
* it can serve to obtain agreements on energy saving projects which affect more than one department
* it can provide a stronger voice to top management than a single manager normally could

Membership will depend on existing management structures at the type and quantity of energy used. When should the Committee meet? Normally a monthly meeting is usual, so that monthly production and energy consumptions may be reviewed, including a comparison of actual performance against previously set targets. Other items for the agenda should be a review of the status of energy conservation investments, in progress or planned.

2.4 The Energy Manager

Forming an Energy Committee is not enough: someone is needed to implement the policies and directives of the Committee, and to provide the data needed by the Committee to make decisions. Appointing an Energy Manager is therefore an essential step in implementing an energy management program in most companies. The role will vary from company to company but he will normally be concerned with the following tasks:

* collecting and analyzing energy related data regularly
* monitoring energy purchases
* identifying energy saving opportunities
* developing projects to save energy, including the necessary technical and economic evaluations
* implementing energy saving projects
* maintaining employee communications and public relations

In some companies, particularly the smaller ones, the Energy Manager may report directly to the General Manager or Plant Manager and may be part-time. Larger companies may appoint a full-time Energy Manager and give him one or more technical assistants, thus forming an "energy conservation group". Wherever possible, the Energy Manager or Group should be independent of the main operating departments: reporting to the highest level, such as the Plant Manager, can often give the needed independence and authority.

The skills and experience of the Energy Manager need careful consideration. Technical competence is usually regarded as the primary qualification, although this may not be as important as often thought. In smaller companies, good technical skills may be helpful because the Energy Manager will probably carry out much of the work himself. In a larger company, where technical skills are more readily available, the Energy Manager may well be someone with experience in accounting or general management.

The particular skills that are important for an Energy Manager include administration and communication. Most Energy Managers need to spend much of their time convincing their colleagues and top management to take a specific line of action. Some typical qualifications are:

* familiarity with the plant, processes and quality needs
* ability to collect and analyze data
* knowledge of energy-consuming equipment and factors affecting its efficiency
* engineering skills to size and select equipment, supervise installation and ensure correct maintenance
* ability to communicate and interact well with both plant management and with line operators and maintenance workers
* good judgement to know when to call upon outside help such as consultants or equipment vendors
* proper perspective of the role played by energy in the company, in relation to other elements such as raw materials, capital and labor
* ability to use initiative, a "self starter"

Above all, the Energy Manager needs an open mind to view problems from different perspectives and the skill to convince others that savings are both possible and worthwhile if the right measures are taken.

III. MEASURING ENERGY AND ITS COSTS

3.1 Introduction

Energy management is concerned with the efficient transfer of the energy in fuels and electricity into useful work or heat. It is essential to be able to measure energy inputs and outputs, using various types of meters and instruments, either fixed in the plant or, in some cases, portable. It also requires knowledge of fuel, steam and electricity characteristics to enable comparisons to be made on a common basis.

3.2 The Heating Values of Fuels

An important characteristic of an energy source is the energy contained per unit of mass or volume (the heating value, heat of combustion or calorific value). There are two values associated with fossil fuels, a higher (or gross) heating value and a lower (or net) heating value. The higher heating value includes the latent heat of water vapor formed during combustion as it condenses back to the liquid state. The heating value generally determined in the laboratory is the higher value. The difference between the higher and lower heating values for a fuel is a function of the hydrogen content of the fuel, as this determines the amount of water formed. Some typical ratios of lower to higher heating values are:

	Ratio LHV/HHV
Natural gas	0.90
Fuel oil	0.94
Coal	0.98
Electricity	1.00

In carrying out energy related calculations, it generally makes little difference which heating value is used. The essential principle is to be consistent and use the same basis for all fuels. The convention used should always be clearly stated.

3.3 Unit Energy Costs

An important step to controlling energy costs in a plant is to determine the unit costs of the different energy forms. For example, the cost may be constant, irrespective of the level of consumption (e.g., 150 USD per ton of a specified fuel oil). Some fuels and electricity may have a tariff which varies in accordance with the quantity consumed in a set period of time (e.g., 4.5 US cents per kWh of electricity up to 100 kWh per month, 2.5 cents per kWh thereafter). There may also be other complication factors, such as a "demand charge" for electricity or gas, which is a cost element set by the highest actual level of demand in the period (e.g., 25 USD per kW maximum demand) or even by the maximum contract or maximum allowable connected load.

Some forms of energy are also subject to a surcharge for peak period. Electricity consumption may be subject to a "power factor penalty" through which the plant is penalized if it consumes too much reactive power.

For practical reasons, it may often be more meaningful for energy savings calculations for the Energy Manager to compute the **marginal cost** of energy, that is, the cost incurred for consuming one more unit of the particular form of energy (or conversely, the amount saved by consuming one unit less of the particular energy form). A cost-conscious manager will know the unit cost of his energy consumptions and will think in terms of cost savings when he observes operations that are perhaps not optimum or when he suggests priority for a particular maintenance job.

3.4 The Cost of Steam

This is a special case of the unit costs mentioned above. The plant Energy Manager should calculate the cost of steam and advise plant managers. The basic calculation requires the cost of boiler fuel, fuel heating value, water costs, condensate recovery temperature and rate, boiler efficiency and the steam characteristics: these are sufficient for estimating a "marginal" steam cost, one that ignores the labor cost for boiler and steam system operation, maintenance costs and the cost of capital investment. For most practical purposes, the marginal cost is sufficient for making decisions on energy saving actions or investments, as 2these are usually based on differences between costs and savings for various options, and the "excluded" costs are typically the same for all options.

A plant Energy Manager can develop his own graph to show his own plant situation most accurately. A graph provides a simple way of evaluating the relative merits of different fuels, the benefits of improvements in boiler efficiency, or the savings possible from reducing steam use.

3.5 Energy Accounting

Accounting for energy, in its simplest terms, means keeping accounts of energy consumption and energy purchases for the plant. At a more detailed level, it may mean assigning energy costs to different departments. The term "monitoring" is used for maintaining a careful check of energy consumption and, usually, to analyzing energy use.

IV. DATA ANALYSIS

4.1 Graphing the Data

Data should be presented graphically as a better appreciation of variations is almost always obtained from a visual presentation. For example, charts of energy consumption and production against time are drawn at many plants and are usually more enlightening than columns of numbers. However, these graphs tell us little about the relationship between energy and production and therefore are not useful for energy management. Unfortunately, many plants fail to go beyond the drawing of the basic graphs, whereas further simple analysis is needed to give us a great deal more useful information quite quickly.

4.2 Energy-Production Relationships

For a typical plant, a plot of "energy used per month" against "monthly production" can reveal a great deal about energy efficiency. Separate graphs should be drawn from fuel and electricity use. For most plants, the energy-production graph will be a straight line. There are two components of the energy consumption:

* energy directly related to production (mP)
* energy not directly related to production (e)

The energy used by the plants is the sum of the two components, represented by the basic equation for a straight line:

$$E = mP + e$$

where E is the monthly energy consumption, P is the corresponding monthly production, **m** represents the slope of the line and **e** is the y-axis intercept (daily or weekly data can be used also). Physically, "e" refers to non-production related energy, that is, energy losses or energy used for general plant services:

* lighting, office equipment, ventilation fans
* space conditioning (heating or cooling)
* unnecessary idling of production equipment
* energy in the steam lost in leaks
* radiation and convention heat losses from boilers
* heat losses from steam distribution piping

A graph of **E** against **P** will quickly show the Energy Manager the proportion of energy consumption which corresponds ton non-productive energy (services and losses). If this is high, the Energy Manager can look for ways of cutting down "e", for example:

* replace old lighting units by high efficiency lighting
* eliminate leaks from the compressed air system
* ensure equipment is switched off when not in use
* improve the insulation of the steam distribution system

To cut down on the use of "productive" energy, he might:

* reduce process temperatures to the minimum permissible
* optimize combustion efficiency of boilers and furnaces
* install a heat recovery system

Through such measures, the Energy Manager will seek to reduce the slope of the E-P line as well as reduce "e".

Scattering of points in the E-P graph is a general indication of the level of energy management in the plant. Widely scattered points usually mean that energy use is not properly controlled and operating practices in general are poorly defined and inadequately monitored by supervisors and managers.

4.3 Specific Energy Consumption

Many plants calculate Specific Energy Consumption (SEC) regularly. SEC is the energy used per unit of output, E divided by P. For a typical plant, where the E-P relationship is a straight line, we have:

$$SEC = \frac{E}{P} = m + \frac{e}{P}$$

A graph of SEC against P will therefore be a curve, not a straight line. Figure 4.3 shows a typical SEC-P graph: points lying below the curve represent improved efficiency in energy use relative to the "average performance" represented by the curve itself. Figure 4.3 also shows two points, A and B. The Specific Energy Consumption is certainly lower at B and many engineers think therefore that the point with the highest energy efficiency is B. Indeed, if the energy, production and SEC data are merely shown as a table of numbers (as too many plants do) it is quite easy to draw this erroneous conclusion. When the points are shown on a graph, it becomes clear that B is a point at which energy efficiency is relatively low while A represents a time of good operation at high energy efficiency, albeit at a low production level.

Specific Energy Consumption figures therefore have little meaning unless they are associated with a production rate. Following SEC alone is not the answer to good energy management in any plant where the production rate varies more than a few percent from day to day or month to month.

4.4 The CUSUM Technique

A simple quantitative procedure allows the Energy Manager to evaluate plant performance month by month and to estimate savings made through implementing energy conservation measures (or conversely, the losses occurring due to deficiencies in performance). The method is known as the CUSUM technique, as it relies on calculating "the Cumulative Sum of Differences". The method is applied in the following way:

(1) Plot the E-P graph for a period in which operations were generally similar and during which no major energy conservation measures were introduced.

(2) Find the best fit straight line for the data points.

(3) From each time period, compute the estimated energy use from the straight line equation.

(4) Calculate the differences between calculated energy use and actual energy consumption for corresponding periods.

(5) Compute the cumulative sum of these differences.

If the differences between actual and calculated energy consumption are random, some positive and some negative, then the cumulative sum of these differences should fluctuate around zero. If there are any significant changes in energy efficiency after the "base period" for

which the straight line was derived, the differences will accumulate (either positive or negative) and a graph of CUSUM against time will show this clearly.

The Energy Manager can thus determine quantitatively the impact of a change in energy efficiency by examining the CUSUM graph. The procedure may be illustrated by a simple example:

Energy consumption and production data were collected for a plant over a period of 18 months. During month 9, a heat recovery system was installed. Using the plant monthly data, estimate the savings made with the heat recovery system. The plant data are:

	E monthly energy use toe/month	P monthly production tons/month
1	340	380
2	340	440
3	380	460
4	380	520
5	300	320
6	400	520
7	280	240
8	424	620
9	420	600
10	400	560
11	360	440
12	320	360
13	340	420
14	372	480
15	380	540
16	280	280
17	280	260
18	380	500

* Step 1 -- plot the E-P graph for the first 9 months
* Step 2 -- draw the best fit straight line
* Step 3 -- derive the equation of the line

The steps are completed in Figure 4.4 and the equation is:

$$E = 0.4\,P + 180$$

* Step 4 -- calculate the expected energy consumption based on the equation
* Step 5 -- calculate the differences between calculated and actual energy use
* Step 6 -- compute the cumulative sum of differences

These steps are done in the table below:

	E act	P	E calc	Eact-Ecalc	CUSUM
1	340	380	332	+8	+8
2	340	440	356	-16	-8
3	380	460	364	+16	+8
4	380	520	388	-8	0
5	300	320	308	-8	-8
6	400	520	388	+2	-6
7	280	240	276	+4	-2
8	424	620	428	-4	-6
9	420	600	420	0	-6
10	400	560	404	-4	-10
11	360	440	356	+4	-6
12	320	360	324	-4	-10
13	340	420	348	-8	-18
14	372	480	372	0	-18
15	380	540	396	-16	-34
16	280	280	292	-12	-46
17	280	260	284	-4	-50
18	380	500	380	0	-50

* Step 7 -- plot the CUSUM graph -- see Figure 4.5

* Step 8 -- estimate the savings accumulated from use of the heat recovery system

From Figure 4.5, we see that the CUSUM graph fluctuates around the zero line for several months and then drops sharply after month 11. This suggests that the heat recovery system took almost two months to commission and reach proper operating conditions, after which steady savings have been achieved. Based on the graph, savings of 44 toe have been accumulated in the last 7 months. This represents savings of almost 2 percent:

$$\frac{44 \times 100}{\text{energy use in months 12-18 (2352 toe)}} = 1.9\ \%$$

The CUSUM technique is a simple but remarkably powerful statistical method which highlights small differences in energy efficiency performances. Regular use of the procedure allows the Energy Manager to follow his plant performance and to spot any trends at an early date.

4.5 Performance Evaluation

Evaluation of plant performance is best done by regularly comparing the actual energy consumption with the expected consumption. Differences between actual energy use and

standards based on past performance will reveal either improvements or a deterioration in performance. The regular data indicate if and where failures have occurred and trigger the necessary remedial action: the data also provide quantified evidence of exactly how successful any energy conservation measures have been.

It is important that performance evaluations be carried out promptly at the end of each month. A review of plant performance is a useful task for the plant Energy Committee. If the analysis is left for too long, it becomes much more difficult to account for any discrepancies that are observed, and of course it is always desirable that corrective measures be taken as soon as possible.

4.6 Monitoring and Targeting

"M & T" is a management approach that enables firms to manage energy as a controllable resource in the same way as they manage other resources such as raw materials and manpower. M and T helps companies eliminate waste and also provides the incentive for further improvement by giving concrete evidence of successful energy conservation activities, from which the economic benefits of energy management become evident.

Central to the success of M and T is the establishment of "energy accountable centers" for which targets can be set. A center might consist of an individual machine, a process department or even the entire site. Recording and reporting procedures for the centers should be set up. Each center should correspond to a nominated individual responsible for operational achievements in that area. Tying resource consumption to those responsible for operational achievement is a key factor in the M and T system since it focusses attention on those with authority to effect improvements in performance. It is also essential that those held accountable for energy performance should be able to assess that performance and have the pertinent information on which to base judgements, decisions and actions to bring about improvements.

Targets may be set using a detailed engineering analysis of operations, or can be developed using historical data such as that described earlier. Graphs of E-P and SEC-P will reveal the occasions when energy efficiency are particularly high, and thus it would be reasonable to use the best historical performance (or something close to that) as a challenging but attainable target.