Industrial Energy Efficiency Opportunities in Ukraine

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ABSTRACT

As part of the energy assistance program to help Ukraine shut down the Chornobyl nuclear reactors, the U.S. Department of Energy (DOE) asked the Pacific Northwest National Laboratory (PNNL) to identify and appraise industrial energy efficiency projects in Ukraine. The industrial sector currently accounts for over 60% of Ukraine's energy consumption. Most industrial enterprises in Ukraine use energy very inefficiently because the former Communist system provided few incentives to conserve energy or even account for its cost. Since 1994, however, the country's energy prices have risen close to world levels, and Ukraine finds itself saddled with very high energy costs. The Ukrainian Government is also under pressure to lower natural gas imports and reduce the country's trade imbalance with Russia. As a result, incentives to save energy in Ukraine are now great, and the market for energy efficiency products is growing. The Ukrainian Government estimates that this market will generate from $700 million to $1 billion worth of new product sales by the year 2000. However, few industrial enterprises have the money necessary for large-scale energy efficiency improvements. Therefore, one of the main goals of this project is to help the most promising enterprises obtain financing for energy efficiency projects from a variety of financial institutions, or through new, creative financing mechanisms.

The project has involved several site visits to different industrial plants in Ukraine to gather preliminary data on the facilities. Most of these plants are in the process of being privatized or have been recently privatized and are financially sound. Among the plants visited have been a glass manufacturing plant, a coke-chemical plant, a paper mill, an alumina plant, a tire factory, a food processing plant, an iron mine, a metallurgical firm, and a steel cable factory. Following a preliminary analysis of the site-specific data obtained during the first visit, a limited number of plants were chosen for a more detailed energy audit and financial assessment. Results of a detailed engineering analysis and a financial assessment of each plant led to a prioritized list of recommended energy efficiency measures. The recommendations made to the plant management at two of these facilities are reported here. In addition, audits were conducted at some of the secondary plants and their results are reported as well. Some specific technologies recommended in the course of this work have included installing a new Western glass furnace at the Gostomel glass plant, which not only saves energy but also increases the volume and quality of glass production. The gas turbine cogeneration plant proposed for the coke-chemical plant will use coke-oven gas, a by-product of the coking process, as the primary fuel. Some of the more generic

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energy saving measures that could apply to a majority of the industrial facilities include replacing an existing compressed-air system with high-efficiency equipment, upgrading the lighting system, and installation of heat recovery systems. This paper describes the process of identifying opportunities and discusses some of the recommendations made to the plant management at some of these facilities. The paper also provides an update on the implementation plans for some of the recommended energy efficiency measures.

BACKGROUND

Ukraine is a large, new market for energy efficiency. The country has a population of 51 million and imports about $12 billion worth of goods and services every year. The market for energy efficiency equipment and services is substantial. Ukrainians can no longer afford to use energy inefficiently because energy prices in Ukraine are now close to world prices and are no longer subsidized, as they used to be under the old Soviet system.

The bulk of the energy efficiency market is in the industrial sector. Industry accounts for 60% of the total energy use in Ukraine. In recent years, industrial enterprises have felt increasing pressure to reduce their energy use; energy subsidies are disappearing and many enterprises are privatized or on the path to privatization, which means they can no longer rely on the state for general subsidies. One might ask why these enterprises have ignored cost-effective energy efficiency opportunities, given the rising energy costs. Part of the reason is that there are several barriers to energy efficiency and business overall in Ukraine, including high risk, the non-payments problem[2], lack of financing, and lack of infrastructure.

While doing business in Ukraine may at first seem a daunting undertaking, companies can take several steps to minimize the risks and difficulties. A reliable local partner is crucial, particularly when a company is first starting to work in Ukraine. One such partner that PNNL staff chose to work with is the Ukrainian Agency for Rational Energy Use and Ecology (ARENA-ECO) that can provide basic market data and can help companies with more specific needs through individual contracts. For example, within the industrial sector, there are a few basic characteristics to look for in an enterprise, that will make structuring and financing deals easier:

- Hard currency earnings
- Proportionally large energy costs
- Market-oriented management team
- Financial viability.

Metallurgical, chemical and oil refining enterprises are likely to export their products and have hard currency earnings. Enterprises in these industries also consume large quantities of energy because of the nature of their businesses. However, the management style of these enterprises in these sectors varies significantly. As a rule, an enterprise that is slated for privatization or is currently privatized is more likely to have a market-oriented management team than one that is protected from privatization and market forces.

[2] Non-payments or arrears problem is one when a plant does not pay in full for the goods and services it consumes. For example, industrial plants often have debts for the natural gas they use.

MOTIVATION

In the fall of 1994, the U.S. Department of Energy (DOE) asked the Pacific Northwest National Laboratory (PNNL) to identify energy efficiency opportunities in Ukraine that could help offset the loss of power from Chornobyl when the damaged reactor and the rest of the plant is closed. To this end, staff from the Advanced International Studies Unit (AISU) of PNNL organized a mission to Ukraine with ARENA-ECO staff. The mission team reviewed information on a large number of Ukrainian industrial enterprises based on their size, energy use and the particular sectors they represented. Later, PNNL also sought the services of a Ukrainian financial appraisal firm called Industrial Real Estate (IRE). Based on the information gathered and discussions with Ukrainian government officials, the team decided to visit several enterprises to meet with the management teams and get some first-hand but preliminary information on the enterprise's status and philosophy with respect to energy efficiency improvements. Most of these plants have either been recently privatized and are financially sound, or are in the process of being privatized. They can afford to spend their own money or obtain financial loans to fund the energy efficiency opportunities identified during this project. Among the various plants visited by the team are a glass manufacturing plant, a coke-chemical plant, a paper mill, an alumina plant, a tire factory, a food processing plant, an iron mine facility, a metallurgical firm, and a steel cable factory. Following a preliminary analysis of the site-specific data obtained during the first visit, a limited number of plants were chosen for a more detailed energy audit and financial assessment. A detailed engineering analysis and a financial assessment of the plant led to a prioritized list of recommended energy efficiency measures. The rest of this paper describes the process of identifying opportunities and discusses the details of the engineering analyses, life cycle cost analyses and other financial considerations that led to some of the recommendations made to the plant management at some of the enterprises. An update of the implementation plans for some of the recommended energy efficiency measures is also provided at the end of this paper.

ENERGY EFFICIENCY AT THE GOSTOMEL GLASS PLANT

The Gostomel Glass Plant produces bottles for beverages, perfumes and pharmaceuticals. Its customers include Coca-Cola, Pepsi-Cola, Obolon (a large Ukrainian brewery) and several Ukrainian cosmetic and pharmaceutical companies. Gostomel's plant is located 16 miles from the city of Kiev. The plant has run continuously at full capacity in recent years. Much of this success can be attributed to Gostomel's creative market-oriented management style, in place since the company was privatized in 1993. Gostomel's management and board of directors realize that the plant uses energy very inefficiently compared to similar plants in the West. This high energy use has created high costs. Gostomel management also knows that it could expand its market and sales if it could increase production capacity. PNNL and ARENA-ECO staff conducted a detailed energy audit of the Gostomel plant, the findings of which are described below.

The most significant energy efficiency measure considered was replacing glass furnace number 3 with a new, Western-design glass furnace. This measure will produce large energy savings and will also allow Gostomel to increase the volume and quality of its production. The energy savings alone will not pay for the furnace, as indicated in the chart below. Nonetheless, the total

improvement to the plant capacity and the product quality due to the new furnace will likely make it a very appealing investment. In addition, the following measures were recommended:

- installing a high-efficiency compressed-air system, including several new compressors, an automatic control system and a refrigerated air dryer system
- installing heat recovery hot water boilers in the glass furnace exhaust system and a new hot water boiler
- upgrading piping insulation on the hot-water distribution system
- relocating the air intake for screw-type air compressors to outside the compressor building.

Table 1 summarizes the results of the energy audit and lists the proposed energy-efficiency measures (along with the internal rates of return (IRR) on the investments) identified to be potentially cost-effective for the Gostomel Glass Plant. The discussion that follows the table is a more detailed description of each of the recommended energy efficiency measures.

Table 1. Summary of Proposed Energy-Efficiency Measures (Gostomel Glass Plant)

Measure	Cost (US $)	Annual Savings (US $)	Simple Payback (years)	Internal Rate of Return (IRR) (%/yr.)
High-efficiency compressed-air system and controls	967,754	193,862	5.0	19.5
Heat recovery hot water boilers in glass furnace exhaust systems	530,900	156,395	3.4	29.3
Relocate compressor air-intake outside the compressor building	4,000	2,130	1.9	53.2
Piping insulation upgrade	39,070	14,550	2.7	25.1
Upgrade glass furnaces*	18,190,000	592,900	--	--

* This measure was recommended as a modernization project. It cannot be economically justified based on energy savings alone. As a result, the simple payback and IRR based on energy savings are not meaningful, so these calculations have been omitted.

Discussion of Gostomel Plant Measures

Upgrade glass furnaces

The largest energy consumers at the Gostomel Glass Plant are the three glass furnaces. The glass furnaces also hold the largest opportunity for energy savings. Unfortunately, as with many manufacturing processes, energy savings alone can not economically justify the replacement and upgrade of the glass furnaces. Energy savings can, however, sometimes justify incremental improvements to manufacturing equipment as they are replaced as part of a modernization process.

Gostomel is currently evaluating a proposal from a glass furnace company, Sorg, as part of a modernization of the manufacturing process. If constructed according to the specifications and recommendations of the glass furnace provider, the industrial enterprise will significantly reduce energy consumption in the production of glass. The existing glass furnace number 3 is the largest and most efficient of the three glass furnaces. In 1995, the unit produced 34,245 tonnes of glass product while consuming 10,784 thousand cubic meters of natural gas, according to a technical review report by Saint-Gobain. This translates into an energy utilization index (EUI) of 2,834 kcal/kg-glass (gas fuel only). The new furnace being proposed as part of the furnace modernization project is estimated to result in an EUI of 1,220 kcal/kg-glass (gas fuel only), or 57% less natural gas fuel per unit of glass produced.

There are, however, several additional changes that also need to be addressed. The existing glass furnace does not use electric fans to supply combustion air to the process or to remove exhaust air from the furnace. Air movement through the existing furnace is by natural draft. The new furnace will use electric-motor-driven fans to supply air to the combustion process. This will allow more precise control of the combustion process but will increase electricity consumption for the process. The new furnaces also use electric heaters to control the glass temperature in the forehearths whereas the existing furnaces use natural gas. While the new furnaces will be able to control the glass temperature more precisely and improve glass quality, it will consume more electric energy. Even though electricity is more expensive per unit of energy than natural gas, the productivity benefits far outweigh the additional costs. Total additional electricity consumption will depend on glass production levels, and will likely range from about 1 to 1.7 million kWh per year.

One of the most important factors that could affect the energy consumption of the proposed new furnace is the selection of the furnace-insulated firebrick. The existing glass furnaces have been constructed using inexpensive, low-quality firebrick. The result has been a short furnace life, significant heat loss and increased fuel consumption. The average life of the existing glass furnaces is approximately 3 years, after which time, the furnaces must be rebuilt. This is primarily because the furnace's firebrick thermally degrades. In addition to becoming structurally unsound, the degradation also results in an increasing heat loss through the furnace walls. During the site visit, the temperature of the furnace external walls was around 140 to 160°C for the 1-year old furnace number 3 and around 300 to 400°C for the 3-year old furnace number 1. To extend the life of the glass furnaces, Gostomel uses a series of electric-driven fans to supply cooling air to the external furnace walls. While this air supply does keep the furnace walls cooler and therefore extends the furnace life, it results in significant heat loss from the furnace which, in turn, increases natural gas consumption and consumes additional electric energy.

For the modernization of furnace number 3, if a higher grade of insulated firebrick were selected, as the glass furnace manufacturer is recommending, the new life of the modernized furnace is estimated to be around 6 to 8 years. In addition, heat loss through the furnace walls would be significantly reduced and the cooling fans could be eliminated. Although the proposed higher-grade firebrick is more expensive, it was highly recommended over the existing lower-grade firebrick.

The new furnace being proposed is also significantly larger than the existing furnace. Furnace number 3 currently has a capacity of 53,500 tonne-glass per year. The new proposed furnace number 3 will have a maximum capacity of 79,350 tonne-glass per year. This is a 48% increase in furnace capacity. Assuming a 25% cullet rate, this implies that the new furnace will be able to produce 59,513 tonnes of glass per year. This is 11% greater than the total glass production of all three glass furnaces combined in 1995.

Based on the information provided in the preliminary proposal submitted by the glass furnace manufacturer, the information from the technical review report generated by Saint-Gobain, and the energy consumption data collected at the site during the audit visit, the potential energy savings from the proposed furnace modernization was estimated. A summary of the results is given in Table 2.

Table 2. Summary of Results (Upgrade glass furnaces)

Based on 1996 manufacturing production level:	30,838 tonnes/yr
Natural gas savings	5,172 1,000 m^3/yr
Electricity increase	973,650 kWh/yr.
Cost reduction	390,300 US dollars/yr
	(702,600 hryvnia/yr)
Based on maximum production level:	59,513 tonnes/yr
Natural gas savings	7,985 1,000 m^3/yr
Electricity increase	1,745,128 kWh/yr
Cost reduction	592,900 US dollars/yr
	(1,067,200 hryvnia/yr)

Install high-efficiency compressed-air system and controls

This measure recommended installing new high-efficiency screw-type air compressors with an automatic sequencing and load control system. The existing air compressor system includes a mix of 10 reciprocating air compressors and 2 screw-type air compressors. The air compressors consist of a variety of capacities, manufacturers, and ages. The compressors are not efficient compared to equipment available today. Specifically, this measure recommends replacing the existing 10 reciprocating air compressors with 4,260-kW (350-hp) water-cooled screw-type air compressors with refrigerated air dryers. A fifth unit could also be installed for reserve capacity, although this is optional. The existing low-pressure reciprocating compressor should remain on-line and operated at full-load. In addition, the two existing 200-kW screw-type air compressors should be operated only as reserve air compressors. To ensure adequate capacity, the other existing air compressors could also remain in the system, but should only be operated as emergency back-up compressors and not allowed to regularly operate in the system. The new air compressors specified would generate 12.28 m^3/kWh of compressed air compared to the average existing air compressor's efficiency of 10.16 m^3/kWh, an improvement of 20%. The useful life of the new compressors is estimated to be 20 years.

In the current compressed-air system, compressor loads are controlled automatically by the individual air compressor control systems. The sequencing of compressors is accomplished manually: the operators are responsible for starting and stopping air compressors as the demand for compressed air increases or decreases. The mix of manual sequencing and individual load control results in inefficient operation of the air compressor system and allows the system-wide air pressure to fluctuate. Compressors operate most efficiently at, or near, full load. With manual sequencing, the load is evenly distributed across each of the operating compressors. This results in the compressors operating at partial load, which is an inefficient condition. With a central automatic sequencing and load control system, the load will be distributed such that most compressors operate near optimal load and only one compressor would operate at a variable load to meet the variable demand for compressed air. The control system would automatically bring additional compressors on-line as the demand for compressed air increases and take compressors off-line as the demand for compressed air decreases. The automatic sequencing and load control system identified for this measure is capable of controlling up to eight air compressors. In the future when the compressed-air system is expanded as part of an overall expansion in manufacturing capacity, a larger automatic sequencing and load control system may need to be specified. Application of the automatic sequencing and load control system could reduce electricity consumption by an estimated 10%.

The control system will also improve the consistency of the air pressure in the distribution system. Under the present operating conditions, pressure varies significantly, typically from 5.0 to 6.25 bars. With the automatic sequencing and load control system, the distribution system pressure will be more consistent. A summary of the economic analysis is given in Table 3.

Table 3. Summary of Results (Install high-efficiency compressed-air system)

Option A	
Electricity savings	4,846,562 kWh/yr
Cost reduction	193,862 US dollars/yr (348,952 hryvnia/yr)
Implementation cost	967,754 US dollars (1,741,957 hryvnia)
Internal rate of return	19.5 %
Net present value at 20% over 20 years	-19,800 US dollars
Simple payback	5.0 years
Data Assumptions	
Electricity cost	$0.04 per kWh
Exchange rate ($1.00 US $)	1.8 hryvnia

Install heat recovery hot water boilers in glass furnace exhaust systems

This measure recommended installing heat recovery boilers in each of the glass melting furnace exhaust systems for the purpose of preheating the water currently being heated by the central boiler plant. Recovering heat from the glass furnaces will reduce the load on the steam boiler system, thereby reducing the natural gas consumed by the boilers. Based on the potential heat recovery rates, there may be periods when the entire hot water demand may be satisfied through the heat recovery boilers. At least one steam boiler should remain active to assure meeting the total hot water demand.

The existing boiler system consumes natural gas and generates high-pressure steam. There are two boilers; however, only one unit typically operates while the second unit is in cold standby. Steam pressure is typically around 6 bars. The steam is used in a shell-and-tube-style heat exchanger to generate hot water. The shell-and-tube-style heat exchanger is located in the boiler facility. The hot water is circulated through three parallel distribution loops that circulate throughout the Gostomel plant grounds, buildings, and some areas of the neighboring town. Hot water generated by the boiler system is used for typical domestic hot water requirements and for space heating during the winter season.

In addition to the installation of the heat recovery boilers, further energy savings will result from replacing the existing steam boilers with a new smaller hot water boiler. Installation of the waste heat recovery boilers will significantly reduce the load on the existing boilers. Also, hot water boilers inherently operate more efficiently than steam boilers. Hot water boilers do not require blowdown to maintain water quality as do steam boilers. Moreover, hot water boilers need less feedwater chemical treatment than steam boilers. A small hot water boiler will also be safer to operate than high-pressure steam boilers. This will allow the existing boiler to be started and brought on-line whenever the heat recovery boilers or the new hot water boiler are down for maintenance and repair. The useful life of the new heat recovery system is estimated to be at least 20 years. A summary of the economic analysis of the measure is given in Table 4.

Table 4. Summary of Results (Install heat recovery hot water boilers in glass furnace exhaust systems)

Heat Recovery Boilers	
Natural gas savings	1,784,313 m^3/yr
Cost reduction	148,100 US dollars/yr (266,580 hryvnia/yr)
Implementation cost	431,700 US dollars (770,060 hryvnia)
Internal rate of return	34.2%
Net present value at 20% over 20 years	241,200 US dollars
Simple payback	2.9 years
Option: Heat Recovery Boilers with Hot Water Boiler	
Natural gas savings	1,884,282 m^3/yr

Cost reduction	156,395 US dollars/yr (281,512 hryvnia/yr)
Implementation cost	530,900 US dollars (955,620 hryvnia)
Internal rate of return	29.3%
Net present value at 20% over 20 years	192,200 US dollars
Simple payback	3.4 years

Upgrade piping insulation on hot water distribution system

This measure recommended replacing damaged insulation on the hot water distribution piping system. An inspection of the insulation on the hot water distribution piping system revealed significant damage. Damaged or wet insulation results in greater heat loss. The result of this heat loss is a lowering of water temperature in the heating system, making it less effective for space heating; and an increase in the heat load on the boiler. Replacing the damaged sections of the insulation will reduce the load on the boiler, thereby saving energy.

The estimated life of the insulation is about 5 years. The life of insulation is a function of the abuse the insulation receives and the type of protective covering, but it is also a function of the quality of installation. The better the quality of installation, the longer the insulation will last.

During the energy audit site visit, the quality of the existing insulation was visually examined. A visual inspection was not sufficient to identify the extent of the damaged insulation. It was recommended that the entire hot water distribution system be inspected with infrared thermography to identify the damaged sections of insulation that need to be replaced. For purposes of this energy-efficiency measure, it was assumed that 20% of the insulation was damaged and had to be replaced (see Table 5). It is possible that a greater amount is severely damaged, making the potential energy savings even greater. The infrared inspection service may be rented and was included in the implementation cost estimate. It was also recommended that the enterprise use the infrared thermography service to inspect the glass furnace structures and inside the major electrical service panels during the same visit. The infrared thermography inspection service may identify additional areas to reduce energy loss.

Table 5. Summary of Results (Upgrade piping insulation on hot water distribution system)

Assuming 20% of insulation is replaced	
Natural gas savings	173,320 m^3/yr
Cost reduction	14,550 US dollars/yr (26,190 hryvnia/yr)
Implementation cost	39,070 US dollars (70,326 hryvnia)
Internal rate of return	25.1%
Net present value at 20% over 5 years	3,700 US dollars
Simple payback	2.7 years

Relocate air intake for screw-type air compressors to outside the compressor building

This energy-efficiency measure recommends modifying the air intake on the two rotary-screw type air compressors to extend the air intake to outside the central air compressor building. The existing air intake vents are located within the insulated housing of the rotary-screw air compressors. Although the compressor housings are ventilated, the air temperature in the vicinity of the air intake is extremely hot. Warm air requires more power and energy to compress than cool air. By extending the air intake to outside the central air compressor building, cooler air will be provided at the inlet requiring less energy to compress.

To implement this energy-efficiency measure, the intake filters should be removed and an oversized pipeline installed from the compressor intake to outside the compressor building. The compressor intake filter should then be re-installed at the new air inlet. It would also be beneficial to insulate the new inlet pipe to minimize heat gain in the compressor building. An oversized pipeline is installed to ensure that the new extended intake line does not cause excessive pressure drop entering the compressor. Extending the intake line to outside the compressor building will ensure the coolest air source for the compressed-air system. The life of this energy-efficiency measure is assumed to be 20 years.

It was noted during the site visit that most of the existing reciprocating air compressors already had intake lines installed outside the compressor building. However, for those compressors that still have their air intake located near the compressor, this same procedure should be used. Care should also be taken to clean the intake filters often. Dirty air filters will result in an increased pressure drop at the air compressor inlet, which will lower compressor efficiency. Intake filters located outside may need to be cleaned more frequently. A summary of the economics of implementing this measure is given in Table 6.

Table 6. Summary of Results (Relocate air intake for screw-type air compressors)

Electricity savings	53,248 kWh/yr
Cost reduction	2,130 US dollars/yr (3,834 hryvnia/yr)
Implementation cost	4,000 US dollars (7,200 hryvnia)
Internal rate of return	53.2%
Net present value at 20% over 20 years	5,300 US dollars
Simple payback	1.9 years
Data Assumptions	
Electricity cost	$0.04/kWh
Estimated average reduction in inlet air temperature	10°C
Existing electrical consumption of screw-type air compressors	1,566,120 kWh/yr

ENERGY EFFICIENCY AT THE AVDEEVKA COKE-CHEMICAL PLANT

Several recommendations for increasing energy efficiency at the Avdeevka Coke-Chemical Plant were made based on a site visit and energy audit of the plant. Avdeevka is located in Donetsk Oblast, just outside the city of Donetsk. It is one of the largest coke-chemical plants in Europe and has a strong market position in Ukraine. In recent years, the plant has sold coke to almost every Ukrainian steel mill. Its primary customer is currently Ilich Steel Plant in Mariupol, a plant with a strong export base. Avdeevka also sells over 20 types of chemicals derived from coal including low-octane gasoline, paint additives, and sulfuric acid, and exports 10% of its products. Avdeevka has financed significant modernization, renovation, and other plant upgrades with its net profits. The company was privatized in 1992 – one of the first Ukrainian enterprises to do so.

Combustion of the coke-oven gas (essentially a free by-product of the coking process) to produce steam and electricity purchases from the local utility cover most of Avdeevka's energy demand. In particular, Avdeevka's combined heat and power station is very outdated; as a result, it produces less electricity and steam than a more modern facility could with the available coke oven gas. Plant management recognized this problem and commissioned a study by Mashproekt staff to assess the feasibility of installing locally designed and manufactured gas turbines with waste heat recovery boilers for meeting Avdeevka's energy needs. The feasibility study by PNNL and ARENA-ECO staff further reinforced the feasibility of installing a gas turbine cogeneration system and made additional recommendations for improving the energy efficiency of the plant as listed below.

- Install a new gas turbine cogeneration system.
- Install efficient outdoor lighting.
- Replace insulation on steam and hot water piping.
- Modify the compressed-air system.
- Identify and repair leaks in the compressed-air system.
- Install steam traps.

The most significant measure considered by PNNL and ARENA-ECO was installation of a new 15 MW gas turbine cogeneration system. The preliminary analysis of the electrical and steam demands at the plant confirmed that a new gas turbine cogeneration system would be a very cost-effective investment. An economic analysis was conducted for three different options involving one, two or three equally-sized gas turbine cogeneration systems. The final recommendation was that two gas turbine cogeneration systems be installed in two phases so the savings from the first phase can help pay for the second phase. However, in the short-term, the plant is only considering the first phase installation of one gas turbine unit. The economic feasibility of the second turbine will significantly improve if selling excess electricity to the local utility in the summer becomes an option for the plant. The second turbine will also enable a more complete utilization of the excess coke-oven gas in the plant. It was estimated that the cogeneration system installation would take about 27 months after the project financing has been approved. A small initial investment of about $12,000 in coke-oven gas flow measuring equipment was also recommended to improve the ability to assess the quantities of the production and consumption of the gas within the plant. The PNNL analysis was based on the products of two potential vendors - Asea Brown Boveri (ABB) of Sweden and the Mashproekt Turbine Plant in Nikolayev, Ukraine. Both vendors had similar performance and cost data for their products, which were used as sample data in the analysis. It was assumed that Avdeevka would go through a competitive bid process and seek full engineering and cost proposals to be able to compare product reliability and the gas turbine vendor's experience with coke-oven gas-fired systems prior to the final selection of a vendor.

Based on the end-use energy efficiency potential at Avdeevka, the audit revealed that the plant has several additional cost-effective opportunities to save energy through such measures as installing efficient outdoor lighting and replacing insulation on steam and hot water piping. The former measure recommends replacing existing low-efficiency incandescent lights with new high-efficiency lamps and lighting fixtures while maintaining a similar level of illumination at the facility. Two high-efficiency lamp (high-pressure sodium and low-pressure sodium) options were considered for the outdoor lighting retrofits. Although not as energy efficient as low-pressure sodium, high-pressure sodium lighting is still about 300% to 600% more energy efficient than the existing incandescent lighting and offers a lamp life 24 times as long. Other recommended measures include modifying the compressed-air system by either replacing the existing unit with a high-efficiency unit equipped with a load control system or installing a series of smaller compressors and automatic load management controls.

Electricity efficiency measures will reduce electricity purchases so the economic analysis of these measures is fairly straightforward. However, thermal energy (steam and/or hot water) is produced on site with coke-oven gas, a by-product of the coking process, so the economic analysis of thermal energy saving measures is slightly more complicated. With the cogeneration

system, thermal energy efficiency measures will allow the plant to produce more electricity, which in turn will reduce electricity purchases. In some cases, thermal energy savings will reduce expenses involved in generating the steam (such as costs for maintenance and the water supply). Thermal energy savings will also prolong the life of the heat-generating equipment, thereby reducing capital expenditures. In addition, thermal energy efficiency measures like steam traps will help reduce the steam demand on the new cogeneration system, particularly in the winter months when steam demand is expected to slightly outpace coke-oven gas availability. These expected thermal energy and electricity savings were included in the analysis when the proposed cogeneration system was sized. The end-use energy efficiency measures are thus an integral part of the proposed strategy. Table 7 lists the proposed energy efficiency measures recommended for implementation at the Avdeevka coke-chemical plant. These measures are all cost-effective, with the returns on investment ranging from 15% to over 1000%.

Table 7. Summary of Proposed Energy-Efficiency Measures (Avdeevka Coke-Chemical Plant)

Measure	Cost* (US $)	Annual Savings* (US $)	Simple Payback (years)	Internal Rate of Return (IRR) (%/yr.)
Cogeneration System				
-- ABB, one unit	13,000,000	5,400,000	2.4	40
-- Mashproekt, one unit	10,000,000	4,700,000	2.1	43
-- ABB, two units	26,000,000	10,900,000	2.4	40
-- Mashproekt, two units	20,000,000	9,400,000	2.1	43
Efficient Outdoor Lighting				
-- High-pressure Sodium	305,900	78,400	3.9	24.7
Piping Insulation	95,000	1,681,000	0.06	1,772
Compressed-Air System	139,000	47,000	3.0	36

* rounded-up figures for costs and savings

DISCUSSION OF OTHER SECONDARY PROJECTS

PNNL and an Ukrainian firm called ESCO-Vostok have conducted an audit of a metallurgical firm, Kerch Metallurgical Combine, located in the Crimean region. An energy audit was also recently completed at Stalkanat, a steel cable manufacturer in Odessa, and the next step is to work with the plant on financing. Stalkanat has committed to providing $8 million of internal financing for implementing some of the recommendations. A preliminary list of the energy conservation measures being considered for Stalkanat is given below.

- Install a gas turbine cogeneration system with a heat recovery steam generator.
- Install a new higher-efficiency boiler and combustion analyzer.
- Install steam traps in addition to the new boiler.
- Install condensate return system in addition to steam traps and the new boiler.
- Install blowers to replace compressed air use in specific applications.
- Install a new higher-efficiency air compressor and compressor control system.
- Install more efficient lighting system.

- Install more efficient furnaces to dry wire product.
- Replace insulation on steam distribution piping.
- Install more efficient thermal treatment ovens.

PNNL also conducted two other audits at relatively smaller plants: Rosava Tire Plant and Rosich Food Processing Plant; these plants have committed to implementing the audit recommendations with internal financing.

Rosava Tire Plant

The joint stock company "Rosava Tire Plant" is located in the Kiev region in the suburbs of Belaya Tserkov. The enterprise specializes in the production of tires. Presently the company produces more than 50 standard sizes of tires for cars, trucks and agricultural equipment. Production capacity in January 1997 was 6,444,300 units per year, and more than 80% of it was being exported. The energy resource requirements are satisfied through purchasing electricity and thermal energy. To make the power use more efficient energy supervision services were created to control equipment utilization, work safety, and energy use monitoring. After a detailed energy audit by ARENA-ECO staff, recommendations were made as to energy efficiency improvements of the compressed-air system (see Table 8).

Table 8. Summary of Proposed Energy-Efficiency Measures (Rosava Tire Plant)

No.	Description of Energy Efficiency Measures	Cost* (US $)	Annual savings* in electricity (kWh)	Annual savings* (US $)	Payback period (years)
1.	Reduction of compressed air leaks	3,400	2,001,100	80,000	0.04
2.	Operation at minimum pressure	--	100,100	4,000	instantly
3.	Replacement of pneumatic tools by electric tools	3,300	212,550	8,500	0.39
4.	Compressor replacement**	307,500	6,200,000	246,600	1.2
	Total	314,200	8,500,000	339,200	0.9

* rounded-up figures for costs and savings

** Energy efficiency measure No. 4 is possible only after implementation of measures 1 and 3.

Rosich Food Processing Plant

The stock company "Rosich Food Processing Plant" is situated in the Kiev region in the town of Belaya Tserkov. The enterprise specializes in food processing and food products (apple juice, non-alcoholic drinks, macaroni, bread, and confectionery) and employs about 350 people. The

plant works 24 hours a day (in three shifts) from June to November, during the apple processing season; the rest of the year, the plant works one shift per day.

The energy demand of the enterprise is not constant. Sometimes production lines are idle due to lack of orders to fill. The plant meets its energy demand by purchasing electricity and natural gas. As a result of energy audits at the plant, recommendations were made by PNNL and ARENA-ECO staff to the plant management and are shown in Table 9.

Table 9. Summary of Recommended Energy-Efficiency Measures (Rosich Food Processing Plant)

Energy-Efficiency Measures	Cost* (US $)	Annual Savings* in Natural Gas (or Electricity)	Annual Savings* (US $)	Payback Period (years)
Condensate recovery	600	5,769 m^3	1,300	0.56
Process steam condensate recovery	1,300	35,400 m^3	4,400	0.3
Elimination of air leaks in exhaust ducts	-	19,520 m^3	1,800	Immediate
Automatic selection of fuel/air ratio	8,800	45,400 m^3	4,150	2.1
Use of frequency converters for exhaust control	8,400	92,700 kWh	3,710	2.3
Total	19,100	105,800 m^3; 92,700 kWh	15,300	1.25

* rounded-up figures for costs and savings

IMPLEMENTATION PLANS

Gostomel Glass Plant

Gostomel has implemented several of the recommendations described in this paper, and the plant is actively seeking financing for the rest. Specifically, Gostomel has installed a waste heat recovery boiler in glass furnace 3. The measure was so effective that Gostomel is now planning to install a second heat recovery boiler at glass furnace 1. The plant has also relocated the air intake for its compressors, and plans to use internal funding to finance the insulation of steam piping. The plant is looking for external financing for the largest cost measures: the furnace upgrade and the new air compressors and controls.

The furnace upgrade is part of a larger modernization plan for which Gostomel is seeking financing. Gostomel would like to set up a joint venture with a strategic investor to realize this modernization plan. This type of joint venture takes time to establish. In the interim, Gostomel

is considering other alternatives such as a loan from the European Bank for Reconstruction and Development (EBRD), vendor financing, and leasing for both the compressor and furnace upgrades. PNNL and IRE are working with Gostomel to structure the different financing options.

Avdeevka Coke-Chemical Plant

Avdeevka's board of directors and senior management have made a formal decision to implement PNNL's recommendations. The company plans to implement most measures with internal financing; these include efficient outdoor lighting, piping insulation and compressed-air system modifications. Avdeevka is preparing tender documents to competitively select a vendor for the cogeneration equipment. The cogeneration project is too large for the plant to finance internally, so PNNL and IRE have developed a preliminary financing plan with Avdeevka. The financing package will only be finalized after the vendor is selected, but it will almost certainly include a significant down payment and collateral from Avdeevka. The structure and sources of financing are currently under discussion, but leasing and vendor financing are two likely options.

CONCLUSIONS

The Ukrainian industry is coming to the realization that it must increase its energy efficiency to cut costs, remain competitive, and at the same time, expand its export markets. Relatively high values of the energy costs to the sales revenue ratios of 12% for the Gostomel Glass Plant and about 30% for the Avdeevka Coke-Chemical Plant are the targets for improvement. A typical value of the ratio for the U.S. industry is about 2%. This realization provides an opportunity for foreign suppliers of energy efficient equipment and services to help implement energy-efficiency measures. Given the constantly changing economic climate and its inherent uncertainties, it is extremely important to carefully review any business opportunities before getting involved. In all likelihood, however, the Ukrainian market for implementing energy-efficiency measures within its industries will only grow, as formerly state-run firms become privatized.

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