Operations Summary December 2016

- <u>UW Milwaukee Energy Assessment</u> Received assessment back in mid-December, as noted the IAC team noticed several outstanding energy practices that exist already. The use of LED lighting outside, premium efficient motors, the sale of treated water to the power plant, plus the use of VFD'S. Heart of the Valley will take some of their recommended measures and use. The replacement of indoor lighting with LED lamps has already been started which there is a payback with Focus on Energy when doing this type of upgrade. Checked into the sewage charge and HOV is not getting charged a sewage charge rather it is a storm water charge. Have switched over to a synthetic motor lubricant and in the process of lowering air compressor pressures.
- <u>Process Return Pump Drives</u> No update at this time, still waiting for quote.
- <u>Operations</u> In 2016 Heart of the Valley had no diversions around secondary treatment, operations is going well with nothing new to report.
- <u>Maintenance</u> No major mechanical or maintenance items to report.

Industrial Assessment Report

Prepared by

University of Wisconsin-Milwaukee Industrial Assessment Center

Conducted on behalf of the U.S. DOE





November 15th, 2016

Report No: WM0098 Assessment Staff:

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UWM Industrial Assessment Center

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Preface

The work described in this report was performed by the University of Wisconsin-Milwaukee Industrial Assessment Center (IAC). The IAC program is managed by Rutgers, The State University of New Jersey, under agreement with the U.S. Department of Energy. The program is financially supported through the Advanced Manufacturing Office (AMO), which is a part of the Office of Energy Efficiency and Renewable Energy (EERE).

The objective of the IAC is to identify, evaluate, and recommend - through analyses of industrial plants' operations - opportunities to conserve energy, minimize waste, and reduce overall cost of operations. Our recommendations are based upon observations and measurements we made in your plant. As our time was limited, we do not claim to have complete detail on every aspect of the plant's operations. At all times we try to offer specific and quantitative recommendations of cost savings, energy conservation, and waste minimization to the plants we serve. However, we do not attempt to prepare engineering designs or otherwise perform services that you would expect from an engineering firm, a vendor, or a manufacturer's representative. When the need for that kind of assistance arises, we urge you to consult them directly. If, however, you want to discuss the contents of this report or if you have other questions about energy use and/or waste minimization, please feel welcome to contact us at the IAC.

The IAC staff can be contacted as follows:

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Executive Summary

The team from the University of Wisconsin-Milwaukee Industrial Assessment Center recommends **7** energy and cost saving measures to implement at your manufacturing facility. The assessment recommendations (ARs) translate into annual cost savings of **\$46,893**, with a total implementation cost of **\$13,254**. Thus, the simple payback period is about **0.29 year**. Table 1 on the next page summarizes each assessment recommendation by showing the annual cost savings, annual energy savings, implementation cost and simple payback period. More detailed calculations for each recommendation are included in the next section. We urge you to consider all of the recommendations. If you need additional information or clarification of any aspect of our recommendations, please contact us as soon as possible. As we mentioned during our visit, we will be contacting you in the future to determine which ARs were implemented.

Report Number: Location: Principle Products: NAICS Code: SIC Code: Assessment Date: Report Date: WM0098 Kaukauna WI Treatment of Wastewater 221320 4952 September 16th 2016 November 15th, 2016

Table 1: Summary of Assessment Recommendations

AR	Description	ARC Code	Annual Cost Savings	Annual Resource Savings	CO2 Reduction (tons/yr)	Implementation Cost	Payback Period (years)
1	Use Synthetic	2 1311	\$31 522	462,359 kWh	39/1 8	\$55.50	0.001
1	Motors Drives	2.4314	Φ31,322	762 kW-mo	374.0	ψ55.50	0.001
2	Replace Indoor	2 71/3	\$2 985	31,440 kWh	26.8	\$6,397 (after \$740 EOE	0.14
2	LED Lamps	2.7143	φ2,705	151 kW-mo	20.0	Incentive)	2.14
3	Heat Recovery from Boiler Stack to Preheat Feed Water	2.2412	\$3,494	709.6 MMBtu	37.6	\$4,661 (after \$2,839 FOE incentive)	1.33
4	Reduce Compressor	2 1231	\$2,481	37,498 kWh	32.0	¢O	0.00
4	Discharge Pressure	2.4231		53.6 kW-mo	32.0	ΦŪ	
5	Recover Waste Heat from Air Compressors	2.2434	\$1,011	205.4MMBtu	103.9	\$1,000	1.00
6	Remove Sewage Charge on Waste Water Treated Within the Plant	3.4116	\$2,334	N/A	N/A	\$0	0.00
7	Schedule to pump the solid sludge at off- peak time	2.3131	\$2,178	N/A	N/A	\$0	0.00
8	Recover Heat from Blower Room for Space Heating	2.2437	\$888	180.3MMBtu	9.6	\$1,140	1.28
Total			\$46,893	1,095.3 MMBtu		\$13,254	0.29
				531,297 kWh	604.8		
				967 kW-mo			

Brief Summary of Recommended Measures

AR #1: Use Synthetic Lubricants for Motors Drives

The IAC team recommends use of synthetic lubricants for the motors in this plant. Synthetic lubricants have high thermal, oxidation and contamination resistance and their usage delivers several benefits. They not only extend equipment life but also allow machinery to operate at highest efficiency for longer periods. This results in reduced energy consumption and improved productivity.

AR #2: Replace Indoor Lights with Energy LED Lamps

By replacing the existing light fixtures with energy efficient LED fixtures, the power consumption of each fixture can be greatly reduced. The light given off by a LED lamp is much easier on the human eyes because its color is similar to daylight.

AR #3: Heat Recovery from Boiler Stack

The heat from the flue gas can be recovered to preheat the cold water entering the boiler. In this way, the amount of energy needed to warm up the water can be reduced.

AR #4: Reduce Compressor Discharge Pressure

Eliminating compressed air leaks will reduce the amount of compressed air consumed and create significant savings. This is because the load on the compressed air system will be reduced. Leaks are most commonly found at pipe connections, fittings, and solenoids.

AR #5: Recover Waste Heat from Air Compressors

Recover waste heat from the compressor to heat the plant during winter. This will reduce the load on the space heating units and lower the operating costs.

AR #6: Remove Sewage Charge on Waste Water Treated Within the Plant

Because there is no sewage at all in this waste water treatment plant, there should be no sewage cost. It is recommended to contact the utility company and remove this charge from the utility bill.

AR #7: Schedule to pump the solid sludge at off-peak time

To pump the solid sludge only takes about two hours per day. It is recommended to

schedule this short time operation to off-peak time to reduce the electricity demand cost.

AR #8: Recover Heat from Blower Room for Space Heating

The hot air from the blower room is currently exhausted to the outside directly. It is recommended to install ductwork to recover this hot air for space heating and save natural gas cost.

Plant Description

This plant belongs to the Sewerage District of the city. It provides cost-effective wastewater conveyance and treatment for its member communities.

The plant has 11 employees who work in a 4.5Acre facility. The plant operates 24/7 with the annual production hours being 8,736 hours/yr¹. Influent pumping, aeration blowers, process return pumping, and digester blowers are the plant's major energy consumers. The major energy consumption equipment is listed in Table 2. The plant layout is shown in Figure 1.

Major Equipment	Numbers
Actiflo	3units
Biological Aerated Filter	1unit
Chlorine Contact Tank	2 units
Blowers	9units
Sludge Storage Tank	2 units
ATAD Reactor	lunits
Post ATAD Nitrifying Reactor	2units
DAF Thickener	2 units

Table 2: Main Equipment List

 $^{^{1}}$ The operation hours are different for various equipment and process. This is the average operation hours for the whole plant.



Figure 1: Plant layout

Process Description

This facility mainly provides wastewater treatment services. The production flow can be divided into liquid train and solids handling train as shown in Figure 2.

In the liquid train, all the income sewer water is filtered through screen at first. Usually, the flow goes through the headworks fine screens. When the flow is greater than 26.4MGD, it goes to the peak flow fine screen. The filtered water is pumped to Pista Grit Chamber on the 4th floor by influent pumping for further treatment. The water then enters into Actiflo Ballasted Sedimentation System, which is one of the most important process. In the Actiflo, Ferric Sulfate and Polymer are added to aid in flocculation of suspended matter. Sand is also added for ballast when the influent flow is greater than 15.6MGD. After the Actiflo, flows in excess of 26.4MGD are diverted to the peak flow disinfection tanks while the remaining flows are treated with an Biostyr for CBOD₅ removal and nitrification. Biostyr System Effluent flows by gravity to the Normal Flow Chlorine Contact Tank. Sodium Hypochlorite is added immediately upstream of the Normal Flow Chlorine Tank and also at the Peak Flow Chlorine Contact Tank inlets for disinfection. At the downstream of the Chlorine Contact Tanks, sodium Bisulfite is added to remove residual chlorine prior to discharging to the river.

In the solid handling train, the settled sludge is pumped from the bottom of each tank in Actiflo to hydrocyclones used to separate the sand and primary sludge. The sand is returned to the Actiflo systems. The sludge is discharged to the Gravity Thickener and then DAF thickener. The thickened sludge is stored in a batch tank and pumped to the ATAD Reactor periodically. The ATAD produces class A biosolids with an HRT of 14 days. Post ATAD Reactors provide nitrification/denitrification of biosolids, and a 10 to 15% reduction in ammonia nitrogen. Finally, all the sludge is stored in the sludge storage tanks for shipping out.



a) Liquid Train



b) Solids Handing Train

Figure 2: Schematic Process Flowchart²

² Obtained from the plant

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Best Practices

During the visit, the IAC team noticed several outstanding energy saving practices. Examples of these practices are:

Use of LED outdoor lights

All the outdoor lights in this plant are high efficient LED fixtures, which consume far less power than traditional HID outdoor lights.

Use of premium efficient motors

Most of the motors in this company are premium efficient motors which are 2 to 8% more efficient than standard motors.

Sell most of the treated water to a nearby power plant directly

There is a power plant next to this facility. The treated water is not qualified for drinking but good enough for cooling purpose in the power plant. Therefore, most of the water is sold to generate profit.

VFD on the pumps and blower

A variable frequency drive is a type of adjustable-speed drive used to control the motor speed and torque by varying motor input frequency and voltage. With VFDs installed the motor will be able to match its speed to the changing load requirements, which enables energy savings.

Energy Usage

Utility bills of this facility were used to determine the energy and resource use patterns and the average usage for the past year. The following figures and tables display trends in the utility data. The primary utilities are divided into two energy sources: electricity and gas.

Figure 3 shows the annual utility costs for the plant.

Table 3 shows yearly usage data, as well as the rates charged for electricity and gas.

Figure 4 shows normalized electricity usage and cost per month.

Figure 5 shows the breakdown of electricity cost.

Figure 6 shows the peak demand and peak demand time for each month.

Figure 7 shows the natural gas usage for each month.

Figure 8 shows the water usage for each month.



Figure 3: Annual Utility Costs

	Energy Sources	Yearly Usage	Yearly Cost	Avg. Unit Price
	Electricity	7,398,639 kWh	\$ 398,678	\$0.0539 /kWh
Electricity	Electric Demand	13948kW	\$119,950	\$8.6/kW
	Other Elect. charges	-	\$(33,005)	-
Gas	•	73,484 therms	\$36,186	\$0.4924/therm
Water		39,030,000gal	\$22,808	\$0.000584/gal
Total Cost		\$574	4,170	

 Table 3: Summary of Current Annual Energy Usage



Figure 4: Normalized Electricity Usage and Cost per Month



Figure 5: Breakdown of Annual Electricity Charges



Figure 6: Electricity Peak Demand and Time of Peak Demand



Figure 7: Normalized Gas Usage



Figure 8: Water Usage Per Month

Assessment Recommendations

AR #1: Use Synthetic Lubricants for Motors Drives

Recommended Action

Use synthetic lubricants or greases to lubricate bearings in electric motors and drives.

Summary of Estimated Savings and Implementation Costs

Annual cost savings:	\$31,522
Implementation cost:	\$55.50
Payback period:	0.001 year
Electric savings:	462,359 kWh/yr.
Demand savings:	762 kW-Mo/yr.

Expected Savings

In this plant, there are several motors of capacities 5-150HP. According to plant personnel about 75 -100 of this motors have an average capacity of 50HP³. These motors use Mobil Polyrex EM, a petroleum based lubricant. The IAC team recommends that synthetic lubricants be used for lubrication of these motor drives.

Regular petroleum lubrication oil can deteriorate quickly compared to synthetic oils. Deterioration leads to oxidation-caused carbo gum and varnish buildups that result in excessive wear of all mechanical moving parts, increased energy costs and reduced motor efficiency and availability. In such an industry synthetics provide the viscosity and stability required for dealing with the extreme pressures and temperatures ranges. They possess better lubricating properties and are more resistant to oxidation than mineral based lubricants^{4.5}

Typically, companies that upgrade their lubricants and reliability practices have been able to document a 5 to 15 percent reduction in power requirements, more than enough to pay for a

³ Obtained from plant personnel

⁴ www.lubriplate.com/pdf/ads-catalogs/SynLubesCtlg.pdf

⁵ www.anderol.com/07_1.php

better-performing lubricant⁶. Savings of 15% in gear boxes, 12 percent in air motors and 4 percent in electric motors has been reported because of lubricant upgrade.⁷,⁸ According to plant personnel, the motors run for 20hrs per day for 7 days a week for 52 weeks which translates to 7,800hrs per year⁹. Taking the equipment operations into account a load factor of 70% and an average motor efficiency of 92.5% is used in this analysis.

The current energy usage (E_C) is calculated as follows:

$$E_{\rm C} = \frac{N \times HP \times H \times LF \times C1}{\eta}$$

Where,

HP	=	Number of electric motor/motors (75)
HP	=	Average horsepower rating of electric motors (50HP)
Η	=	Annual operating hours (7,800Hrs/yr.)
LF	=	Load factor; no units (70%)
C1	=	Conversion constant (0.746 kWh/hp.)
η	=	Average Efficiency of motor (92.5%) ¹⁰

Therefore,

$$E_{C} = \frac{75 \times 50 \times 7,800 \times 0.70 \times 0.746}{0925}$$
$$E_{C} = 15,411,957 \text{ kWh/yr.}$$

The Proposed Energy usage (E_P) for motors is given by the following equation which closely resembles the Current Energy usage (E_C) equation except for one small difference. A PEC variable has been added to the numerator to represent a 3% energy reduction because of using synthetic lubricants.

⁶ Lubrication Engineers, Inc. http://www.lelubricants.com/lit/news/White%20Papers/lec.pdf

⁷ http://www.machinerylubrication.com/Read/214/lubricant-enery-savings

⁸ Lubrication Engineers, Inc., ZAP flyer, www.le-inc.com/documents/Zap_Flyer.pdf.

⁹ Estimates provided by plant personnel

¹⁰ http://www.engineeringtoolbox.com/electrical-motor-efficiency-d_655.html

$$E_P = E_p = E_C \times PEC$$

Where,

Therefore,

PEC = Percent of energy consumed (97% or 0.97) $E_P = 15,411,957 \times 0.97$

 $E_P = 14,949,598 \text{ kWh/yr}$

The Annual Energy Savings (AES) is calculated as follows:

Use of synthetic lubricant reduces the amount of traction from the motors. That will reduce the amount of power consumption by the motors. Motors will not run at full capacity to produce the same amount of traction force required to perform the specific operation. This will reduce the total electric demand. The demand reduction, DR, is therefore calculated using following equation:

DR =
$$\frac{AES}{H} \times M$$

Where,
M = Months per year demand is reduced (12 months/yr)

Therefore,

$$DR = \frac{462,359}{7.800} \times 12$$

Demand Reduction (**DR**) = 762 kW-mo. /yr.

The Annual Cost Savings (ACS) for this plant is calculated as the sum of the annual energy savings and the demand savings, multiplied by their respective utility charges. The average electricity rate, as calculated from the company's utility bills will be used.

$$ACS = AES \times R_{Ea} + DR \times R_D$$

Where,

$$R_{Ea}$$
 = Average Electricity cost (\$0.054/kWh)¹¹
 R_D = Peak demand cost (\$8.6/kW)¹²

Therefore,

$$ACS = 462,359 \times 0.054 + 762 \times 8.60$$

Annual Cost Savings (ACS) = \$31,522

Implementation Costs and Payback Period

There are several classes of synthetic lubricants that differ in their chemical and physical properties (including compatibility with hydrocarbons) and lubricating ability. It is suggested that expert advice from vendors or engineering firms should be sought before implementing this AR. The price of synthetic lubricating grease ranges from \$12.75 - \$27.75per tube^{13,14} dependent on the brand and manufacturer. According to plant personnel, the plant uses 2 tubes of lubricant per year. Now, compared to typical mineral-based lubricants with a recommended maximum life of 5,000 hours, synthetics are often rated for up to 15,000 hours¹⁵, thus reducing the frequency of lubrication, downtime, maintenance and environmental impact. It will therefore require 2 tubes of lubricating grease per year at a total implementation cost of \$55.50. Since plant personnel already have a greasing schedule or ever machine, there is no additional labor costs as it is already accounted for.

Therefore, the total implementation cost for this recommendation is \$55.50. The payback

¹¹ Obtained from utility analysis by averaging the summer and winter on and off peak rates.

¹² On peak demand charge.

¹³ https://www.google.com/webhp?sourceid=chrome-instant&ion=1&espv=2&ie=UTF-8#q=Synthetic+grease+prices

¹⁴ http://www.mscdirect.com/product/details/00265470?mkwid=txg6YEZy&cid=PLA-Google-PLA+-+Test&gclid=CjwKEAiA0pDBBRCFtoPyguTh8AUSJADNWeuxw1ccxVIjtllBVQQwEDDZZHuYFX9kW6KbjADJsMtuBoC05bw_wcB

¹⁵ http://www.plantengineering.com/home/single-article/proper-lubrication-plays-a-role-in-energyefficiency/67bedf96c82e870082ea0d4a224094a4

period is the time it takes to recoup implementation costs. A simple payback period is calculated as follows:

Daubaak Dariad	_	Implementation Cost (\$)	
Payback Period	_	Annual Cost Savings $(\frac{\$}{yr})$	
Payback Period	=	\$55.50 31,522	
Payback Period	=	0.001 years	

The simple Payback Period is less than 1month which is almost immediate.

AR #2: Replace Indoor Lights with Energy LED Lamps

Recommended Action

Replace the current T8 fluorescent lamps and metal halide lamps to LED lamps.

Summary of Estimated Savings and Implementation Costs

Annual cost savings:	\$2,985
Implementation cost:	\$6,397 (after \$740 FOE Incentive)
Payback period:	2.14 years
Energy savings:	31,440 kWh/yr.
Demand savings:	151 kW-mo./yr.

Expected Savings

There are many advantages of replacing metal halide (MH) and T8 fluorescent lighting with LED lamps. Energy consumption is reduced and electricity demand during peak hours could also be reduced. Thus, savings can be achieved on the facility's utility bills. LED lamps also have a faster start-up and re-strike time, which makes them safer and more effective in case of emergencies and power outages. Beyond that, the color of the light matches natural day lighting more closely, which makes it easier for human eyes to see, resulting in fewer mistakes and higher productivity.

Energy efficient LED light fixtures are available that send most of the light to usable areas. By replacing the current lighting with energy efficient high-bay fixtures, the power consumption of each fixture can be greatly reduced. Even though each fixture consumes significantly less power, most one-to-one replacement projects result in better lighting quality due to better color rendition and higher pupil lumens¹⁶.

The plant has a total of 26 MH lamps installed in the intake building and 45 T8 lighting fixtures installed in the underground tunnel, the details of which are shown in Table 1 17 18 .

The intake area is illuminated for approximately 10 hours per day, five days a week, 50 weeks a year, for a total of 2,500. The tunnel area is illuminated for approximately 24 hours, 7 days and 52 weeks for a total of 8,736 hours. The proposed energy savings is calculated assuming; high-bay LED 2-bulb T8 8ft retrofits are used as replacements for the T12 8ft fixtures and 60W LED retrofits for 170W MH fixtures¹⁹. A summary of all replacements is provided in Table 4.

	Existing		Proposed			Difference	Time
Type of Lighting	Watts per fixture	No. of fixtures	LED Replacement	Watts per fixture	No. of fixtures	(Watts)	(Hours)
MH 170W	185	26	60W LED	60	26	129	2,500
2-bulb T12 8ft	62	45	2-bulb T8 8ft LED	60	45	125	8,736

Table 4: Current and Proposed Lighting Fixtures

It is highly recommended that when retrofitting LED to metal halides or HID fixture, the ballast be by-passed if present. Eliminating the ballast saves additional costs related to maintenance, energy consumption and performance. Further, by-passing ballast will insure no radio frequency interference (RFI), electromagnetic interference (EMI) or audible buzz.

¹⁶ http://www.greenlight-ventures.com/assets/files/GLV_MH_vs_T5HO_Fluorescent.pdf

¹⁷ Counted by IAC staff

¹⁸ http://www.xcelenergy.com/staticfiles/xe/Marketing/Lighting-Wattage-Guide.pdf

¹⁹ http://www.ledglobalsupply.com/led-retrofit-kit/100-watt-led-hid-retrofit-kit/

The annual energy savings (AES) can be determined by comparing this facility's current energy usage with the energy usage proposed by replacing light fixtures as follows.

$$E_{\rm C} = \frac{\sum (N_{\rm IL} \times W_{\rm IL}) \times H}{1,000}$$

Where,

Therefore,

$$E_{C} = \frac{(26 \times 185) \times 2,500}{1000} + \frac{(45 \times 62) \times 8,736}{1000}$$

$$E_C = 36,398 \text{ kWh/yr}.$$

And,

$$E_P \qquad = \qquad \frac{\sum (N_f \times W_f) \times H}{1000}$$

Where,

$$E_P$$
=Proposed annual energy usage (kWh/yr.) N_f =Number of LED fixtures W_f =Wattage rating of fixtureH=Operating Hours

Therefore,

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$$E_{P} = \frac{(26\times40)\times2,500}{1,000} + \frac{(45\times12)\times8,736}{1,000}$$

 $E_P = 4,959 \text{ kWh/yr.}$

Annual Energy Savings is calculated by the following equation:

$$AES = E_C - E_P$$

AES = 36,398 - 4,959

Annual Energy Savings = 31,440 kWh/yr.

The reduction of lighting fixtures will most likely also reduce demand. The demand reduction (DR) is calculated as follows:

$$DR = \frac{AES}{H} \times 12$$

Where,

Therefore,

$$DR = \frac{31,440}{2,500} \times 12$$

Demand Reduction (DR) = 151 kW-mo./yr.

The annual cost savings (ACS) is calculated using the electricity and demand rates. The cost savings is calculated as follows:

 $ACS = AES \times R_{Ea} + DR \times R_D$

Where,

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R_{Ea}	=	Average Electricity Rate (\$0.0539/kWh)
100		

 R_D = Demand Rate (\$8.600/kW)

Therefore,

ACS =
$$(31,440 \times 0.0539) + (150 \times 8.6)$$

Annual Cost Savings (ACS) = \$ 2,985/yr.

Implementation Cost and Payback Period

The cost of retrofitting the respective lighting fixtures is shown in Table 5. The total purchase cost of fixtures would be \$3,587. Taking the labor cost of retrofitting as \$50 per retrofit, the total installation cost is \$3,550 and the total implementation cost will be \$7,137.

The Focus on Energy (FOE) group in Wisconsin offers incentives on energy-efficient lamps. The price per fixture is shown in Table 5 20 . Taking into account a total of \$740 Focus on Energy incentives, the net implementation cost is \$6,397. It is suggested that a qualified vendor be contacted before implementing this recommendation.

 Table 5: Cost Estimate of the Proposed Lighting Fixtures Retrofits

Type of fixture	Watts per Retrofit	No. of fixtures	Cost per fixture	Total cost	FOE Incentives per fixture	Total FOE incentives
60W LED	40	26	$$112.00^{21}$	\$2,912	\$25	\$650
2-bulb T8	12	45	\$15.00 ²²	\$675	\$2	\$92
4ft LED						
Total		71		\$3,587		\$740

²⁰ https://focusonenergy.com/sites/default/files/Application_PDFs/2016_Lighting_Catalog_Final.pdf

²¹ https://www.1000bulbs.com/category/175w-mh-equal-led-retrofit-for-hid-high-and-low-bay/

²² https://www.1000bulbs.com/category/1500-1700-lumens-plug-n-play-t8-led-tubes/

The payback period is the number of years it will take for the implementation cost to be recouped. The simple payback period is calculated as follows:

Davisaals Daviad -	Implementation Cost (\$)		
rayback renou –	Annual Cost Savings (\$/yr)		
=	\$6,397 \$2,985/yr		
Payback Period =	2.14 years		

AR #3: Heat Recovery from Boiler Stack to Preheat Feed Water

Recommended Action

Recover heat from the boiler stack using condensing economizer to pre-heat boiler feed water.

Summary of Estimated savings and Implementation Cost

Annual cost savings:	\$3,494
Implementation cost:	\$4,661 (after \$2,839 FOE incentive)
Payback period:	1.33 years
Natural Gas Savings:	709.6 MMBtu/yr

Expected Savings

There are two big water boilers and one small water heater in the boiler room. Two big boilers are mainly used for the space heating in the facility, while the smaller one is just used for hot water supply over a year. Therefore, the small one was in operation during the audit and two big ones were completely off. Based on the utility analysis in the previous section, natural gas consumption drastically increases in the heating months, typically from October to May of the following year, which accounts for eight months as heat months in a year. Compared to the small one, two boilers consume the majority of natural gas in a year, so the efficiency of two boilers become much more important for the gas saving. Although two big water boiler are well maintained very year, the stack test report shows two boilers have high temperature flus gases in the stack at median and high firing rates, 355°F was recorded on the test report at their high firing rate with nearly 84% of combustion efficiency. Considering other losses such as shell losses, the overall efficiency is as low as 82%. To continuously reduce gas consumption and improve performance for these two boilers, heat recovery system can be adopted at the stack location to reclaim waste heat for other uses. According to U.S. DOE, a condensing economizer can improve

overall heat recovery and system efficiency by up to 10%.²³ Some condensing boiler achieves more than 90% of the overall efficiency,²⁴ some of them are nearly 95%.^{25,26} Basically, condensing stack economizers are designed to recover heat from hot boiler flue gases. It improves waste heat recovery by cooling the flue gases below its dew point, which is about 135°F for products of combustion of natural gas. That is to say it reclaims both sensible heat from the flue gases and latent heat by condensing flue gas water vapor. Recovered heat is totally used to preheat boiler feed water. The schematic diagram of condensing economizer is shown below.



Figure 9: Schematic diagram of condensing economizer²⁷

In order to calculate annual energy savings by this measure, using a general rule of thumb that for every 39.6 °F reduction in flue gas temperature which is achieved by passing the flue gas

²³ https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/steam26a_condensing.pdf

²⁴ https://en.wikipedia.org/wiki/Condensing_boiler

²⁵ http://www.usboiler.net/condensing-boilers-efficiency.html

²⁶ https://www.energystar.gov/index.cfm?c=most_efficient.me_boilers

²⁷ The minimum stack temperature for a condensing economizer is 135°F from DOE, Steam Tip Sheet #26B, Advanced Manufacturing Office, Washington, D.C., U.S.

air through an economizer or a heat exchanger, there is a 1% saving of fuel in the boiler,²⁸ the efficiency improvement can be quantified. Therefore, annual energy savings can be calculated with the following equation published on Illinois Technical Reference Manual.²⁹

AES =
$$N \times SF \times P \times H \times LF/100$$

Where,

$$SF = \frac{(T_{Existing} - T_{Eff} \times TRE)}{40}$$

$$AES = Annual Energy Savings$$

$$N = Number of boilers (2)$$

$$SF = Saving factor$$

$$T_{Existing} = Existing full fire boiler flue gas temperature (355°F)30$$

$$T_{Eff} = Efficient full fire boiler flue gas temperature ((355+135)/2 = 245°F)31$$

$$TRE = \% \text{ efficiency increase for 40°F of stack temperature reduction}$$

$$(1\%)^{32}$$

- P = Rated boiler input capacity (3000 MBH)³³
- H = Annual operating hours $(4,301)^{34}$

²⁸ http://www.nrel.gov/docs/fy02osti/31495.pdf

²⁹ http://www.ilsag.info/il_trm_version_5.html

³⁰ Boiler stack test report

³¹ The minimum stack temperature for a condensing economizer is 135°F from DOE, Steam Tip Sheet #26A, Advanced Manufacturing Office, Washington, D.C., U.S.

³² United States EPA, Climate Wise: Wise Rules for Industrial Efficiency, July 1998.

³³ From boiler nameplate

³⁴ 24 hr/day, 7day/wk, 4wk/month, 8month/yr, 80% of occupancy factor included.

$$LF$$
 = Average load factor or boiler (75%)³⁵

Therefore,

Annual Energy Savings (AES) = 7,096.3 Therms

The Annual Cost Savings (ACS) is given by:

$$ACS = AES \times R_{ag}$$

Where,

ACS	=	Annual Cost Savings
R _{ag}	=	Average natural gas rate (\$0.4924 /Therm) ³⁶

Therefore,

Annual Cost Savings (ACS) = \$3,494/yr

Implementation Cost and Payback Period

The implementation of this recommendation needs the installation of a condensing economizer and some duct work. The economizer must be installed on a boiler exhaust stack. Heat captured by the economizer is to be used to pre-heat boiler feed water. Based on DOE, the simple paybacks for condensing economizer projects are often less than two years.³⁷ Therefore, for the conservative reason, the system costs about \$7,500 including installation^{38,39,40}. Focus on energy group provides \$0.4/therm incentives for gas savings.⁴¹ Therefore, the total project cost is \$4,661 after incentives. It is recommended to contact with a professional vendor before implementation,

http://www.cleaverbrooks.com/Products-and-Solutions/Heat-Recovery/Condensing-

Economizer/C1X/Index.aspx

³⁵ Obtained from the plant personnel

³⁶ Obtained from utility analysis

³⁷ https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/steam26a_condensing.pdf

³⁹ http://victoryenergy.com/economizer/

⁴⁰ http://www.combustionandenergy.com/condex-condensing-economizer-system.html

⁴¹ https://focusonenergy.com/sites/default/files/2016_Custom_Incentive_Guide_FINAL.pdf

since the condensed flue gas water vapor sometimes needs to be removed from the stack to keep the stack from corrosion.

The payback period is the number of years we expect it to take to recoup the implementation cost. The payback period is determined by:

Dauback Daried	=	ImplementationCost (\$)		
Payback Periou		AnnualCostSavings $(\frac{\$}{yr})$		
Payback Period	=	4,661 3,494		
Payback Period	=	1.33 years		

AR #4: Reduce Compressor Discharge Pressure

Recommended Action

Reduce the set pressure of the air compressor to reduce load requirements. This will also reduce energy usage and demand.

Summary of Estimated Savings and Implementation Costs

Annual Cost Savings:	\$2,481
Implementation Cost:	\$0
Payback Period:	Immediate
Electricity Savings:	37,498 kWh/yr
Demand Savings:	53.6 kW-mo/yr

Expected Savings

Currently, the plant has two compressors, 20 and 25hp capacity. At the time of the visit it was observed that the pressure is 120 psi. From conversations with plant personnel on the day of the energy audit, it was established that no equipment within the facility requires this amount of compressed air pressure. Most of the equipment needs a maximum pressure of 100 psi. The proposed action is to lower the air compressors' set pressures from 120 to 105 psi to save on energy costs, as well as reduce demand.

The compressor operates 24/7 and taking into consideration two weeks for annual maintenance and holidays, the total operating hours for 50 weeks amounts to 8400 hours

The current energy usage of the compressors can be calculated as follows:

$$E_{\rm C} = \frac{PR \times H \times LF_C \times C_1}{\eta}$$

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Where,

Ec	=	Current energy usage
PR	=	Power rating of compressor (45 hp)
Η	=	Annual operating hours of compressor (8,400 hr/yr)
LFc	=	Current load on compressor (100%)
C_1	=	Conversion factor from hp to kW (1 kW = 0.746 hp)
η	=	Efficiency of the compressor (94 %) ⁴²

Therefore,

$$E_c = \frac{45 \times 8400 \times 1 \times 0.746}{0.94} = 299987.2$$

Current Energy Usage (Ec) = 299,987.2 kWh/year

The proposal for this assessment recommendation is to lower the set pressure of the air compressor from 120 to 105 psi. The new load on the compressor is calculated using a ratio of the current load, current pressure, proposed load, and proposed pressure as follows:

$$LF_f = \frac{LF_c}{P_c} \times P_f$$

Where,

- LF_f = Final load factor on air compressor
- P_c = Current pressure provided by air compressor
- $P_{\rm f}$ = Proposed pressure provided by air compressor

⁴² Obtained by IAC team

Therefore,

$$LF_{fl} = \frac{1}{120} \times 105 = 0.875$$

The proposed energy usage for this recommendation will be the energy used after the pressure has been changed for the air compressor. It is calculated as follows:

$$E_{p} = \frac{PR \times H \times LF_{f} \times C_{1}}{\eta}$$

$$E_{P} = \frac{45 \times 8400 \times 0.875 \times 0.746}{0.94} = 262488.8$$

Proposed Energy Usage (E_P) = 262,488.8 kWh/year

The annual energy savings is the difference between the current and proposed energy usage.

AES =
$$E_C - E_P$$

AES = 299987.2-262488.8 kWh

Annual Energy Savings (AES) = 37,498.4 kWh/year

Since the compressor operates 24/7 the annual cost savings will be calculated using the average electricity rates.

Apart from the savings from energy usage there is also saving realized from demand reduction; Demand is only charged during the on-peak billing of the facility. To calculate the demand reduction from this recommendation, the following equation is used:

$$DR = \frac{AES}{H} \times M$$

Where,

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DR	=	Reduction in demand
Η	=	Annual operating hours of compressor
М	=	Months/year

Therefore,

$$DR = \frac{37,498.4}{8400} \times 12$$

The annual cost savings can be calculated as follows:

$$ACS = AES \times R_{Ea} + D_R \times R_D$$

Where,

$$R_{Ea} = Average Electricity Rate ($0.0539 / kWh)^{43}$$
$$D_{R} = Demand Rate ($8.6 / kW)$$

Therefore,

$$ACS = 37,498.4 \times 0.0539 + 53.57 \times 8.6 = \$2021.1 + \$460.7$$

Annual Cost Savings(ACS) = \$2,482 per yr

Implementation Cost and Payback Period

Lowering a compressor's discharge pressure does not require any implementation cost. With an annual cost savings of \$2,482, the payback period is **immediate**.

It is suggested that plant personnel repair the existing compressed air leaks before implementing this recommendation. Additionally, the plant personnel should reduce the air

⁴³ Obtained from Utility Data Analysis

pressure gradually. For example: first, reduce the pressure by two psi and check if all the equipment is working properly before doing any further reductions to the desired pressure.

AR #5: Recover Waste Heat from Air Compressors

Recommended Action:

Recover the waste heat from the air compressor room and reroute to heated areas during winter. This will reduce the load on the HVAC system and the operating costs.

Summary of Estimated Savings and Implementation Costs:

Annual Cost Savings:	\$ 1,011
Implementation Costs:	\$1000
Payback Period:	1.0 year
Natural Gas Savings:	205.4 MMBtu/yr

Expected Savings:

Currently, the plant has one 20HP air compressor in the compressor room. The exhaust heat from the air compressors is currently ejected to the outside by ducts, thus it is a waste of heat. In fact, nearly all (96%) of the electrical energy used by an industrial air compressor is converted into heat while the rest remains in the compressed air or radiates from the compressor into the immediate surroundings^{44, 45}. This heat could be redirected to the plant, which will reduce load on the roof top units that provide hot air for comfort heating purposes.

To calculate the savings associated with the redirection of hot air, heat generated by the compressor will need to be calculated. Ideally this would be done by measuring temperature, and volumetric flow rate of air from the radiator. However, it is also possible to calculate the BTUs saved with compressor specifications and an experimental constant as seen below.⁴⁶ This plant

⁴⁴ http://www.cagi.org/news/heatrecovery.pdf

⁴⁵ http://us.kaeser.com/Images/US96-645US_Heat%20Recovery%20Systems-tcm9-9542.pdf

⁴⁶ From the DOE Office of Industrial Technologies' "Compressed Air Systems Fact Sheet #10"

operates 24 hours, seven days a week. This translates to 4,704 hours during a 7-month winter heating period for this facility. A conservative estimate of 70% was used for the compressor heat recovery.⁴⁷

AES =
$$C_r \times HP \times C_c \times H \times 10^{-6} / \eta_r$$

Where,

AES	=	Annual energy savings (MMBtu/year)
Cr	=	Percentage of input energy recoverable as heat $(0.70)^1$
HP	=	Horsepower of the compressor (20HP) 48
Cc	=	Conversion factor (2,545 Btu/(hp · hr))
Н	=	Hours of compressor operation (672 hours) ⁴⁹
η_r	=	HVAC units efficiency $(0.85)^{50}$

Therefore,

Annual Energy Savings (AES) =205.4 MMBtu

Knowing the energy created by the air compressor, it is possible to calculate the annual cost savings (ACS) by calculating how much energy the roof top units would use to create the same amount of heat.

ACS =
$$AES \times R_{Ga}$$

Where,

⁴⁷ https://www.compressedairchallenge.org/library/articles/2010-09-CABP.pdf

⁴⁸ Obtained from plant personnel

⁴⁹ Using a four week month heating season, H = (24hours/day)(7 days/week)(4weeks/month)(7months/yr)

⁵⁰ https://www.compressedairchallenge.org/library/articles/2010-09-CABP.pdf.

 R_{Ga} = Average natural gas rate (\$4.924/MMBtu)⁵¹

Therefore,

Annual Cost Savings (ACS) = \$1,011

Implementation Cost and Payback Period

Ductwork, with damper, will be needed from the compressor outlet of hot air to the area to be heated and to the outside. Cost of material, ductwork and damper, for one compressor is estimated as \$400. Labor cost to drill holes and install ductwork is \$600. Implementation cost for one compressor is \$1,000. The payback period is the time it takes to recoup implementation costs. A simple payback period is calculated as follows:

Payback Period	=	Implementation Cost (\$)
		Annual Cost Savings $(\frac{\$}{yr})$
Payback Period	=	\$1000 \$1011/yr
Payback Period	=	1.0 year

⁵¹ Obtained from Utility data analysis

AR #6: Remove Sewage Charge on Waste Water Treated Within the Plant

Recommended Action

Petition Water Company to remove sewage charge for waste water that is produced and treated within this plant.

Summary of Estimated Savings and Implementation Costs

Annual Cost Savings:	\$2,334/yr.
Implementation Cost:	\$0
Payback Period:	Immediate

Expected Savings

Some processes in the facility use water supplied from the city's water department. This facility is primarily a waste water treatment plant. The waste water from the plant is therefore treated within plant before it is disposal to the river or sold to a third party company. A review of the facility's water bill indicated that the facility is charged a sewer fee by the utility company. Hence, the company is charged sewer fee for water that does not actually go down the city's sewage system since it is treated by the plant itself. Table 6 shows the water billing regime for this plant.

By logging and maintaining data to document the amount of water that is sent down the drain the company can petition the water provider to issue credit for a portion of the sewer fee. In most instances, the water provider will issue a credit for a portion of the sewer fee.

Table 6:	Water	and	Sewer	Charges	for t	the l	Plant
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Date	Water Charges	Sewer Charges	Total
Jun-15	1,683.26	187.55	1,870.81

Jul-15	1,397.16	187.55	1,584.71
Aug-15	1,695.96	187.55	1,883.51
Sep-15	1,433.32	187.55	1,620.87
Oct-15	2,087.00	187.55	2,274.55
Nov-15	1,486.78	187.55	1,674.33
Dec-15	1,746.00	187.55	1,933.55
Jan-16	1,607.00	202.33	1,809.33
Feb-16	1,499.44	204.60	1,704.04
Mar-16	1,765.46	204.60	1,970.06
Apr-16	2,096.88	204.60	2,301.48
May-16	1,301.96	204.60	1,506.56
Total	19,800.22	2,333.58	22,133.80

From the foregoing data in Table 6 obtained from the plant personnel, the provider charges \$2,334/year as sewer charges. This is the amount that the company will save annually by bringing this to the attention of the utility company. Therefore, Annual Cost Savings (ACS) is:

Annual Cost Savings (ACS) = \$2,334/yr

Implementation Cost and Payback Period

There is no investment required to implement this recommendation. Therefore, the payback period is immediate.

AR #7: Schedule to pump the solid sludge at off-peak time

Recommended Action

Schedule the operation of pumping solid sludge to the off-peak time to reduce the electricity demand cost.

Summary of Estimated savings and Implementation Cost

Annual cost savings:	\$2,178
Implementation cost:	\$0
Payback period:	Immediate

Expected Savings

Currently, the solid sludge is pumped to the sludge storage tank for delivery every day. The whole process takes about two hours per day. The total blower/pump power engaged in this process is 115hp. Because no exact schedule exists for this operation, it may happen any time, which will cause about 115hp electricity demand every month. It is recommended to schedule this operation to the off-peak time to reduce both the electricity demand cost and electricity usage cost.

The cost savings related with this action can be calculated through:

ACS =
$$HP \times C1 \times R_{ed} + HP \times C1 \times H \times (R_{ep} - R_{eo})$$

Where,

HP	=	Horse power of the motors (115hp)
C1	=	Conversion factor (0.746kW/hp)
R.	_	Electricity demand rate (\$8.6/kW-mo)

$$R_{ed}$$
 = Electricity demand rate (\$8.6/kW-mo)

R _{ep}	=	On-peak electricity usage rate (\$0.0684/kWh)
R _{eo}	=	Off-peak electricity usage rate (\$0.0454/kWh)
н	=	Operation hours (730hours)

Therefore,

ACS = 738+1440

Annual Cost Savings (ACS) = \$2,178/yr

Implementation Cost and Payback Period

The implementation of this recommendation needs the operator to schedule the pumping of the solid sludge to before 9am or after 9pm. There is no extra cost for this recommendation, therefore the payback period is immediate. It is also possible to install an alarm connected with a timer to the pump switches. In this way, the operator would know it when they accidently violate the operation schedule. Remember, misconduct in one day will cause a charge for the whole month.

AR #8: Recover Heat from Blower Room for Space Heating

Recommended Action

Recover the heat in the blower room for space heating in winter.

Summary of Estimated savings and Implementation Cost

Annual cost savings:	\$888
Implementation cost:	\$1,140
Payback period:	1.28year
Natural Gas Savings:	180.3MMBtu

Expected Savings

There are nine 75hp blowers in the blower room. According to the plant personnel, there are always six blowers running. In order to keep the blower room cool, the massive heat generated by the blower motors are exhausted outside by exhaust fans. Huge amount of heat is wasted in this way in winter. Therefore, it is recommended to recover the heat from the blower room for space heating in winter.

The heat generation from the blowers can be calculated through:

HG =
$$HP \times N \times C1 \times (1 - Eff) \times H \times C2$$

Where,

HG	=	Heat generation (MMBtu)
HP	=	Horse power of the blower (75hp)
N	=	Number of the running blowers (6)
C1	=	Conversion factor (0.746kW/hp)

Eff	=	Motor efficiency (95%)
Η	=	Operation hours (3,600hours)
C2	=	Conversion factor (0.0034MMBtu/kWh)

Therefore,

HG = 206MMBtu

It is recommended to install duct work to direct dump the heat into the area where space heating is needed in winter. The annual energy savings can be calculated as:

AES =
$$HG \times HRE/Eff_h$$

Where,

HRE	=	Heat recovery efficiency $(70\%)^{52}$
Ef f _h	=	Space heating efficiency (80%)

Therefore,

AES = 180.3MMBtu

The Annual Cost Savings (ACS) is given by:

ACS =
$$AES \times R_{ag}$$

Where,

Therefore,

Annual Cost Savings (ACS) = \$888/yr

⁵² Estimated by IAC team.

⁵³ Obtained from utility analysis

Implementation Cost and Payback Period

The implementation of this recommendation needs the installation of ductwork from the exhaust fans to the area that needs space heating in winter. To redistribute hot exhaust air, the required materials, labor and associated costs are show in the implementation table below⁵⁴:

Part	Cost
Duct	\$200
Labor fee	\$30/hour
Labor hours	8 hours
Dampers	\$100
Drill a hole	\$600
Total Cost	\$1,140

Table 7: I	mplementation	cost details
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The payback period is the number of years we expect it to take to recoup the implementation cost. The payback period is determined by:

_	ImplementationCost (\$)	
=	AnnualCostSavings (<mark>\$</mark> yr)	
=	<u>\$1,140</u> \$888	
=	1.28year	
	= =	

⁵⁴ Estimated by IAC team.

Appendix A: Environmental Impact

I. Impact of Energy Usage

The recommendations from this report will not only reduce energy usage and costs, but will reduce the negative environmental impacts of producing electricity. Reduction in energy consumption reduces the electricity the power plant must supply. Coal, natural gas and petroleum are the main fuels used for electricity generation, making up about 81% of the electricity generated in Wisconsin in 2007⁵⁵. All fossil fuels release pollutants when burned to produce electricity.

The Intergovernmental Panel on Climate Change (IPCC) concluded that human consumption of fossil fuels has led to climate change. Some of the effects of climate change include loss of glaciers, loss of species, increase in severe weather, increased flooding, acid rain, and respiratory problems in humans including higher incidences of asthma⁵⁶.

The harmful emissions from power plants include carbon dioxide (CO₂) gas which contributes to climate change, nitrous oxide (NO_x) and sulfur oxide (SO_x) which lead to acid rain, small particulates (< 10 μ m [PM 10]) which cause respiratory irritation, volatile organic compounds (VOC), and mercury (Hg).

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⁵⁵ http://energyindependence.wi.gov/docview.asp?docid=15822&locid=160

⁵⁶ Edenhofer et. al, IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. Intergovernmental Panel on Climate Change, 2011.

Table A1 below shows the annual reduction of carbon dioxide if each recommendation is implemented.

AR	Annual Resource Savings	CO2 Reduction (tons/yr)
1	462,359 kWh	394.8
2	31,440 kWh	26.8
3	709.6 MMBtu	37.6
4	37,498 kWh	32.0
5	205.4MMBtu	103.9
6	N/A	N/A
7	N/A	N/A
8	180.3MMBtu	9.6
Total		604.8

Table A1: Annual Reduction of Pollutants as a Result of Implemented AR's

Additional pollutant reduction values can be calculated using the following rates:

- CO₂ reduction for natural gas 117.1 lbs/MMBtu
- CO2 reduction for electricity 1.885 lbs /kWh*
- VOC reduction for electricity 0.036 lbs /MWh*
- NOx reduction for electricity 2.57 lbs /MWh*
- CO reduction for electricity 0.74 lbs /MWh*
- SO₂ reduction for electricity 5.35 lbs /MWh*
- PM 10 reduction for electricity 0.23 lbs /MWh*
- Hg reduction for electricity 17.40 mg /MWh

*Source: http://www.cleanerandgreener.org/resources/emissions-reductions-

calculator.html (Rates are for the average kWh produced in Wisconsin power plants)

Appendix B: Financial Analysis

I. Calculations of Cost Savings

To estimate the dollar savings for an AR involving a reduction in electrical consumption, the IAC analyzes both total power consumption (kWh) and maximum power draw or demand (kW) savings separately. Your monthly bill from the power company is based on consumption (kWh), billing demand (kW) and applicable taxes and surcharges. Many utilities have different on peak and off peak rates for electricity usage. Rates can also depend on total usage. Since an AR could affect any combination of the above parameters, the actual dollar savings could differ from the estimated dollar savings shown on the report. Additionally, an AR involving only a reduction in demand (kW) or power factor (PF) improvement saves only dollars and no energy consumption (kWh).

In order to simplify calculations of cost savings due to a reduction in natural gas or fuel oil use, all of our calculations use average values of the price of fuel. It is normal for the prices to fluctuate throughout the year, so the actual cost savings may differ slightly from what is reported. We expect no significant changes in potential dollar savings for most of our recommendations involving natural gas or fuel oil.

This report includes monthly energy consumption data, however does not relate energy consumption to monthly production. Energy consumption is usually closely tied to production rates, so considering the ratio of monthly energy consumption to monthly production can be very useful. A measure of production consistent with company production record keeping procedures should be used. Examples of appropriate measures are gross sales, number of units produced or processed, or pound of raw material used. It is important that the same time period be used for energy consumption and plant production.

Unlike energy, the data regarding waste streams and associated costs (disposal, handling labor, and others) is generally not readily available. Our center always makes substantial efforts to use the actual documentation from company records to quantify the number needed for the

calculation of waste reduction and cost savings. If possible, we always attempt to collect such data by suitable measurements during the visit. In cases where enough documentation is not available, the quantification is based on discussions with the plant manager and other appropriate plant personnel. In the very extreme case, subjective estimates of such numbers are used.

All the ARs provide enough technical information for the calculation of energy, waste and cost savings. The numbers used in our calculations can be updated or corrected easily and a revised estimate can be obtained if deemed necessary.

II. Financial Analysis and Evaluation

While many assessment recommendations may be found during a close examination of the plant and operations, some can be quickly rejected because of a low or negative return on investment. First-level measures of performance can be useful in screening out such ARs without application of more sensitive second-level measures. In general, however, first-level measures should not be used for justifying major investments for energy conservation projects since these measures do not reflect the time value of money. Because first-level measures, such as "payback period" and "return on investment", are often referenced and are useful for screening candidate investments, it is desirable to show how they are computed and why they are not complete.

The information required to calculate these performance measures is:

- First Cost, FC
- Annual Operating Cost (if any due to investment), AOC
- Projected Fuel Price, PFP
- Estimated Lifetime, EL
- Annual Fuel Saving, AFS

The first cost is the estimated dollar cost of labor and materials required to implement the scheme. The other four items determine the annual benefit stream. The salvage value of the investment is disregarded here. The projected fuel price represents an average fuel price during the estimated lifetime of the investment. The use of current fuel prices will result in a lower saving estimate than can be reasonably expected, inducing bias against making energy conservation

investments.

The net annual saving S is defined as: S = (AFS)(PFP) - AOC

A. The Payback Period

The payback period, PP, is defined as the first cost divided by the net annual saving, or

PP = FC/S. The payback period is then compared to the expected lifetime of the investment in order to make a rough judgment as to its potential for recoupment. A payback period of less than one-half the lifetime of an investment would generally be considered to be profitable where the lifetime is ten years or less.

B. The Return on Investment

The return on investment (ROI) takes into account the depletion of the investment over its economic life by providing for renewal through a depreciation charge. A straight line depreciation charge DC is defined as: DC = FC/EL. The percent return on investment can be calculated from it as: ROI (%/yr) = 100 x (S-DC) / FC. The ROI measure has the advantage over the PP measure of putting investments with different life expectancies on a comparable basis. However, where the rate of return is small (less than 20%) second-level measures are called for. Second-level measures of performances incorporate an allowance for the time value of money. Several second-level measurements for evaluating ARs are available, such as, time to recoup capital investment and internal rate of return.

C. Time to Recoup Capital Investment

The time to recoup capital investment, or "break-even" period, is similar to the payback period (PP) discussed earlier, except that the break-even period (BP) can be approximated by use of Table B1. In the column for the appropriate discount rate (D) locate the present worth factor (PWF) of either side of the payback period (PP) calculated as shown previously. The break-even period (BP) will be between these two years. Interpolation will allow close approximation of the break-even period.

D. Internal Rate of Return

The internal rate of return (IRR) is defined as that discount rate (D) which reduces the stream of net returns associated with the investment to a present value of zero. Unfortunately, the

calculation of IRR is not straightforward but requires an iterative approach to converge to the solution. IRR is obtained by the following equation for "i": PW (i) = 0

In this equation, PW is the present worth of cash flow streams (annual savings).

Example Calculation

Management is considering a capital investment in its manufacturing process for energy conservation purposes. It will cost \$100,000 to design and install but will involve no new recurring costs. This project is expected to save an average of 15,500 MMBtu/yr of natural gas for the next 5 years with the fuel cost projected to be \$3.50/MMBtu. Assuming that a 20% discount rate is appropriate, will this be a profitable investment?

First Cost (FC) = \$100,000 Estimated Life (EL) = 5 years Annual Fuel Saving (AFS) = 15,500 MMBtu/yr Projected Fuel Price (PFP) = \$3.50/MMBtu Net Annual Saving (S)= (AFS) x (PEP) = AOC = 15,500 MMBTU x 3.50/MMBTU =

Net Annual Saving (S)= (AFS) x (PFP) – AOC = 15,500 MMBTU x 3.50/MMBTU = \$54,250/yr

First-Level Measures of Performance

1. Payback period (no discounting)

PP = FC/S =\$100,000/(\$54,250/yr) = 1.84 yr

2. Return on Investment

DC = FC/EL = \$100,000/5 yrs = \$20,000/yr

ROI = 100 x (S-DC)/FC = 100 x (\$54,250/yr - \$20,000/yr)/\$100,000 = 24.25%/yr

The return on investment (ROI), a measure of profitability, shows this to be an attractive investment. Second-level measures of performance are needed, however, if the time value of money is to be incorporated into the analysis.

Second-Level Measures of Performance

3. Time to Recoup Investment

The time to recoup investment can be approximated by using Table B1 and the payback period (PP) of 1.84 years. In the 20% discount rate column the present worth factor closest to 1.04

is 1.528, indicating that the investment will be entirely recouped in about 18 months. While this is approximately the same as the payback period without discounting, it provides a much better indication of the profitability of this investment because it includes the cost of foregone investment opportunities. If the proper discount rate has been used, any investment in which the initial cost is recouped in a period less than its lifetime should be considered to be profitable.

4. Internal Rate of Return (IRR)

The internal rate of return is obtained by solving for "i" in the following equation.

PW (i) = 0 - 100,000 + 54,250 (1 + i) - 1 + 54,250 (1 + i) - 5 = 0

i = 45%

The internal rate of return (IRR) is approximately 45%. As this rate is greater than the discount rate of 20%, the investment is justified.

Lifetime (EL)	Discount Rate (D)								
Year	1%	3%	5%	6%	8%	10%	12%	15%	20%
1	0.99	0.97	0.95	0.94	0.93	0.91	0.89	0.87	0.83
2	1.97	1.91	1.86	1.83	1.78	1.74	1.69	1.63	1.53
3	2.94	2.83	2.72	2.62	2.58	2.49	2.4	2.28	2.11
4	3.9	3.72	3.54	3.46	3.31	3.17	3.04	2.85	2.59
5	4.85	4.58	4.33	4.21	3.99	3.79	3.61	3.35	2.99
6	5.8	5.42	5.08	4.92	4.62	4.36	4.11	3.78	3.33
7	6.73	6.23	5.79	5.58	5.21	4.87	4.56	4.16	3.6
8	7.65	7.02	6.46	6.2	5.75	5.33	4.97	4.49	3.84
9	8.57	7.79	7.11	6.8	6.25	5.76	5.33	4.77	4.03
10	9.47	8.53	7.72	7.36	6.71	6.14	5.65	5.02	4.19

Table B1: Present Worth Factors (PWF)

UWM Industrial Assessment Center

12	11.26	9.95	8.86	8.38	7.54	6.81	6.19	5.42	4.44
15	13.87	11.94	10.38	9.71	8.56	7.61	6.81	5.85	4.68
20	18.05	14.88	12.46	11.47	9.82	8.51	7.47	6.26	4.87
30	25.81	19.6	15.37	13.76	11.26	9.43	8.06	6.57	4.98
40	32.84	23.12	17.16	15.05	11.92	9.78	8.24	6.64	5
50	39.2	25.73	18.26	15.76	12.23	9.91	83	6.66	5

Appendix C: Conversion Factors

Energy Unit	Equivalent
1 KWH	3,412 BTU
1 MMBTU	293 KWH
1 HP	2,545 BTU/hr
1 HP	0.746 KW
1 HP (boiler)	33,500 BTU
1 ton capacity (A/C)	12,000 BTU/hr
1 ton capacity (A/C)	3.517 KWH
1 therm	100,000 BTU
1 cu ft natural gas	1,000 BTU ¹
1 ton coal	25,000,000 ¹ BTU
No. 2 oil (HHV) ²	140,000 ¹ BTU/gall
No. 6 oil (HHV) ²	152,000 ¹ BTU/gall
1 gallon (water)	8.34 lbs
1 cu ft (water)	7.5 gallons
1 drum	55 gallons
1 bale	1,000 lbs
1 ton	2,000 lbs

Table C1: Conversion Factors

¹ Varies slightly with supplier ² Higher Heating Value

	Base	Speed	
НР	3600 RPM	1800 RPM	1200 RPM
1	75.5	82.5	80.0
1.5	82.5	84.0	85.5
2	84.0	84.0	86.5
3	85.5	87.5	87.5
5	87.5	87.5	87.5
7.5	88.5	89.5	89.5
10	89.5	89.5	89.5
15	90.2	91.0	90.2
20	90.2	91.0	90.2
25	91.0	92.4	91.7
30	91.0	92.4	91.7
40	91.7	93.0	93.0
50	92.4	93.0	93.0
60	93.0	93.6	93.6
75	93.0	94.1	93.6
100	93.6	94.5	94.1
125	94.5	94.5	94.1
150	94.5	95.0	95.0
200	95.0	95.0	95.0
AVE. 36 HP	89.6	91.0	90.0

Table C2: Electric Motor System Horsepower vs. Efficiency