PLAN IT GREEN
Sustainable Energy Developement

In December 2020, PlanIt Green LLC facilitated the performance of an in depth energy audit for a lettuce processing facility in Pennsylvania. The following report is the result of the audit.

EXECUTIVE SUMMARY

Report No:	DL0187	# of Employees:	50
Assessment Date:	12/21/2020	Operating Hours:	5,125
		Facility Size (sf):	~90,000

RECOMMENDATIONS AND RESULTS

Implementation of **all** the assessment recommendations (ARs) in this report would:

- Reduce electric energy consumption by **1,310,887 kWh** or **39.4%** per year.
- Reduce Natural Gas consumption by **95 MMBTU** or **20%** per year.
- Reduce carbon dioxide emission from electricity generation and heating by **1,622,851 lbs.** per year. This equates to a **39.18% reduction in the projected facility carbon footprint**.
- Produce a total cost savings of **$89,891** per year, a reduction of **29.8%.**
- The total implementation cost of all recommendations is **$157,022** with an average payback of **1.67 years**

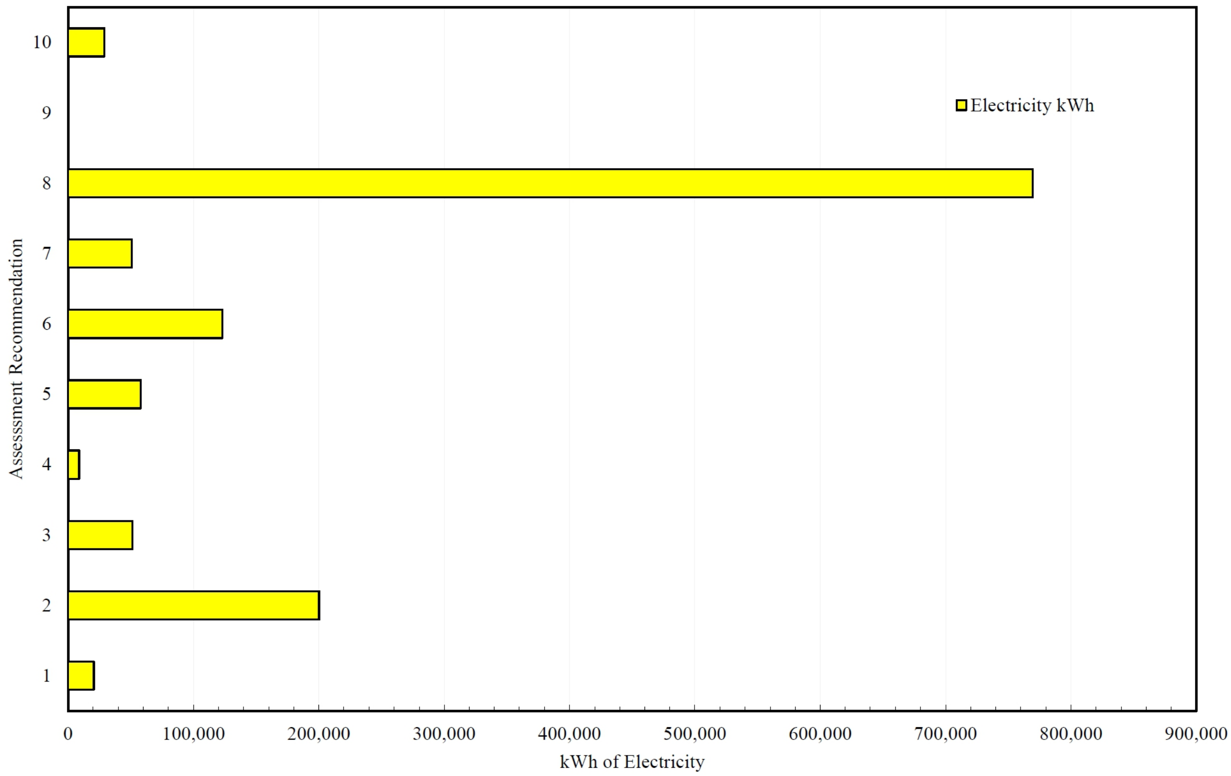
TABLE I: SUMMARY OF ASSESSMENT RECOMMENDATIONS

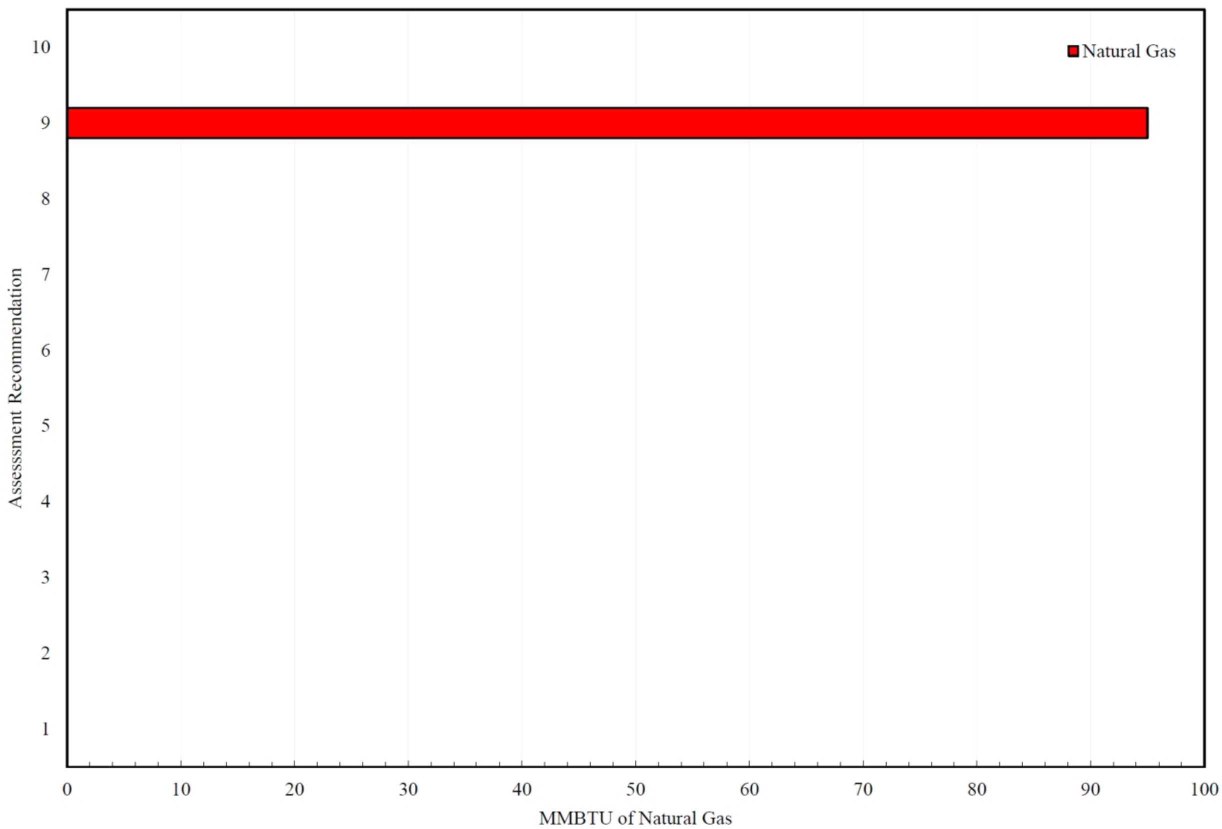
This table summarizes the energy savings of each individual assessment recommendation.

Assessment Recommendation Summary

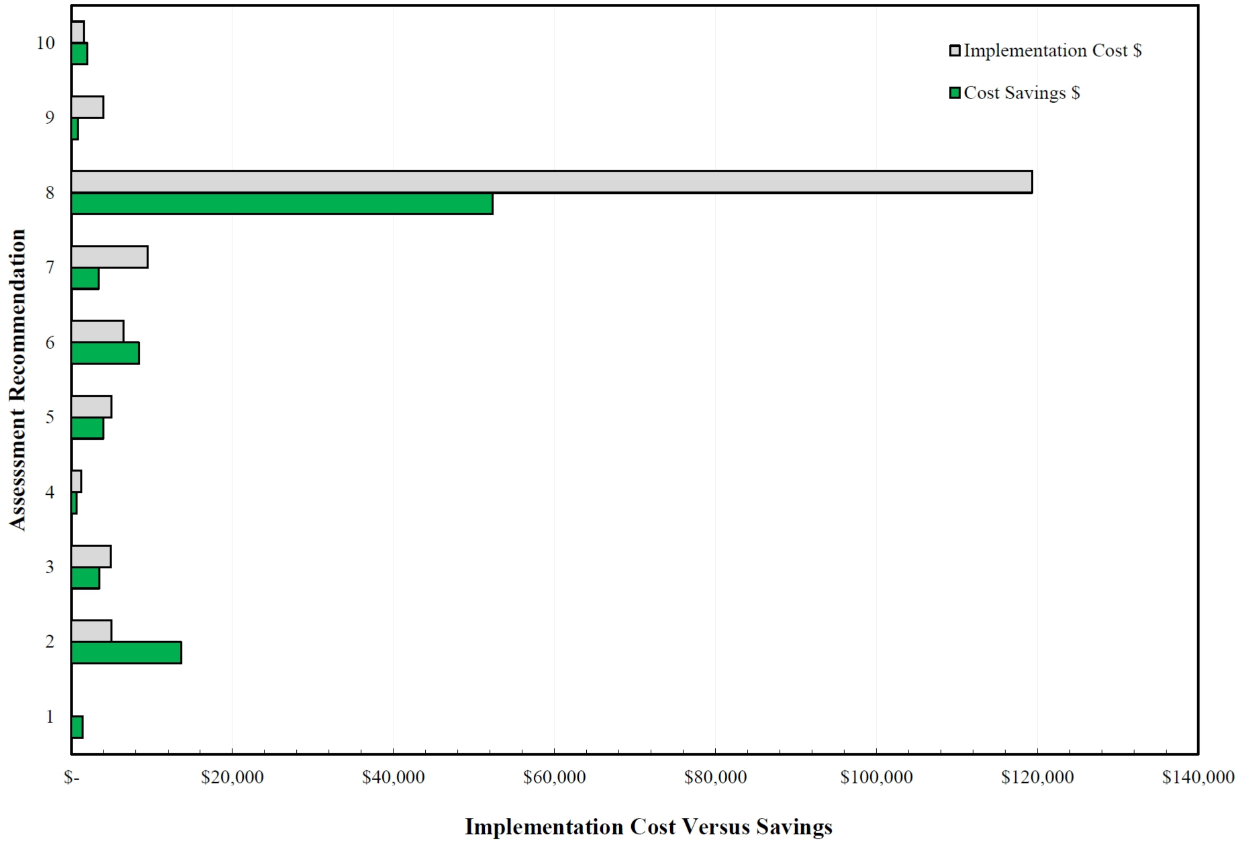
AR No.	Description	ARC Code	Electricity kWh	Natural Gas MMBtu	Cost Savings $	Implementation Cost $	Payback Period years
1	Switch Office And Break Room RTUs To Fan Auto	2.7316	20,420	0	$1,390	$0	0.00
2	Switch Evaporators To Fan Auto Mode	2.7316	200,269	0	$13,620	$5,000	0.37
3	Replace Evaporator Motors With More Efficient Models	2.4133	51,190	0	$3,480	$4,900	1.41
4	Repair the 1 kW "Vampire Load" On The 30 HP Air Compressor	2.4224	8,766	0	$596	$1,200	2.01
5	Repair Compressed Air Leaks	2.4236	57,990	0	$3,940	$5,000	1.27
6	Install Variable Speed Drive On Glycol Pump And Convert 3-Way Valves to 2-Way Valves	2.4146	123,050	0	$8,370	$6,500	0.78
7	Install Variable Drives On Boiler Circulation Pumps And 2-Way Valves On Fan Coil Units	2.4146	50,700	0	$3,400	$9,500	2.79
8	Replace Slide Control Ammonia Compressor With Variable Frequency Drive Compressor	2.4146	769,470	0	$52,324	$119,348	2.28
9	Port Air Compressor Exhaust Into The "Attic" Area In The Winter	2.2491	0	95	$797	$4,000	5.02
10	Replace 24/7 Lighting With LED Lighting	2.7142	29,032	0	$1,974	$1,574	0.80
		Total Savings	**1,310,887**	**95.0**	**$89,891**	**$157,022**	**1.67**
		Current Consumption	**3,324,000**	**474.0**	**$301,306**		
		% Reduction	**39.4%**	**20.0%**	**29.8%**		

ANNUAL RESOURCE SAVINGS

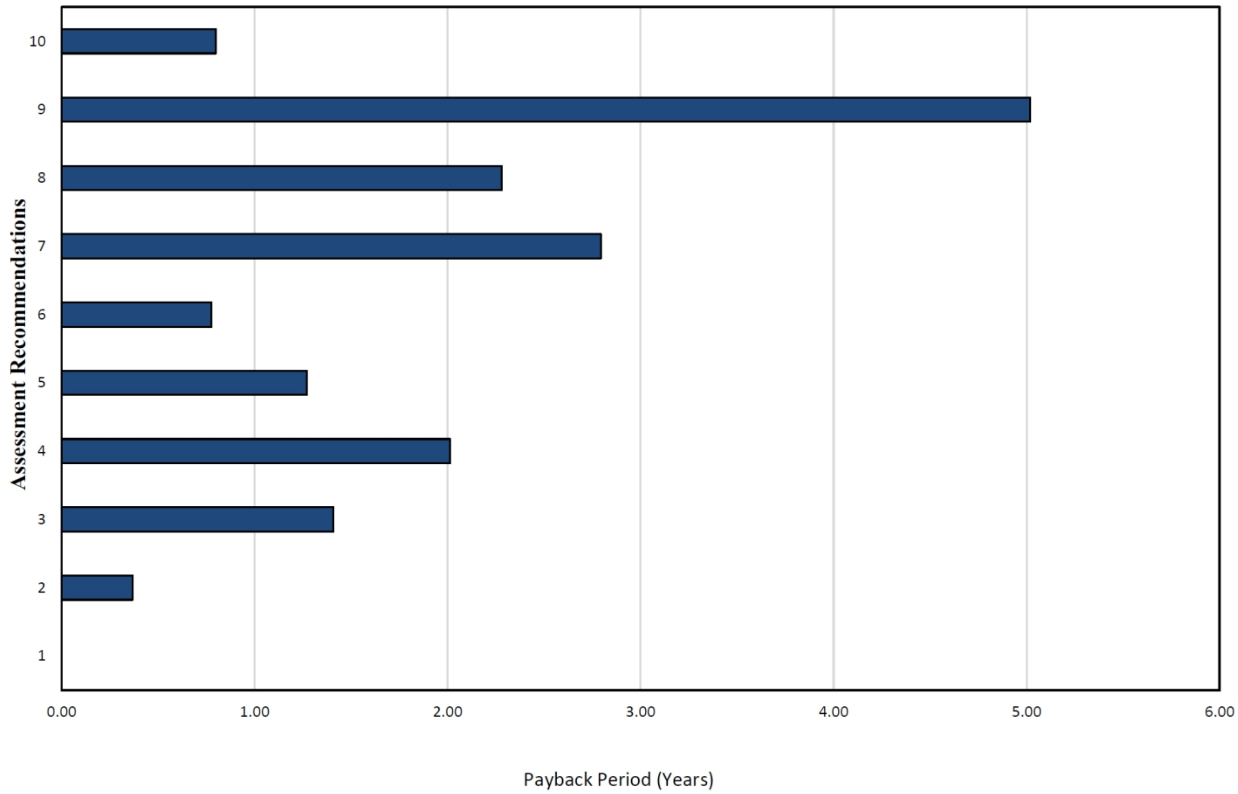



Natural Gas
Assesssment Recommendation
MMBTU of Natural Gas
0
10
20
30
40
50
60
70
80
90
100
1
2
3
4
5
6
7
8
9
10

IMPLEMENTATION COST VERSUS SAVINGS



PAYBACK PERIOD



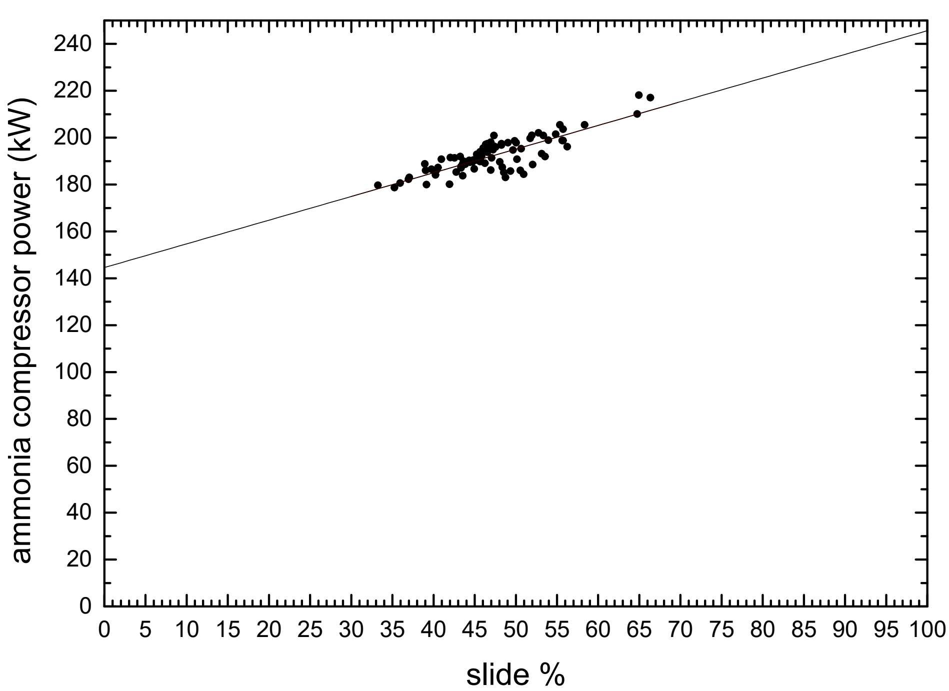
CURRENT FACILITY OPERATIONS

FACILITY DESCRIPTION

The plant manufactures packaged vegetable and salad related products using a process including washing, shredding, and bagging. Production hours are 7:00 AM – 9:00 PM Sunday through Wednesday, and additionally cleaning is performed following each production night. Most equipment is turned off then around 1:30p Thursday, until 7:00 AM the following Sunday. Thus, production hours, using 50 weeks/year, taking into account holidays, is $14 * 4 * 50 = \mathbf{2,800/year}$, while plant hours are approximately $102.5 * 50 = \mathbf{5,125/year}$. In addition, shipping and the office have nearly 24/7 occupancy due to continuous shipping of product. Also, the air compressor is left on 24/7, to provide pressure to packaging machinery in order to keep water out.

The entire plant except for office and breakroom areas is kept at about 40°F. Refrigeration is provided by identical lead/lag 400 HP slider ammonia compressors that cool a glycol loop via a heat exchanger. The glycol is pumped to 18 evaporators throughout the plant via a 20 HP pump. **The evaporators were logged and evaporators 4, 17, and 18 were off the whole time, and so will be treated as decommissioned in this report's calculations**. The evaporators have bypass valves so flow is constant, and the glycol pump is approximated then to consume $20 * 0.746\ (kW/HP)/0.93\ (rated\ eff) * 8{,}766 = \mathbf{140,630\ kWh/year}$.

The ammonia compressor provided a readout of slider opening percentage and current (in Amps), and a sampling of readings was performed at the assessment, with power calculated based upon 480 V and the nameplate Power Factor of 87.9 %:



The average slider position during the spot measurement was 47.21%, and hence the average power was **192.3 kW**. **From the ammonia compressor log, it runs at approximately 90 % of production-hours power during non-production hours.** Hence ammonia compressor consumption is $192.3 * 5{,}125 + 0.9 * 192.3 * 3{,}641 = \mathbf{1,632,990}\ \boldsymbol{kWh/year}$.

The evaporators are defrosted daily for about 45 minutes using hot gas from the ammonia heat reject line.

The evaporator fans are run in fan-continuous mode. They were measured and units (designated "AH") 1-3, 5-16 consume **44.10 kW** total. AH unit 4 was in in defrost mode where the fans are off, and apparently units 17 and 18 (which measured 0 current) were down for maintenance. **During the data log evaporators 4, 17, and 18 were off the whole time, and thus they are excluded from calculations here.** Here is the spreadsheet of the powers of the units:

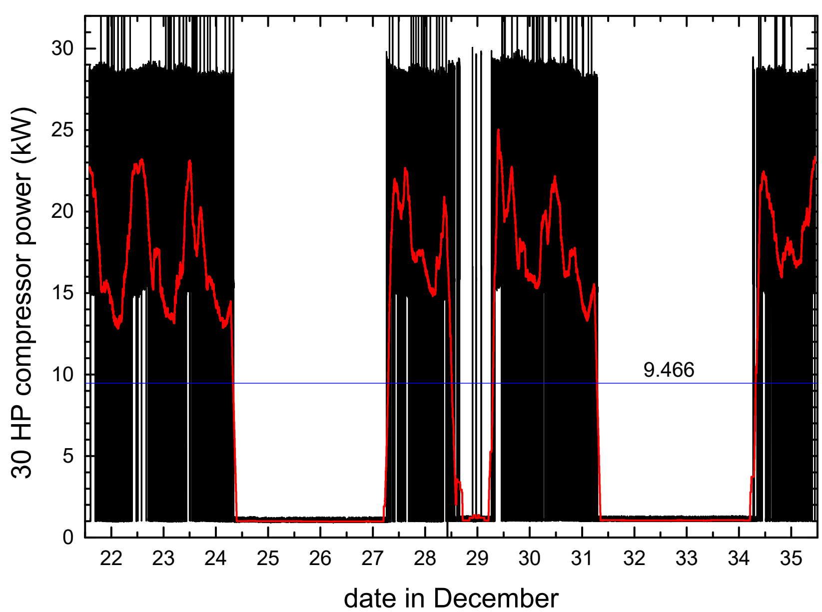
AH	kW-on
1	4.08
2	3.85
3	3.09
5	2.93
6	3.23
7	3.23
8	2.33
9	2.25
10	2.25
11	4.5
12	2.25
13	2.33
14	2.03
15	2.18
16	2.14
kWtotave (taking into account defrost)	41.34
kWh/year (all during production; 3, 14, 15, 16 otherwise)	245147
plant hours = 5125	
non-plant hours = 3641	

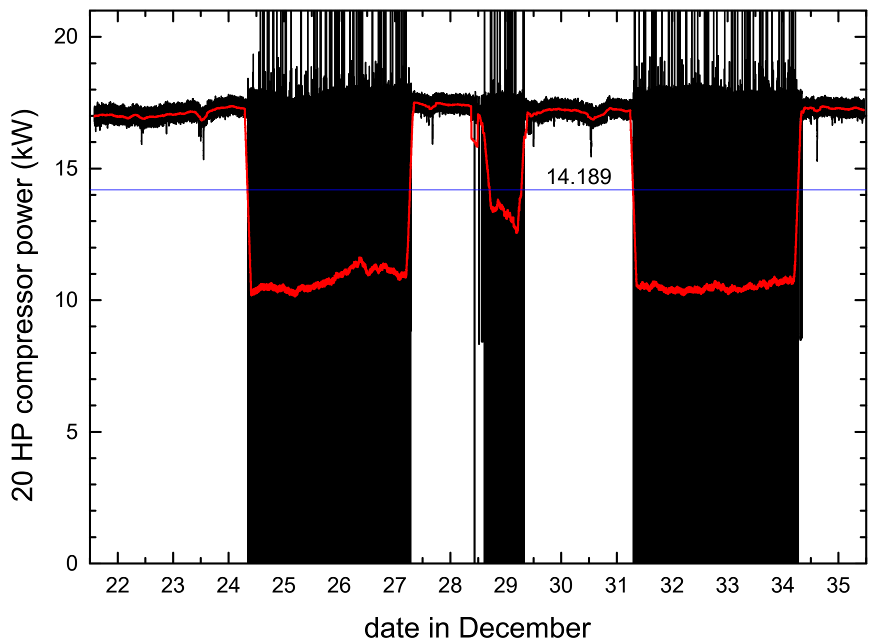
Plant personnel report that outside plant hours, all but 3, 14, 15, and 16 are turned off. Thus, the total consumption of all the evaporators is **245,147 kWh/year**.

The ammonia compressor reject is condensed using a wet/dry cooling tower. The cooling tower fans were off during the cold assessment day, relying upon ambient cooling. The fans are reported to be on variable drives already.

There is a 15 HP makeup air unit with a glycol loop for the production area that is reported to come on to provide over-pressure to the area to keep particulates out. It was not on during the assessment. It is assumed here since it was off that it is being properly controlled to come on when needed and does not require adjustment for energy savings.

The plant has small compressed air requirements primarily for actuators on the production equipment, that is supplied by 20 and 30 HP load/unload units, that were both on during the assessment, loading up to 115 psi. The 30 HP unit is rated to provide 117.2 cfm and the 20 HP unit is rated for 72.9 cfm. The 30 HP was measured to consume **27.76 kW** loaded and **14.15 kW** unloaded, (using a Power Factor of 0.8). A spot measurement found a loaded duty cycle of $50\ seconds/102\ seconds = \mathbf{49\%}$. The 20 HP was measured to consume **17.54 kW** loaded; when it "unloaded," consumption was measured at **17.35 kW**, which clearly is not right as the consumption in air compressors drops considerably in the unload state. It is the audit team's belief that the inlet valve is sticking so that the unit doesn't actually fully unload. It was measured to have a loaded "duty cycle" of $37\ seconds/152\ seconds = \mathbf{24\%}$, low because it wasn't fully unloading. Assuming this spot measurement is reflective of production hours (which plant personnel said it probably did), the average consumption of both compressors during production hours is $14.15 + 0.49 * 13.61\ (30\ HP\ Unit) + 17.35 + 0.24 * 0.19\ (20\ HP\ Unit) = \mathbf{38.21\ kW}$. During non-production hours, probably the 20 HP is on, and probably remains in its "unload" state, consuming **17.35 kW**. Thus, the air compressors consume $38.21 * 2{,}800 + 17.35 * 5{,}966 = \mathbf{210{,}500\ kWh/year}$. Data loggers were left on both compressors to get better data, which can be seen below:





As can be seen, during production hours the 20 HP remains fully loaded, perhaps as an artifact of the inlet vane being stuck. However, this has the very serendipitous result that the pair operate at near perfect efficiency, with the 20 HP fully loaded and the 30 HP handling the swing. Furthermore, both have very good time-out operation, which acts to give them a near-VFD like performance. Hence, it is recommended that they just continue to operate as-is, during production hours.

However, there are 2 issues that the logs reveal: the first is that the 30 HP does not time-out to zero, but to a baseline of 1 kW. It is not clear why this would be, and it should be explored and corrected. Second, the 20 HP performs a time-out of ~ 10.5 kW during non-production hours. Since the only stated operation during non-production hours is to maintain pressure, which should require no flow, it is estimated below that conservatively 90 % of this consumption is leaks (which plant personnel agreed with).

While the log encompassed holidays, it is used here to provide annual consumption of both compressors as $(9.466 + 14.189) * 8{,}766 \ = \ \boldsymbol{207{,}360\ kWh/year}$, very near the value obtained from the spot measurement during the assessment.

There is a hot water boiler that was firing at 140 F for space heat, supplying hot water to fan coil units in the warehouse and "attic" areas. (The "attic" is an short height volume above the inner-building cold rooms, and is heated to avoid freezing.) There is a natural gas DHW heater, but it is not working, so there it has no consumption.

The boiler hot water is routed to the fan coil units by two 7.5 HP circulation pumps that serve two loops, one for the warehouse and one for the attic (if a pump goes down, there is a check valve that opens so the other can provide partial pressure). They were measured to consume **5.95** and **5.24 kW**. From the utility analysis, they appear to operate 7 out of 12 months of the year, and hence consume $(5.95 + 5.24) * \left(\frac{7}{12}\right) * 8{,}766 = \mathbf{57{,}220\ kWh/year}$. Data loggers were left on them.

The office/break room areas are served by 3 RTUs, which are set to fan-on mode. RTU1 (as labeled on the side of the unit) was apparently serving the break room, and could be measured; its fans consume **1.34 kW**. The ones above the office could not be measured (as they were not safely reachable in the snow and ice), and are approximated here based upon similar units to consume **0.7 kW**, and thus the 3 RTUs fans consume $(1.34 + 0.7 + 0.7) * 8{,}766 = \mathbf{24{,}020\ kWh/year}$.

There is an electric DHW heater that was measured to consume 15.6 A @ 206.3 V or 3.22 kW, and using an average firing rate of 30 % of the time (which facility personnel reported was an accurate assumption), it consumes $3.22 * 0.3 * 8{,}766 = \mathbf{8{,}460\ kWh/year}$. The logger data revises this **to 3,226 kWh/year.**

Production area lighting is all LED. The warehouse has 50 8’ T12 that are assumed to be 75W, and the office area hallways have 48 T8 32W, and according to facility personnel, those areas are lit 24/7. This gives non-LED lighting consumption as $(50 * 0.075 * 1.12\ (T12\ ballast\ factor) + 48 * 0.032) * 8{,}766 = \mathbf{52{,}910\ kWh/year}$.

Plant existing Best Practices include LED lighting, hot gas defrosts, recycling of production drainage water for cooling tower makeup, and cold-water cleaning or equipment.

ENERGY AND WASTE ACCOUNTING

ENERGY MANAGEMENT

One of the most practical strategies to analyze and control costs is an effective energy management program. Keeping up-to-date records of monthly energy consumption and associated costs using spreadsheets and bar charts can help track energy usage and identify opportunities to increase production efficiency and reduce energy costs. Separate analyses should be carried out for each primary energy type and all units should be converted to a common basis for easy interpretation and comparison.

The primary electric unit used in this report is kilowatt-hours per year (kWh/yr); electric demand savings are reported in kilowatts per year (kW/yr). The primary gas energy unit used is therms of natural gas (thm). The energy units used for liquid fuels (diesel, propane, gasoline) is British Thermal Units (Btu) per unit volume. All electric energy and gas energy savings are also reported in the common unit of Btu/yr), or million Btu's per year (MMBtu/yr). Some common conversion factors are listed below.

Energy Unit	**Equivalent Value**
GENERAL	
1 MMBtu	1,000,000 BTU
1 gallon of water	8.33 lbs
1 Kilojoule	0.94782 BTU
ELECTRICITY	
1 kWh	3,413 Btu or 0.003413 MMBtu
1 MMBtu	293.0 kWh
1 hp-h (electric)	2,545 Btu or 0.002545 MMBtu
1 hp (electric)	0.746 kW
1 kW	1.341 hp (electric)
NATURAL GAS	
1 therm (thm)	100,000 Btu
1 decatherm (Dth)	10 therms = 1,000,000 Btu = 1 MMBtu
100 cu. ft. natural gas (ccf)	~92.02 therms = 9.202 MMBtu*
1 hp-h (boiler)	33,500 BTU
OTHER	
1 gallon No. 2 Fuel Oil (Diesel)	140,000 BTU*
1 gallon No. 4 Fuel Oil	144,000 BTU*
1 gallon No. 6 Fuel Oil	152,000 BTU*
1 gallon gasoline	130,000 BTU*
1 gallon propane	92,000 BTU*
1 ton Coal	20,000,000 BTU*
1 Ton Refrigeration	12,000 BTU/hr

* Energy content varies with supplier

Energy Consumption Breakdown

DETAILED ELECTRICITY CONSUMPTION SUMMARY

Plant electric consumption is **3,324,000 kWh/year @ $0.062/kWh**, and including demand charges gives an average yearly rate of **$0.068/kWh**. From above a partial breakdown is:

End Use Equipment	Estimated Annual Usage (kWh)	% of Total Usage
Ammonia compressors	1,630,990	49.1%
Evaporators	245,147	7.4%
Air compressors	207,360	6.2%
Glycol pump	140,630	4.2%
Boiler circulation pumps	57,220	1.7%
RTU fans (fan-on)	24,020	0.7%
DHW heater	3,226	0.1%
Warehouse and office hallway lighting	52,910	1.6%
Other	962,497	29.0%
Total	3,324,000	

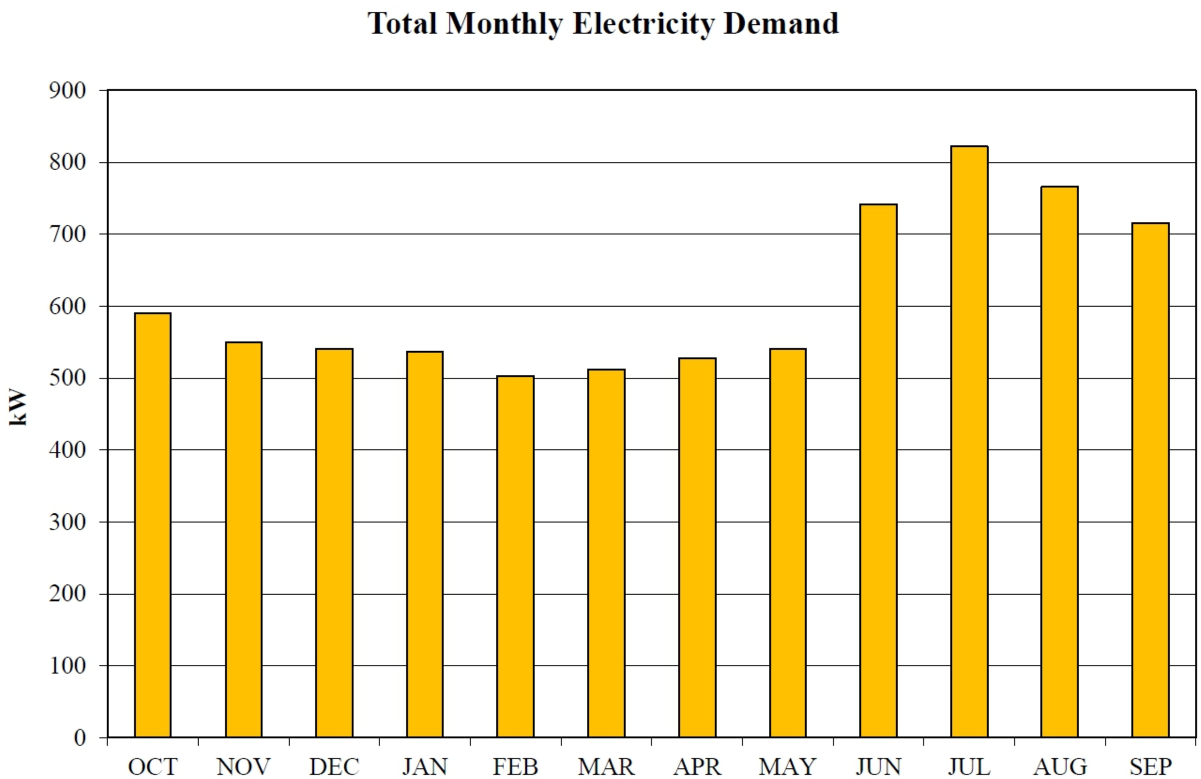
***Please note that only 71% of the plant's total electric consumers were able to be assessed during the audit due to time constraints*

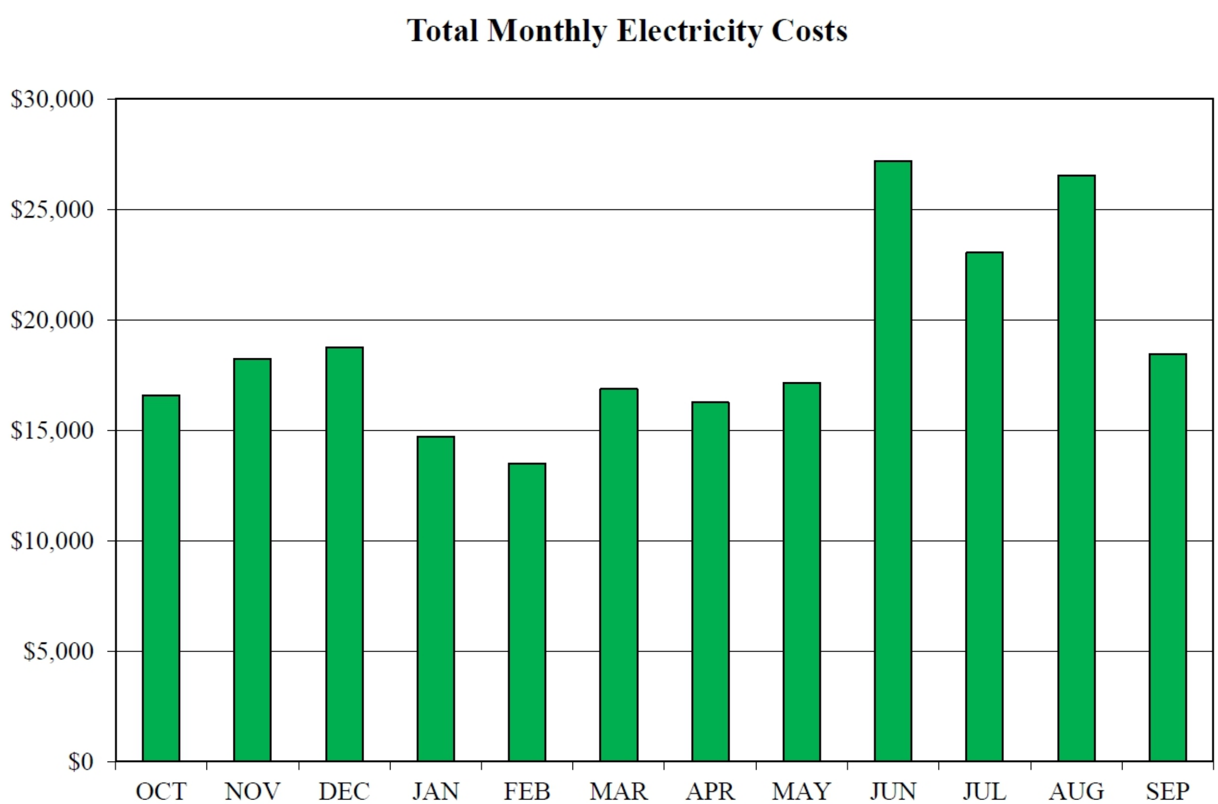
Facility Electricity Consumption:

Month	kWh	$/kWh	Monthly Total ($)
OCT	226,800	$0.066	16,600
NOV	254,400	$0.066	18,256
DEC	264,000	$0.065	18,751
JAN	210,000	$0.063	14,735
FEB	224,400	$0.054	13,494
MAR	247,200	$0.062	16,884
APR	236,400	$0.062	16,268
MAY	250,200	$0.062	17,155
JUN	409,800	$0.061	27,188
JUL	339,000	$0.061	23,054
AUG	394,200	$0.062	26,564
SEP	267,600	$0.062	18,467
TOTALS:	**3,324,000**	**$0.062**	**$227,416**

Charts for the total site electric consumption and costs are shown on the following page:

DETAILED ELECTRICITY COST AND CONSUMPTION GRAPHS





DETAILED NATURAL GAS CONSUMPTION SUMMARY

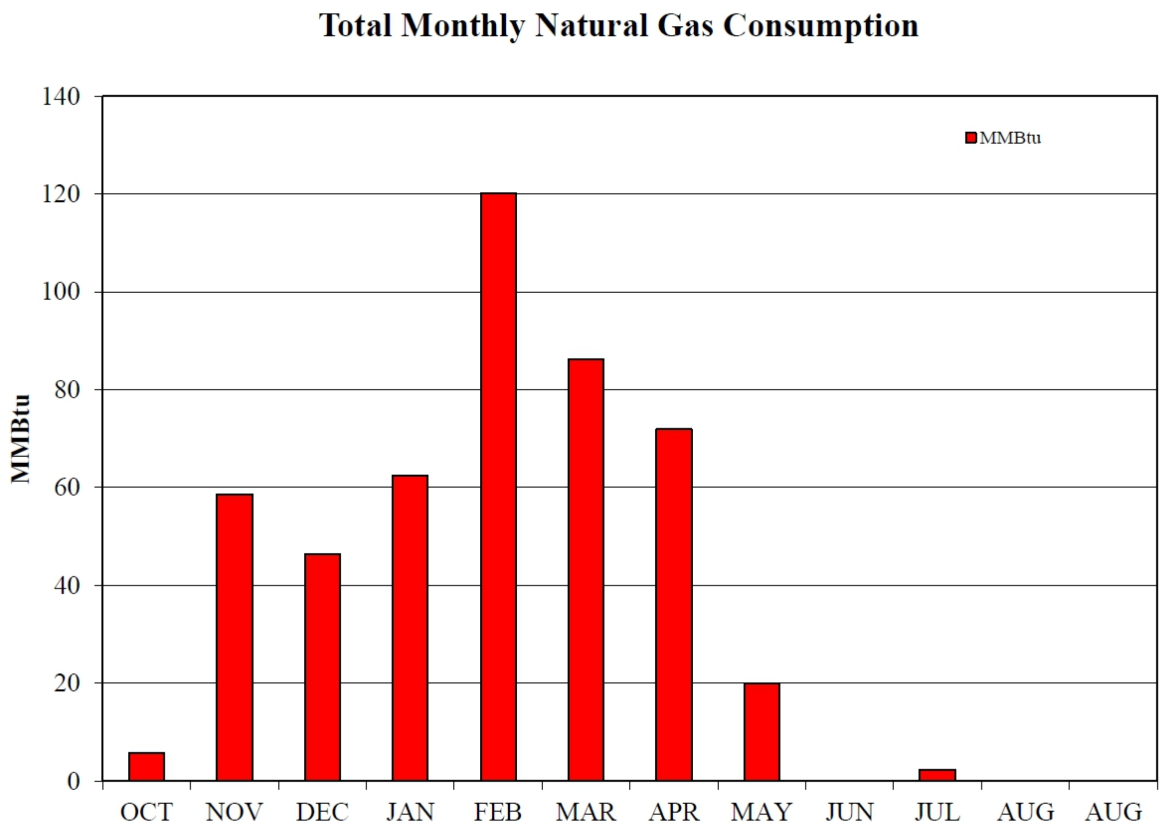
Plant gas consumption is 474 MMBTU/year @ $8.39/MMBTU, all for space heat in the boiler and also two RTU's above the office area.

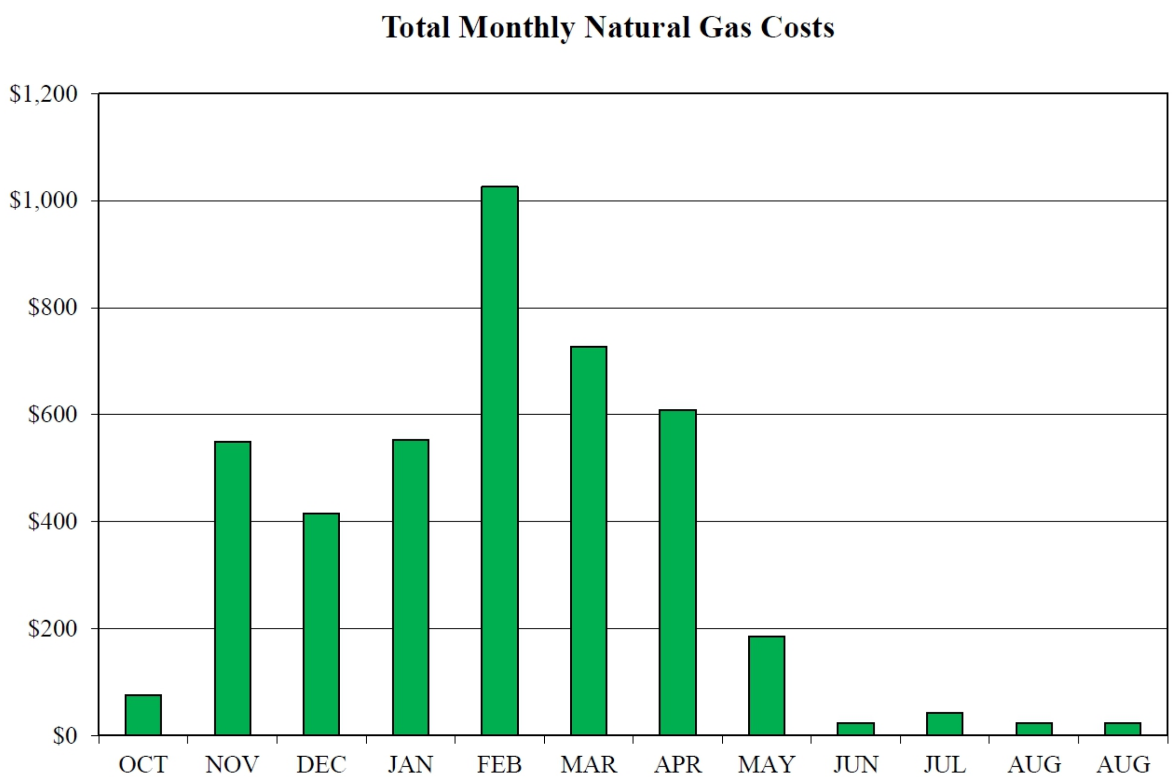
Facility Natural Gas Consumption:

Month	MMBTU	$/MMBTU	Monthly Total ($)
OCT	5.7	$9.27	$76
NOV	58.7	$8.96	$549
DEC	46.3	$8.48	$416
JAN	62.4	$8.48	$553
FEB	120.2	$8.34	$1,026
MAR	86.3	$8.14	$726
APR	71.9	$8.14	$609
MAY	19.9	$8.15	$186
JUN	0.0	$0.00	$24
JUL	2.3	$7.84	$43
AUG	0.0	$0.00	$24
SEP	0.0	$0.00	$24
TOTALS:	**474**	**$8.39**	**$4,256**

Charts for the total site Natural Gas consumption and costs are shown on the following page:

DETAILED NATURAL GAS COST AND CONSUMPTION GRAPHS





WATER CONSUMPTION SUMMARY

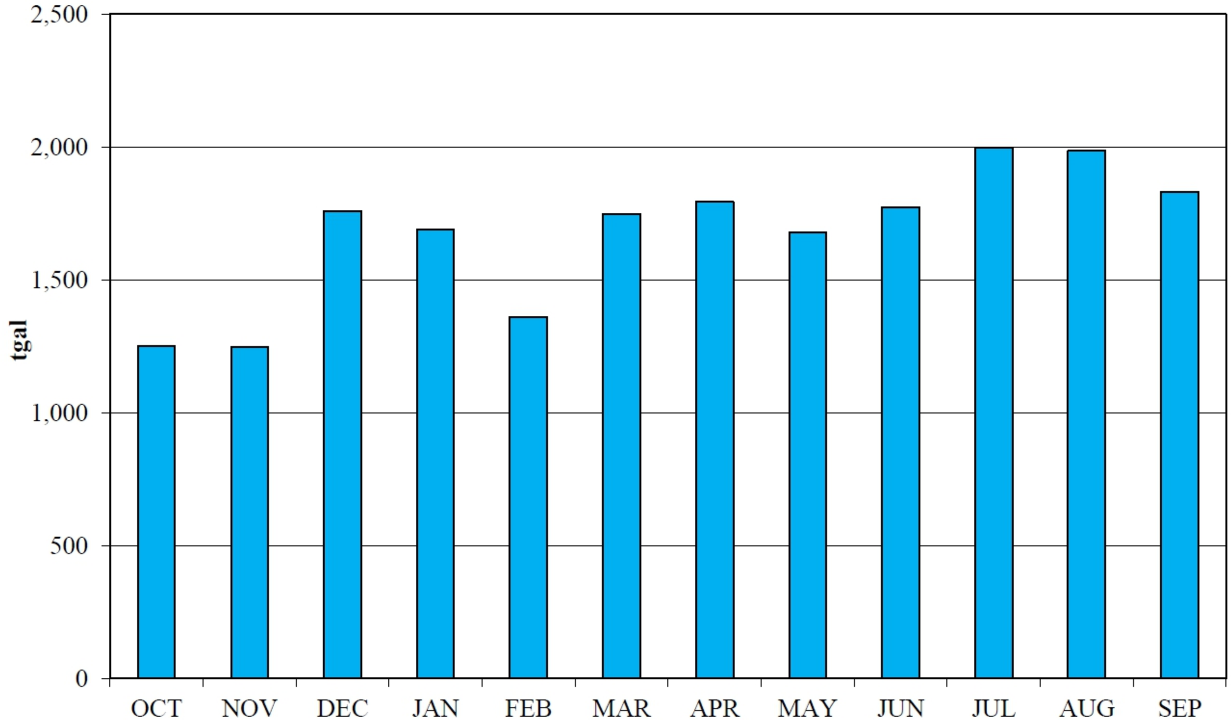
A monthly breakdown of water usage can be seen below:

Month	Thousand Gallons	$/Thous gal	Monthly Total ($)
OCT	1,250	$3.33	$4,382.02
NOV	1,249	$3.33	$4,377.15
DEC	1,758	$3.33	$6,075.52
JAN	1,689	$3.33	$5,844.97
FEB	1,362	$3.33	$4,754.45
MAR	1,747	$3.33	$6,038.45
APR	1,793	$3.33	$6,192.37
MAY	1,680	$3.33	$5,815.08
JUN	1,772	$3.33	$6,123.28
JUL	1,999	$3.33	$6,878.74
AUG	1,986	$3.33	$6,833.91
SEP	1,831	$3.33	$6,318.99
TOTALS:	**20,116**	**$3.33**	**$69,634.93**

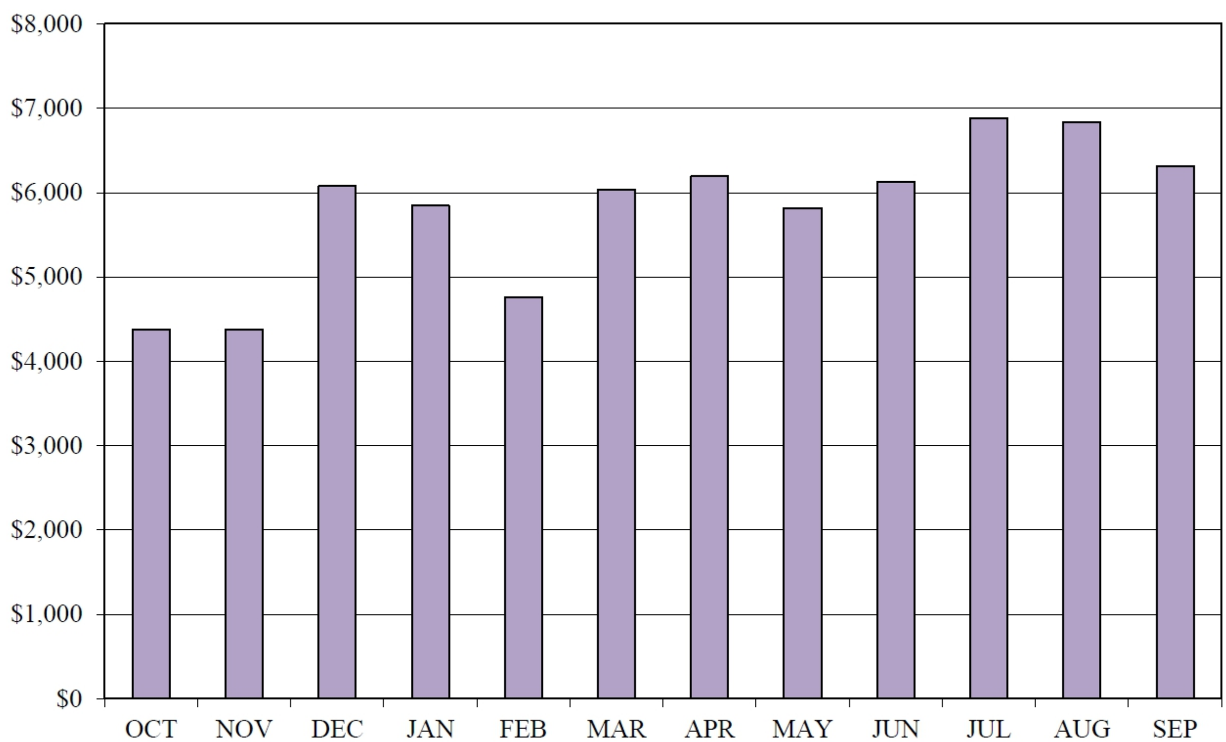
Charts for the total site Water consumption and costs are shown on the following page:

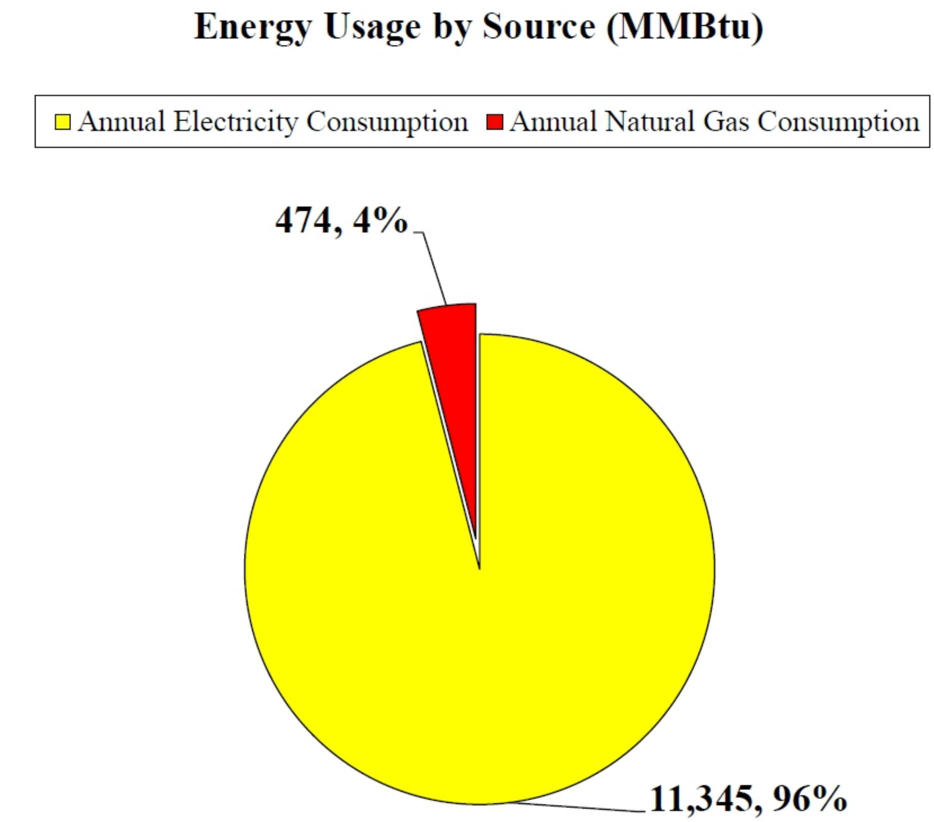
DETAILED WATER COST AND CONSUMPTION GRAPHS

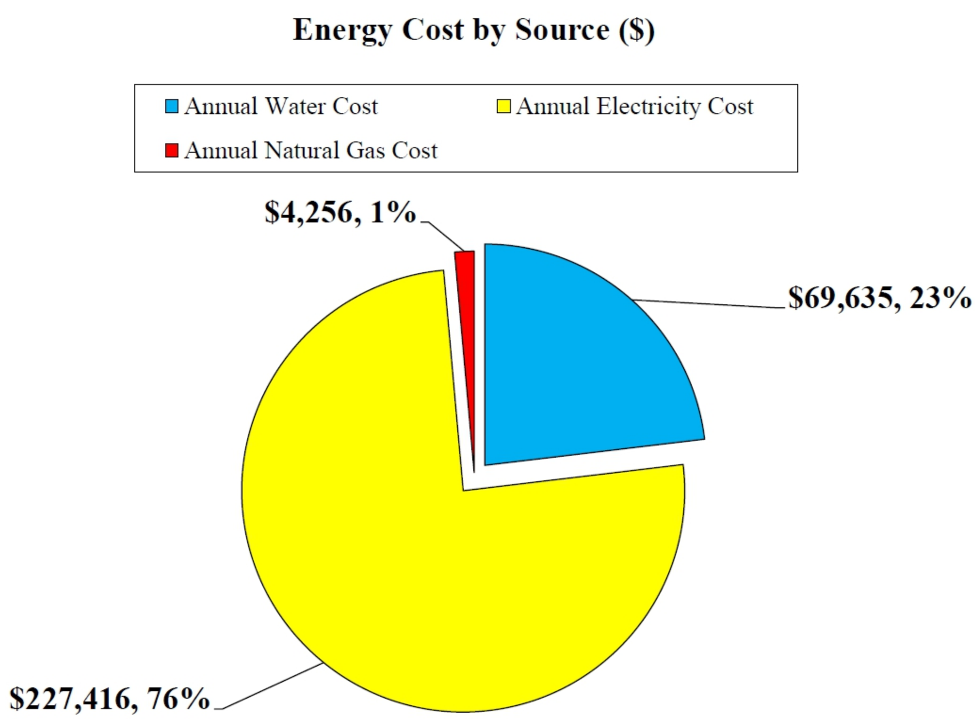
Total Monthly Water Usage

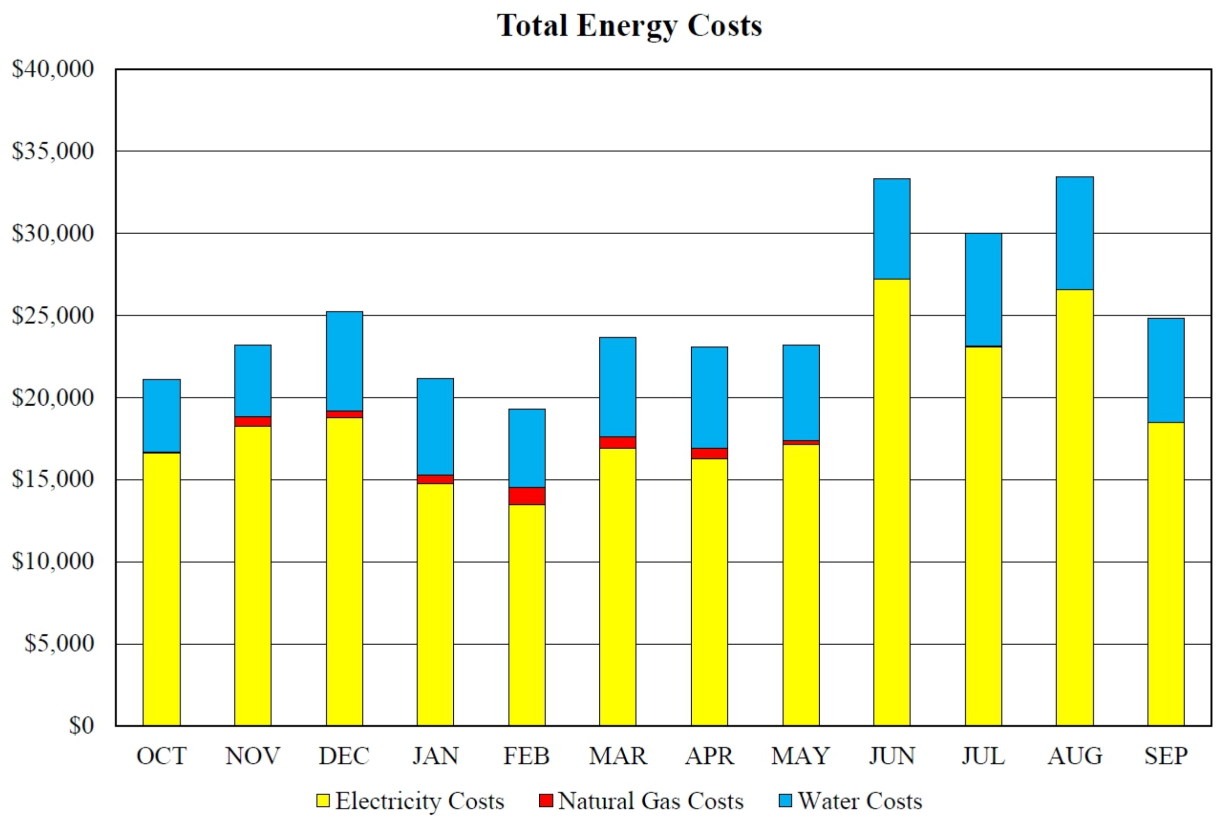


Total Monthly Water Costs




Energy Usage by Source (MMBtu)
Annual Electricity Consumption
Annual Natural Gas Consumption
474, 4%
11,345, 96%


Energy Cost by Source ($)
Annual Water Cost
Annual Electricity Cost
Annual Natural Gas Cost
$4,256, 1%
$69,635, 23%
$227,416, 76%


Total Energy Costs
$40,000
$35,000
$30,000
$25,000
$20,000
$15,000
$10,000
$5,000
$0
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
Electricity Costs
Natural Gas Costs
Water Costs

ASSESSMENT RECOMMENDATIONS

ASSESSMENT RECOMMENDATION #1
ARC #2.7316 CENTRALIZE CONTROL OF EXHAUST FANS TO ENSURE THEIR SHUTDOWN, OR ESTABLISH PROGRAM TO ENSURE MANUAL SHUTDOWN
SWITCH OFFICE AND BREAK ROOM RTUs TO FAN AUTO

Annual Resource Savings			Annual Cost Savings	Implementation Costs	Simplified Payback Period
Electricity	**20,420**	**kWh**	**$1,390**	**$0**	**IMMEDIATE**

RECOMMENDATION:
During the assessment, it was recorded that the RTUs that maintained the office and break rooms were set to fan continuous mode. It is recommended here that the thermostats for these RTUs be changed to fan auto mode.

ACTIONS:
Under automatic control the fans only come on when an RTU is actively cooling or heating. This allows the RTU to be automatically turned off when not in use, providing savings. The fraction of the time of active cooling or heating of an RTU could be roughly estimated from the measured fan consumption and the compressor consumption determined from the seasonal analysis, which provides a good estimate of the savings provided from this measure.

ANTICIPATED SAVINGS:
Based upon countless other assessments performed by this center, it has been found that on average, the RTUs perform heating or cooling 15% of the time (this number was discussed with and agreed upon with facility personnel). Using this number, the savings of this measure can be calculated as:

a =	0.85	85% fan savings
b =	24,020	Current kWh consumption

$$0.85 * 24{,}020 = \mathbf{20,420}\,\frac{\boldsymbol{kWh}}{\boldsymbol{year}}$$

$$20{,}420\,\frac{kWh}{year} * \frac{\$0.068}{kWh} = \mathbf{\$1,390/}\boldsymbol{year}$$

Annual Reduction in Electric Use: 20,420 kWh
Annual Savings: $1,390

Total implementation cost: $
Calculated Payback Period: IMMEDIATE

ASSESSMENT RECOMMENDATION #2
ARC #2.7316 CENTRALIZE CONTROL OF EXHAUST FANS TO ENSURE THEIR SHUTDOWN, OR ESTABLISH PROGRAM TO ENSURE MANUAL SHUTDOWN
SWITCH EVAPORATORS TO FAN AUTO MODE

Annual Resource Savings			Annual Cost Savings	Implementation Costs	Simplified Payback Period
Electricity	**200,269**	**kWh**	**$13,620**	**$5,000**	**0.37**

RECOMMENDATION:
Currently at the facility, it was recorded that the evaporator fans on the AU units were continuously running whether or not glycol was running to the unit. It is recommended here that these fans be set to fan-auto mode, which will allow the fan in the unit to come on only when glycol is running through the coils. A spot measurement of the evaporators was performed using a clamp meter and information provided by a GUI panel, and the results are shown below:

AH	kW	hours/year	kWh/year*	% glycol	projected kWh/year (x % glycol)
1	4.08	5125	20257	0	0
2	3.85	5125	19115	12.8	2447
3	3.09	8766	26240	0	0
5	2.93	5125	14547	1.9	276
6	3.23	5125	16036	47.2	7569
7	3.23	5125	16036	13	2085
8	2.33	5125	11568	0	0
9	2.25	5125	11171	13.9	1553
10	2.25	5125	11171	100	11171
11	4.5	5125	22342	9.3	2078
12	2.25	5125	11171	0	0
13	2.33	5125	11568	0	0
14	2.03	8766	17239	63.8	10998
15	2.18	8766	18513	36.2	6702
16	2.14	8766	18173	0	0
			245147		44878
*kWh/year takes into account 45 min/day defrost					

**Please note that to obtain this kWh/year the equation is* $kW * \frac{hours}{year} * \frac{23.25}{24} \left(45 \frac{min}{day}\ defrost\right)$

ACTIONS:
To perform this action, the system that is controlling the glycol flow system may have to be modified in order to allow this fan-auto mode to be obtained, but this audit team is not sure if this function is already built into the currently installed system. However, fan-auto mode will allow the fans in the evaporator units to not run continuously, instead only running when glycol is running through the coils, providing electrical savings to the facility.

ANTICIPATED SAVINGS:

Based on all of the information above, the savings from this measure can be calculated as:

a = 245,147 Current kWh Fan Consumption

b = 44,878 Projected kWh Fan Consumption

$$a - b = \mathbf{200,269}\ \boldsymbol{kWh/year}$$

$$200{,}269 \frac{kWh}{year} * \frac{\$0.068}{kWh} = \$\mathbf{13,620}/\boldsymbol{year}$$

Annual Reduction in Electric Use: 200,269 kWh

Annual Savings: $13,620

IMPLEMENTATION COSTS:

Material and Labor Costs			
Item Description:	**Quantity:**	**Unit Cost:**	**Total Cost:**
Labor	~	$5,000	$5,000
Total Implementation			$5,000

- As mentioned in the AR description, it is unclear if the current system that is in place has this feature already installed. If not, An HVAC specialist or similar software engineer may need to be hired to alter the current control system. 100 hours or more may be needed to determine a new control system for this, and the average hourly rate for software engineers is $34
    - https://www.salary.com/research/salary/benchmark/software-engineer-i-hourly-wages

Total implementation cost: $5,000

Calculated Payback Period: 0.37 years

ASSESSMENT RECOMMENDATION #3
ARC #2.4133 USE MOST EFFICIENT TYPE OF ELECTRIC MOTORS
REPLACE EVAPORATOR MOTORS WITH MORE EFFICIENT MODELS

Annual Resource Savings			Annual Cost Savings	Implementation Costs	Simplified Payback Period
Electricity	**51,190**	**kWh**	**$3,480**	**$4,900**	**1.41**

RECOMMENDATION:
It is recommended here that the inefficient evaporator motors continue to be upgraded to the more efficient models that have already been installed. Currently at the facility, evaporator units 1, 2, 3, 5, 6, 7, and 11 have the original, inefficient motors installed (it is unclear to the audit team what model these motors are). A table of spot measurements taken is shown below (and a complete table of spot measurements is show in the previous recommendation):

AH #	kW Reading
1	4.08
2	3.85
3	3.09
5	2.93
6	3.23
7	3.23
11	4.5

It is also reported by facility personnel, that in the other evaporator units (8, 9, 10, 12, 13, 14, 15, and 16), more efficient motors have been installed, with an average kW measurement of 2.22 kW.

ACTIONS:
To follow this recommendation, facility personnel must continue to install the efficient motors in that are currently installed in the listed units above, in the units that currently have the inefficient motor. This will allow the evaporator units to run when needed, but the fan motor will require less power. This will provide electrical savings to the facility.

ANTICIPATED SAVINGS:
Based on the spot measurements taken from the table in Assessment Recommendation 2, and using the average of 2.22 kW as the power of these newer efficient motors, the savings of this recommendation can be calculated as:

$$(\underset{\text{AH1}}{4.08} + \underset{\text{AH2}}{3.85} + \underset{\text{AH5}}{2.93} + \underset{\text{AH6}}{3.23} + \underset{\text{AH7}}{3.23} + \underset{\text{AH11}}{4.5} - 6 * \underset{\text{AVG}}{2.22}) * \underset{\text{HRS/YR}}{5{,}125} + (\underset{\text{AH3}}{3.09} - \underset{\text{AVG}}{2.22}) * \underset{\text{HRS/YR}}{8{,}766}$$
$$= \mathbf{51{,}190}\ \boldsymbol{kWh/year}$$

$$51{,}190 \frac{kWh}{year} * \frac{\$0.068}{kWh} = \$\mathbf{3{,}480}/\boldsymbol{year}$$

Note that if measure 2 is implemented, so that the AH units only come on when the glycol valve is open the new savings of this measure would be:

$$[(4.08-2.22)*0\,(AH1)+(3.85-2.22)*0.128\,(AH2)+(2.93-2.22)*0.019\,(AH5)+(3.23-2.22)*0.472\,(AH6)+(3.23-2.22)*0.13\,(AH7)+(4.5-2.22)*0.093\,(AH11)]*5{,}125+(3.09-2.22)*0*8{,}766\,(AH3)=\mathbf{5,340\ kWh/year}$$

**Please note the equation for the savings for each AH is $Current\ Motor\ kW - 2.22\ (New\ Motor\ kW) * Average\ Recorded\ Glycol\ Usage$*

$$5{,}340\frac{kWh}{year}*\frac{\$0.068}{kWh}=\$\mathbf{360/year}$$

Clearly, this measure should be focused on the evaporators whose glycol valves are open a lot if measure 2 is implemented.

Annual Reduction in Electric Use: 51,190 kWh
Annual Savings: $3,480

IMPLEMENTATION COSTS:

Material and Labor Costs			
Item Description:	**Quantity:**	**Unit Cost:**	**Total Cost:**
New Efficient Motors	7	$200	$1,400
Installation/Labor	7 Units	$500	$3,500
Total Implementation			$4,900

- Note here that the motor cost is reported by the plant, so no source is needed
- As reported by https://www.fixr.com/costs/refrigerator-repair, the national range of refrigerator repair is $200-$500 per unit. We will use the upper end of this range as these are commercial units, and all 7 units need to be upgraded

Total implementation cost: $4,900
Calculated Payback Period: 1.41 years

ASSESSMENT RECOMMENDATION #4
ARC #2.4224 UPGRADE CONTROLS ON COMPRESSORS
REPAIR THE 1 KW "VAMPIRE LOAD" ON THE 30 HP AIR COMPRESSOR

Annual Resource Savings			Annual Cost Savings	Implementation Costs	Simplified Payback Period
Electricity	**8,766**	**kWh**	**$596**	**$1,200**	**2.01**

RECOMMENDATION:
Currently at the facility, noticed by the data logger left on the 30 HP compressor, there is a "vampire load" that consumes 1 kW even while the unit is off. It is recommended here to hire an electrician or maintenance crew in order to eliminate this load.

ACTIONS:
Data loggers were left on both of the air compressors at the plant (graphs can be seen in the facility description section). Using these it was diagnosed that the 30 HP compressor has this unnecessary and unknown load. Eliminating this load will eliminate this unnecessary consumption, saving the facility electricity

ANTICIPATED SAVINGS:
The savings from this measure can easily be calculated as the power of the "vampire load" times the number of production hours the compressor is on. Therefore, the savings of this measure can be calculated as:
a = 1 Current kW of "Vampire Load"
b = 8,766 Hours Per Year of Operation

$$a * b = \mathbf{8,766\ kWh/year}$$

$$8{,}766 \frac{kWh}{year} * \frac{\$0.068}{kWh} = \$\mathbf{596/year}$$

Annual Reduction in Electric Use: 8,766 kWh
Annual Savings: $596

IMPLEMENTATION COSTS:

Material and Labor Costs			
Item Description:	**Quantity:**	**Unit Cost:**	**Total Cost:**
Installation/Labor	~	$1,200	$1,200
Total Implementation			$1,200

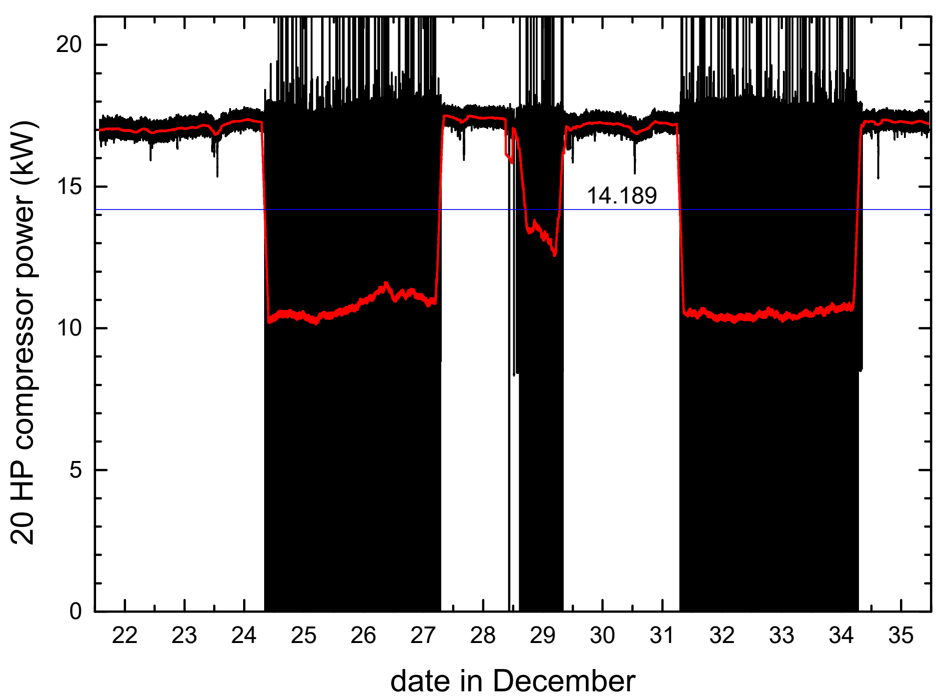
- The company at the following link: http://www.procompressor.net/ (an air compressor repair company near the facility) said that the quote for an issue of this nature is around $1,200. It is unknown if parts will need to be purchased to resolve this issue

Total implementation cost: $1,200
Calculated Payback Period: 2.01 years

ASSESSMENT RECOMMENDATION #5
ARC #2.4236 ELMINATE LEAKS IN INERT GAS AND COMPRESSED AIR LINES/VALVES
REPAIR COMPRESSED AIR LEAKS

Annual Resource Savings			Annual Cost Savings	Implementation Costs	Simplified Payback Period
Electricity	**57,990**	**kWh**	**$3,940**	**$5,000**	**1.27**

RECOMMENDATION:
During the assessment, it was mentioned by facility personnel that there may be leaks in the compressed air system. A data logger was left on the 20 HP compressor, and its graph is shown below:



Looking at this log, we can see that during non-production hours, the 20 HP compressor still consumes ~10.5 kW. Discussing with facility personnel, we have quantized that 90% of this consumption is leaks in the system.

ACTIONS:
This recommendation will require a leak assessment of the compressed air system. Initially, this can be done in house with maintenance staff. Trace the compressed air lines and tag any location that a leak can be felt or heard. In theory these leaks can be fixed with replacement parts that the maintenance staff acquires, or with patches that maintenance staff can install. For a more careful

assessment, consider contacting a contractor to come in and perform a full leak check. This typically fixes around 70% of leaks based on past assessments.

ANTICIPATED SAVINGS:
Using the fact that 90% of the overnight consumption is due to leaks, and that analyzing the compressed air system and fixing leaks can fix about 70% of leaks (again, this was discussed and agreed upon with facility personnel), the savings from this measure can be calculated as:

a =	10.5	Current Overnight kW Consumption
b =	0.9	90% Consumption Is Due To Leaks
c =	0.7	70% Leaks Repaired
d =	8,766	Hours Per Year of Operation

$$a * b * c * d = \mathbf{57,990}\ \boldsymbol{kWh/year}$$

$$57{,}990\frac{kWh}{year} * \frac{\$0.068}{kWh} = \$\mathbf{3,940}$$

Annual Reduction in Electric Use: 57,990 kWh
Annual Savings: $3,940

IMPLEMENTATION COSTS:

Material and Labor Costs			
Item Description:	**Quantity:**	**Unit Cost:**	**Total Cost:**
Labor	~	$5,000	$5,000
Total Implementation			$5,000

- Based on https://www.pickhvac.com/hvac-repair-costs-and-rates/ the upper end of the average cost per hour of an HVAC specialist is $150. Based upon the size of the facility, and the span of the air compressor system, this service may take upwards of 30 hours. Based upon this, the cost of repairing all air compressor leaks will be $5,000

Total implementation cost: $5,000
Calculated Payback Period: 1.27 years

ASSESSMENT RECOMMENDATION #6
ARC #2.4146 USE ADJUSTABLE FREQUENCY DRIVE OR MULTIPLE SPEED MOTORS ON EXISTING SYSTEM
INSTALL VARIABLE SPEED DRIVE ON GLYCOL PUMP AND CONVERT 3-WAY BYPASS VALVES TO 2-WAY VALVES

Annual Resource Savings			Annual Cost Savings	Implementation Costs	Simplified Payback Period
Electricity	**123,050**	**kWh**	**$8,370**	**$6,500**	**0.78**

RECOMMENDATION:
During the assessment it was recorded that the glycol pump was a single speed 20 HP pump. This pump currently runs in a load/unload fashion, where if any single one of the evaporators are calling for glycol, the pump will switch to a loaded state. It is recommended here that this 20 HP pump be placed on a variable frequency drive, and install 2-way valves instead of 3-way valves with a bypass in order for glycol flow to be modulated by the variable speed pump.

ACTIONS:
In order to follow this recommendation, firstly the 3-way glycol valves currently installed on the evaporators will need to be changed to 2-way valves in order to allow the variable speed motor to handle the needed glycol flow (please note this is as simple as manually closing the bypass valve on the current 3-way valve). Then the currently installed 20 HP glycol motor will need to be equipped with a variable frequency drive. These two installations will allow the motor to swing up and down based upon glycol demand instead of it running in a fully loaded state when a single evaporator is calling for glycol.

ANTICIPATED SAVINGS:
From the analyzation done in Assessment Recommendation 2, we can see that the evaporators call for glycol 18.6% of the time. Based on this the average speed of the pump would be $0.186 * 60\ Hz = \mathbf{11\ Hz}$**,** which is too low for most variable drive systems. Thus it is assumed in this calculation that the glycol pump will average a speed of 50% or 30 Hz (which was agreed upon with plant personnel). Thus, the savings of this measure can be calculated as:

a = 20 Horsepower Rating of Glycol Pump
b = 0.746/0.93 Motor Efficiency Rating
c = $1\text{-}0.5^3$ Reduction to 50% Average Speed
d = 8,766 Hours Per Year of Operation

$$a * b * c * d = \mathbf{123,050\ kWh/year}$$

$$123{,}050 \frac{kWh}{year} * \frac{\$0.068}{kWh} = \mathbf{\$8,370/year}$$

Annual Reduction in Electric Use: 123,050 kWh
Annual Savings: $8,370

IMPLEMENTATION COSTS:

Material and Labor Costs			
Item Description:	**Quantity:**	**Unit Cost:**	**Total Cost:**
Variable Frequency Drive	1	$1,500	$1,500
Installation/Labor	40 hours	$100/hour	$4,000
Total Implementation			$6,500

- A variable drive system will need to be purchased for the upgrade. 20 HP variable drives of similar costs are linked below
  - **https://www.mscdirect.com/product/details/35954510**
  - **https://vfds.com/20hp-230v-mitsubishi-vfd-fre720600scna**
  - **https://www.wolfautomation.com/ode-3-440300-3f42-ac-drive-20hp-30a-380-480v-3-phase/**
- Installation of a variable drive as well as the insurance that it is working the way that it should will need to be performed by an electrician. It is estimated here that about 40 working hours will be needed to upgrade the system, and according to https://www.homeadvisor.com/cost/electrical/hire-an-electrician/#:~:text=Electricians%20usually%20charge%20between%20%2450,experience%20of%20the%20service%20provider, the average cost of hiring an electrician per hour is $50-$100 per hour. Using the upper end of this estimate as this is a commercial facility, the installation of this will cost around $4,000
-

Total implementation cost: $6,500
Calculated Payback Period: 0.78 years

ASSESSMENT RECOMMENDATION #7
ARC #2.4146 USE ADJUSTABLE FREQUENCY DRIVE OR MULTIPLE SPEED MOTORS ON EXISTING SYSTEM
INSTALL VARIABLE DRIVES ON BOILER CIRCULATION PUMPS AND 2-WAY VALVES ON FAN COIL UNITS

Annual Resource Savings			Annual Cost Savings	Implementation Costs	Simplified Payback Period
Electricity	**50,700**	**kWh**	**$3,400**	**$9,500**	**2.79**

RECOMMENDATION:
Currently at the facility, the fan coil units are serviced by two 7.5 HP boiler circulation pumps, that service different areas of the facility. On the fan coil units that are serviced by the boiler, are installed 3-way valves (inlet, outlet to the fan coil unit, and bypass). It is recommended here to install variable frequency drives on the boiler circulation pumps and install 2-way valves instead of 3-way valves on the Fan Coil Units (please note this is as simple as manually shutting the bypass valve).

ACTIONS:
In order for this recommendation to be implemented, variable drives for each of the boiler circulation pumps, and the 3-way valves must be changed to 2-way valves on each of the fan coil units. This will allow flow to be modulated by the change of speed in the pump, instead of the pump being in a fully loaded state when it is unnecessary. Doing these actions will save the facility electricity.

ANTICIPATED SAVINGS:
It was observed during the assessment that well over half of the fan coil units were off (and facility personnel agreed this was probably a good assumption of normal operation). Based on this, the average speed of each of the circulation pumps will be 30 Hz (as explained in the previous recommendation, anything below this is not possible for a VFD). Utilizing all of this the savings of this measure can be calculated as:

a =	5.95	Circulation Pump One's kW Consumption
b =	5.24	Circulation Pump Two's kW Consumption
c =	$1\text{-}0.5^3$	50% Reduction in Average Speed
d =	7/12	Months Per Year of Heat
e =	8,766	Hours Per Year of Operation

$$(a + b) * c * d * e = \mathbf{50,070} \frac{\boldsymbol{kWh}}{\boldsymbol{year}}$$

$$50{,}700 \frac{kWh}{year} * \frac{\$0.068}{kWh} = \mathbf{\$3,400/year}$$

Annual Reduction in Electric/Natural Gas/Propane/Water Use: 50,070 kWh
Annual Savings: $3,400

IMPLEMENTATION COSTS:

Material and Labor Costs			
Item Description:	**Quantity:**	**Unit Cost:**	**Total Cost:**
Variable Frequency Drives	2	$750	$1,500
Installation/Labor	80 hours	$100/hour	$8,000
Total Implementation			$9,500

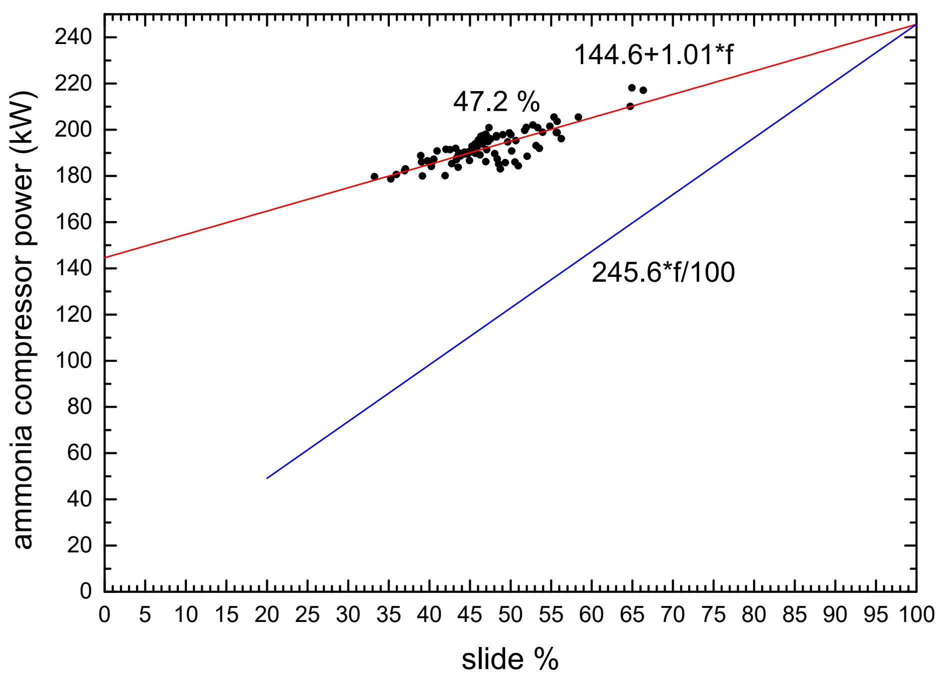
- Variable Frequency Drive Kits of similar cost can be found at the following links:
    - http://www.gohz.com/7-5-hp-vfd-single-phase-to-three-phase
    - https://www.wolfautomation.com/ode-3-320240-3f4a-ac-drive-7-5hp-24a-200-240v-3-phase-nema-4x/
    - https://www.grainger.com/product/SCHNEIDER-ELECTRIC-Variable-Frequency-Drive-443L61
- As explained in the previous recommendation, the cost of hiring an electrician per hour for a variable drive installation is on average $100 per hour. Here the electrician will have two variable drives to install, so we can double the man hours from the previous recommendation

Total implementation cost: $9,500
Calculated Payback Period: 2.79 years

ASSESSMENT RECOMMENDATION #8
ARC # 2.4146 USE ADJUSTABLE FREQUENCY DRIVE OR MULTIPLE SPEED MOTORS ON EXISTING SYSTEM
REPLACE SLIDE CONTROL AMMONIA COMPRESSOR WITH VARIABLE FREQUENCY DRIVE COMPRESSOR

Annual Resource Savings			Annual Cost Savings	Implementation Costs	Simplified Payback Period
Electricity	**769,470**	**kWh**	**$52,324**	**$119,348**	**2.28 Years**

RECOMMENDATION:
During the assessment, it was noticed that the ammonia compressors would benefit from replacing the slide control with variable speed drives. The experimental power vs. load was recorded during the audit and yielded the following results:



The red line is the fit to the experimental data recorded during the audit and the blue line is if variable speed drives were used instead of the slide control. The average slider position measured during production hours during the assessment was 47.2%, and average production hours power was 192.3 kW (both numbers facility personnel agreed were good averages for normal production hours).

ACTIONS:
Purchase and install variable speed drives for the two ammonia compressors in the plant to replace the slide control. Slide control compressors are load/unload type compressors that in order to control the flow of ammonia, have a slide that acts as a variable valve to control the

ammonia flow. When ammonia is needed, the compressor goes into a loaded state, and the slide valve changes how much ammonia it allows through based on demand. Replacing this system with a variable drive system would allow the compressor itself to control the ammonia flow by allowing the compressor to swing up and down as ammonia is needed. This will allow the compressor to not run at full speed when it is not needed, providing electrical savings to the facility.

ANTICIPATED SAVINGS:
From the above plot, the experimental slide control yields a fit line of Power = 144.6 + 1.01*f where f is the slide control percentage. The compressor log showed that during non-production hours, the compressor averaged consumption 90% of production hours. Thus, the average consumption is as follows:

a =	192.3	Average Power During Production Hours (kW)
b =	5,125	Production Hours Per Year
c =	3,641	Non-Production Hours Per Year
d =	0.9	Non-Production to Production Compressor Consumption Ratio
e =	8,766	Hours Per Year

$$\frac{[(a*b)+(a*c*d)]}{e} = 184.3kW$$

By rearranging the trend line equation, we can find the average slide control position:

$$Power = 144.6 + 1.01 * f$$

$$f = \frac{Power - 144.6}{1.01} = \frac{184.3kW - 144.6}{1.01} = 39.3\%$$

The power vs. load curve for the variable speed drive is projected to be Power = 2.456*f, as is typical, linear vs. load with the curve pointing towards the origin. Thus, the final annual savings will be as follows:

f =	184.3	Average Power of Compressors (kW)
g =	2.456	Trend Line Coefficient
h =	39.3	Average Slide Control Position (%)
i =	8,766	Hours Per Year

$$i * [f - (g * h)] = \mathbf{769,470\ kWh/year}$$

$$769{,}470 \frac{kWh}{year} * \frac{\$0.068}{kWh} = \mathbf{\$52,324/year}$$

Annual Reduction in Electric Use: 769,470 kWh
Annual Savings: $52,324

IMPLEMENTATION COSTS:

Material and Labor Costs			
Item Description:	**Quantity:**	**Unit Cost:**	**Total Cost:**
Variable Speed Drive	2	$19,274	$38,548
Installation	-	$80,800	$80,800
Total Implementation:			$119,348

- The cost of each variable speed drive is linked below as reference, although depending on the model the price may change based on availability: https://www.electricmotorsforless.com/-400-HP-VFD-Variable-Frequency-Drive-Inverter-460-Volt-A510-4425-C3-U_p_1358.html?network=g&device=c&keyword=&campaign=1651356883&adgroup=pla-761980582533&gclid=CjwKCAiAr6-ABhAfEiwADO4sfeUxBpOkAMYy5oxxub8erv2ImsH6gvCvj1RW1Jn__B-jTv9NiofXshoCE78QAvD_BwE.
- The installation cost is estimated based on an article linked below: http://smartenergy-form.arch.illinois.edu/pdf/TechNote_VFD.pdf. This article states that installation for large VFD's cost $101 per VFD. Since two VFD's will be installed, the total installation cost will be as follows: 2 * $101/HP * 400HP = $80,800.

Total Implementation Cost: $119,348
Calculated Payback Period: 2.28 Years

ASSESSMENT RECOMMENDATION #9
ARC # 2.2491 USE COOLING AIR WHICH COOLS HOT WORK PIECES FOR SPACE HEATING
PORT AIR COMPRESSOR EXHAUST INTO THE "ATTIC" AREA IN THE WINTER

Annual Resource Savings			Annual Cost Savings	Implementation Costs	Simplified Payback Period
Natural Gas	**95**	**MMBTU**	**$797**	**$4,000**	**5.02 Years**

RECOMMENDATION:
During the assessment, it was noted that there is a large attic area which is heated during the winter. The heat in this attic space is currently supplied by small space heaters that utilize hot water from the boiler to provide heat. To conserve energy, it is recommended that the air compressor's exhaust be ported into the attic area during the winter to offset space heat provided by space heaters.

ACTIONS:
To implement this recommendation, port the air compressor's exhaust into the attic area. The air compressors are located in a room that is adjacent to the attic space, so all that would need to be done is to install ductwork on the current exhaust being ported outside, and add ductwork leading to the attic space. A gate would also need to be installed in order to switch where the exhaust is going as well. This would allow the space heaters to run less in the winter, providing gas savings.

ANTICIPATED SAVINGS:
The heat available from the air compressor's during the winter months is as follows:

a =	207360	Annual Air Compressors kWh Consumption
b =	293	kWh to MMBTU Conversion Factor
c =	7/12	Number of Winter Heating Months Per Year

$$\frac{a * c}{b} = 413\ MMBTU\ of\ heat$$

From many previous audits, boiler efficiencies are around 70% (this number was agreed upon with facility personnel), this corresponds to 413/0.7 = 590 MMBTU of gas, greater than total plant gas consumption. Thus, the maximum potential savings is the amount of gas consumed to heat the attic space, which was also agreed upon with facility personnel.

A complete measurement of relative space heat requirements could not be performed at the assessment, and so, this is approximated based upon conversations with plant personnel to be 40% of total space heat, with total space heat consuming 474 MMBTU/year.

So, 0.4 * 474MMBTU/year = 190 MMBTU/year. Plant personnel feel that the venting of the cooling exhaust may not reach the entire attic area. Assuming it reaches 50% of the area, the savings of the measure is:

$$0.5 * 190 \frac{MMBTU}{year} = \mathbf{95\ MMBTU/year}$$

$$95 \frac{MMBTU}{year} * \frac{\$8.39}{MMBTU} = \$\mathbf{797/year}$$

Annual Reduction in Natural Gas Usage: 95 MMBTU
Annual Savings: $797

IMPLEMENTATION COSTS:

Material and Labor Costs			
Item Description:	**Quantity:**	**Unit Cost:**	**Total Cost:**
Parts/Labor	-	$4,000	$4,000
Total Implementation			$4,000

- The upper end cost of installing ductwork in a residential home can cost around $2,000 including parts and labor. The following article from HomeAdvisor, https://www.homeadvisor.com/cost/heating-and-cooling/install-ducts-and-vents/, has commercial rates being about double that of residential systems. Therefore, it is estimated that this recommendation will cost about $4,000 for total installation and parts costs.

Total Implementation Cost: $4,000
Calculated Payback Period: 5.02 Years

ASSESSMENT RECOMMENDATION #10
ARC # 2.7142 UTILIZE HIGHER EFFICIENCY LAMPS AND/OR BALLASTS
REPLACE 24/7 LIGHTING WITH LED LIGHTING

Annual Resource Savings			Annual Cost Savings	Implementation Costs	Simplified Payback Period
Electricity	**29,032**	**kWh**	**$1,974**	**$1,574.10**	**0.80**

RECOMMENDATION:
It is recommended that the 24/7 lighting in the warehouse and office areas be replaced with LED counterparts. Lumen measurements were made, and an equal lumen replacement is recommended below.

ACTIONS:
To follow this recommendation, the facility must purchase and make light replacements. This includes 50 T12 tubes and 48 T8 replacement tubes. By purchasing LEDs and replacing the lights in the areas mentioned above, there will be a significant savings. LEDs (light emitting diodes) are ten times more efficient at turning energy to light than traditional incandescent bulbs. LEDs turn nearly 100% of energy to light and therefore, are the preferred lighting replacement to save energy.

ANTICIPATED SAVINGS:
At this facility, there were 50 8ft T12 fluorescent tubes rated at 75W. These are to be replaced by 36W LED replacement tubes. In the office space, there were 48 4ft T8 fluorescent tubes rated at 32W. These are to be replaced by 13W LED replacement tubes. This lighting is on 24/7 per facility personnel and this recommendation will incur the following savings:

a =	50	Number of T12 Tubes to be Replaced
b =	0.075	kW Rating of Fluorescent T12 Tubes
c =	0.036	kW Rating of Replacement T12 LED Tubes
d =	1.12	T12 Ballast Factor
e =	48	Number of T8 Tubes to be Replaced
f =	0.032	kW Rating of Fluorescent T8 Tubes
g =	0.013	kW Rating of Replacement T8 LED Tubes
h =	8,766	Hours Per Year

$$h * \{[a * ((b * d) - c)] + [e * (f - g)]\} = \mathbf{29,032\ kWh/year}$$

$$29{,}032 \frac{kWh}{year} * \frac{\$0.068}{kWh} = \mathbf{\$1,974/year}$$

Annual Reduction in Electric Use: 31,660 kWh
Annual Savings: $2,153

IMPLEMENTATION COSTS:

Material and Labor Costs			
Item Description:	**Quantity:**	**Unit Cost:**	**Total Cost:**
32W T12 LED Tube	50	$14.95	$747.50
13W T8 LED Tube	48	$4.20	$201.60
Installation/Labor	-	$625	$625
Total Implementation			$1,574.10

- The cost of each 13W T8 LED tube references the following link for pricing:
  - https://www.1000bulbs.com/product/209609/PLT-11349.html.
  - https://www.bulbs.com/product/13T8-LED-48-5000-IF-DIM-1PK
- The cost of each 32W T12 LED tube references the following link for pricing:
  - https://www.superbrightleds.com/moreinfo/led-t8-tubes-replacement-bulbs/36w-t8t12-led-tube-4320-lumens-8ft-ballast-bypass-type-b-59w-equivalent-5000k-30-pack/6523/14800/?utm_campaign=Child+-+Organic+Shopping&utm_source=Industrial+%26+Commercial+LED+Lighting+%3E+T8%2C+T5%2C+%26+T12+LED+Tubes&utm_medium=T8B-50K36W-8-30PK.
  - https://www.amazon.com/Hyperikon-Shatterproof-Fluorescent-Replacement-Warehouse/dp/B00SUMEM40
- To replace the T12 tubes, a ballast bypass must be performed for each tube fixture, where this amounts to 50 total bypasses. From previous audit experience, a bypass takes approximately 10 minutes to complete. This would require 8.33 hours of electrical work to completely replace all the tubes. HomeAdvisor reports the average electrician charges between $50 and $100 per hour, https://www.homeadvisor.com/cost/electrical/hire-an-electrician/, where we will use the average of $75 per hour to calculate the total labor charge. 8.33hrs * $75/hour = $625 labor charge to properly install the T12 tubes.

Total Implementation Cost: $1,574.10
Calculated Payback Period: 0.73

ADDENDUM

APPENDIX I: SECONDARY EFFECTS OF ENERGY EFFICIENCY ON AIR POLLUTION

Implementing the proposed energy efficiency recommendations will decrease the amount of electricity that must be generated and fuel that must be consumed and contribute directly to reductions in common air pollutants. Reducing energy consumption will decrease carbon dioxide (CO_2), sulfur dioxide (SO_2) and nitrogen oxides (NO_x) emissions directly from plant fuel consumption as well as indirectly at power generating stations. The table below shows the emission factors of each air pollutant based on each fuel source (see footnote references for emission factor sources).

Emissions Factors	Electricity (lbs/kWh)[1]	Natural gas (lbs/mmBTU)[2]	No 2 Fuel Oil (lbs/mmBTU)[3]	No 6 Fuel Oil (lbs/mmBTU)[3]	Propane (lbs/mmBTU)[4]
CO2 Factor	1.2295	117.0000	160.4317	179.8561	137.3626
SO2 Factor	0.0072	0.0006	1.1295	1.1295	0.0011
NOX factor	0.0020	0.0920	0.1727	0.3957	0.1429

If all of the recommendations in this report were implemented, electricity consumption would be reduced by **1,310,887 kWh**. Carbon dioxide emissions would decrease by **1,622,851 lbs/year**, sulfur dioxide emissions by **9,438 lbs/year**, and nitrogen oxide emissions by **2,631 lbs/year**. Total carbon footprint reduction is **39.18%** of the projected footprint of **4,142,316 lbs/year**. Total SO_2 reduction would be **39.44%** of the projected total of **23,933 lbs/year**, while total NO_x reduction would be **39.31%** of the projected **6,692 lbs/year** emissions. The table on the following page provides a breakdown of how air emissions are reduced for each assessment recommendation:

[1] Source: PJM Regional Average Disclosure Label for 2008: https://gats.pjm-eis.com/mymodule/rpt/myrpt.asp?r=112

[2] Source: Energy Information Agency (EIA) - Natural Gas Issues and Trends 1998: http://www.eia.doe.gov/pub/oil_gas/natural_gas/analysis_publications/natural_gas_1998_issues_trends/pdf/chapter2.pdf

[3] Source: EPA AP-42 Emission Factors: http://www.epa.gov/ttn/chief/ap42/ch01/final/c01s03.pdf

[4] Source: EPA AP-42 emission factors: http://www.epa.gov/ttn/chief/ap42/ch01/final/c01s05.pdf

AR No.	Assessment Recommendation	Energy Savings	CO_2 Reduction (lbs/yr)	SO_2 Reduction (lbs/yr)	NO_x Reduction (lbs/yr)
1	Switch Office And Break Room RTUs To Fan Auto	20420 kWh	25,106	147.0	40.8
2	Switch Evaporators To Fan Auto Mode	200269 kWh	246,231	1441.9	400.5
3	Replace Evaporator Motors With More Efficient Models	51190 kWh	62,938	368.6	102.4
4	Repair the 1 kW "Vampire Load" On The 30 HP Air Compressor	8766 kWh	10,778	63.1	17.5
5	Repair Compressed Air Leaks	57990 kWh	71,299	417.5	116.0
6	Install Variable Speed Drive On Glycol Pump And Convert 3-Way Valves to 2-Way Valves	123050 kWh	151,290	886.0	246.1
7	Install Variable Drives On Boiler Circulation Pumps And 2-Way Valves On Fan Coil Units	50700 kWh	62,336	365.0	101.4
8	Replace Slide Control Ammonia Compressor With Variable Frequency Drive Compressor	769470 kWh	946,063	5540.2	1,538.9
9	Port Air Compressor Exhaust Into The "Attic" Area In The Winter	95 MMBTU	11,115	0.1	8.7
10	Replace 24/7 Lighting With LED Lighting	29032 kWh	35,695	209.0	58.1
TOTALS			**1,622,851**	**9,438**	**2,631**
CURRENT EMISSIONS FOOTPRINT			**4,142,316**	**23,933**	**6,692**
TOTAL % REDUCTION OPPORTUNITY			**39.18%**	**39.44%**	**39.31%**

END OF REPORT