IMPLEMENTING AND PLANNING BEST MANAGEGEMENT PRACTICES FOR UTILITY EFFICIENCY IN FOOD PROCESSING ESTABLISHMENTS

A UTILITY MANAGEMENT GUIDE

When you consider your next capital investment budget, ask this question:

"Can we really raise prices enough to improve the Gross Margin without losing sales?"

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1.0 EXECUTIVE SUMMARY

This bulletin is designed to provide quick tips for food and beverage processors that seek to save money on their utility bills and reduce emissions. This publication provides background data and tips to help justify equipment improvements and upgrades. The figures used in this bulletin are based on the compiled results of over 100 Ontario food plant audits and 175 international food-industry case studies.

This bulletin is designed to provide a practical link between Best Management Practices and greenhouse gas (GHG) reduction. This bulletin demonstrates payback-driven opportunities for the food and beverage sector, directly linked to GHG emission reduction.

Recent efficiency audits in Ontario's food and beverage plants consistently demonstrate 15% savings for energy, water and wastewater projects with 1 to 2 year paybacks (a simple annual rate of return of 55%$^+$). These same 3rd-party audits indicate projects that reduce energy, water and sewer use by 35% to 50% often have an 18% to 30% simple rate of return.

There are 8 general opportunity areas identified in this bulletin.

- Gas, Oil and Propane-fired Boilers
- Waste Heat and Co-Generation
- Steam and Condensate Recovery
- Water Heating Systems
- Process Water and Wastewater
- Electrical Service and Motors
- Process Cooling and Refrigeration Systems
- Compressed Air Systems

Each opportunity area is discussed in 4-parts.

1. "Investigate your Savings Potential", some tips to gauge potential project returns
2. A "Worked Example" of how to estimate project payback and reduce emissions
3. "Tips to Improve the Efficiency of your Equipment", are proven efficiency targets
4. "Best Management Practices", the documented habits of highly-efficient operators

The bulletin also contains a checklist of **Best Management Practices** for you to follow, as well as a summary of **Greenhouse Gas Emission Co-efficients** as background data for your own calculations.

2.0 GAS, OIL AND PROPANE-FIRED BOILERS AND HEATERS

This section is designed to provide quick tips for boiler or furnace improvement projects that save money and reduce emissions. This publication provides background data and tips to help justify equipment improvements and upgrades. [1]

2.1 INVESTIGATE YOUR SAVINGS POTENTIAL

The following examples are "rule of thumb" benchmarks compiled from 100 food plant audits in Ontario and 175 international food-industry case studies. These represent a range of tips that may help gauge the potential return on utility efficiency projects. Each industrial application is unique and paybacks should be calculated on an individual basis.

Typical Combustion Performance Benchmarks

- A typical boiler or furnace has a combustion efficiency of 75% to 80%. Typical losses of the total energy input in the fuel due to boiler operation:
  - 4% from boiler envelop,
  - 18% in the flue gasses and
  - 3% in the blowdown
- Older boilers and boilers converted from coal tend to have 60%-70% combustion efficiency
- Each fuel type and firing method has an optimal air/fuel ratio
  - Optimum excess air for a pulverized coal boiler is 15%-20% (3% to 3.5% excess O_2), and
  - Optimum excess air for a forced draft gas boiler is 5%-10% (1% to 2% excess O_2)
- High efficiency boilers have up to 90% combustion efficiency

Barriers to Operating Efficiency

- A 1/32-inch scale deposit increases fuel use by 2%
- A 1/8-inch deposit increases fuel use by over 8%

Tips for Potential Savings

- **Save** 2% of fuel use with a 3% decrease in flue gas O_2
- **Increase** boiler efficiency 1.5% by reducing excess oxygen 10% and flue gas temperature by 2.5%
- **Reduce** net stack temperature 40°F to save 1% to 2% of a boiler's fuel use[2]
- **Drop** flue gas exit temperature 20ºC to improve boiler efficiency by 1%
- **Reduce** boiler fuel use 1% for every 11°F that the entering feedwater temperature is increased
- **Reduce** space heating energy use for areas with high ceilings by 30% with overhead infra-red heating systems

[1] The figures used in this are crude estimates and are provided as a reference point for investigation. Actual project costs may vary.
[2] Net stack temperatures are typically 600°F to 800°F. A 50% stack heat reduction can reduce particulate emissions by up to 80%.

2.2 WORKED EXAMPLE: BOILER REPLACEMENT PROJECT

Project Payback Calculations

Background: Plant operations want to calculate the potential cost savings on a boiler upgrade and the possible benefit of carbon trading credits that arise from the upgrade.

Key data required:

	A) Old boiler efficiency rating	***A*** *= 62%*
	B) Estimated efficiency of replacement boiler	***B*** *= 90%*
	C) Current average annual cost of fuel	***C*** *= $120,000*

Calculations using key data shown in 2 steps (sample formulas in ***bold Italics***):

Step 1. Calculate difference in boiler efficiencies,

(B – A) ÷ A = Y (efficiency improvement factor)

[[New boiler efficiency – old boiler efficiency] ÷ old boiler efficiency]

or ((90% - 62%) ÷ 62) = 0.45

Step 2. Calculate reduced fuel consumption for current utilization,

C x Y = X (projected fuel consumption decrease)

[Current fuel cost x difference in boiler efficiencies from Step 1]

or ($120,000 x .45) = **$54,000**

Net Amount and Value of GHG Emissions Reduction[3]

Key GHG data:

- **a**) Estimate value of 1m^3 of natural gas consumption — ***a*** *= $0.16/m³*
- **b**) Estimated value of gas consumption avoided (“X” from step 2) — ***b*** *= $54,000*
- **c**) GHG co-efficients (from Appendix 12.2 GHG Co-efficients)
  - **ca**) = Carbon dioxide (CO_2) — ***ca*** *= 1.88kg/m³*
  - **cb**) = Methane (CH_4) — ***cb*** *= .42kg/m³ x 21*
  - **cc**) = Nitrous oxide (N_2O) — ***cc*** *= .02kg/m³ x 310*
- **d**) Estimate of 1000kg CO_2e GHG emission credit trading value[4] — ***d*** *= $10*

Calculations using key data and key GHG data shown in 4 steps (sample formulas in ***bold Italics***):

Step1: Calculate projected reduction of gas volume in m^3,

(b ÷ a) = m³ (cubic meters of natural gas)

[Value of savings ÷ price per m^3] or ($33,600 ÷ $0.16/$m^3$) = 337,500 m^3

Step 2: Calculate GHG reduction in CO_2e from lowered gas consumption,

(m³ x ca)+(m³ x cb x 21)+(m³ x cc x 310)=M

CO_2 or (m^3 x ca) = (337,500 x 1.88 kg) = 634,500 kg

CO_2e of CH_4 or (m^3 x cb x 21) = (337,500 x .42) x 21 = (141,750 x 21) = 2,976,750 kg

CO_2e of N_2O or (m^3 x cc x 310) = (337,500 x .02) x 310 = (6,750 x 310) = 2,092,500 kg

M = (634,500)+(2,976,750)+(2,092,500) = 5,406,750 kg CO_2e

Step 3: Calculate reduction of emissions in tonnes of CO_2e,

M ÷ 1000 = R (emissions reduction)

5,406,750 kg CO_2e ÷ 1000 = 5,406.75 tonnes CO_2e

Step 4: Calculate emissions trading value,

R x d [total tonnes CO_2e x $10] or (5,406.75 x $10) = **$54,067.50**

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[3] According to “*Measuring the Potential of GHG Emissions Reductions on the Agri-Food Sector in Ontario”* by Jacques Whitford in 2000, boiler equipment upgrades such as this can contribute up to ½ of a food or beverage facility’s GHG reduction.

[4] This is a hypothetical estimate used for demonstration purposes. Environment Canada sources routinely estimated the value of CO_2e credits at $10/tonne prior to Canada’s ratification of the Kyoto Protocol in 2002.

2.3 TIPS TO IMPROVE THE EFFICIENCY OF YOUR EQUIPMENT

Maintenance and Management

- **Tune-up** with precision testing equipment to detect and correct excess air losses, smoking, unburned fuel loss, sooting, and high stack temperatures, to result in boiler fuel savings of 2% to 20%
- **Upgrade** the boiler maintenance program including optimizing air-to-fuel ratio, burner maintenance, and tube cleaning, can save about 2% of a facility's total energy use with an average simple payback of 5 months
- **Implement** effective boiler management techniques such as operating on high fire settings and installing smaller boilers to save over 7% of a typical facility's total energy use with an average simple payback of less than 2 years. Preheated combustion inlet air saves about 3% of a facility's total energy use with an average simple payback of 8 months
- **Use** load management measures. Match boiler size to optimal boiler loads to save as much as 50% of a boiler's fuel use

Control Equipment

- **Install** automated blowdown controls to reduce energy use by 2% to 3% and reduce blowdown water losses by up to 20%
- **Install** over fire draft control systems to control excess air to save 2% to 10% of a boiler's fuel use for about $2,500
- **Use** a characterizable fuel valve to match the air/fuel ratios across the load range to save 2% to 12% of a boiler's fuel use
- **Install** stack dampers to prevent heat from being pulled up the stack and can save 5% to 20% of a boiler's fuel use
- **Convert** conventional burners to air or steam atomizing burners and reduce boiler fuel use by 2% to 8%
- **Use** an economizer to capture flue gas waste heat and preheat boiler feedwater can reduce a boiler's fuel use by up to 5%
- **Employ** direct contact condensation heat recovery to save 8% to 20% of a boiler's fuel use (payback is 3-7 years)

Blowdown Technology

- **Reduce** boiler fuel use by 2% to 5% with blowdown heat recovery, a proven technology
- **Minimize** energy loss from boiler blowdown to save about 2% of total energy use with an average payback under 1 year

2.4 BEST MANAGEMENT PRACTICES

<u>Boiler Management</u>

- **Set up** a chemical treatment program to reduce scaling and fouling of heating surfaces. Ensure this is a closed-loop system to prevent increased sewage treatment concerns
- **Set up** the boiler to achieve optimum combustion efficiency (air/fuel ratio).
- **Prevent** ingress of extra air to the combustion chamber.
- **Keep** boiler blowdown levels and frequency to the absolute minimum.
- **Set up** a maintenance program for de-scaling both sides of the heat transfer interfaces everywhere.
- **Size to fit** the use of boilers in multiple boiler installations to fit the production schedule.

<u>Steam Management</u>

- **Set up** a steam trap maintenance program
- **Identify** and correct steam and condensate leaks
- **Insulate** steam, hot water and condensate return lines and components properly
- **Consider** recovery of flash steam from condensate and consider using the recovered low-pressure steam elsewhere
- **Decommission** redundant steam and condensate return pipes
- **Collect** all possible condensate and return to boiler make-up water tank.
- **Consider** replacing live steam injection that consumes water and necessitates make-up and heating with heat exchangers

<u>Stack Emissions Management</u>

- **Check** flue gas oxygen and carbon monoxide levels regularly with a manual or automatic flue gas analyzer. Typical ranges for oxygen levels are as follows:

  Natural gas = 2.0% to 2.7%
  Light oil = 2.3% to 3.5%
  Heavy fuel/bunker oil = 3.3% to 4.2%

- **Compress** the schedule in the low production periods to avoid stops and starts of large boilers
- **Evaluate** the flue gas heat recovery system for pre-heating of feedwater and/or boiler air intake

<u>Record Keeping</u>

- **Check** boiler efficiency regularly and maintain records (e.g. boiler efficiency = fuel used in BTU/steam generated in BTU in given period)

3.0 WASTE HEAT RECOVERY AND CO-GENERATION

This section is designed to provide quick tips for possible heat recovery or co-generation projects that save money and reduce emissions. This publication provides background data and tips to help justify equipment improvements and upgrades.[5]

3.1 INVESTIGATE YOUR SAVINGS POTENTIAL

The following examples are "rule of thumb" benchmarks compiled from 100 food plant audits in Ontario and 175 international food-industry case studies. Every industrial application is unique. All project payback estimates should be calculated on an individual basis.

Barriers to Operating Efficiently

- About 4% of the cost of electricity is caused by transmission losses in distribution in the provincial grid[6]
- A power factor utilization rate of 90% is considered the acceptable industry target. Highly efficient facilities target power factor utilization rates of up to 94%

Typical Performance Benchmarks

- **Recover** waste heat to cut total facility energy use by about 5% with an average simple payback of 16 months
- **Preheat** furnace combustion air with recovered waste heat to reduce 50% of the furnace's energy use
- **Heating,** ventilation, air conditioning and cooling represent 10% to 20% of food plant energy requirements
- **Install** a monitoring and tracking system to manage and help reduce facility energy requirements 6%. The accurate measurement of energy and water use can be used to identify potential opportunity targets. Thoughtful tracking and analysis can isolate and identify operator error and oversight

Some Considerations for Co-generation Projects

- **Install** gas turbines with heat recovery equipment. They typically cost from $900/kW to $1,600/kW. Larger gas turbines, i.e. larger than 50 MW, may be available for half the cost/kW
- **Reduce** primary energy consumption (including fuel inputs at off-site powerplants for purchased electricity) with a co-generation project to reduce primary energy consumption for steam and electricity generation by 10% to 15%
- **Co-generation** systems can save about 9% of a typical facility's primary fuel inputs for on-site energy use (i.e., including fuel savings at off-site powerplants for purchased electricity) with an average payback of 34 months

[5] The figures used in this are crude estimates and are provided as a reference point for investigation. Actual project costs may vary.
[6] *"The Electric Utilities Industry in Canada: In a Good Position to Overcome the Restructuring."* W. Schroeder and J. Catalfo, 1998.

3.2 WORKED EXAMPLE: HEAT RECOVERY FROM AIR COMPRESSORS

Project Payback Calculations

Background: Waste heat recovery is identified as a potential cost saving project. The suggestion is to install a conduit system out of the compressor room. One conduit exhausts heat outside and a second vent can be used to feed plant heating conduits. The facility uses about $20,000 worth of natural gas per year for space heating.

Key data required:

A) Estimate of offset space heating energy — ***A*** *= $6,000*
B) Estimate for fan and venting installation — ***B*** *= $2,500*
C) Estimate for operational cost of fan operation — ***C*** *= $1,125*
D) Months in a year — ***D*** *= 12*

Calculations using key data shown in 2 steps (sample formulas in ***bold Italics***):

Step 1: Estimate project costs, ***B + A = Z (project costs)***
[Fan and vent installation + annual operating cost] or ($2,500+$1,125) = $3,675

Step 2: Calculate payback, ***Z ÷ (A ÷ D) = Y (months to full cost recovery)***
[[Project savings ÷ [project cost ÷ 12 months]
or ($3,675 ÷ ($6,000 ÷ 12) = ($3,675 ÷ 500) = 7.35 months

Net Amount and Value of GHG Emissions Reduction

Key GHG data required:

a) Estimate value of 1cubic meter of natural gas consumption — ***a*** *= $0.16/m³*
b) Natural gas GHG co-efficients (from Appendix 12.2 GHG Co-efficients)
ba) Carbon dioxide (CO_2) — ***ba*** *= 1.88kg/m³*
bb) CO_2 equivalent for Methane (CH_4) — ***bb*** *= 0.42kg/m³ x 21*
bc) CO_2 equivalent for Nitrous oxide (N_2O) — ***bc*** *= 0.02kg/m³ x 310*
c) Electricity GHG co-efficient for Ontario — ***c*** *= 0.18kg/kWh*
d) Estimate GHG emission credit trading value of 1-tonne CO_2e — ***d****= $10*

Calculations using key data and key GHG data shown in 6 steps (sample formulas in ***bold Italics***):

Step1: Calculate estimated reduction of gas volume, ***A ÷ a = X (volume of natural gas)***
[Value of savings ÷ price per cubic meter] or ($6,000 ÷ $0.16/m³) = 37,500 m³

Step 2: Calculate GHG reduction in CO_2e,
(m³ x ba)+(m³ x bb x 21)+(m³ x bc x 310) = Mng (natural gas emissions)
For CO_2 e [cubic meters of gas x emission factor] or (37,500 x 1.88) = 70,500kg
For CH_4 as $C0_2$ e [cubic meters of gas x emission factor]
or (37,500 x .42) x 21 = (15,750 x 21) = 330,750kg
For N_2O as $C0_2$ e [cubic meters of gas x emission factor]
or (37,500 x .02) x 310 = (750 x 310) = 232,500kg
[CO_2 + $C0_2$ e of CH_4 + $C0_2$ e of N_2O] = (70,500 + 330,750 + 232,500) = 633,750kg CO_2e

Step 3: Calculate increased electricity consumption in kWh,
C ÷ a = X (increased electricity consumption)
[Estimated cost of electricity ÷ kilowatt per hour charge]
or ($1,125 ÷ $0.09/kWh = 12,500kWh

Step 4: Calculate GHG increase in CO_2e from electricity consumption,
X x c = Me(indirect electricity emissions)
[Electricity consumption x emissions co-efficient for electricity]
or (12,500 x .18) = 2,250kg CO_2e

Step 5: Calculate estimate of net reduction of emissions in CO_2e,
Mng - Me = M (net emissions) [Reduced emissions – increased indirect emissions]
or (633,500kg CO_2e - 2,250kg CO_2e) **=** 631,250kg CO_2e

Step 6: Calculate emissions trading value, ***M ÷ 1000 x $10***
[CO_2e in tonnes x $10] or (631,250kg ÷ 1000 x $10) **= $6,310**[7]

[7] Environment Canada sources routinely estimated the value of CO_2e credits at $10/tonne prior to Canada's ratification of the Kyoto Protocol in 2002.

3.3 Tips to Improve the Efficiency of Your Equipment

System Planning

- **Install** gas turbines with heat recovery equipment typically cost from $900 to $1,600/kW. Larger gas turbines, i.e. larger than 50MW, may be available for half the cost per kW
- **Reduce** primary energy consumption (including fuel inputs at off-site powerplants for purchased electricity) for steam and electricity generation by 10% to 15% with co-generation
- **Co-generate** steam and electricity to save about 9% of a typical facility's primary fuel inputs for on-site energy use (i.e., including fuel savings at off-site powerplants for purchased electricity) with an average simple payback of 34 months

Recovery Equipment

- **Preheat** furnace combustion air with recovered waste heat to save 50% of a furnace's energy use
- **Recover** waste heat to reduce a total facility energy use by 5% with an average simple payback of 16 months

3.4 Best Management Practices

Electrical Load Management

- **Stagger** the start-up of equipment that has high power consumption to avoid brownouts and undue wear on other electric motors that are already on
- **Reschedule** production to lower demand periods
- **Schedule** operation of "can wait" power users (e.g. charging batteries, filling up water reservoir) during off-peak hours
- **Shut down** (even briefly) non-essential loads at peak demand periods
- **Shut down** equipment when not needed
- **Replace** standard electric motors with high-efficiency types when replacement is necessary

Control Equipment

- **Install** soft starts on high horsepower motors (greater than 50HP) to reduce peak demand
- **Install** variable speed drives and improved controls
- **Install** a computerized automatic system for monitoring and controlling electrical and thermal energy consumption (particularly in large facilities)

Steam Management

- **Identify** and correct steam and condensate leaks
- **Properly** insulate steam, hot water and condensate return lines and components
- **Set up** a steam trap maintenance program
- **Set up** a chemical treatment program to reduce scaling and fouling of heating surfaces
- **Set up** the boiler to achieve optimum combustion efficiency (air/fuel ratio)
- **Prevent** ingress of extra air to the combustion chamber
- **Check** boiler efficiency regularly and maintain records (e.g. boiler efficiency = fuel used in BTU/steam generated in BTU in given period)

Record Keeping

- **Analyze** electricity demand and usage. Optimize load shifting, load shedding and the power factor (desired power factor is greater than 0.90)

4.0 STEAM AND CONDENSATE RECOVERY

This section is designed to provide quick tips for possible project opportunities for steam and condensate recovery that save money <u>and</u> reduce emissions. This publication provides background data and tips to help justify equipment improvements and upgrades. [8]

4.1 INVESTIGATE YOUR SAVINGS POTENTIAL

The following examples are "rule of thumb" benchmarks compiled from 100 food plant audits in Ontario and 175 international food-industry case studies. Each industrial application is unique and paybacks should be calculated on an individual basis.

<u>Typical Benchmarks for Estimating Steam Losses</u>[9]

- Costs associated per 100 feet of uninsulated pipe at a specified pressure[10]:
  - 25-psi steam = $605/100 ft/shift/year or $19.98/meter/shift/year
  - 50-psi steam = $695/100 ft/shift/year or $22.95/meter/shift/year
  - 75-psi steam = $775/100 ft/shift/year or $25.59/meter/shift/year
  - 100-psi steam = $830/100 ft/shift/year or $27.41/meter/shift/year
- A steam trap leaking 7-bar steam through a 2mm orifice will lose 10kg of steam/hour and cost 12¢/hour for the steam and another 1¢ to 3¢/hour for wasted water and sewer use

<u>Tips for Potential Savings</u>

- Steam trap audits routinely reveal 10% of the steam traps in an industrial plant are defective
- Quality pays. Lower cost traps have been demonstrated to have significantly higher defects
- An ultrasonic monitor costs about $400 and can be used to test steam and air lines for leaks
- Scaling can occur within steam lines, reducing their heat transfer potential by 2%/mm of scale deposit
- Badly pitted lines are leaky lines and leaks cost money. 1 kg of steam is about the same as 1L (liter) of water
- Combined water and sewer rates can cost 25¢ to $1 per 1000 liters. A single 2.5kg/hour steam-leak costs $30 to $180 in lost steam, and $2.50 to $15.00 in wasted water and sewer costs/year

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[8] The figures used in this are crude estimates and are provided as a reference point for investigation. Actual project costs may vary.
[9] Assuming a natural gas fuel source costing $0.16/m^3 = 4.53/MCF (thousand cubic feet) and boiler efficiency of 80%.
[10] Based on 2,000 hours/shift, with one shift being 8 hours/day, 5 days/week and 50 weeks/year

4.2 WORKED EXAMPLE: PAYBACK ON 10-METERS OF PIPE INSULATION

Project Payback Calculations

Background: **In the heat of summer an employee suggested that the radiant heat coming off an uninsulated 25-psi steam line was a health and safety risk that contributed to excess heat in the workplace.**

Key data:

A) Hourly cost of labour	***A*** *= $16.05*
B) Estimated time to complete job	***B*** *= 2 hours*
C) Estimated cost of pipe insulation	***C*** *= $4.40/meter*
D) Operational shifts in hours	***D*** *= 2 shifts @ 2,000 hours each*
E) Estimate of savings per meter per shift per year	***E*** *= $19.98*
F) Meters of pipe to insulate	***F*** *= 10 meters*
G) Number of months in a year	***G*** *= 12*

Calculations using key data shown in 5 steps (sample formulas in ***bold Italics***):

Step 1. Calculate labour cost, ***A x B = Z (labour cost)***
[Wages x time required for job] or ($16.05 x 2) = $32.10

Step 2. Calculate material cost, ***F x C = Y (material cost)***
[Length of pipe to insulate x cost of insulation] or (10 meters x $4.40/meter) = $44.00

Step 3. Calculate reduced cost of combustion, ***E x F x D = X (reduced cost of combustion)***
[Savings per meter per shift x number of shifts x number of meters]
or ($19.98 x 2 x 10 meters) = $399.60

Step 4. Calculate first year payback, ***X – (Z +Y) = P (simple payback)***
[Savings minus [labour plus materials]] or (399.60 – (32.10+$44.00)) = $323.50[11]

Step 5. Calculate payback period, ***(Z +Y) ÷ (X ÷ 12) = Q (months required for payback)***
[[Material + labour]÷[savings ÷ 12 months]]
or ($32.10 + $44.00)÷($399.60 ÷ 12) = ($76.10 ÷ $33.30) = 2.28 months

Net Amount and Value of GHG Emissions Reduction

Key GHG data:

a) Estimate value of 1m^3 of natural gas consumption	***a*** *= $0.16/m^3*
b) Estimate value of avoided gas consumption	*b = $399.60*
c) GHG co-efficients (from Appendix 12.2 GHG Co-efficients)	
ca) Carbon dioxide (CO_2)	***ca*** *= 1.88kg/m^3*
cb) CO_2 e methane (CH_4) x 21	***cb*** *= 0.42kg/m^3 x 21*
cc) CO_2e nitrous oxide (N_2O)	***cc*** *= 0.02kg/m^3 x 310*
d) Estimated value of 1000kg CO_2e GHG emission trading credits	***d*** *=$10*

Calculations using key data and key GHG data shown in 4 steps (sample formulas in ***bold Italics***):

Step1: Calculate estimated reduction of gas volume, ***b ÷ a = G (reduced fuel requirement)***
[Value of savings ÷ price per m^3] or ($399.60 ÷ $0.16/m^3) = 2,497.5 m^3

Step 2: Calculate GHG reduction in CO_2e from reduced gas consumption,
(ca x G) + (cb x G) + (cc x G) =T (CO_2e)
[CO_2 co-efficient x volume of gas] or (1.88 x 2,497.5m^3) = 4,695kg CO_2
[CH_4 co-efficient x volume of gas] or (2,497.5 x .42) x 21 = (1,049 x 21) = 22,028kg CO_2e
N_2O (2,497.5 x .02) x 310 = (49.95 x 310) = 15,485kg CO_2e
CO_2 + CO_2eCH4 + $CO_2e N_2O$ = (4,695+22,028+15,485) = 42,208 kg CO_2e

Step 3: Calculate reduction of emissions in tonnes of CO_2e,
T ÷ 1000 = V (reduced CO_2e in tonnes)
[Total kg CO_2e ÷ number of kilograms in a tonne] or (42,208 kg CO_2e ÷ 1000) = 42 tonnes CO_2e

Step 4: Calculate emissions trading value, ***V x d***
[Total tonnes CO_2e x value of CO_2e credits] or (42.2 x $10.00) **= $420**

[11] The estimated value of possible emissions trading credits is not calculated into the payback.

4.3 TIPS TO IMPROVE THE EFFICIENCY OF YOUR EQUIPMENT

Maintenance and Management

- **Maintain** steam traps to save 3% of total energy use with an average simple payback of 2 months
- **Reduce** boiler fuel use 10% to 20% with an effective steam trap maintenance program
- **Insulate** steam lines to save 1% of total energy use with an average simple payback of 10 months
- **Repair** steam leaks to save 1% of total energy use with an average simple payback of 3 months
  - A high-pressure steam leak (125psi) can cost from $1,065 to $3,500/year (8,760 hrs)
  - A single low-pressure steam leak (15psi) can cost $210 to $725/year (8,760 hrs)

Control Equipment

- **Save** 90% to 905% of the energy needed to raise steam pressure to the same pressure as the boiler with vapor recompression
- **Reduce** heat loss from condensate in a steam system to save over 1% of a facility's total energy use with an average simple payback of 8 months

4.4 BEST MANAGEMENT PRACTICES

Maintenance

- **Identify** and correct steam and condensate leaks
- **Insulate** steam, hot water and condensate return lines and components
- **Set up** a steam trap maintenance program
- **Set up** a chemical treatment program to reduce scaling and fouling of heating surfaces
- **Check** boiler efficiency regularly and maintain records (e.g. boiler efficiency = fuel used in BTU/steam generated in BTU in given period)

Operational Practices

- **Compress** the schedule in the low production periods to avoid stops and starts of large boilers
- **Consider** recovery of flash steam from condensate and consider using the recovered low-pressure steam elsewhere
- **Collect** all possible condensate and return to boiler make-up water tank
- **Decommission** redundant steam and condensate return piping
- **Consider** replacing live steam injection that consumes water and necessitates make-up and heating with heat exchangers
- **Evaluate** the flue gas heat recovery system for pre-heating of feedwater and/or boiler air intake

5.0 WATER HEATING SYSTEMS

This section is designed to provide quick tips for possible improvement projects for water heating systems that save money <u>and</u> reduce emissions. This publication provides background data and tips to help justify equipment improvements and upgrades. [12]

5.1 INVESTIGATE YOUR SAVINGS POTENTIAL

The following examples are "rule of thumb" benchmarks compiled from 100 food plant audits in Ontario and 175 international food-industry case studies. Each industrial application is unique and paybacks should be calculated on an individual basis.

<u>Typical Performance Barriers</u>

- Electric water heat costs twice as much as gas-fired water heat. In Ontario, GHG emissions from gas-fired water heat has about 3-times that of electrically heated water. Other provinces may differ, depending upon the fuel source of electricity. On the other hand, water heated from recovered heat sources like stack heat are essentially GHG "free"
- Look for evidence of scaling on autoclaves, blanchers, kettles, steam tables, scalding tanks, evaporators, water heaters, boilers and other water-contact equipment for heat transfer processes
- Surface scale on heating equipment increases fuel use 2% per 1 mm of deposit
- Soft water (from lakes, rivers and reservoirs) can have dissolved mineral content of 150ppm - 300ppm
- Hard water (well water) can have a dissolved mineral content in excess of 700ppm
- Measure the depth of scale to estimate heating equipment efficiency
    - Soft water can deposit 1mm scale per year
    - Hard water deposits more scale than soft water

<u>Tips for Potential Savings</u>

- **Save** 2% to 6% of water heating fuel use with a scale control program on water heating equipment.
- **Increase** boiler efficiency 2% with annual de-scaling and water treatment.
- **Increase** boiler efficiency by 4% to 6% with regular scaling treatment if hard water is used.
- **Estimate** commercial/residential hot water heaters to use about $20 to $200 worth of fuel/month.

[12] The figures used in this are crude estimates and are provided as a reference point for investigation. Actual project costs may vary.

5.2 WORKED EXAMPLE: THE PAYBACK ON BOILER MAINTENANCE

Project Payback Calculations

Background: In a facility's budget review the cost-cutting impact of improved boiler maintenance is questioned.

Key data required:

A) Period of time since last service:	***A*** *= 3 years*
B) Estimated efficiency loss due to 1mm scale	***B*** *= 2%*
C) Average annual cost of fuel	***C*** *= $120,000*
D) Factory rated fuel efficiency of boiler	***E*** *= 82%*
E) Mineral content of water	***D*** *= 450ppm*
F) Estimated hardness to create 1mm of accretion per year	***F*** *= 300ppm*
G) Cost of boiler scaling	***G*** *= $4,000*
H) Number of months in a year	***H*** *= 12*

Calculations using key data shown in 5 steps (sample formulas in ***bold Italics***):

Step1: Estimate rate of scale accretion, ***F ÷ E = Z (estimated rate of scale accretion)***
[Mineral content of water ÷ Estimated hardness for 1mm/year accretion]
or (450 ÷ 300) = 1.5mm/year

Step 2: Calculate the depth of scale, ***Z x A = Y (estimated depth of scale)***
[Annual accretion x years] or (1.5mm x 3 years) = 4.5mm

Step 3: Calculate efficiency losses, ***Y x B = X (efficiency losses due to scale)***
[Total accretion x 2% loss/mm of accretion] or (4.5mm x 2%) = X = 9% efficiency loss

Step 4: Calculate fuel loss, ***C x X = W (avoided fuel use due to proper maintenance)***
[Annual cost of fuel x % efficiency loss] or ($120,000 x 9%) = **$10,800**

Step 5: Calculate payback, ***G ÷ W x H = P (payback)***
[Projected cost ÷ avoided fuel cost x months in a year] or ($4,000 ÷ $10,000) x 12) = 4.8 months

Net Amount and Value of GHG Emissions Reduction Potential

Key GHG data required:

a) Estimate value of 1m^3 of natural gas consumption — ***a*** *= $0.16/m^3*
b) Estimate value of gas consumption avoided (W) — ***b*** *= $10,800*
c) Natural gas GHG co-efficients (from Appendix 12.2 GHG Co-efficients)
- **ca**) Carbon dioxide (CO_2) — ***ca*** *= 1.88kg/m^3*
- **cb**) CO_2e of Methane (CH_4) — ***cb*** *= 0.42kg/m^3 x 21*
- **cc**) CO_2e of Nitrous oxide (N_2O) — ***cc*** *= 0.02kg/m^3 x 310*

d) Estimated value of GHG emission credit per tonne of CO_2 equivalent — ***d*** *= $10*

Calculations based on key data and key GHG data shown in 4 steps (sample formulas in ***bold Italics***):

Step1: Calculate reduced natural gas use, ***b ÷ a = U (potential fuel reduction)***
[Value of savings ÷ price per cubic meter] or ($10,800 ÷ $0.16/m^3) = 67,500m^3

Step 2: Calculate CO_2, CH_4 and N_2O emissions reductions in CO_2e,
(ca x U) + (cb x U) + (cc x U) = T (CO_2e)
For CO_2 [CO_2 e x volume of gas) or (1.88kg x 67,500) = 253,800kg
For CH_4 CO_2 e [Methane CO_2 e x gas volume]
or (67,500 x .42) x 21 = (28,350 x 21) = 980,000kg
For N_2O CO_2 e [Nitrous oxide CO_2 e x gas volume]
or ((.02kg x 310) x 67,500m^3)= (1,350 x 310) = 837,000kg
[CO_2 + CH_4 CO_2 e + N_2O CO_2 e] = T
or (235,000 + 980,700 + 837,000) = 2,052,700 kg CO_2e

Step 3: Calculate CO_2 e in tonnes, ***T ÷ 1000 = R (tonnes of CO_2e)***
kg *CO_2 e÷ 1000*] or (2,052,700kg ÷ 1000) **= 2,052.7 tonnes CO_2 e**

Step 4: Calculate potential emissions trading value, ***R x d***
[Total tonnes CO_2e x $10[13]] or (2,052.7 X $10) **= $20,530**

[13] Environment Canada sources routinely estimated the value of CO_2e credits at $10/tonne prior to Canada's ratification of the Kyoto Protocol in 2002.

5.3 TIPS TO IMPROVE THE EFFICIENCY OF YOUR EQUIPMENT

Maintenance and Management

- **Install** reflective barriers like ceramic paint can increase heat containment within "hot" zones in a plant and reduce radiant heat penetration into "cool" zones

Control Equipment

- **Use** heat containment to save 2% of total energy use with a simple payback of 9 months
- **Insulate** furnaces with refractory fiber liners to improve the thermal efficiency of the heating process up to 50%
- **Recover** waste heat from furnaces, ovens, kilns, and other equipment to save 5% of a typical facility's total energy use with an average simple payback of 16 months
- **Use** direct fire natural gas heat in place of indirect steam heat can save 33% to 45% of process heating energy use. Payback ranges from a few months to 6 years
- **Install** direct electric heating (infrared, microwave, or dielectric) can reduce process heating energy use up to 80% with typical payback periods of 1 to 3 years

5.4 BEST MANAGEMENT PRACTICES

Processing Area Management

- **Use** ceramic paint as a wall covering to deflect radiant heat back into the process area
- **Install** setback timers on thermostats controlling space heating during non-working hours
- **Ensure** that outside doors are closed
- **Shut** down exhaust fans during non-working hours
- **Minimize** unwanted infiltration of outside air into the plant

Steam Management

- **Set up** a steam trap maintenance program
- **Identify** and correct steam and condensate leaks
- **Insulate** steam, hot water and condensate return lines and components properly
- **Recover** flash steam from condensate and consider using the recovered low-pressure steam elsewhere
- **Decommission** redundant steam and condensate return piping
- **Collect** all possible condensate and return to boiler make-up water tank
- **Consider** replacing live steam injection that consumes water and necessitates make-up and heating with heat exchangers

Equipment Maintenance

- **De-scale** heat transfer equipment that comes in contact with water
- **Evaluate** paybacks on a variety of hot water heating energy sources including direct fired natural gas, microwave, indirect steam heat from natural gas or simple electric heat

Record Keeping

- **Check** heat transfer efficiency regularly and maintain records (e.g. boiler efficiency = fuel used in BTU/steam generated in BTU in given period)

6.0 PROCESS WATER AND WASTEWATER SYSTEMS

This section is designed to provide quick tips for possible process water and wastewater system improvement projects that save money <u>and</u> reduce emissions. This publication provides background data and tips to help justify equipment improvements and upgrades. [14]

6.1 INVESTIGATE YOUR SAVINGS POTENTIAL

The following examples are "rule of thumb" benchmarks compiled from 100 food plant audits in Ontario and 175 international food-industry case studies. Each industrial application is unique and paybacks should be calculated on an individual basis.

<u>Typical Performance Benchmarks</u>

- Food plants that use water efficiently discharge 50% to 25% of the water they use to sewers. Highly efficient food plants discharge less than 25% of their water use to sewage
- A 5/8" hose uses $7.00 worth of water/hour
- It costs $1 to $3.50 per hour less to run a 3/8" valve for 2000 hours at 60psi than a ½" valve
- Every $1.00 spent on water and sewer can add $0.40 in associated energy costs
- Every $1.00 spent on water will add an extra $1.05 to your municipal sewer bill
- A kilogram of waste costs 10-times more as a sewer surcharge than a kilogram of solid waste sent to landfill

<u>Tips for Potential Savings</u>

- Assuming the cost of water and sewer in Ontario is $0.60 to $1.35/m^3 plus energy, in 1 year, a leak costs:
    - 1 drop/second (6 liters/day) = $1.31 to $4.30 per year
    - 1.6mm stream (318 liters/day) = $69.64 to $219.37 per year
    - 4.8mm stream (1.6 m^3/day) = $350.40 to $1,103.76 per year
    - 6.4mm stream (3.5 m^3/day) = $776.50 to $2,414.48 per year
- Closed loop cooling towers have a 4 to 21-month payback period and can reduce water use 10%-20%
- If a raw material is 10% of the cost of production, a 1-% improvement in product recovery increases the gross margin 0.2%. The following table illustrates the relationship between gross margin improvement and improved product recovery

Assuming Price is Constant and Raw Product is the following percentage of the Cost of Production	1% Recovery Increase Raises the Gross Margin by:	2% Recovery Increase Raises the Gross Margin by:	5% Recovery Increase Raises the Gross Margin by:	10% Recovery Increase Raises the Gross Margin by:
5%	0.1%	0.2%	0.5%	1.0%
10%	0.2%	0.4%	1.0%	2.0%
15%	0.3%	0.6%	1.5%	3.0%
20%	0.4%	0.8%	2.0%	4.0%
25%	0.5%	1.0%	2.5%	5.0%
30%	0.6%	1.2%	3.0%	6.0%

[14] The figures used in this are crude estimates and are provided as a reference point for investigation. Actual project costs may vary.

6.2 WORKED EXAMPLE: COOLING TOWER INSTALLATION

Project Payback Calculations

Background: A $25m^3$ cooling tower was suggested as a potential way to reduce water and sewer use. The plant manager needs to understand potential impacts on increased sewage strength, operating costs and potential payback.

Key data required:

A) Estimated daily water use	***A*** *= 640m³*
B) Estimated daily sewer discharge	***B*** *= 600m³*
C) Estimated daily water volume used for non-contact cooling	***C*** *= 150m³*
D) Number of production days per year that need cooling water	***D*** *= 246*
E) Estimated cost of cooling tower installation	***E*** *= $25,000*
F) Estimated operating cost of equipment	***F*** *= $0.10/m³*
G) Estimated cost for water and sewer charges[15]	***G*** *= $0.80/m³*
H) Current Biochemical Oxygen Demand (BOD) levels	***H*** *= up to 210 BOD*
I) Volume of water in closed loop cooling tower	***I*** *= 25m³*
J) Number of months in a year	***J*** *=12*

Calculations from key data shown in 5 steps (sample formulas in ***bold Italics***):

Step1: Estimate annual water volume required for cooling, ***D x C = Z (water volume reduction)***
[Number of production days x daily cooling water use]
or (246 days x $150m^3$ per day) = $36,900m^3$/yr

Step 2: Estimate annual operating cost of cooling equipment (i.e. electric pumps)
Z x F = Y (cost to run cooling tower)
[Water volume reduction x cubic meter cost of operation]
or ($36,900m^3$ x $0.10/$m^3$) = $3,690/year

Step 3: Estimate water/sewer cost avoidance, ***Z x G = X (water and sewer cost avoidance)***
[Water volume reduction x cubic meter charge for water]
or ($36,900m^3$ x $0.80) = $29,520

Step 4: Ensure BOD levels in sewer discharge stay under 300ppm[16],
((C ÷ B) x H) + H = W (increased sewage strength)
[[[Current sewage volume – cooling use]] x BOD] + BOD]
or (((600 –150)) x 210) + 210) = 262.5ppm

Step 5: Estimate payback, ***((E + Y) ÷ X) x J = P (payback in months)***
[Cost savings ÷ [project cost + cost to run cooling tower] x 12]
or ($29520 ÷ ($25,000 + $3,690) x 12 = 11.66 months

Net Amount and Value of GHG Emissions Reduction Potential[17]

Key GHG data required:

a) CO_2e emission factor of electricity consumption in Ontario	***a*** = .18kg/kWh
b) Estimated cost of electricity	***b*** = $0.09/kWh
c) Estimated additional use of electricity (Y)	***c*** = $3,690
d) Estimated value of 1-tonne $C0_2$e credits (1-tonne = 1000kg)	***d*** = $10

Calculations using key data and key GHG data shown in 2 steps (sample formulas shown in ***bold Italics***):

Step 1: Estimate indirect emissions from hydro use, ***(c ÷ b) x a = M (indirect emissions)***
[[Electricity needed to run cooling tower ÷ cost of electricity] x emission factor]
or (($3,690 ÷ $0.09) x .18 = 7,380kg $C0_2$e

Step 2: Calculate GHG impact and credits[18], ***M ÷ 1000 x d = Q (cost to buy emission credits)***
[[Kg of indirect emissions ÷ 1000] x value carbon credits]
or (7,380 ÷ 1000 x $10) = ($73.80)

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[15] Based on approximate water and sewer costs for Toronto or Peel Region in 1999.
[16] This is considered the upper limit for BOD content in wastewater discharged to municipal waterworks. Higher levels trigger $0.25 to $1.00/kg surcharges in many municipalities.
[17] Refer to Appendix Section 12.2, GHG Co-efficients
[18] Environment Canada sources routinely estimated the value of CO_2e credits at $10/tonne prior to Canada's ratification of the Kyoto Protocol in 2002.

6.3 TIPS TO IMPROVE THE EFFICIENCY OF YOUR EQUIPMENT

Maintenance and Management

- **Downsize** valves where hydraulic capacity, product quality or mandated health and safety requirements are not affected
- **Install** low volume automatic-flush faucets, toilets and urinals to save $7.50 to $32.00 per employee per year
- **Drain off** canned ingredients into solid waste containers rather than into sewers if the packing liquid is an unrecoverable input. Solid waste costs 1/10th as much as a sewer surcharge. This practice has helped some food processors reduce their discharge by as much as 1,000 BOD (Bio-chemical Oxygen Demand)

Sanitation Management

- **Scrape**, shovel and squeegee prior to washdown as this reduces BOD and suspended solids in wastewater as much as 50%

Control Equipment

- **Install** monitoring and tracking systems to help manage water consumption by function, (14 or more points) including:
  - Boiler; make-up water (1) and steam and condensate return (2)
  - Hydraulic water used to move product (3)
  - Sanitation (4) and washwater, primary (5), secondary (6) and final rinse (7)
  - Thermal processes; water heaters (8), cooling water (9) and blanchers/steamers/autoclaves (10)
  - Sanitary sewage discharge (11)
  - Out door use; irrigation (12) and vehicle cleaning (13)
  - Administrative office and lavatory (14)
- **Use** the Monetary Concessions Programs in Toronto, Peel Region and Guelph. These municipalities will rebate up to 50% of sewer surcharges from the previous 3 years when sewage loads are reduced to by-law limits or by a minimum of 50%. These rebates can be used for capital equipment, engineering and equipment installation
- **Target** solid matter content of wastewater as this discharge from food and beverage processing facilities is estimated to emit 15% of all greenhouse gasses for this sector.[19] These emissions are largely emitted as methane from decomposition.
- **Documented** diversion from sewage (or documented consumption) reduces wastewater charges where municipal wastewater services encourage wastewater conservation as per this table:

DISCHARGE FACTOR: (SEWER DISCHARGE AS A PERCENT OF WATER USE)	ANNUAL WATER USE[20]	2,724M^3 .6-MILLION GALLONS	27,240M^3 6-MILLION GALLONS	272,400M^3 60-MILLION GALLONS
90%	Estimated savings versus 100% return to sewer if sewer charges are $0.50/m^3 or $2.2727/'000 gallons	0	$1,362.00	$13,620.00
80%		$272.40	$2,724.00	$27,240.00
70%		$544.80	$5,448.00	$54,480.00
50%		$681.00	$6,810.00	$68,100.00
30%		$935.40	$9,534.00	$95,340.00

[19] *Measuring the Potential of GHG Emissions Reductions on the Agri-Food Sector in Ontario,* Jacques Whitford, 2000.
[20] The volume of 1 cubic meter is equal to 220 Imperial gallons or 262 US gallons. The gallons listed in this document are Imperial gallons.

6.4 BEST MANAGEMENT PRACTICES

Water Management

- **Turn off** unnecessary water flow
- **Ensure** that hoses with the smallest diameter necessary are used. Fit hoses with automatic cut-off valves (guns) where appropriate
- **Ensure** that water supply for process stops during idle periods
- **Repair** leaks promptly
- **Optimize** pump impellers to ensure the duty point is within the optimum zone on the pump curve.
- **Install** water meters in different process areas to monitor consumption on an ongoing basis. Use data to identify areas of inconsistent and inefficient water usage, correct deficiencies and set progressively tighter consumption targets
- **Install** water recuperation and re-use systems throughout the plant

Wastewater Management

- **Collect** uncontaminated cooling water for re-use
- **Install** closed-loop-cooling water systems where feasible to eliminate once-through cooling water
- **Re-use** secondary rinse waters where possible, with due regard to product quality implications
- **Modify** process equipment and/or process procedure to prevent effluent contamination
- **Separate** high-strength effluent streams at source to enable cost effective waste recovery

Record Keeping

- **Install** water meters in different process areas to monitor consumption on an ongoing basis. Use data to identify areas of inconsistent and inefficient water usage, correct deficiencies and set progressively tighter consumption targets
- **Analyze** production by liter of water use per kilogram of product manufactured

6.5 IMPORTANT WATER AND WASTEWATER REGULATIONS

In Ontario the use of wastewater treatment equipment requires a Certificate of Approval from the Ministry of the Environment pursuant to Regulation 347 of the Environmental Protection Act. For further details and instructions please contact the Ministry of the Environment at:

The Environmental Assessment and Approvals Branch, 416-314-8001

Waterworks within food processing establishments must comply with Ontario Drinking Water Standards and Guidelines. A "Waterworks" is defined as a source of water derived from a groundwater or surface water source that is intended for human consumption. These waterworks are required to have the following:

1. A waterworks license (obtained through local Ministry of the Environment offices.)
2. Approved disinfection system (chlorination, chloromines, ozone or ultra-violet radiation are a few of the approved methodologies.)
3. Compliance with water testing guidelines for raw and finished water.
4. Retain a licensed waterworks operator on site.

Further information pertaining to these regulations can be found on the Ministry of the Environment's website: http://www.ene.gov.on.ca/envision/gp/index.htm#PartWater

7.0 ELECTRICAL SERVICE AND MOTORS

This section is designed to provide quick tips for possible electrical service and motor improvement projects that save money and reduce emissions. This publication provides background data and tips to help justify equipment improvements and upgrades. [21]

7.1 Investigate your Savings Potential

The following examples are "rule of thumb" benchmarks compiled from 100 food plant audits in Ontario and 175 international food-industry case studies. Each industrial application is unique and paybacks should be calculated on an individual basis.

Typical Performance Benchmarks

- Monitoring and Tracking systems can help pinpoint and reduce unnecessary electricity use by 6% to 15%
- About 60% of industrial electricity consumption is used to power electric motors
- At 75% efficiency a 1hp motor draws 1kWh/hour with an energy output of 0.746kWh/hour
- Small standard motors (>1.5hp) are rated at 75% efficiency, but a high-efficiency 3-phase motor is rated at 87.5% to 89.5%
- Larger standard motors have the following estimated efficiencies
    - A 5hp-20hp standard engine should have a standard efficiency rating of 88%
    - A 40hp standard engine should have a standard efficiency rating of 89%
- Optimum power factor for a manufacturing plant is 90% to 92%

Barriers to Peak Efficiency

- The typical unimproved power factor for a manufacturing plant is 80% to 84%
- High-horsepower motors that lack soft start mechanisms tend to inflict motor damage to small other motors in your plant

Tips for Potential Savings

- Save $41,000 per year on a 6000kVA reactive power demand by correcting an 80% power factor to 90%
- Power factor correction payback is 6 months to 2 years

Soft Start Installation Costs

- In 2002, a "soft start" mechanism for a 50HP motor costs about $1,100 to $1,300 ($1500 to $3,000 installed)[22]
- In 2002, a "soft start" mechanism for a 100HP motor costs about $2,700 to $3,200 ($3,500 to $6,500 installed)
- In 2002, a "soft start" mechanism for a 300HP motor costs about $5,400 to $6,200 ($6,500 to $12,500 installed)

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[21] The figures used in this are crude estimates and are provided as a reference point for investigation. Actual project costs may vary.

[22] Installation costs can be as low as a few hundred dollars to equal the cost of the soft start package, depending upon the complexity of the installation (for instance if watertight electrical box enclosure like a NEMA4 box is required. NEMA stands for National Electrical Manufacturers Association.)

7.2 WORKED EXAMPLE: SOFT START MOTORS IN A FOOD PROCESSOR[23]

Project Payback Calculations

Background: A food manufacturer uses three 300HP motors to power cooling needs. In hot weather, the ignition of the 3rd motor causes a plant-wide brownout. These brownouts cause equipment malfunctions throughout the plant that idle equipment, create added re-work and cleanup.

Key data required:

A) Average number of hot weather events per year	***A*** = ***10***
B) Number of production workers idled per event	***B*** = *54*
C) Average hourly cost of labour	***C*** = *$16.02/hour*
D) Estimated downtime per event	***D*** = *1 hour*
E) Estimated volume of waste generation	***E*** = *8 tonnes*
F) Estimated value of lost material or production[24]	***F*** = *$500/tonne*
G) Estimate of cost of lost profitability	***G*** = *$20/tonne*
H) Estimate of added cost of disposal (tipping fee, labour, transport)	***H*** = *$80/tonne*
I) Number of soft start units to install	***I*** = *3*
J) Estimated cost of installation	***J*** = *$40,000*
K) Months in a year	***K*** = *12*

Calculations from key data show in 6 steps (sample formulas in ***bold Italics***):

Step 1: Calculate cost of labour for 10 events, ***A x (D x C x B) = Z (labour cost)***
[Events x hours per event x wages x number of workers] or (10 x 1 x $16.02 x 54) = $8,567.80

Step 2: Calculate lost material for these events, ***A x E x F = Y (cost of lost material in process)***
[Events x volume of loss per event x material cost]or (10 x 8 x $500) = $40,000

Step 3: Calculate lost profits for 10 events, ***A x E x G = X (cost of lost profits)***
[Events x volume of loss per event x profit per tonne x tonnes] or (10 x 8 x $20) = $1,600

Step 4: Calculate added landfill costs for 10 events, ***A x E x H = W (cost of disposal)***
[10 events x volume of waste x disposal costs] or (10 x 8 x $80) = $6,400

Step 5: Calculate accumulated costs, ***Z + Y + X + W = U (total costs)***
[Labour + lost material + lost profit + landfill costs]
or $8,567.80 + $40,000 + $1,600 + $6,400 = $56,567.80

Step 6: Calculate payback, ***J ÷ U x K = P (payback in months)***
[[Cost of project ÷ value of annual estimated losses] x 12]
or (($40,000 ÷ $56,567.80) x 12) **= 8.33 months**

Net Amount and Value of GHG Emissions Reduction Potential[25]

Key GHG data required:

a) The co-efficient for methane conversion from potatoes (CH_4)[26]	***a*** *≈ 0.5kg/kg*
b) CO_2e emission factor of Methane (CH_4) to CO_2 equivalents	***b*** = *21*
c) Estimate volume of wasted potatoes	***c*** = *80,000kg*
d) Value of 1 tonne CO_2e (for estimate purposes only)	*d = $10*

Calculations from key data and key GHG data show in 2 steps (sample formulas in ***bold Italics***):

Step 1. Calculate reduction of GHG emissions as $C0_2$e (Refer to Appendix 12.2 GHG Co-efficients)
c x a x b = W (C0₂e)
[Reduced waste potatoes to landfill x methane conversion co-efficient x CO_2e coefficient of CH_4]
((8,000kg waste potatoes x 0.50) x 21) = (4000 x 21) = 84,000 kg $C0_2$e = 84tonnes $C0_2$e

Step 2: Calculate potential emissions trading value, ***W x d***
[total tonnes CO_2e x $10] (84 tonnes x $10) **= $840**

23 The projected impact on profitability from this type of project is dramatic. A $56,500-loss avoidance is the same as a $113,000 profit increase. If we assume Statistics Canada (2000) profit rate of about 4% for food processing establishments, this is the same as a $2,825,000 (at 4% profit) increase in sales.

24 This includes wages, energy, packaging, water use and overhead costs that were used to make the product that was disposed, not the cost of cleanup labour.

25 It is unlikely that this kind of project will generate GHG trading credits. Carbon equivalent credits are estimated at $10/tonne for illustrative purposes only.

26 Based on the solids to methane conversion co-efficients developed for Humpty Dumpty in 2001.

7.3 Tips to Improve the Efficiency of your Equipment

Maintenance and Management

- **Upgrade** to an energy efficient motor saves about 5% over the operating costs of a standard motor
- **Upgrade** to 3-phase high efficiency motor to reduce energy (kWh) and demand (kW) costs 7% to 10%) over a standard motor. Electric motor manufacturers like Westinghouse and Gould have upgraded their product lines and no longer make "standard" electric motors. Their models are either 'efficient" or "high-efficiency" models. Re-conditioned or rewound motors may still be available from local electrical supply and service companies. Price comparisons for a 5HP electric motor are as follows:
  - Used, rewound/reconditioned standard motor (75% to 84% efficient): $150-$240
  - New, efficient model (87.5% efficient)[27]: $240-$330
  - New, high-efficiency model (up to 89.5% efficient): $290-$380
- **Install** a monitoring and tracking system to identify electrical loads for specific production functions and potentially reduce electrical consumption by 6% to 15%
- **Ensure** all water, sewage, electrical, gas and production conduits/pipes/lines do not touch. The flow of matter through metallic lines will also conduct a low-voltage electrical current that can corrode the lower density metal

7.4 Best Management Practices

Motor Management

- **Identify** motors that idle excessively and carefully shut down motors when not needed
- **Replace** standard electric motors with high-efficiency types when replacement is necessary
- **Replace** motors that operate at less than their optimum rated load with smaller high-efficiency units
- **Install** variable speed drives and improved controls
- **Replace** compressors with the most efficient type available when justified
- **Maintain** screw compressors at full load when reciprocating compressors and screw compressors are used in parallel. When partial loads are required, use the reciprocating compressor and shut down the screw compressor

Electrical Service Management

- **Analyze** electricity demand and usage. Optimize load shifting, load shedding and the power factor (desired power factor is greater than 0.90)
- **Install** soft starts on high horsepower motors, (greater than 50HP) to control self-inflicted brownouts

Electric Motor Waste Heat Management

- **Discharge** air-cooled compressors exhaust outdoors during the summer and use indoors for space heating during winter

Electricity Load Management

- **Reschedule** loads where possible to lower demand time periods
- **Install** a computerized automatic system for monitoring and controlling electrical energy consumption (particularly in large facilities)
- **Sequence** compressors on the basis of their loads and respective efficiencies. Ensure that only one compressor operates at part-load
- **Switch** off compressors, motors and fans when production is down

Record Keeping

- **Install** a computerized automatic system to analyze, monitor and control electrical energy consumption (particularly in large facilities)

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27 The legislated efficiency for a 3-phase motor is 87.5%

8.0 PROCESS COOLING AND REFRIGERATION SYSTEMS

This section is designed to provide quick tips for process cooling and refrigeration system improvement projects that save money <u>and</u> reduce emissions. This publication provides background data and tips to help justify equipment improvements and upgrades. [28]

8.1 INVESTIGATE YOUR SAVINGS POTENTIAL

The following examples are "rule of thumb" benchmarks compiled from 100 food plant audits in Ontario and 175 international food-industry case studies. Each industrial application is unique and paybacks should be calculated on an individual basis.

<u>Typical Performance Benchmarks</u>

- Optimum insulation for small refrigeration area under 2,000 ft^2 is 10 inches
- Rooftop temperature impacts radiant heat penetration. A typical blacktop roof can reach 70°C on a 40°C day and can increase cooling energy requirements to 3-times the average requirement
- Rooftop chillers operate at peak efficiency at 10°F ≈ -15°C

<u>Barriers to Operating Efficiently</u>

- A 1°C reduction in evaporation temperature/pressure (heat added to refrigerant in an evaporator) of a refrigeration system will increase the costs 2% to 4%
- Rooftop chillers loose 2% efficiency for every 1°C that rooftop temperatures rise over 50°C[29]
- Freezer ceilings will accumulate ice when water penetrates through the roof. Ice reduces insulation performance by up to 90% and is a structural hazard that could add more weight than the design weight of the roof

<u>Tips Potential Savings</u>

- **Increase** chilled water output temperature by 1°C to reduce chiller energy use by 0.6% to 2.5%
- **Reduce** condenser pressure by 10psi to decrease refrigeration system energy use/tonne of refrigeration (kW/tonne) by about 6%
- **Decrease** condenser cooling water temperature by 0.5°C increments, until optimal water temperature is reached or chiller energy use drops by up to 3.5%. (Hint, monitor the water temperature and chiller energy use)
- **Decrease** condensing temperature/pressure 1°C (i.e. heat removed from the refrigerant in the condenser) of a refrigeration system to decrease electrical operation costs by 2% to 4%
- Radiant heat penetration from rooftop sources **will increase** cooling peak electricity energy requirements by 40% when hourly energy costs can be 300% to 800% above off-peak rates

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[28] The figures used in this are crude estimates and are provided as a reference point for investigation. Actual project costs may vary.

[29] Electric energy prices typically spike between 3-times to 8-times off peak rates during hot weather incidents.

8.2 WORKED EXAMPLE: PASSIVE ENERGY DEMAND MANAGEMENT

Project Payback Calculations

Background: It is time to repair the warehouse roof. The plant manager wants to consider ceramic roofing paint.

Key data:

A) Estimated cost for roof repair	***A*** = *\$360,000 for a 360,000 ft² roof*
B) Estimated cost of ceramic paint project	***B*** = *\$432,000*[30]
C) Annual cost of energy for cooling	***C*** = *\$1,440,000*
D) Energy demand during summer season	***D*** = *+ 25% above average*[31]
E) Peak vs. average hydro costs (including demand charges)	***E*** = *\$0.09/kWh vs. \$0.12/kWh*[32]
F) Estimate of average non-summer monthly cost	***F*** = *\$112,941.16 (See footnote 4)*
G) Estimate average summer monthly cost	***G*** = *\$141,176.45 (See footnote 4)*
H) Estimate forecast average for future summer months	***H*** = *\$176,470.56 (See footnote 4)*
I) Estimate US EPA documented reduction from ceramic treatment	***I*** = *40% (from peak summer load)*
J) Number of months in a year	***J*** = *12*

Calculations based on key data shown in 5 steps (sample formulas shown in ***bold Italics***):

Step1: Calculate the cost of maintenance versus the ceramic paint cost,

B – A = Z (increase of capital budget) [Ceramic cost – maintenance cost]
or (\$432,000 - \$360,000) = \$72,000

Step 2: Calculate the increased cost of refrigeration in summer,

(G x 3) – (F x 3) = Y (summer refrigeration variance)
[[Average summer month x 3] - [average other month x 3]]
(\$141,176.45 x 3) – (3 x \$112,941.16) = \$87,705.87

Step 3: Calculate estimated cost savings, ***(G x 3) x I = X (estimate of savings from ceramic roof paint)***
[40% of summer use](\$141,176.45 x 3) x .40 = \$169,411.74

Step 4: Calculate estimated cost savings if summer electricity rates rise 25%,

H x 3 x I = P (impact of higher costs)
[Summer month forecast x 3 months x EPA estimate]
(\$176,470.56 x 3) x .40 = \$211,764.67[33]

Step 5: Calculate potential payback using lowest energy cost, ***(Z ÷ X) x J÷ 3(number of summer months)***
[Increased capital spending ÷ savings] x [months in a year ÷ 3]
or (\$72,000 ÷ \$169,411.74) x (12÷ 3) **= 1.7 months**

Net Amount and Value of GHG Emissions Reduction Potential

Key GHG data required:

a) CO_2e emission factor of electricity consumption in Ontario	***a*** = *0.18kg/kWh*
b) Estimated cost of electricity	***b*** = *\$0.09/kWh*
c) Estimated reduced use of electricity (X)	***c*** = *\$169,411.74*
d) Estimated value of 1 tonne CO_2e	***d*** = *\$10*

Calculations using key data and key GHG data shown in 2 steps (sample formulas in ***bold Italics***):

Step 1. Calculate CO_2e in tonnes (Refer to Appendix 12.2 GHG Co-efficients),

(X÷ b) x a = P (CO_2 equivalents) [[Electrical cost reduction ÷ kWh cost] x CO_2 equivalent]
((\$169,411.74 x \$0.09) x 0.18) = 338,823kg $C0_2$e = 339t CO_2e

Step 2. Calculate value of emissions trading credits,[34] ***P x d*** **= \$3,390**

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[30] Assuming the price is \$1.20/ft², actual costs may vary.

[31] The algebraic equation for calculating the average impact of summer is Y= [9M+1.25M+1.25M+ .23 M]= [12M + 3/4M]. If Y = annual cost of electricity and M = average monthly (excluding summer) cost of electricity, the common denominator in the equation is 4,

so 12M = 48/4Y = 48/4 + 3 /4 = 51/4
¼ M = Y/51 or \$1,440,000 ÷ 51 **= \$28,235.29**
M = Y/51 x 4 or (\$1440,000 ÷ 51) x 4 **= \$112,941.16**
A summer month would then be M + 1/4M = \$112,941.16 + \$28, 235.29 **= \$141,175.45**
A post-deregulation summer month could be calculated as another 25% = \$141,175.45 x 1.25 **= \$176,470.56**

[32] Based on actual average costs in Ontario in 2002.

[33] The simple payback vs. regular repair is 2 months (a 235% rate of return) and reduces electricity for refrigeration 11% to 14%.

[34] Environment Canada sources routinely estimated the value of CO_2e credits at \$10/tonne prior to Canada's ratification of the Kyoto Protocol in 2002.

8.3 TIPS TO IMPROVE THE EFFICIENCY OF YOUR EQUIPMENT

Maintenance and Management

- **Reduce** total energy use with "free cooling". Water cooling towers have an average simple payback of 14 months
- **Reduce** cooling system energy use with "free cooling" by as much as 40%
- **Eliminate** heat loss from leaks and improper defrosting to cut refrigeration energy use by 10% to 20%
- **Use** ceramic paint as a roofing treatment to reduce summer peak electric energy demands 40%

Control Equipment

- **Improve** control of auxiliary equipment in a refrigeration system to cut costs by 20% or more
- **Install** energy efficient chillers and refrigeration systems to save 1% of a total facility energy use for 23-month payback
- **Install** variable speed drives to reduce cooling system energy use by 30% to 50%, depending on load profile
- **Install** refrigeration compressor controls to reduce system operation costs by 20% or more
- **Install** monitoring and tracking systems to measure and control refrigeration energy demand. M&T systems typically help reduce utility use 6% to13% with a simple payback of 2 to 23 months

8.4 BEST MANAGEMENT PRACTICES

Refrigeration Management

- **Implement** good housekeeping practices, e.g. keep the doors to refrigerated areas closed; separate the cold areas from the rest of the plant by installing doors, plastic curtains, swing doors; use as little water as possible in refrigerated rooms
- **Use** low ambient temperatures to provide free cooling during winter, spring and fall

Property Management and Construction

- **Segregate** refrigeration systems according to temperature
- **Optimize** the thermodynamic balance of the refrigeration cycle with dedicated equipment for the minimum required conditions of each process
- **Minimize** items or equipment that generate heat in, or close to, refrigerated or cooled space
- **Replace** inadequate doors to cold areas
- **Consider** ceramic roofing as an option for flat roof maintenance to reduce the peak energy demands of cooling systems

Equipment Set Up

- **Sequence** compressors on the basis of their loads and respective efficiencies.
- **Ensure** that only one air compressor operates at part-load

Record Keeping

- **Review** refrigeration plant regimen as process requirements and ambient weather changes
- **Ensure** the controls for defrosting are set properly and review the settings frequently
- **Ensure** that defrosting operates only when necessary and for as short a period as necessary
- **Review** system controls and correctly set points for evaporating and condensing temperatures

9.0 COMPRESSED AIR SYSTEMS

This section is designed to provide quick tips for possible improvement projects for compressed air systems that save money and reduce emissions. This publication provides background data and tips to help justify equipment improvements and upgrades.

9.1 INVESTIGATE YOUR SAVINGS POTENTIAL

The following examples are "rule of thumb" benchmarks compiled from 100 food plant audits in Ontario and 175 international food-industry case studies. Each industrial application is unique and paybacks should be calculated on an individual basis.[35]

Typical Performance Benchmarks

- It takes 2.5kWh to 5.0kWh to compress 1,000ft^3 of air to 100-psi
- At \$0.09/kWh for electricity, it costs \$0.225 to \$0.45 to compress 1,000ft^3 air to 100-psi
- Air compression is typically 1.5% to 3% of the total energy use and 3% to 6% of the energy cost in a food plant
- Every 1-psi increase in air compressor pressure gained by periodic filter changes, air compressor energy drops by about 0.5%. Change dryer filters at 8-psi to 10-psi drop per filter to eliminate this waste

Reducing Electricity Use

- Reduce air compressor pressure by 2-psi to reduce compressor energy use by 1% (at 100-psi)
- A 10-psi reduction in compressor discharge pressure results in 5% reduction in energy consumption (for a 100-psi compressed air system)

Potential Savings for Selected Targets

- Decrease air compressor working temperature by 5°C (11°F) with careful intercooler maintenance to decrease energy use by 1%
- At 100-psi a 10HP air compressor consumes about \$7,000 worth of hydro per year, working 40 hours/week.
- Leaks in an 87-psi system have the associated cost if electricity costs \$ 0.09/kWh:
    - 1 mm = 1.0 L/s and \$18/month;
    - 3 mm = 10.0 L/s and \$198/month;
    - 5 mm = 26.7 L/s and \$540/month;
    - 10 mm = 105.0 L/s and \$2,124/month.

[35] The figures used in this are crude estimates and are provided as a reference point for investigation. Actual project costs may vary.

9.2 WORKED EXAMPLE: AIR SYSTEM REPAIR AND MAINTENANCE

Project Payback Calculations

Background: There is a noticeable hiss from compressed air lines in a factory. When the facility auditor of a key customer noticed this background noise in the same conversation as the upcoming price negotiation, the plant manager realized there is a painless opportunity for improvement.

Suggested repair procedure:

1. Purchase ultrasonic monitor
2. Sweep lines with meter to detect air leaks
3. Mark all leaks for repair and apply temporary clamps
4. Take measurements for replacement lines and determine material costs
5. Replace defective lines during off-production period

Key data:

A) Daily compressed air use	***A*** *= 125,000ft*^{3}
B) Number of production shifts per year	***B*** *= 246*
C) Labour cost	***C*** *= $16.05/hour*
D) Estimate of time required to fix lines	***D*** *= 16 hours*
E) Estimated cost of materials for line replacement	***E*** *= $1,500*
F) Cost of hand-held ultrasonic monitor	***F*** *= $400*
G) Best guess at compressed air loss	***G*** *= up to 30% (.3)*
H) Estimate of cost of hydro[36]	***H*** *= $0.09/kWh*
I) Estimated cost to compress 1000ft^3 air	***I*** *= $0.45*

Calculations using key data shown in 6 steps (sample formulas in ***bold Italics***):

Step 1. Calculate repair cost***, C x D = Y (repair cost)*** = $256.80
[Wage rate x estimated job time] ($16.05 per hour x 16 hours)

Step 2. Calculate cost of repair/replacement project, ***Y + F + E = X (material costs)*** = $2,156.80
[Labour + monitor + materials] ($256.80 + $400 + $1,500)

Step 3. Calculate annual air use, ***A x B = Z (air use)*** [Daily use x 246 shifts]
(125,000 ft^3 x 246) = 30,750,000ft^3

Step 4. Calculate annual cost of air use, ***Z x I = P (cost of air use)***
[Annual volume x $0.45/1000 ft^3] (30,750 x $0.45) = $13,837.50/year

Step 5. Calculate estimated savings, ***P x .30*** [30% of $13,837.50] ($13,837.5 x .3) = $4,121.25/year

Step 6. Calculate reduced electricity use, ***P ÷ H= Q (reduced electricity consumption)***
[Cost divided by $0.09/kWh] ($4,121.25 ÷ $0.09) = 46,125kWh

Net Amount and Value of GHG Emissions Reduction Potential[37]

Key data required:

a) CO_2e emission factor of electricity consumption in Ontario	***a*** *= 0.18kg/kWh*
b) Estimate of reduced use of electricity	***b*** *= 46,125kWh*
c) Estimated value for 1 tonne of CO_2e trading credits	***c*** *= $10*

Calculations using key data and key GHG data shown in 2 steps (sample formulas in ***bold Italics***):

Step 1. Calculate reduction of GHG emissions as $C0_2$e
Q x a = R (C0$_2$***e)*** [Reduced hydro use in kWh x .18 CO_2e/kWh] (46,125 x .18) = 8,303kg $C0_2$e

Step 2: Calculate emissions trading value, ***R x c*** [CO_2e x $10/tonne]
or (8.3 tonnes x $10) **= $830**

[36] Assuming the facility uses a reciprocating compressor. A facility that needs constant pressure should investigate the installation of screw-type compressors.

[37] *It is arguably unlikely that this type of project would generate GHG trading credits*

9.3 TIPS TO IMPROVE THE EFFICIENCY OF YOUR EQUIPMENT

Maintenance and Management

- **Reduce** compressed air system energy use by 20% to 50% with efficiency improvements
- **Use** cooler intake air for compressors to reduce compressed air system energy use by 1% per 5°C (11°F) reduction. The payback period for this measure is usually less than 2 years
- **Reduce** air compressor pressure to reduce total facility energy use by 0.5% with an average simple payback of 4 months
- **Eliminate** or reduce compressed air usage for certain activities can reduce a facility's total energy use by more than one-half percent, with an average simple payback of 6 months
- **Repair** air leaks to reduce compressed air system energy use by 30% or more
- **Repair** air leaks to reduce a facility's total energy use by about 0.5%, with an average simple payback of 3 months

Control Equipment

- **Install** or adjust unloading controls to reduce compressed air system energy use by about 10%
- **Reduce** overall facility energy use 0.5% with compressed air system efficiency improvements
- **Use** cooler intake air for compressors to save 0.5% of total energy for a 5-month payback
- **Upgrade** controls of screw air compressors to reduce total facility energy use by 1% with an average 8 month payback
- **Recover** air compressor waste heat to reduce facility energy use 2% for a 10-month payback
- **Find** air leaks with an ultrasonic monitor. Ultrasonic monitors cost about $400

9.4 BEST MANAGEMENT PRACTICES

Compressed Air Management

- **Replace** compressors with the most efficient type available, when justified
- **Generate** compressed air at the lowest pressure required
- **Use** intake air from coolest location, probably by direct ducting of fresh intake air from outside
- **Discharge** air from air-cooled compressors outdoors during the summer
- **Use** waste heat from air-cooled compressors as an indoor heat source heating during winter
- **Invest** in a leak detector/air leak tester to measure total volumetric leakage throughout the compressed air system and also the compressor capacity
- **Recover** heat from air compressor cooling water

System Management

- **Switch** off compressors when production is down
- **Compress** low production periods to avoid stops and starts of large compressors
- **Maintain** screw compressors at full load where reciprocating compressors and screw compressors are used in parallel
- **Use** reciprocating compressors and shut down screw compressors if partial loads are needed
- **Collect** all possible condensate and divert to storm drainage

Record Keeping

- **Check** compressor efficiency regularly and maintain records (e.g. compressor efficiency = electricity used in kWh used per kilogram or liter of production)

10.0 OTHER IMPORTANT CONSIDERATIONS

In Ontario, industrial combustion equipment requires a Certificate of Approval from the Ministry of the Environment pursuant to the Environmental Protection Act, Regulation 346. For further details and instructions please contact the Ministry of the Environment at:

The Environmental Assessment and Approvals Branch, 416-314-8001

Food and beverage factories that have more than 10-million BTU's of combustion capacity are required to comply with Regulation 127 (Mandatory Emissions Reporting). The first reporting period for food and beverage processors is the 2002 calendar year, with a report due to MOE on June 1, 2003. For further instructions on MOE reporting criteria, please visit their website at::

http://www.moe.gov.on.ca

The Ministry of Agriculture and Food has developed an Excel-based screening tool for food and beverage stakeholders. This tool can be used to estimate food plant emissions for MOE reports. For further information on this e-tool, please call Phil Dick, Ministry of Agriculture & Food. Tel. 519-826-4385

11.0 FURTHER INFORMATION ON ENERGY EFFICIENCY

For more information on energy efficiency visit the following web sites:

Some Canadian Websites …

Agri-food Forum	http://www.agrifood-form.net/home.asp
Canadian Biosystems Engineering	http://www.engr.usask.ca/societies/csae/journal.html
CIPEC[38]	http://www.cipec.org/
Enbridge Consumers Gas	http://www.cgc.enbridge.com/G/G05-00_environment.html
OCETA[39]	http://www.oceta.on.ca/
Office of Energy Efficiency	http://oee.nrcan.gc.ca cipec/ieep/cipec/index.cfm
or	http://oee.nrcan.gc.ca/english/index.cfm?Text=N
P2 Pays	http://www.p2pays.org/

Some U.S. Websites …

Envirosense U.S. EPA	http://es.epa.gov/
U.S. Department of Energy	http://www.energy.gov/

Some Global Websites …

CADDET[40]	http://caddet-ee.org/index.php
Environment Australia	http://www.erin.gov.au
Global Environmental Management Initiative	http://www.gemi.org/
United Nations Environmental Program	http://www.unep.ch/

[38] Canadian Industrial Program for Energy Conservation
[39] Ontario Centre for Environmental Technology Advancement
[40] Centre for Analysis and Dissemination of Documented Energy Technology

12.0 APPENDICES

12.10 BEST MANAGEMENT PRACTICES CHECKLIST

This appendix follows the general outline of the eight opportunity areas identified in this bulletin. These are as follows:

- Oil, gas and propane-fired boilers and heaters
- Waste heat and co-generation
- Steam and condensate recovery
- Water heating systems
- Process water and wastewater systems
- Electrical service and motors
- Process cooling and refrigeration systems
- Compressed air systems

Each opportunity area has been reduced to a 1-page checklist of opportunities related to a discreet area. While some efficiency opportunities may be inter-related to several opportunity areas, the checklists are focused on the “best fit”.

Each checklist is divided into 4 parts.

1. The “Best Management Practice” is a recognized practice that will reduce both operating costs and emissions. These opportunities are ranked according to potential impact.

2. A quantified number based on proven technology or published case studies to demonstrate the relative impact of each opportunity. Some BMP’s lack a corresponding “Efficiency Opportunity” number due to variability in their nature.

   A BMP like “decommissioning redundant steam and condensate lines” has more of an impact on operator behavior management. Staff behavior, what people do, how they do it or what they forget to do may have as much as a 6% impact on your overall utility use. Pro-active actions such as this may be no-cost or preventative measures that avoid operator errors. These BMP’s are marked with an asterisk (*).

   A BMP like “recover waste heat from air compressors” may be marked with the letter “f” to identify this type of opportunity that can impact total facility energy use.

   A BMP like “upgrade boiler maintenance program” may be unmarked, which identifies the opportunity as related to a specific Utility opportunity.

3. The “Action Planned” column relates to your actions.

4. The “Action Taken” should only be ticked if the opportunity is a project previously undertaken or if it has occurred due to planned and executed actions.

12.11 START A UTILITY EFFICIENCY TEAM IN YOUR PLANT

Start a Utility Efficiency Team in your plant to look at efficiency opportunities that includes:

Maintenance staff
Production staff
Production and engineering management
Operations management
Financial management
Sales and Marketing management

Some team members can identify and implement opportunities in their respective areas. Other team members are important for buy-in, like Finance to support projects or Sales and Marketing who need to know the implications of efficiency projects on gross margins.

To learn more about energy efficiency, visit the Canadian Industrial Program for Energy Conservation website at:

http://www.cipec.org/

Consider signing your company up to become eligible for federally funded energy efficiency programs. Then consider participating in a quarterly CIPEC meeting.

BMP	Efficiency Opportunity	Action Planned	Action Taken
Team-building and awareness			
1. Identify plant champion/leader	pre-requisite	☐	☐
2. Develop departmental teams	pre-requisite	☐	☐
3. Strike an inter-departmental committee	pre-requisite	☐	☐
Implementation and Management			
1. Ask the most important question. ***Can your sales department successfully pass through enough of a price increase to improve your gross margin?***		☐	☐
2. Engage your employees in behavior modification. The Office of Energy Efficiency has a number of promotional kits that are free for the asking. You can find them at their website: http://oee.nrcan.gc.ca cipec/ieep/cipec/index.cfm	6% to 13%	☐	☐
3. Investigate and promote utility efficiency projects based on the following criteria:			
• Improved profitability	20% to 200%	☐	☐
• Payback (these simple rates of return are all above 20% corporate rates of return)			
• 0 to 2 years	15% to 20%	☐	☐
• 2 years to 5 years	30% to 50%	☐	☐
• Access to various government programs		☐	☐
• Reduce Workman Compensation Rates		☐	☐
• Reduce facility emissions below provincial reporting thresholds		☐	☐
• Generation of saleable GHG credits		☐	☐
• Reduce environmental liability insurance		☐	☐

12.12 Gas, Oil and Propane-fired Boilers or Heaters

BMP[41]	**Efficiency Opportunity**	**Action Planned**	**Action Taken**
Maintenance and Management			
1. Manage and match boilers for optimal loads	up to 50%	☐	☐
2. Boiler tune-up	2% to 20%	☐	☐
3. Implement high fire settings	7%	☐	☐
4. Upgrade boiler maintenance program	2%	☐	☐
5. Set up chemical treatment to reduce scaling	2%	☐	☐
6. Prevent extra air ingress to combustion chamber*		☐	☐
Control Equipment			
1. Install stack dampers	5% to 20%	☐	☐
2. Install characterizable fuel valves	2% to 12%	☐	☐
3. Install fire draft control systems	2% to 10%	☐	☐
4. Install air or steam atomizing burners	2% to 8%	☐	☐
5. Install an economizer to capture flue gas waste heat to preheat boiler feedwater	up to 5%[f]	☐	☐
6. Install automated blowdown controls	2% to 3%	☐	☐
Combustion Equipment			
1. Install direct-contact hot water boilers	up to 50%	☐	☐
5. Replace overhead heaters with infra-red heaters in warehouse and production areas	up to 30%	☐	☐
Blowdown Technology			
1. Install blowdown heat recovery	2% to 5%	☐	☐
Stack Heat Emissions Management			
1. Check flue gas oxygen and carbon monoxide levels		☐	☐
2. Compress production schedules to avoid boiler stops and starts*		☐	☐
Record Keeping			
1. Check boiler efficiency and maintain benchmark records(e.g. boiler efficiency/fuel used in BTU or steam generated in BTU for a given period)*		☐	☐

[41]Some BMP's may have codes; "*" behavior-related opportunity or "[f]" total facility energy use opportunity. Uncoded efficiency opportunities related to specific opportunity areas like boiler fuel or electric energy use.

12.13 Waste Heat and Co-Generation

BMP		Efficiency Opportunity	Action Planned	Action Taken
System Planning				
1.	Optimize electricity and steam use prior to co-generation installation			
	Steam	10% to 50%[f]	☐	☐
	Electricity (including air compression)	5% to 30%[f]	☐	☐
	Water and sewer	10% to 70%[f]	☐	☐
Equipment Selection and Control Equipment				
1.	Install direct condensate heat recovery	8% to 20%	☐	☐
2.	Install monitoring and tracking systems	up to 6%	☐	☐
3.	Recover waste heat from air compressors	5%[f]	☐	☐
4.	Install an economizer to capture flue gas waste heat to preheat boiler feedwater	up to 5%	☐	☐
5.	Install gas turbines with heat recovery	2% to 5%	☐	☐
6.	Install blowdown heat recovery	2% to 5%	☐	☐
7.	Install soft starts on motors over 50HP*		☐	☐
Co-generation Efficiency Opportunities				
1.	Reduce primary energy consumption			
	- including off-site energy generation sources	10% to 15%	☐	☐
	- excluding off-site energy generation sources	9%[f]	☐	☐
2.	Electrical distribution line loss avoidance	4%	☐	☐
Record Keeping				
1.	Analyze electricity demand, electricity use and steam use*		☐	☐
2.	Benchmark electricity demand, electricity use and steam use with reference to actual production*		☐	☐

Special Note: Food plants that consider co-generation should review their steam and electricity requirements. Co-generation units typically generate 35% of their energy load as steam. This profile may not fit a food plant's energy requirements.

Many of Ontario's food processors with co-generation units use them for peak demand requirements and use parallel steam generating systems for off-peak production.

12.14 Steam and Condensate Recovery

BMP		Efficiency Opportunity	Action Planned	Action Taken
Maintenance and Management				
1.	Steam trap maintenance to reduce fuel use	10% to 20%	☐	☐
	or also expressed as	3% [f]	☐	☐
2.	De-scale contact heating surfaces	2% to 6%	☐	☐
3.	Reduce scale with chemical treatment	1% to 2%	☐	☐
4.	Repair steam leaks	1%	☐	☐
Control Equipment				
1.	Install vapor recompression for boiler water	90% to 95%	☐	☐
2.	Install a condensate steam saver	1% [f]	☐	☐
Operational Practices				
1.	Recover flue gas heat to pre-heat feedwater	5% to 11%	☐	☐
2.	Collect condensate for boiler make-up water	0.5% [f]	☐	☐
3.	Compress low production schedules to reduce stops and starts*		☐	☐
4.	Decommission redundant steam and condensate lines*		☐	☐
5.	Consider replacing live steam injection with heat exchangers*		☐	☐
6.	Consider flash steam and condensate recovery*		☐	☐
Record Keeping				
1.	Analyze steam fuel use relative to steam use*		☐	☐
2.	Benchmark fuel use and steam use against actual production*		☐	☐

12.15 WATER HEATING SYSTEMS

BMP	Efficiency Opportunity	Action Planned	Action Taken
Maintenance and Management			
1. De-scale contact heating surfaces	2% to 6%	☐	☐
2. Install reflective barriers like ceramic paint in “hot” zones to reduce radiant heat penetration into “cool” zones	under 0.5% to 2% [f]	☐	☐
4. Repair steam leaks	1%	☐	☐
Control Equipment			
1. Install direct infrared, microwave or dielectric heating systems	up to 80%	☐	☐
2. Insulate furnaces with refractory liners	up to 50%	☐	☐
3. Use direct fire natural gas heat in place of indirect steam heat	33% to 45%	☐	☐
4. Install direct contact condensate heat recovery equipment	8% to 20%	☐	☐
5. Recover waste heat for water heating	5% [f]	☐	☐
6. Install an economizer to capture flue gas waste heat to preheat boiler feedwater	up to 5% [f]	☐	☐
Record Keeping			
1. Install monitoring and tracking systems*		☐	☐
2. Check heat transfer efficiency regularly and maintain records (e.g. boiler efficiency = fuel used/steam generated in BTU in a given period*		☐	☐

12.16 PROCESS WATER AND WASTEWATER SYSTEMS

BMP	Efficiency Opportunity	Action Planned	Action Taken
Maintenance and Management			
1. Downsize values where hydraulic capacity, product quality or food safety requirements are not affected*		☐	☐
2. Install low volume, automatic flush toilets, urinals and faucets*		☐	☐
3. Turn off unnecessary water flow*		☐	☐
4. Ensure all water supply to process stops during idle periods*		☐	☐
5. Collect uncontaminated cooling water for re-use*		☐	☐
6. Modify process equipment and procedures to prevent effluent contamination (this is a preliminary step to by-product recovery)*		☐	☐
7. Repair leaks promptly*		☐	☐
Solid Waste and Wastewater Management			
1. Drain liquids from canned foods into solid waste	up to 90%	☐	☐
2. Collect uncontaminated cooling water for re-use	10% to 25%	☐	☐
3. Modify equipment to prevent effluent contamination*		☐	☐
4. Design equipment to prevent effluent stream contamination*		☐	☐
5. Scrape and shovel before washdown*		☐	☐
Record Keeping			
1. Install monitoring and tracking systems in at least these 16 points of use or potential heat transfer* • Boiler makeup water (1) and condensate return (2) • Hydraulic water used to move product (3) • Sanitation lines (4) and washwater – primary (5), secondary (6) and final rinse(7) • Thermal processes – water heaters (8), cooling water (9) and blanchers/autoclaves (10) • Sanitary sewer discharge (11) • Out door use – irrigation (12) and vehicle cleaning (13) • Administrative offices (14) • Quality Assurance laboratory (15) • and lavatories (16)		☐	☐
2. Use monetary concessions programs and sewer use rebate programs to justify equipment purchases*		☐	☐
3. Analyze production by liter of water used/kg of product*		☐	☐

12.17 Electrical Service and Motors

BMP	Efficiency Opportunity	Action Planned	Action Taken
Maintenance and Management			
1. Maintain screw compressors at full load if sequenced where screw and reciprocating compressors are run in sequence	10% to 50%	☐	☐
2. Upgrade to energy-efficient 3-phase motors	7% to 10%	☐	☐
3. Ensure all utility lines/pipes and conduits do not touch*		☐	☐
Control Equipment			
1. Install a monitoring and tracking system to identify electrical loads for specific functions in at least 10 locations* • Plant (1) and warehouse (2) area lighting • Exhaust fans (3) and air compression room (4) • Individual production lines (5) and forklift recharge area (6) • Boiler room (7) • Conveyors and elevators (8), and packaging lines and equipment (9) • General office use (10)	6% to 15%	☐	☐
2. Sequence compressors on the basis of their loads and efficiencies*		☐	☐
3. Discharge air-cooled compressors outside during the summer*		☐	☐
4. Switch off compressors, motors and fans when production ends*		☐	☐
5. Install automatic switches for motors that idle excessively*		☐	☐
6. Install variable speed drives and improved controls*		☐	☐
Capital Equipment Replacement and Upgrades			
1. Install capacitors and improve plant power factor	6% to 10%	☐	☐
2. Replace standard motors with high efficiency motors*		☐	☐
3. Replace air compressors with higher efficiency models when needed*		☐	☐
4. Install soft starts on all high-horsepower motors*		☐	☐
Record Keeping			
1. Install computerized automatic system to analyze, monitor and control electrical energy consumption*		☐	☐

12.18 PROCESS COOLING AND REFRIGERATION SYSTEMS

BMP		Efficiency Opportunity	Action Planned	Action Taken
Maintenance and Management				
1.	Install cooling towers for water cooling	up to 40%	☐	☐
2.	Use ceramic paint roofing treatments	up to 40%	☐	☐
3.	Eliminate leaks and improper defrosting	10% to 20%	☐	☐
4.	Use low ambient temperatures for cooling*		☐	☐
4.	Remove heat sources from cooled areas*		☐	☐
4.	Use low ambient temperatures for cooling*		☐	☐
4.	Use low ambient temperatures for cooling*		☐	☐
Control Equipment				
1.	Install variable speed drives on cooler systems	30% to 50%	☐	☐
2.	Improve auxiliary equipment controls	20% or more	☐	☐
3.	Install monitoring and tracking equipment	6% to 15%	☐	☐
4.	Install energy efficient chillers	1%[f]	☐	☐
5.	Optimize the thermodynamic balance of temperature-specific zones with dedicated equipment*		☐	☐
6.	Sequence air compressors based on efficiency and load*		☐	☐
7.	Ensure only 1 compressor works on a partial load*		☐	☐
Refrigeration Management				
1.	Segregate refrigeration systems by temperature*		☐	☐
2.	Remove heat-generating equipment away from refrigerated zones*		☐	☐
3.	Implement good housekeeping practices • Keep doors to refrigerated areas closed • Use as little water as possible in refrigerated areas • Replace and repair inadequate doors immediately • Check ceiling insulation for ice build-up		☐	☐
Record Keeping				
1.	Review refrigeration plant energy use as process needs change*		☐	☐
2.	Review refrigeration plant energy use as ambient weather changes *		☐	☐
3.	Ensure defrosting controls are set properly and reviewed frequently*		☐	☐
4.	Ensure defrosting operates minimally		☐	☐
5.	Review controls and set evaporating and condensing temperatures*		☐	☐

12.19 COMPRESSED AIR SYSTEMS

BMP		Efficiency Opportunity	Action Planned	Action Taken
Maintenance and Management				
1.	Reduce compressed air operating pressure	20% to 50%	☐	☐
2.	Fix compressed air system leaks	up to 30%	☐	☐
3.	Reduce or eliminate compressed air use	up to 0.5% [f]	☐	☐
Control Equipment				
1.	Install or adjust unloading controls	10%	☐	☐
2.	Recovery air compressor waste heat	2% [f]	☐	☐
3.	Upgrade screw compressor controls	1%	☐	☐
Compressed Air Management				
1.	Choose replacement compressors based on efficiency criteria	up to 50%	☐	☐
2.	Retro-fit air driven equipment to generate compressed air at the lowest pressure	up to 50%	☐	☐
3.	Use intake air from the coolest source	1% to 5% [f]	☐	☐
4.	Discharge air compressor air outside during hot months*		☐	☐
5.	Invest in leak detection equipment*		☐	☐
6.	Recover heat from air compressor cooling water*		☐	☐
Production management				
1.	Switch compressors off when production is down*		☐	☐
2.	Compress low production runs to reduce compressor starts*		☐	☐
3.	Maintain screw compressors at full load*		☐	☐
4.	Use reciprocating compressors for partial loads*		☐	☐
5.	Divert condensate to storm drains*		☐	☐
Record Keeping				
1.	Install monitoring and tracking equipment on air compressors		☐	☐
2.	Check compressor efficiency and maintain records (e.g. compressor efficiency = electricity used in kWh/kg or liter of production		☐	☐

12.20 Greenhouse Gas Co-efficients

This appendix contains a range of "loose ends" that may be useful for planning purposes. For instance, the table in Section 12.21 provides a clue to how utility costs impact profit margins. Section 12.22 provides a crude guide for estimating energy costs. Some standard co-efficients are provided in Section 12.23 and 12.24.

12.21 Profit is Linked to Efficiency of Utility Use

Profits are optimized when every possible gram of raw material, calorie of energy, liter of water and penny of labour creates salable product. [42] Gross margins decline geometrically with every gram of raw material, calorie of energy, liter of sewage, unit of labour and penny of capital investment that fails to be converted into salable product.

The following table aptly demonstrates the impact energy and water efficiency on profitability.

If the original profit margin is: ⇓	If the food/beverage processor's utility expenditures are the following percentage of gross revenue					
	3%	**4%**	**5%**	**6%**	**7%**	**8%**
	And utility costs are reduced by 35%, then the profit margin percentage will increase by the percentage below.					
1%	104%	139%	173%	208%	242%	277%
2%	51%	69%	86%	103%	120%	137%
5%	20%	27%	33%	40%	46%	53%
10%	9%	13%	16%	19%	22%	25%

According to the 2002 Deloitte Touche benchmarking study, Ontario's food processors profitability averages about 4%. The cost of utilities (water, sewer, gas, hydro, carbon dioxide and nitrogen) is 4% to 24% of the cost of manufacturing, depending on the process. It is easy to see how a significant reduction in utility use per unit of production will impact profits for this sector.

12.22 Energy Pricing

The cost of energy is used to justify the business case for efficiency projects. The following chart outlines some historic price trends and preliminary estimates for 2002 and 2003.

Year	**Electricity**[43]	**Natural Gas**[44]		
1998	0.08/kWh	$0.10/m^3$	or	$2.83/MCF
1999	0.08/kWh	$0.12/m^3$	or	$3.40/MCF
2000	0.08/kWh	$0.16/m^3$	or	$4.53/MCF
2001	0.09/kWh	$0.30/m^3$	or	$8.49/MCF
2002	0.10/kWh	$0.18/m^3$	or	$5.09/MCF
2003 (Feb)	0.10/kWh	$0.35/m^3$	or	$9.90/MCF

Prices for electricity in Ontario in 2002 have varied since deregulation in May. May's electric energy price was lower than the previous year's average, July and August pricing fluctuated between $0.10 and $0.12/kWh. Natural gas prices have declined in 2002, but spiked up again during February 2003.

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[42] Adapted from Energy Efficiency Opportunities in the Canadian Brewing Industry, 1998. Page 16.
[43] Based on estimates provided by the Dominion Bond Rating Service, 1998 and Waterloo North Hydro
[44] Average burner-tip price for large volume natural gas users. Source: Enbridge Consumers Gas, 2002

12.23 The Link between Wastewater and GHG's

Solid matter content of wastewater discharge from food and beverage processing facilities is estimated to emit 15% of all greenhouse gasses for this sector.[45] These emissions are largely emitted as methane from decomposition.

12.24 Emission Factors for Combustion

The following table outlines GHG emissions for fuel used in food industry applications. The emission factors are for carbon dioxide ($C0_2$), methane (CH_4) and nitrous oxide (N_20).

Fuel	**Use**	**$C0_2$**	**CH_4**	**N_20**
		(g/m^3 of fuel)	(g/m^3 of fuel)	(g/m^3 of fuel)
Natural Gas				
	Utility Boiler	1,880	0.048	0.02
	Industrial Boiler	1,880	0.048	0.02
	Commercial Boiler	1,880	0.043	0.02
	Other burners	1,880	0.043	0.02
Natural Gas Liquids		(g/L fuel)	(g/L fuel)	(g/L fuel)
Propane		1,530	0.03	-
Butane		1,760	0.03	-
Ethane		1,110	0.03	-
Liquid Fuels		(g/L fuel)	(g/L fuel)	(g/L fuel)
Light Oil	Utility Boiler	2,830	0.006	0.013
	Industrial Boiler	2,830	0.006	0.013
	Commercial Boiler	2,830	0.026	0.013
	Other burners	2,830	0.026	0.013
Heavy/Bunker Oil	Utility Boiler	3,090	0.03	0.013
	Industrial Boiler	3,090	0.12	0.013
	Commercial Boiler	3,090	0.06	0.013
	Other burners	3,090	0.06	0.013
Diesel		2,730	0.26	0.40

[45] Food and Beverage GHG Emissions, Jacques Whitford, 1999.

12.25 INDIRECT EMISSIONS FROM ELECTRICITY[46]

Province	kg CO_2e /kWh[47]
Newfoundland	0.1900
Prince Edward Island	0.5460
Nova Scotia	0.7800
New Brunswick	0.5460
Quebec	0.0014
Ontario	**0.1800**
Manitoba	0.0110
Saskatchewan	0.8620
Alberta	0.9910
British Columbia	0.0200

12.26 REGULATORY COMPLIANCE AND AIR EMISSIONS

In Ontario, industrial combustion equipment, air emissions and sewage systems require a Certificate of Approval from the Ministry of the Environment (MOE) pursuant to Regulations 346 and 347 of the Environmental Protection Act. For further details and instructions please contact the MOE at:

The Environmental Assessment and Approvals Branch, 416-314-8001.

Food and beverage factories with more than 10-million BTU's of combustion capacity must comply with Regulation 127 (Mandatory Emissions Reporting). The first reporting period for food and beverage processors is the 2002 calendar year, with a report due to MOE on June 1, 2003. For further instructions on MOE reporting criteria, please visit their website at:

http://www.moe.gov.on.ca

The Ministry of Agriculture and Food has developed an Excel-based screening tool for food and beverage stakeholders. This tool can be used to estimate food plant emissions for MOE reports. For further information on this e-tool, please call:

Phil Dick, Ministry of Agriculture & Food. Tel. 519-826-4385

[46] Canada's Climate Change 1999 Registration Guide, page 34 (Canadian Electricity Association 1997 emission averages.)
[47] kg of carbon equivalents per kilowatt-hour of electricity use. This equivalent factor includes carbon dioxide, methane and nitrous oxide emissions.

12.3 SOURCES

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2. *Energy Efficiency Opportunities in the Canadian Brewing Industry*, 1998

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5. CH_4 Emission Factors: *Light and Heavy Distillates, Natural Gas Liquids* – U.S. EPA, 1985

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