Energy efficient food processing: focus on refrigeration

Food Manufacturing Industry
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Franklin Energy

Agenda

• Agenda review and introductions
• Food Industry Energy Efficiency
  • A look at energy consumption
  • Opportunities for energy savings
  • Case studies for energy efficiency
  • Process load reduction
• Industrial refrigeration systems and technologies
  • Opportunities through operation changes
  • Variable frequency drives
  • Implementation strategy
• Question and answer
Introductions
Energy efficient food processing: focus on refrigeration

Getting to Know You

• Name
• Company
• Role
• Concerns coming into this course?
Learning Objectives

• Recognize and prioritize opportunities for energy savings.
• Recognize energy saving options as it relates to refrigeration equipment.
• Identify specific strategies for improving performance of industrial refrigeration systems.
• Discuss specific improvement implementation strategies and their challenges.

A look at energy consumption by sector and process

Energy efficient food processing: focus on refrigeration
Energy Consumption Agenda

Look at the Food Manufacturing Industry’s energy consumption

1. Energy data benchmarks
2. General Mills energy management case study
3. Audience participation exercise (energy allocation)

Energy Consumption

Food Industry in Wisconsin

From MNI.net September 21, 2016 regarding Wisconsin Manufacturers
- Wisconsin’s 10,694 manufacturers employ 572,981 in the state
- Since May of 2010, Wisconsin has added 21,000 jobs, or 3.8%; job gains for fifth straight year
- Tom Dubin, President of MNI publishing company, states
  - “Wisconsin’s stronghold in the food processing sector combined with a skilled labor pool, and growing focus on technology and innovation, have all contributed to the state’s success.”
- Food processing industry was the star of this year’s survey
  - Adding over 2,000 jobs, or 3.4%
  - Food processing ranks as the state’s second-largest sector by employment with 72,049 jobs.

Source: https://mni.net/news/story/wisconsin-manufacturers-add-jobs-for-a-fifth-straight-year
Energy Consumption

Energy Data Benchmarks

Food Industry Benchmarks
- Average enclosed space: 102,589 sqft
- Avg. electric use: 9,123,240 kWh
- Avg. natural gas use: 764,986 therms

Benchmarking terms
- Baseline – must start somewhere
- EUI – Energy Use Intensity
- Normalization
  1. Weather effects (HDD, CDD*)
  2. Industry differences
- Energy per unit
  1. Square Foot Building Area
  2. Pounds Produced
  3. Normalized Production Unit (such bottle, case, barrels equivalents)

*Note: HDD – Heating Degree Day and CDD – Cooling Degree Day are used to adjust temperature variations.

Cost: $832,952
Cost: $446,905

Annual energy use =
\[ 9,123,240 \text{ kWh} \times 3.412 + 764,986 \text{ therms} \times 100 = 107,627,095 \text{ kBtu} \]

- EUI = 107,627,095 kBtu / 102,589 sqft = 1,049 kBtu/sqft
- ECI (Energy Cost Intensity) = $1,279,857 / 102,589 sqft = $12.48/sqft*

*Note: An office building in Wisconsin costs about $2 to $3/sqft

August 2017: $0.0913/kWh and $0.5842/therm average Wisconsin industrial
Energy Consumption

Energy Data
Benchmarks

- Sectors of Food Manufacturing
  - Natural, Processed & Imitation Cheese
  - Flour and Other Grain Mill Products
  - Fluid Milk
  - Bread and Other Bakery Products
  - Meat Packing
  - Prepared Feed and Feed Ingredients
  - Sausage and Other Prepared Meats
  - Poultry Processing

- Benchmarks
  - Cost of energy as per cent of sales
  - Energy use per square foot

August 2017: $0.0913/kWh and $0.5842/therm average Wisconsin Industrial
http://www.eia.gov/consumption/

Energy Consumption

Top 10 Food Manufacturing Energy Uses

Source: Energy Information Agency (EIA) 2010 Manufacturer Energy Consumption Survey (MECS)
Energy Consumption

Steps to getting started

From Focus on Energy’s Dairy Process Guidebook

1. Establish the baseline energy use
2. Estimate energy use for major systems
3. Identify best practice opportunities
4. Quantify savings and project costs of best practice opportunities
5. Prioritize projects
6. Manage projects

Table 1: Average Energy Use per Ton of Product

<table>
<thead>
<tr>
<th>Product</th>
<th>Energy Consumption/1000 lb of product</th>
<th>Energy Consumption/1000 lbs of milk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butter</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cooling</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6%</td>
<td>1.85</td>
</tr>
<tr>
<td></td>
<td>Cleaning in Place</td>
<td>26%</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>100%</td>
</tr>
<tr>
<td>Cheese</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reception/Thermization</td>
<td>19%</td>
</tr>
<tr>
<td></td>
<td>Cheese Processing</td>
<td>24%</td>
</tr>
<tr>
<td></td>
<td>Cheese Treatment/Storage</td>
<td>19%</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>100%</td>
</tr>
<tr>
<td>Fluid Milk</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reception/Thermization</td>
<td>1%</td>
</tr>
<tr>
<td></td>
<td>Storage</td>
<td>1%</td>
</tr>
<tr>
<td></td>
<td>Centrifugation/Flavorization</td>
<td>19%</td>
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<tr>
<td></td>
<td>Packaging</td>
<td>15%</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>100%</td>
</tr>
</tbody>
</table>

Energy Consumption

Case Study: General Mills Energy Management


- Combined the best practices and concepts from ISO 50001 and Energy Star guidelines with its existing Continuous Improvement (CI) program
- Better Plants Challenge has given General Mills the motivation to push forward with their energy management structure and savings goals
Energy Consumption

Case Study: General Mills Energy Management


1. Establish energy as a program
   • “Manage energy as an ingredient”
2. Develop site energy allocation
   • Standard tools
3. Identify energy losses
   • Sub-meter to identify overuse
4. Execute proven solutions
   • Share results internally
   • Better Plants Challenge
5. Sustain results
   • “Manage energy as an ingredient”

Energy Consumption

Case Study

General Mills Energy Allocation

From [https://www4.eere.energy.gov/seeaction/system/files/documents/saving_energy_industrials_0.pdf]

Standardized tools that allow energy engineers to deliver savings quickly.
• Account for every BTU being consumed in different systems.
• Electrical side energy usage
  • Lighting, compressed air, refrigeration, pumps and fans, processing motors broken out by line, and HVAC.
• Thermal side, natural gas usage
  • HVAC, hot water, and each processing unit’s steam or gas usage.
• Energy allocation exercise identifies the areas of high energy consumption.
Energy Consumption

Your Facility’s Energy Allocation

Objective: Establish framework to identify cost of key energy uses/processes → simple energy model of the facility.

Premise: Equipment that uses no/little energy ignored.

Process: Start with Food Industry Benchmark

1. Enter plant area square feet, energy use and cost.
2. Add/remove uses as appropriate
3. Adjust kWh/sqft and therms/sqft for total usage
   • Compare EUI and ECI to benchmark
4. Refine as data is improved → energy use breakdown

### Application

<table>
<thead>
<tr>
<th>Facility Name</th>
<th>Square Feet</th>
<th>Annual Electricity Usage (kWh)</th>
<th>Annual Electrical Cost ($/kWh)</th>
<th>Annual Gas Usage (therms)</th>
<th>Annual Natural Gas Cost ($/therm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>102,589</td>
<td>9,123,240</td>
<td></td>
<td>754,986</td>
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<tr>
<td>Electricity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elec - HVAC</td>
<td>695,388</td>
<td>6.33</td>
<td>21.60</td>
<td>2.1%</td>
<td>59,289</td>
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<tr>
<td>Elec - Lighting</td>
<td>616,012</td>
<td>6.03</td>
<td>20.57</td>
<td>2.0%</td>
<td>56,479</td>
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<td>Elec - Motors/Drives</td>
<td>4,386,985</td>
<td>42.86</td>
<td>146.24</td>
<td>13.9%</td>
<td>401,443</td>
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<tr>
<td>Elec - Other</td>
<td>717,977</td>
<td>6.99</td>
<td>23.85</td>
<td>2.3%</td>
<td>65,471</td>
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<tr>
<td>Elec - Refrigeration</td>
<td>2,437,512</td>
<td>23.76</td>
<td>81.07</td>
<td>7.7%</td>
<td>222,545</td>
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<td>Elec - Process Heating</td>
<td>303,663</td>
<td>2.96</td>
<td>10.10</td>
<td>1.0%</td>
<td>27,724</td>
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<tr>
<td>Gas - Boilers</td>
<td>315,554</td>
<td>3.08</td>
<td>307.59</td>
<td>29.3%</td>
<td>184,546</td>
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<tr>
<td>Gas - CHP/Cogen</td>
<td>-</td>
<td>50,546</td>
<td>48.27</td>
<td>4.7%</td>
<td>29,529</td>
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<tr>
<td>Gas - HVAC</td>
<td>-</td>
<td>46,241</td>
<td>47.96</td>
<td>4.6%</td>
<td>28,732</td>
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<tr>
<td>Gas - Motors/Drives</td>
<td>- 17,758</td>
<td>0.17</td>
<td>17.31</td>
<td>1.6%</td>
<td>10,576</td>
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<tr>
<td>Gas - Other</td>
<td>-</td>
<td>35,516</td>
<td>34.62</td>
<td>3.3%</td>
<td>20,769</td>
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<tr>
<td>Gas - Refrigeration</td>
<td>- 10,926</td>
<td>0.11</td>
<td>10.65</td>
<td>1.0%</td>
<td>6,383</td>
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<td>Gas - Process Heating</td>
<td>- 271,840</td>
<td>2.65</td>
<td>264.98</td>
<td>25.3%</td>
<td>258,809</td>
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<td>Gas for Electric Generation</td>
<td>- 13,885</td>
<td>0.33</td>
<td>13.92</td>
<td>1.3%</td>
<td>7,893</td>
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<tr>
<td></td>
<td>9,123,240</td>
<td>88.93</td>
<td>754,986</td>
<td>7.46</td>
<td>1,049.11</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,270,056</td>
</tr>
</tbody>
</table>
Energy Consumption

Your Facility’s Energy Use Breakdown

Objective: Derive accurate use data for key energy consumers.
Premise: Start with information at hand, then add sub-metering.
Process: Start with your facility’s energy allocation

1. Identify key (i.e. big) energy users—each belongs on the allocation.
2. Use combination of graphical approximations, equipment specifications, direct measurement, and sub-metering as available
   - Graphical method for space heat – see Graphical Energy Use Breakdown slide.
   - Motors and drives – develop machine inventory with motor sizes and estimated loads.
     - Compressors, refrigeration, material handling are likely sub-sets of Motors.
     - Use multimeter or motor sizes with estimated loads to calculate kW and annual kWh.
     - See Basis Relationship slide in Resource section.
   - Lighting – see lighting Example slide.
3. Revise energy allocation with calculated kWh/sqft or therms/sqft.
4. Use Annual $ to help prioritize project ideas.

Energy Consumption

Energy Data Usage – Graphical Energy Use Breakdown

**Electricity Usage – Monthly (kWh)**

Annual electric use: 7,949,497 kWh
Annual electric cost: $720,618

**Natural Gas Usage – Monthly (therms)**

Annual natural gas use: 464,656 therms
Annual natural gas cost: $232,328
Energy Consumption

Energy Data Usage – Graphical Energy Use Breakdown

**Electricity Usage – Monthly (kWh)**

- Monthly baseload electric: 550,000 kWh
- Annual baseload electric: 6,600,000 kWh
- Annual seasonal electric: 1,349,497 kWh
- Annual seasonal cost: $122,331

**Natural Gas Usage – Monthly (therms)**

- Monthly baseload natural gas: 30,000 therms
- Annual baseload natural gas: 360,000 therms
- Annual seasonal natural gas: 104,656 therms
- Annual seasonal cost: $52,328

Opportunities for energy savings

Energy efficient food processing: focus on refrigeration
Opportunities for Energy Savings Agenda

• Project ideas for energy efficiency (what’s popular now)
• Non-energy savings considerations

Opportunities for energy savings
Top 10 uses account for 96.4% of energy cost

Prioritize Projects by Energy Cost?
• Electric Motors and Drives (31.4%)
• Process Cooking (17.4%)
• Gas Boilers and Process Heating (26.8%)
• Electricity – Other (5.1%)
• HVAC – electric and gas (6.8%)
• Lighting (4.4%) Most Common
• Combined Heat & Power and Cogeneration (2.3%)
• Electric Process Heating (2.2%)

Source: Energy Information Agency (EIA) 2010 Manufacturer Energy Consumption Survey (MECS)
Opportunities for energy savings

Why are lighting projects most common?

Project criteria
1. Excellent payback – often < 2 years
   - Easy to determine cost savings
   - Supported by incentive programs
   - Refrigeration savings!
2. Highly visible projects – pun intended
   - Yes we ARE going green
3. Enhanced productivity due to improved lighting
   - Over or under lit
   - Improved color rendering
4. Maintenance and other Non-Energy Improvements
   - Reduce cost and time spent replacing lamps and ballasts
   - Wash down issues
   - Mercury elimination
   - Glass versus polymer materials

Opportunities for energy savings

Project ideas for energy efficiency

What’s Popular Now
1. Lighting
2. Process Heating
3. Compressed Air (sub-set of motors)
4. Refrigeration (sub-set of motors)
5. HVAC Heating and Cooling
6. Motors and Controls
## Opportunities for energy savings

### Project ideas for energy efficiency

- **Lighting → LED**
- **Refrigeration → Tune-up & fine tune**
- **Compressed Air → Reduce, eliminate losses, add storage, optimize controls, replace.**
- **Heat recovery → EE first, then look for large Delta T adjacent to need for heat (boilers, compressors)**
- **Motors & Drives → VFDs, motor efficiency (ECM)**
- **Ventilation → Optimize intake and exhaust (Demand Control)**
- **Others**
  1. Free cooling
  2. Direct-fired water heating
  3. Electric-to-Gas fuel switch
  4. Employee involvement

### Project ideas: Savings potential by sub-sector

<table>
<thead>
<tr>
<th>Food Manufacturing Sub-sector</th>
<th>Facilities</th>
<th>Total Use (therms)</th>
<th>Potential Savings (therms)</th>
<th>Estimated Savings (%)</th>
<th>Total Use (kWh)</th>
<th>Potential Savings (kWh)</th>
<th>Estimated Savings (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheese and Butter Processing</td>
<td>22</td>
<td>11,348,282</td>
<td>1,017,200</td>
<td>9.00%</td>
<td>76,246,307</td>
<td>10,510,200</td>
<td>13.80%</td>
</tr>
<tr>
<td>Poultry Processing</td>
<td>24</td>
<td>10,903,658</td>
<td>903,200</td>
<td>8.30%</td>
<td>108,000,000</td>
<td>16,200,000</td>
<td>15.00%</td>
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<tr>
<td>Rendering</td>
<td>4</td>
<td>10,766,071</td>
<td>1,155,300</td>
<td>10.70%</td>
<td>24,948,375</td>
<td>1,532,800</td>
<td>6.10%</td>
</tr>
<tr>
<td>Dried Foods</td>
<td>10</td>
<td>9,506,837</td>
<td>110,000</td>
<td>1.20%</td>
<td>6,357,072</td>
<td>833,700</td>
<td>13.10%</td>
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<tr>
<td>Fruit and Vegetable Canning</td>
<td>14</td>
<td>7,126,977</td>
<td>372,500</td>
<td>5.20%</td>
<td>26,910,996</td>
<td>2,703,900</td>
<td>10.00%</td>
</tr>
<tr>
<td>Soybean Processing</td>
<td>2</td>
<td>3,304,160</td>
<td>450,000</td>
<td>13.60%</td>
<td>21,509,620</td>
<td>1,112,100</td>
<td>5.20%</td>
</tr>
<tr>
<td>Meat Processing (not poultry)</td>
<td>19</td>
<td>1,437,624</td>
<td>26,200</td>
<td>1.80%</td>
<td>83,622,144</td>
<td>8,942,000</td>
<td>10.70%</td>
</tr>
<tr>
<td>Margarine Manufacturing</td>
<td>1</td>
<td>422,316</td>
<td>65,700</td>
<td>15.60%</td>
<td>10,182,948</td>
<td>441,800</td>
<td>4.30%</td>
</tr>
<tr>
<td>Bakeries</td>
<td>31</td>
<td>341,488</td>
<td>64,400</td>
<td>18.90%</td>
<td>51,000,000</td>
<td>7,650,000</td>
<td>15.00%</td>
</tr>
<tr>
<td>Food Processors w/ Water Heating</td>
<td>44</td>
<td>330,416</td>
<td>42,200</td>
<td>12.80%</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

### Opportunities for energy savings

#### Project ideas for Natural Gas

<table>
<thead>
<tr>
<th>Food Manufacturing Energy Efficiency Opportunities</th>
<th>Savings Range</th>
<th>Bakeries</th>
<th>Fruit and Vegetable canning</th>
<th>Rendering</th>
<th>Dried Foods</th>
<th>Meat Processing (not poultry)</th>
<th>Soybean Processing</th>
<th>Poultry Processing</th>
<th>Margarine Manufacturing</th>
<th>Cheese and Butter processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler improvements / best practices</td>
<td>1 to 8 %</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Direct fired improvements / best practices</td>
<td>0.1 to 1%</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Process equipment heat recovery</td>
<td>0.5 to 13%</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Facility HVAC improvements</td>
<td>1 to 8 %</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Improved process equipment</td>
<td>0.5 to 4%</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Product wash improvements</td>
<td>1%</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Steam best practices and improvements</td>
<td>0.5 to 11%</td>
<td>✓</td>
<td>✓</td>
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<td>✓</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Water heating improvements</td>
<td>2 to 10%</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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</tbody>
</table>

Best opportunity for sub-sector Recommended


### Opportunities for energy savings

#### Project ideas for Electricity

<table>
<thead>
<tr>
<th>Food Manufacturing Energy Efficiency Opportunities</th>
<th>Savings Range</th>
<th>Bakeries</th>
<th>Fruit and Vegetable canning</th>
<th>Rendering</th>
<th>Dried Foods</th>
<th>Meat Processing (not poultry)</th>
<th>Soybean Processing</th>
<th>Poultry Processing</th>
<th>Margarine Manufacturing</th>
<th>Cheese and Butter processing</th>
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<tbody>
<tr>
<td>Compressed air improvements</td>
<td>0.5 to 3%</td>
<td>✓</td>
<td>✓</td>
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<td>✓</td>
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<tr>
<td>Facility HVAC improvements</td>
<td>0.5 to 2%</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<td>✓</td>
</tr>
<tr>
<td>Improved process equipment</td>
<td>9.7%</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Lighting improvements</td>
<td>0.5 to 2%</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Motor improvements including pumps and fans</td>
<td>1 to 1.5%</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Process design improvements</td>
<td>2 to 4%</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Refrigeration improvements</td>
<td>2 to 10%</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Best opportunity for sub-sector Recommended

## Lighting

Energy efficient food processing: focus on refrigeration

### Opportunities for energy savings - Lighting

**Lighting by Space Type – Food Making**

<table>
<thead>
<tr>
<th>Space</th>
<th>Typical Existing Lighting</th>
<th>Energy Efficient Options</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low ceiling production or lab</td>
<td>• Vapor tight fluorescent (T12 or T8)</td>
<td>• High performance T8</td>
<td><img src="https://via.placeholder.com/150" alt="Photo" /></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Low-watt T8</td>
<td><img src="https://via.placeholder.com/150" alt="Photo" /></td>
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<tr>
<td></td>
<td></td>
<td>• TLED</td>
<td><img src="https://via.placeholder.com/150" alt="Photo" /></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• LED fixture</td>
<td><img src="https://via.placeholder.com/150" alt="Photo" /></td>
</tr>
<tr>
<td>High ceiling production or storage</td>
<td>• Metal Halide</td>
<td>• High bay fluorescent (to replace metal halide)</td>
<td><img src="https://via.placeholder.com/150" alt="Photo" /></td>
</tr>
<tr>
<td></td>
<td>• High bay fluorescent</td>
<td>• TLED (to upgrade high-bay fluorescent)</td>
<td><img src="https://via.placeholder.com/150" alt="Photo" /></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• LED fixture</td>
<td><img src="https://via.placeholder.com/150" alt="Photo" /></td>
</tr>
<tr>
<td>Walk-in coolers</td>
<td>• Incandescent (if small)</td>
<td>• Screw-in LED</td>
<td><img src="https://via.placeholder.com/150" alt="Photo" /></td>
</tr>
<tr>
<td></td>
<td>• Vapor tight fluorescent (T12 or T8)</td>
<td>• High performance T8</td>
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**Lighting by Space Type**

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<tr>
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<th>Typical Existing Lighting</th>
<th>Energy Efficient Options</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office / Sales / Support areas</td>
<td>• 4’ or u-tube T12 or T8&lt;br&gt;• CFL downlights&lt;br&gt;• Incandescent track/spot lighting</td>
<td>• High performance T8&lt;br&gt;• Low-watt T8&lt;br&gt;• TLED&lt;br&gt;• LED fixture&lt;br&gt;• LED retrofit kit&lt;br&gt;• LED downlights</td>
<td><img src="https://via.placeholder.com/150" alt="Images" /></td>
</tr>
<tr>
<td>Exterior</td>
<td>• Metal Halide or High Pressure Sodium&lt;br&gt;• pole mount&lt;br&gt;• wall-pack&lt;br&gt;• Flood</td>
<td>• LED fixtures</td>
<td><img src="https://via.placeholder.com/150" alt="Images" /></td>
</tr>
</tbody>
</table>

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**Opportunities for energy savings - Lighting**

**Maximize Task Lighting**

- When upgrading lighting, maximize task lighting and minimize ambient or overhead lighting
  - Put light where needed
- Look into adding surface reflectivity

---

*Photos courtesy of Mississippi Power and Improved Illumination*

*Photos courtesy of Cree, Sylvania, and GE*

*Image Courtesy foodprocessing.com*
Opportunities for energy savings - Lighting

Example

What is the cost to run a 400 W Metal Halide fixture for 1 year?

\[
\frac{455 \text{ input watts}}{1,000} = 0.455 \text{ kW}
\]

\[
0.455 \text{ kW} \times 3,000 \text{ hours/year} = 1,365 \text{ kWh/year}
\]

\[
3,000 \text{ hrs/year} = \approx 11.5 \text{ hrs/day} \times 5 \text{ days/wk or} \approx 8.25 \text{ hrs/day} \times 7 \text{ days/wk}
\]

\[
$0.11/\text{kWh} \times 1,365 \text{ kWh} = $150.15/\text{year}
\]

What is the cost to run a 6 lamp T8 high bay fixture for 1 year?

\[
\frac{224 \text{ input watts}}{1,000} = 0.224 \text{ kW}
\]

\[
0.224 \text{ kW} \times 3,000 \text{ hours/year} = 672 \text{ kWh/year}
\]

\[
$0.11/\text{kWh} \times 672 \text{ kWh} = $73.92/\text{year}
\]

Savings: 693 kWh

$76.23

LED Lighting

• Light Emitting Diode (LED) also known as Solid State Lighting (SSL)
• Average rated life of anywhere between 15,000 and 100,000 hours.
• Multiple point source directional lighting
• No IR or UV
• Most are dimmable
• Wide variety of control options
• Most other lighting technologies have matured and have minimal opportunities to improve efficiency...LED continuing to improve

Image courtesy of CREE Lighting
Opportunities for energy savings - Lighting

LED Best Practices

• LEDs work best when the luminaire is designed around the LED instead of a more traditional lighting technology.
• Using LED products for most ambient lighting applications is possible however it is not yet always economical when compared with other lighting technologies.

Images Courtesy of Cree, GE, Phillips and Sylvania Lighting

Opportunities for energy savings - Lighting LED Fixture

LED lamp options

Vapor Tight Fixture LED Options
• Relamp with TLED (fast, low cost)
• LED retrofit kit (better efficiency, all new parts, mid-level cost)
• New vapor tight linear LED fixture (best efficiency and lighting distribution, most costly)

High Bay LED Options
• Relamp with TLED if have high bay fluorescent (fast, low cost)
• New LED high bay fixture
  • Many form factors available
  • Vapor tight versions available
Opportunities for energy savings - Lighting

LED Fixture Options

**Office / Sales Area LED Options**
- Relamp with TLED (fast, low cost)
- LED retrofit kit, integrated or strip (better efficiency, all new parts, mid-level cost)
- New LED fixture: troffer, downlight track / mono-point / accent
- Refrigerated cases in sales area: vertical and horizontal LED case lighting

**Exterior LED Options**
- New LED Fixture
  - Wall mount, Pole mount, Flood
- Better color / visibility
- More uniform lighting distribution
- 40-60% savings possible
- Most mature LED application

Lighting Controls

- Install automated controls where lighting might be left on when not in use
- Occupancy sensors can save up to 80% or more in energy costs in low traffic areas
- Sensor Types
  - Passive Infrared
  - Ultrasonic
  - Microphonic
  - Multi-technology (two of above types)
- Dimming / Day lighting controls can reduce energy costs and extend lamp life
Opportunities for energy savings – Lighting

Likely Opportunities

• Energy Efficiency
  • Fixture replacement to LED
  • Refrigerated space lighting to LED
  • Lighting controls
• Process heat recovery
  • None

Compressed Air

Energy efficient food processing: focus on refrigeration
Opportunities for energy savings – Compressed Air

How is Compressed Air Used

Computing Full Load Energy Costs

Annual electricity cost (simple formula)

\[ bhp \times 0.746 \times \text{hours} \times \text{rate} \]

Where:
- \( bhp \) = motor full-load horsepower (brake horsepower)
- 0.746 = kW/hp
- Hours = annual hours of operation at full load
- Rate = electricity cost in $/kWh
- Motor efficiency = motor nameplate full-load efficiency
Computing Full Load Energy Costs

**Example:**
100 bhp compressor, 95% efficient motor, 8,760 hours per year of operation, and $0.08/kWh electricity rate

\[
100 \text{ bhp} \times 0.746 \times 8,760 \text{ hours} \times $0.08/\text{kWh} \times 0.95
\]

Annual electricity costs = $55,031 per year

Opportunities for energy savings – Compressed Air

**Compressed Air Best Practice**

- Reduce Leaks
- Lower Pressure
- Low Loss Drains
- Pressure Controller
- New VSD Air Compressor
- Heat Recovery
- Proper Air Use
Opportunities for energy savings – Compressed Air

Compressed Air Best Practice

New VSD Air Compressor

Courtesy of Atlas Copco

Opportunities for energy savings – Compressed Air

Compressor Performance
Opportunities for energy savings – Compressed Air

Eliminating Misuse of Air

<table>
<thead>
<tr>
<th>Inappropriate application</th>
<th>Description</th>
<th>Alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open blowing</td>
<td>Used for cooling, drying, cleanup, and other purposes.</td>
<td>Low-pressure blowers or fans</td>
</tr>
<tr>
<td>Sparging</td>
<td>Aaerating, agitating, oxygenating, or percolating liquid with compressed air.</td>
<td>Low-pressure blowers or fans</td>
</tr>
<tr>
<td>Ascinating</td>
<td>Using compressed air to induce the flow of another gas.</td>
<td>Low-pressure blowers or fans</td>
</tr>
<tr>
<td>Atomizing</td>
<td>Using compressed air to deliver a liquid to a process as an aerosol.</td>
<td>Low-pressure blowers or fans</td>
</tr>
<tr>
<td>Dilute phase transport</td>
<td>Using compressed air to transport solids, such as powdered material, in a diluted format.</td>
<td>Low-pressure blowers or fans</td>
</tr>
<tr>
<td>Personnel cooling</td>
<td>Using compressed air to cool personnel.</td>
<td>Fans</td>
</tr>
<tr>
<td>Vacuum generation</td>
<td>Applications that use compressed air with a venturi, eductor, or ejector to create a vacuum. Examples are shop vacuums, drum pumps, palletizers, de-palletizers, box makers, packaging equipment, and automatic die-cutting equipment.</td>
<td>Vacuum pump</td>
</tr>
<tr>
<td>Diaphragm pumps</td>
<td>Often installed without a shut-off valve or regulator.</td>
<td>Mechanical pump</td>
</tr>
<tr>
<td>Cabinet cooling</td>
<td>Open blowing and air bars (tubes with holes drilled into them), sometimes used for cabinet cooling.</td>
<td>Fan or dedicated cabinet cooler</td>
</tr>
</tbody>
</table>

Source: Adapted from the Compressed Air Challenge, Best Practices for Compressed Air Systems

Opportunities for energy savings – Compressed Air

Rules of Thumb

• Every 2 psig of pressure increases or decreases the power draw of a air compressor 1%.

• Size of control-air receiver located after the compressor for about 1 gallon capacity per cfm of compressor capacity.

• Total compressed air drop across all components, including piping, should not exceed 15psi.

• For every 10 degree drop in intake air, reduce energy cost by 2% (Min. of 40 degrees) compressor becomes MUA unit.

• Compressor element (airend) performance can vary 20% depending on size/style; drive motor efficiency at 100 hp only varies 2%; compressor controls can result in savings of 45% (doing right way vs doing bad way).
Opportunities for energy savings – Compressed Air

Likely Opportunities

• Energy Efficiency
  • Leak repair
  • Flow controllers with storage
  • Distribution optimization
  • Replace inappropriate air use with alternatives such as blowers
  • Variable Speed Drives: variable loads, eliminate other forms of modulation.
  • System controllers: Multiple compressor optimization.

• Process heat recovery
  • Space heating

Process Heating

Energy efficient food processing: focus on refrigeration
Opportunities for energy savings – Process Heating

Why heat recovery?

• Any process that adds or removes energy from the product.
• Energy → Heat
• Heat moves from hotter temperature to cooler temperature.
• Option 1 – Reduce energy in
• Option 2 – Recovery heat out

Opportunities for energy savings – Process Heating

Where’s the heat?

• Lighting
  • Incandescent → 10 lumens/Watt
  • LED → 50 lumens/Watt
• Compressed Air
  • 8:1 heat energy to air energy
• Boilers
  • 20% heat energy up the stack
  • Total heat losses in the system
• Refrigeration
  • How much heat is being moved compared to electric input?

• Temperature differences
  • From pasteurizer to refrigerator
  • From steam condensate to waste water treatment
  • From well water to process cooling
  • From wash down to the drain
  • From well water to process heating
Opportunities for energy savings – Process Heating

Where’s the heat?

<table>
<thead>
<tr>
<th>Food and Beverage Industrial Processes</th>
<th>Temperature (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drying (food processing, breweries, dairy)</td>
<td>85-435</td>
</tr>
<tr>
<td>Yogurt maturation (dairy)</td>
<td>105-115</td>
</tr>
<tr>
<td>Heat treating (food processing)</td>
<td>105-140</td>
</tr>
<tr>
<td>Clean-in-place washing, washing bottles, clothes etc.</td>
<td>105-195</td>
</tr>
<tr>
<td>Solvent extraction and distillation of vegetable oil (food processing)</td>
<td>140-230</td>
</tr>
<tr>
<td>Pasteurizing (food processing, breweries, dairy)</td>
<td>160-250</td>
</tr>
<tr>
<td>Boiling (food processing)</td>
<td>200-220</td>
</tr>
<tr>
<td>Distilling (breweries)</td>
<td>205-215</td>
</tr>
<tr>
<td>Evaporating (dairy)</td>
<td>140-300</td>
</tr>
<tr>
<td>Sterilizing (food processing)</td>
<td>285-300</td>
</tr>
<tr>
<td>Frying (food processing)</td>
<td>175-430</td>
</tr>
</tbody>
</table>


Opportunities for energy savings – Process Heating

Assessing the opportunity

• Heat recovery potential is 30% to 90% of the waste heat
• Look for presence and nature of contaminants in exhaust streams
• Where will the heat be used?
• Is it physically possible to install the recovery system?
• Is the waste heat available when needed?
• Are there maintenance costs?

Opportunities for energy savings – Process Heating

Likely Opportunities

- Energy Efficiency
  - Steam systems
  - Compressed air systems
  - Fans and pumps
  - System enclosures
  - Combustion burners
  - Refrigeration systems

- Process heat recovery
  - Combustion air preheating
  - Liquid heating
  - Space heating

HVAC Heating and Cooling

Energy efficient food processing: focus on refrigeration
Opportunities for energy savings – HVAC

HVAC Heating and Cooling

Heating – boiler and heated air systems (rooftop, unit heat & air makeup)
  • Efficiency gains of 10 to 15%

Cooling – chiller and direct expansion (dx) units (rooftop, split systems)
  • Efficiency gains of 10 to 30%

Ventilation/exhaust/air makeup – Controls improvements (drives, sensors and damper controls)

Opportunities for energy savings – HVAC

Ventilation Concerns

• Airborne Contamination
• Negative Air Pressure
• Air Turns necessary
• Equipment Needed
• Air Filtration
• Temperature Range
Opportunities for energy savings – HVAC

General Ventilation Requirements

- RTE (Ready to Eat) product air requirements
  - 20 to 25 air turns per hour.
  - Air traveling from one process to the next should be 300 feet/min.
  - Actual number of air movement must be designed by a competent HVAC engineer to fit the facility and the process
- The air turns per hour are important to remove:
  - Off odors
  - Steam
  - Airborne contaminants

Air intake units, RTU/AHU or MUA
- Intake needs to be filtered to degree needed for your operation

Exhaust Stacks
- Intake openings should have noncorrosive insect screen with a half-inch mesh cover.
- Should have hood to keep out snow, rain and prevent downdrafts
- Should not be positioned close to intake ventilation or extend higher to prevent contamination.
Opportunities for energy savings – HVAC

Ventilation Best Practice

• Air flow to start from cheese packaging area and flow to other areas
• Areas to have positive pressure to prevent drawing in any contaminants
• Airflow must be filtered

Opportunities for energy savings – HVAC

Ventilation Equipment

• Types of ventilation you could have in your operation:
  1. Roof Top Units (RTU)
  2. Air Handling Units (AHU)
  3. Make-up Air (MUA)

It is important to remember what purpose this equipment has and how it is maintained.
Opportunities for energy savings – HVAC

Ventilation – RTU

• Energy efficiency steps
  • Variable frequency drives on fan motors
  • Economizers – must be maintained.
  • Energy recovery ventilators (ERV)
  • Demand control ventilation (DCV)
  • Programmable thermostats or building automation system (BAS)

Opportunities for energy savings – HVAC

Ventilation – AHU

• Variable frequency drives
• Outside air requirements - (minimize)
• Only use necessary filter MERV levels

Air Intake

Photo Courtesy of FDA
Opportunities for energy savings – HVAC

Ventilation – MUA

• Only run with exhaust fans
  • MUA unit should be interlocked with exhaust fans.
• Filter to necessary level for your operation
• 100% OA unit or mixing box % of OA

Likely Opportunities

• Energy Efficiency
  • Distribution optimization
  • Duct leak repair, pipe insulation.
  • Isolate heating and cooling sources (e.g. avoid placing an air compressor in a refrigerated space).
  • Building envelope air sealing and fast overhead doors.
• Flow optimization
  • Variable pumps, variable blowers.
  • Exhaust filtration, demand ventilation controls.
• Efficient boilers, chillers, and other heat/cooling equipment.

• Process heat recovery
  • Space heating / cooling?
  • Ceiling fans, 3-way exhaust fans
  • Load reduction such as free cooling / dry coolers / economizers
  • Boiler makeup water preheat, combustion air preheat.
Non-energy savings considerations

Energy efficient food processing: focus on refrigeration

Opportunities for energy savings

Non-energy savings considerations

Project criteria

1. Excellent payback – often < 2 years
   • Easy to determine cost savings
   • Supported by incentive programs
   • Refrigeration savings!

2. Highly visible projects – pun intended
   • Yes we ARE going green

3. Enhanced productivity due to improved lighting
   • Over or under lit
   • Improved color rendering

4. Maintenance and other Non-Energy Improvements
   • Reduce cost and time spent replacing lamps and ballasts
   • Wash down issues
   • Mercury elimination
   • Glass versus polymer materials

Source: https://www.amazon.com/VaporTight-High-Fluorescent-Fixture-6-Lamp/dp/B005713OVO
Opportunities for energy savings

Non-energy savings considerations

Other paths to project approval
1. Sustainability Initiatives
2. Process Improvements
   - Waste reduction
   - Safety enhancement
   - Productivity enhancement
3. Maintenance Improvements
   - Longer equipment life
4. Improved Customer Satisfaction and Customer Ratings

Have you considered...
1. Confirming the cost components of your energy bills (TOU*, Demand, Taxes)?
2. Wisconsin sales tax-exemption for energy purchased to manufacture goods.
   - https://www.revenue.wi.gov/Pages/TAXD/tse-exemptn.aspx
3. Savings by managing energy services.
   - Electricity demand reduction
   - Power factor improvement
   - Natural gas purchases from brokerage firms
4. Treating energy costs not as overhead, but as a service (i.e. measure instead of allocate).
5. Incentives from utilities and government.
   - http://www.dsireusa.org/

*Note: TOU = Time of Use, may include Peak/Off-Peak costs. Also includes Seasonal, Load Factor and other costs.
Opportunities for energy savings

Non-energy savings considerations

For the next 5 years, would you rather commit to:

Do one project that saves $6,400 in energy costs/year  
or  
Sell an additional $128,000 of product/year?

Example is based upon a 5% sales margin.

---

Case Studies

Energy efficient food processing: focus on refrigeration
Case Studies Agenda

Heat recovery
Compressed air
Burner efficiency

Case Study
Heat Recovery – Gilman Cheese

Energy Efficiency Improvements:
1. Boiler Stack Economizer
2. Boiler Blow Down Heat Recovery
3. Repair or Replace Steam Traps
4. Insulate Steam Piping and Boiler Make-Up Tank
5. Reduce System Steam Pressure
6. Eliminate Air Exhausters
7. Replace Unit Heaters with Direct-Fired Make-Up-Air in Cheese Making Area
8. Install Air Compressor Heat Recovery

Source: Focus on Energy's Jeff Danielson and Gilman Cheese
Case Study
Heat Recovery – Gilman Cheese

Other Energy Efficiency Improvements:

Compressed Air:
  • Reduce Compressed Air Pressure
  • Repair Compressed Air Leaks
  • Install VFD Air Compressor
  • Replace Inappropriate Compressed Air Usage with Blowers
  • Install Air Compressor Heat Recovery

Lighting:
  • Upgrade T12 Lighting in Facility

Gilman Cheese makes a variety of products including flavored, smoked, low-fat, and no-fat cheeses for private label, direct sale, and the gift pack industry.

Processes include melting and blending, flavoring and smoking, and a full line of cutting and packaging lines.

Project Results:
  • Overall ongoing energy reduction is ~20%!
  • Overall simple payback on projects is 2.5 years.
  • Water cooled to air cooled refrigeration changeover reduced water usage 50%.
  • Integrated with energy and water savings projects was a reduction of product waste of 8%.
  • Award Winner WMC Business Friend of the Environment
Case Study

Compressed Air – Mead-Johnson Nutritionals

Energy Efficiency Improvements:
1. Optimized use of three 300-hp lubricant-free rotary screw compressors, producing up to 3,000 scfm with discharge pressures between 95 and 105 psig.
2. Installed centralized compressor control system to allow the compressors to work together.
3. Increase air storage from 1000-gallon receiver to compensate for intermittent retort purge process.
4. Resolved 10 to 15 psig pressure drop due to constricted flow through air filtration system.
5. Repaired air leaks due to old piping and loose fittings that consumed one-third of air systems’ peak output (1000 scfm).

Mead-Johnson Nutritionals, a subsidiary of Bristol-Myers Squibb. Project at Evansville, IN plant that produces infant formulas and adult nutritional supplements. Compressed air supports packing machines, actuators, and sterilizer retort purges.

Project Results:
• Overall ongoing savings of 2,542,000 kWh annually
• Project cost of $412,000 ($264,000 after rebate)
• Annual energy savings of $102,000
• Overall simple payback is 2.6 years.
• Avoided alternative of purchasing more compressed air capacity. 

Source: https://www.nrel.gov/docs/fy01osti/30231.pdf

Case Study

Burner Upgrade – JR Simplot

Energy Efficiency Improvements:
1. Evaluated steam system with DOE’s Steam System Assessment Tool (SSAT)
2. Replaced burners with high-efficiency units.
3. Reduced excess combustion air from 50% to 10% by adding oxygen trim equipment to optimize air-to-fuel ratio.
4. Increased condensate recovery rate to 50% while taking five condensate pumps off-line.

JR Simplot is a $3 Billion food and agribusiness corporation. Project at Caldwell, ID, plant that produces 270 million pounds of frozen French fries per year. Steam supports potato peeling, blanching and frying processes.

Project Results:
• Overall ongoing savings of 520,000 therms and 526,000 kWh annually
• Project cost of $373,000
• Annual energy and maintenance savings of $329,000
• Overall simple payback is 1.1 years.

Source: https://energy.gov/sites/prod/files/2014/05/f16/simplotburnercasestudy.
Process Load Reduction Agenda

- Doorway infiltration basics and door technologies
- Regeneration effectiveness in high temperature/short time pasteurization

Industrial refrigeration system and technologies

Energy efficient food processing: focus on refrigeration
Question and answer
Energy efficient food processing: focus on refrigeration

Resources

• Focus on Energy’s Dairy Process Guidebook
• Travis, Rob. “Industrial refrigeration energy-saving best practices” video series, Seventhwave.org 2016
• Industrial Refrigeration Consortium (IRC) Industrial Refrigeration Energy Efficiency Guidebook www.irc.wisc.edu/
Resources

• Compressed Air and Gas Institute
  www.cagi.org
• Compressed Air Challenge
  www.compressedairchallenge.org
• U.S. Department of Energy Industrial Technologies Program
  www1.eere.energy.gov/industry/bestpractices
• Don Graham, president of Graham Sanitary Design Consulting, LLC.
  grahamdj@prodigy.net or 517-796-1733

Basic Relationships

• POWER
  • Watts (single phase) = Volts * Amps * PF
  • Watts (3 phase) = Volts * Amps * 1.732 * PF
  • PF – Power Factor; real vs. apparent power

• HP to kW conversion
  • 1 HP = 0.7456 kW
Resources

Typical Motor Loading

• Most motors are sized to run at 80% of full load for safety

• At 80% load the current ≈ 80%, voltage is constant so power ≈ 80%

• An overloaded motor will not be able to manage the heat and will fail prematurely

• Some motors have a service factor which is a multiplier for maximum safe load vs. rated hp (10 hp motor w/ SF 1.2)

Energy efficient food processing: focus on refrigeration

Food Manufacturing Industry