Integrating Energy Efficiency Into Cold Storage Design

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&

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• Henningsen Cold Storage Co.
  – Est. 1923
  – 10 Facilities (8 NH$_3$, 2 Freon)
  – 40 Million ft$^3$

• Continuous Improvement Program for Energy Consumption
  – Worked into culture in late 1980’s
  – Full Commitment and Implementation 1996
  – Incorporated into both new and existing facilities
  – Easier with progressive Industries, Utilities, and States
• GCCA Service Partner – Energy Efficiency
• We don’t sell equipment, we have no vendor preferences
• Offices in Oregon, Utah, and Washington – 75 people
• Industrial energy efficiency consulting
  – Food processing, pulp & paper, petrochemical, manufacturing
  – Worked on 700 to 800 ammonia refrigeration systems
• Services include:
  – Energy management services, tools and software
  – Traditional retrofit or new construction project engineering
  – Tune-ups (i.e., kaizen blitzes or retro-commissioning)
  – Design and management of utility energy efficiency programs
• Corporate energy management
  – e.g. Americold, etc.
  – e.g. Sysco, SuperValu, Ben E. Keith, etc.
    • Approximately 300 DCs and PRWs
Continuous Improvement

• Process
  – Know where you are today
  – Know where you want to be in the future
  – Take stock of the tools available
  – Devise a plan of how to get there
  – Tackle small manageable steps
  – Evaluate each step, refine, repeat
  – Plan for the future (new technology and improvements that don’t pencil today)
  – Select Qualified Contractors & Consultants
Where are you today?

• Establish a Baseline
  – Industry Baseline (ASHRAE)
  – Company Baseline (Historical Practices)

• What is Current Cost Structure
  – Capital Costs
  – Operating Costs
    • Maintenance
    • Utilities (Consumption & Rate)

• Know the Corporate Culture
  – Quality Level
  – Payback Period
  – Partnership Tendency
Stats from 2010 GCCA Benchmarking

- Average Energy Use: 5,200,000 kWh/yr
- Average Energy Rate: 7.4¢/kWh
- Average Energy Cost: ≈$400,000
- Typical Range: 0.5 to 3.0 kWh/ft³
  – Nearly 6:1 variation!
2010 Benchmarking Results

2010 IARW Benchmarking Data
133 Participants (262 Warehouses)
2010 Benchmarking Close-Up

2010 IARW Benchmarking Data
133 Participants (262 Warehouses)

Annual Energy (kWh/yr) vs. Total Cubic Feet

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What is the Lay of the Land?

IARW Benchmark Frequency Distribution of kWh/cuft

Most 0.5 to 3.0

Complicating Factors
- Space Makeup?
- Climate?
- Blasting?

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Develop a plan

• Prioritize - Focus on low hanging fruit first
  – No to low capital investments
  – Shorter paybacks
  – Compare to alternative investments

• Look for Windows of Opportunity
  – New construction
  – Renovation
  – Upgrades
  – New Incentives

• Take a Holistic Approach
  – Fairly Obvious: Lighting upgrades also reduce refrigeration load
  – Often known, but frequently overlooked: Reduced Maintenance E.g. LED lights
  – Not So Obvious: Extra Insulation cost may be offset by reduced structural (Girts)
Take manageable steps

• Research and Test
  – Try one on a small scale before doing all
  – Examples
    • Test light fixtures in one aisle and compare to existing light in adjacent aisle
    • Install VFD(s) at one location or on part of a system (evaporator(s) in one room, condenser, or one compressor)
    • Try one Battery Charger with a designated forklift and battery(s)
Evaluate, Refine, Repeat

• Monitor and Record Results
  – Sub-meter (Lighting by Room, Charging, Office, Refrigeration by Component)
  – Compare results to projections
  – Compare results to baseline
  – Validate savings and payback

• Determine if project was acceptable and see if it can be improved

• Look to duplicate the project elsewhere. Put your knowledge to use
Process for Owner & G.C.

- When are efficiency upgrades identified?
- When are efficiency upgrades analyzed?
- When are efficiency upgrades priced?
- When does owner make decisions for efficiency upgrades?
- When is utility incentive program engaged?
- When is facility commissioned for energy performance?
- When does utility program close out?
Including Efficiency & Utility in Process

- Decision to Build
- Facility Design
- Request GC Bids
- Receive GC Bids
- Identify Upgrades
- Bid Out Upgrades
- Price Upgrades
- Engage Util. Prog*
- Analyze Upgrades
- Bid Out Upgrades
- Select GC
- Build Facility
- Facility Start-Up
- Steady Oper.
- Select Upgrades
- Implement Upgrades
- Design Assist.
- Energy Commiss.
- Get Util. Approval*
- Utility Close-Out

*Missing these steps will cost you $'s!

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Where do you want to be tomorrow?

- Create a Wish List of Upgrades
  - Lighting (T-8, T-5, LED, Motion Sensors)
  - Insulation (Increased Thickness)
  - Doors (Fast Acting)
  - Controls (Computer)
  - VFDs
  - Over sizing for future (Piping, Condenser, Evaporators)
  - Efficient equipment selection (BHP/TR)
  - Oil Cooling (Thermo-siphon)
  - Battery Chargers (kw & kwh)
  - Under-floor Heat (Air/Glycol/Electric)
  - Alternative Energy Generation (Solar, Wind)
  - Power Purchasing Options (Primary or Secondary, Voltage Level)
Where is the Energy Used?

• **Major**
  – **Refrigeration** *(40% to 70%)*
  – Warehouse Lighting *(10% to 25%)*
  – Battery Charging *(5% to 15%)*
  – Dock & Freezer Doors *(Heaters & Blowers)*

• **Minor**
  – Exterior / Parking Lot Lighting
  – Freezer Floor Heating
  – Offices *(Lighting, HVAC, Plug Loads)*
  – Truck/Maintenance/Storage Out Buildings
Refrigeration Efficiency Opportunities

1. Reducing System “Lift”
2. Improving Part-Load Performance
3. Upgrading Equipment
4. Improving System Design
5. Reducing Refrigeration Loads
1. Reducing System “Lift”

- **Raise Suction Pressure (Temperature)**
  - Rule of Thumb: 2% per degree
  - May be limited by process, equipment or system
    - Mismatch of suctions to load
    - Evaporator coil selection
    - Suction line pressure drop

- **Reduce Discharge Pressure (Temperature)**
  - Rule of Thumb: 1½% per degree
  - May be limited by process, equipment or system
    - Defrost system design
    - Freezer floor heat
    - Condenser selection
    - Compressor limitations
2. Improved Part-Load Performance

- **Evaporators**
  - Optimum Control Algorithms
  - **Variable Frequency Drives (VFDs)**
- **Compressors**
  - Improved Control System Sequencing
  - VFD Control
- **Condensers**
  - Improved Control System Algorithms
  - VFD Control
Screw Compressor Slide Valve Unloading
Sample VFD Installation

Variable speed control is **ALWAYS** the most efficient form of part load control.

Sample Evaporator & Condenser Fan VFDs
VFD-Rated Compressor Motor
3. Upgrading Equipment

- **Evaporators**
  - Select low hp/ton units
  - Defrost hoods or socks
- **Compressors**
  - Thermosiphon rather than liquid injection
  - New screw compressor rotor profiles
- **Condensers**
  - Larger units (more surface area)
  - Select high-efficiency units
  - Integral sumps vs. remote sumps
  - High performance water treatment systems
  - Easy & safe catwalk & access
Efficient Coil Defrost Hoods or Socks

Evaporator Return Air Defrost Hood

Defrost Hoods and Socks
Efficient Compressor Cooling

Liquid Injection

Thermosiphon
Efficient Condenser Selections

Sample Condenser Series Efficiency

Nominal Heat Rejection - MBH

MBH per Fan/Pump HP

Ammonia Charge

Highest MBH/hp
(This is the efficient selection)

Lowest $/MBH
(This is likely what is bid)
4. Improved System Design

- Single vs. Two-Stage
- CO₂ Cascade
- Piping / Pressure Drop
- Defrost System
- Purgers (Air & Water)
- Proper Pump Selection
5. Reducing Refrigeration Load

- Insulation Levels
- Under-Floor Heating
- Warehouse Doors
- Leveler Seals
- Warehouse Lighting
Warehouse Envelope

- Roof and wall insulation levels
- Under-floor insulation level
- Structural considerations
- Tradition or convention seems to dominate design

- Is life-cycle analysis performed?
  - Remember, energy rates vary 10:1 or more
  - Remember, utility incentive vary from 0% to 70%
Under-Floor Heating Systems

• Glycol vs. air
  – What is source of heat?
    • Hot gas ammonia
    • Electric
    • Natural gas
• Is air forced or gravity?
• How is pump & heating controlled?

• Recommendations
  – Avoid electric or natural gas heat
  – Avoid ammonia designs that penalize system
Traditional Freezer Doors

- Electric defrost systems
  - 20 kW will cost $10k to $20k/yr (incl. refrig.)
- Poor sealing
- High maintenance
- Prone to damage
- Prone to frost build-up
- Slow
Today’s Fast Roll-Up or Sliding Doors

- High speed
- Impactable
- Self-healing
- Insulated
- Fewer sealing edges to leak
- Minimal to no heating requirement

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Recirculatory Air Doors

- High traffic applications
- Improved safety...
- Consider fan energy use
- Recirculatory air heated
  - Avoid electric
  - Avoid hot gas with high pressure requirement
- Fans can be VFD controlled
- Consider premium hybrid configuration
  - Mated to fast or bi-parting door, VFD on fans, heating disabled
Dock Leveler Seals
Reducing Lighting Load

• Currently: T5/T8 Fluorescent vs LED?
  – LED twice the cost
  – LED is more efficient
  – LED can shut off completely in freezers
  – LED has the mesh & dimming controls
  – LED is only at half its theoretical efficiency!
  – The correct technology isn’t always clear

• What about HID?

• What about Induction?

• Future plasma, neutrino, magneto-hydro-dynamic, string theory, fusion-based technology……..
Why Post-Construction Energy Commissioning?

• Functional ≠ Efficient
• The facility & people needs to settle in for a while – say 3 to 6 months
• Energy optimization requires experimentation, patience & time
• Vendors or contractors may not have energy expertise
• The intent of the energy upgrade may not be known by startup team
• It may be hard to get installer or setup staff to return after sign-off
Impact of Energy Commissioning

Impact of Commissioning on Total Plant Energy Use

Date


kW

Commissioning Complete

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What tools are available?

• Get Familiar with Agencies with Programs Available
  – Utility Rebates
  – City, State, Fed Programs (Tax Credits, Grants, Rebates)
  – Consortiums E.g. NEEA, ETO (Grants, Free Training)

• Include Non-Capital Investment Programs
  – Commissioning
  – Training
  – Kaizen

• Use Consultant and Contractor Knowledge
  – Contacts
  – Options
Why Utilities Offer Incentives

1. Because someone makes them
   – Integrated Resource Plans
   – State Utility Commissions
   – State Initiatives

2. Because they need to
   – Need to add resources
   – Energy efficiency is the lowest-cost resource

3. Because they want to
   – Good customer service
   – Healthy customers = healthy utility!
   – Can sell excess power to neighbors for a profit
Utility Incentive Programs

• Typically X¢/kWh, up to Y% of project cost
  – Commonly 5 to 30¢/kWh
  – Commonly 50% to 70% of project cost
  – May have a minimum allowable simple payback
  – May vary by technology or retrofit vs. new construction

• Also prescriptive rebates
  – $X/light fixture
  – $Y/hp for variable frequency drives
Never Say “No Brainer” or “Never”

• Energy rates vary from 1¢ to 16+¢/kWh
• Incentives vary from 0% to 100% of project cost
• Hot & humid vs. cool & dry climate?
• Any blasting of product?
• 0°F or -20°F design?
• New technology & reduced cost
  – Remember, LED was $1500/fixture just 2 years ago
• Every project and every site can have radically different economics!
Sample #1 Energy Incentives

What financial incentives are available for energy savings?

The ESI Program will pay for up to 100% of the technical consulting work needed to identify energy savings opportunities, analyze the impact of projects and generate the appropriate technical reports.

- **Project incentives** – $0.25 per kWh of verified energy savings up to 70% of incremental project cost.

In addition, these projects may qualify for federal, state, and/or local tax credits.
custom rebates

TID offers pre-calculated rebates for high efficient motors and some common energy efficient retrofit applications. TID cannot offer a standard program for every foreseeable energy conservation opportunity.

The Custom Rebate Program enables TID to address the unique needs of our customers and encourage them to develop and implement innovative, cost-effective, energy efficient technologies and processes. The TID Custom Rebate offers an incentive $0.05 per kWh of estimated first years saving covering up to 50% of the project cost. It is expected that most custom rebates will address areas such as lighting, compressed air systems, refrigeration systems, chillers and other systems and components.
Increased Custom Incentives!

Custom applications submitted after October 20, 2010 may be eligible for a bonus incentive. Complete your Custom project by March 31, 2011 for a 2¢ early bonus incentive for each kilowatt-hour (kWh) saved. If you can’t finish your project by then, but can finish it up by April 30, 2011, we’ll still provide a 1¢ bonus for each kWh saved. After April 30, 2011, your project will no longer be eligible for bonuses — but if it’s completed before May 31, 2011, we will still honor the base incentive.

<table>
<thead>
<tr>
<th>Project Completed by</th>
<th>Early Bonus Incentive</th>
<th>Bonus Incentive</th>
<th>Base Incentive</th>
</tr>
</thead>
<tbody>
<tr>
<td>March 31, 2011</td>
<td>$0.07/kWh saved per year</td>
<td>$0.06/kWh saved per year</td>
<td>$0.05/kWh saved per year</td>
</tr>
<tr>
<td>April 30, 2011</td>
<td>$0.08/kWh saved per year</td>
<td>$0.07/kWh saved per year</td>
<td>No Bonus</td>
</tr>
</tbody>
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Typical Incentive Program Flow

1. Contact utility & sign necessary paperwork
2. Identify efficiency opportunities
3. Complete required energy analysis & cost estimating
4. Ensure clarity on end-game process & deliverables
5. Get utility OK to implement project BEFORE YOU ORDER OR START
6. Ensure clarity with implementation team on roles and responsibilities
7. Implement project
8. Commission or fine-tune project
9. Follow process for Measurement & Verification (M&V)
10. Gather invoices, document incremental costs
11. Submit final report to utility program
Plan for the Future

• Make Provisions for Future Opportunities
  – Roof Load: Solar panels, Wind
  – Wall Space: VFDs, Inverters, Transfer Switch, etc.
  – Utilities and Space for Generator: Distributed Generation, Peak Shaving
  – Plugs for Lighting vs. Hardwire
  – Adequate Electrical for Fast Chargers
  – Compressor Oil Separator for Lower Head Pressures
Obtain qualified assistance

• Contractor and Consultant Selection
  – Familiar with the Incentive Program Processes
  – Familiar with the Industry (Energy Usage Profile and Trends)
  – Familiar with the Company (Culture)
  – Provides value engineering
  – Demonstrate alternative costs and energy savings
  – Understands the life-cycle cost of alternatives
  – Proven track record
Real Life Results

• Henningsen Cold Storage Co.
  – Cuft: +122%
  – KWH +19%
  – $/KWH +100%

• Retrofits & Upgrades: Freon (24-36% reduction)
• Retrofits & Upgrades: NH₃ (34-44% reduction)
• New Construction: NH₃ (11-25% reduction)
Existing Facilities - Freon
Existing Facilities – NH₃
New Facilities - NH$_3$
Opportunity for Contractors

• Become a value add partner
  – Explore new technologies and bring them to the table
  – Collect/Share success/failure information between projects
  – Lobby manufacturers for improved products
  – Keep an open mind on customer ideas
  – Don’t be afraid of change

• Manage or actively participate in the process

• Save the customer money

• Make more money
  – Sell bigger equipment
  – Sell more equipment

• Take care of the customer

• Repeat sales

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LEED? How much time do you have?!

- **Energy & Atmosphere**
  - Prereq: Minimum Energy Performance
  - Prereq: Fundamental Refrigerant Mgmt
  - Credit: Optimize Energy Performance (1-18 pts)
  - Credit: Demand Response (1-2 pts)
  - Credit: Renewable Energy (1-3 pts)
  - Credit: Enhanced Refrigerant Mgmt (1 pt)
  - Credit: Green Power & Carbon Offsets (1-2 pts)

- **Performance**
  - Prereq: Building-Level Energy Metering
  - Prereq: Fundamental Commissioning & Verif.
  - Credit: Enhanced Commissioning (3 pts)
  - Credit: Monitoring Based Commissioning (1 pt)
  - Credit: Advanced Energy Metering (1 pt)
  - Credit: Reconcile Projected & Actual Energy Perf (1 pt)

Unfortunately, ASHRAE 90.1 doesn’t address refrigerated warehouses very well........
New Construction Advice

- Consider efficiency early in design & bid phase
- Owner, GC, subs, vendors, utility, energy consultant, are all part of the team
- Engage utility program early
  - Coming to them late will fail
- Let utility program know if the project scope or timeline has changed
- Always include contingency in budgets
- Ensure contractors and vendors track and document costs per needs of program
- Plan for energy commissioning 3 to 6 months after facility startup
Thanks!