MetEd / EPRI
Energy Efficiency Workshop

Mark Stephens, PE, CEM, CP EnMS
EPRI Principal Project Manager
Industrial Energy Efficiency & Power Quality Services

Baskar Vairamohan, PE, CEM
EPRI Project Manager
Technical Leader, Energy Utilization

Met-Ed/FirstEnergy
October 26, 2015
MetEd / EPRI Energy Efficiency Workshop

Improving efficiency for Met-Ed’s governmental, non-profit and institutional (NGI) customers

FirstEnergy and the Electric Power Research Institute (EPRI) are sponsoring the following workshop for Met-Ed’s governmental, non-profit and institutional (NGI) customers. For those needing continuing education certification, this workshop qualifies for four (4) Professional Development Hour (PDH) credits.

MONDAY, October 26, 2015 (10:00 AM - 3:00 PM)
Location: Met-Ed Main Auditorium, 2800 Centre Ave., Reading PA 19605

KEEPING MET-ED’S GOVERNMENTAL, NON-PROFIT & INSTITUTIONAL CUSTOMERS COMPETITIVE AND PRODUCTIVE WITH ENERGY EFFICIENCY SOLUTIONS

Course Description: This workshop, which is intended for Met-Ed’s NGI customers (hospitals, schools, government buildings), will provide information on different EE project options that can be implemented to reduce energy costs and improve facility operation. Experts from the Electric Power Research Institute (EPRI) will provide information on lighting and controls, premium efficiency motors, adjustable speed drives, compressed air best practices, chiller plant optimization, and PC power management. Case studies for specific customer applications and an overview of Met-Ed EE Programs and incentives under PA’s Act129 will be provided.

Instructors:
- **Mark Stephens**, EPRI Principal Project Manager, Industrial PQ/EE, PE, CEM, CPEnMS - Industrial
- **Baskar Vairamohan**, EPRI Project Manager/ Technical Leader, Energy Utilization

Course Abstract:

This course is designed to help facility managers, technicians and engineers understand how to improve their building’s productivity per unit of energy use. Attendees will learn about the merits of upgrading lighting technology and using premium efficiency motors. Application of drives for increased efficiency will be reviewed as well as best practices for compressed air systems. Finally, chiller plant optimization and PC power management will be discussed for increased energy efficiency. Select case studies will be provided to highlight customer applications of these technologies. The session will conclude with a review of Met-Ed EE Programs and incentives under PA’s Act129.
MetEd / EPRI Energy Efficiency Workshop
Improving efficiency for Met-Ed’s governmental, non-profit and institutional (NGI) customers
Monday, October 26, 2015, 10:00 a.m. – 3:00 p.m.

10:00 AM Kickoff

1. Making Energy Management Part of Your Culture
2. Upgrading Lighting and Controls;
3. Premium Efficiency Motors and Application of Adjustable Speed Drives;

12:00-12:45 PM Lunch

4. Compressed Air Best Practices;
5. Chiller Plant Optimization;
6. PC Power Management.
7. Case Studies
8. MetEd Program Description (30 Minutes)

Adjourn 3:00 PM
Mark Stephens manages research and services work related to Industrial Power Quality and Energy Efficiency as well as Retrofit Energy Savings Devices (RESDs) at EPRI. He is a Senior Member of the Association of Energy Engineers, and several power quality standards working groups in IEEE and CIGRE. With over 27 years of professional experience, he has a solid background in all aspects of industrial plant systems including control systems, power quality, energy efficiency and energy management systems.

Stephens joined EPRI in 1997 as an employee of the former Power Electronics Application Center (PEAC). His most visible projects include extensive research and management of the seminal EPRI System Compatibility Task 24 research program which led to the development of the SEMI F47 power quality standard. Since then, he was worked to characterize and improve power quality and energy efficiency issues in all manufacturing sectors by leading testing and site audits at customer locations in the worldwide. Working extensively to resolve industrial power quality and energy efficiency issues at the equipment level and process level, Stephens has taught over 60 industrial related courses and is commonly asked to lecture on the subject at conferences worldwide. He has written over 20 conference papers on the subject matter as well.

Stephens received a Bachelor Science degree in electrical engineering from the University of Tennessee in 1988 and has been a registered professional engineer in the state of Tennessee since 1995, a certified energy manager since 2010 and an ISO 50001 certified practitioner of energy management systems since 2012.
Baskar Vairamohan is a Project Manager at the Electric Power Research Institute (EPRI).

Mr. Vairamohan has a decade of laboratory and field experience in testing, monitoring, evaluation and application of end-use technologies. He is currently responsible for managing industrial energy efficiency projects related to process heating, motors, pumps and drives, advanced manufacturing technologies and additive manufacturing technologies such as 3D printing. He is part of the core EPRI team that conducts industrial energy assessments. He also oversees the 80 PLUS® related computer, server, storage and industrial power supply testing.

Mr. Vairamohan has co-authored several industry relevant research papers that were published in technical journals and conferences. He was one of the key authors who developed the power supply efficiency test measurement standard which is now adopted by ENERGY STAR and followed by power supply manufacturers worldwide.

Prior to working at EPRI, Mr. Vairamohan worked as a Programmer Analyst at Cognizant Technology Solutions in India. Mr. Vairamohan holds a Bachelor of Engineering degree in Electrical Engineering from Anna University (India) and Master of Science from the University of Tennessee, Knoxville. He is also a Certified Energy Manager (CEM).
Seminar Outline

- **10:00 AM Kickoff**
  - Making Energy Management Part of Your Culture
  - Upgrading Lighting and Controls
  - Premium Efficiency Motors and Application of Adjustable Speed Drives

- **12:00-12:45 PM Lunch**
  - Compressed Air Best Practices
  - Chiller Plant Optimization
  - PC Power Management
  - MetEd Program Description (30 Minutes)

- **Adjourn 3:00 PM**
Who is EPRI?

- Founded by and for the electricity industry in 1973
- Independent, nonprofit center for public interest energy and environmental research
- Collaborative resource for the electricity sector
- Work with Utilities, Industry, and Government
- Major offices in Palo Alto, CA; Charlotte, NC; Knoxville, TN

Making Energy Management Part of Your Culture

Mark Stephens, PE, CEM, CP EnMS
EPRI Principal Project Manager
Industrial Energy Efficiency & Power Quality Services
Roller Coaster Approach to Energy Efficiency

- Energy costs rise, audit done
- Some energy efficiency measures implemented, no long-term commitment
- Energy costs a little lower, Facility Systems stable
- Equipment failure, Facility Systems shut down
- Energy costs much lower, Facility stable again, but for how long?

Source: Aimee McKane, LBNL

Continuous Approach to Energy Efficiency

- Energy costs rise, senior management commits to ISO 50001
- Energy management measures implemented, long-term commitment
- Further investments, energy costs lower, Facility Systems Stable
- Energy management continues, new opportunities uncovered
- Energy management becomes part of corporate culture, energy savings are persistent

Source: Aimee McKane, LBNL
Project vs. Program Focus

- Energy programs focus on continuous improvement
- Companies with energy programs save more energy
- Sustaining energy savings requires a programmatic approach

ABC Total Energy Use

XYZ Total Energy Use

Implementation Trap

Source: Fred Schoeneborn, Exxon Mobil (ret.)
Typical barriers for ongoing Energy Efficiency Efforts

- Low understanding of efficiency opportunities by management
- Lack of funding for engineering studies
- Short corporate pay back periods
- Competition with other types of projects
- Lack of manpower for project implementation & management
- Little political support within organization to get approvals

ENERGY STAR for Industry

ENERGY STAR offers proven guidance for developing strong energy management programs. Key tools include:

Guidelines for Energy Management
- Provides a framework for how to implement an energy program; based on a “plan-do-act-check” approach.

Energy Program Assessment Matrix
- Evaluates energy management practices and program to identify gaps.

Facility Energy Assessment Matrix
- Evaluates facilities energy management practices to identify gaps.

Teaming Up to Save Energy
- Provides guidance on how to build an energy team and program across an organization.
- Challenge: 10% minimum improvement goal over 5 years
Scoring Energy Performance
Energy Performance Scores

ENERGY STAR Energy Performance Scores (EPS):

- Sector-specific Key Performance Indicators (KPIs) for energy
- Evaluates whole-plant performance for all fuels.
- Compare the energy efficiency of a plant or building against the performance of the industry/sector.
- Based on annual energy use intensity:
  - MMBTU/Unit of production for industrial sites
  - KBTU/SQ FT for commercial buildings
- Normalized for product mix, size, climate, and other factors.
- Establishes an energy performance scale for the industry.
- Recertification is required each year

Energy Star Portfolio Manager

- **Portfolio Manager:**
  - EPA’s online energy management and tracking tool calculates 1 – 100 ENERGY STAR scores for eligible commercial and institutional buildings, such as K-12 schools, office buildings, and many others.
  - Portfolio Manager also allows you to track improvements over time, compare similar buildings within a portfolio, generate reports, and quantify greenhouse gas emissions.
Energy Star – Target Finder

- **Target Finder:**
  - This tool is similar to Portfolio Manager, except it's used to estimate performance.
  - By entering the estimated energy use of a commercial building design or renovation project, you can project its future 1 – 100 ENERGY STAR score.

- **How Target Finder Works**
  - Like Portfolio Manager, Target Finder accounts for building and operating characteristics, such as operating hours and number of PCs, as well as 30-year weather data for your project site.
  - It then compares this data to the actual energy consumption of real buildings, as collected by nationally representative surveys, such as DOE’s Commercial Buildings Energy Consumption Survey (CBECS).
  - The data from these surveys are built into Target Finder, meaning that, with a couple mouse clicks, you can assess your designs against the best-available data sample in the nation, plus have it normalized for size, operating characteristics, and weather.

ISO 50001 – Energy management systems — Requirements with guidance for use

ISO 50001 establishes a framework for industrial and commercial facilities and organizations to manage energy.

Potential impacts:
- Could influence up to 60% of the world’s energy use across many economic sectors

Uptake of ISO 50001 will be driven by companies seeking an internationally recognized response to:
- Corporate sustainability programs
- Energy cost reduction initiatives
- Demand created along the manufacturing supply chain
- Future national cap and trade programs; carbon or energy taxes; increasing market value of “green manufacturing” / reduced carbon footprint
- International climate agreements

Based on the principals and practices of ISO 9001

Status of ISO 50001
- Under development by ISO Project Committee 242; United States and Brazil lead effort with the United Kingdom and China
- 54 countries participating, 12 of which are observing
- Draft International Standard released April 2010
- Final Document Published August 2011
ISO 50001 Concept

E-guide Offers Guidance to Standard Implementation

Ref: DOE E-Guide for ISO 50001:
https://save-energy-now.org/EM/SPM/Pages/Home.aspx
ISO 50001/SEP Guidance in Energy Planning

Planning Inputs

- Past and present energy uses

Energy Review

- A. Analyze energy use and consumption
- B. Identify areas of significant energy use and consumption
- C. Identify opportunities for improving energy performance

Planning Outputs

- Energy baseline
- InP(s)
- Objectives
- Targets
- Action plans

Identification of Facility Energy Use

- Total Plant Energy Use (MMBtu/month)
  - Electrical Energy (kWh/month)
    - Motors (kWh/month)
    - Lighting (kWh/month)
    - HVAC (kWh/month)
  - Natural Gas (Therms/Month)
    - Steam (Therms/Month)
    - Heating (Therms/Month)
Where Should Energy Efforts Be Focused?
It Depends on What is Using the Most Energy!

Ref: DOE E-Guide for ISO 50001:
https://save-energy-now.org/EM/SPM/Pages/Home.aspx

What Can You do? Workforce Roles and Responsibilities.
Upgrading Lighting and Controls

Mark Stephens, PE, CEM, CP EnMS
EPRI Principal Project Manager
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Baskar Vairamohan, PE, CEM
EPRI Project Manager
Technical Leader, Energy Utilization

Areas for Lighting Improvement

I. Replace Incandescent lamps with fluorescent, compact fluorescent lamps (CFLs), or LED lamps

II. Upgrade fluorescent fixtures with improved components

III. Install lighting controls to minimize energy costs

IV. Employ New Lighting Technologies

Ref: see CEM training material
Potential Lighting Energy Savings Opportunities

- LED/Fluorescent Upgrades
- De-Lamping
- Incandescent Upgrades
- HID Upgrades
- Controls Upgrades
- Daylight Compensation

Lighting Comparisons: Metal Halide vs. Others

<table>
<thead>
<tr>
<th>Fixture &amp; lamp #</th>
<th>W/lamp</th>
<th>rated life</th>
<th>initial lumens/ lamp</th>
<th>mean lumens/ lamp</th>
<th>lumens/ fixture</th>
<th>kWh/yr, 24/7 (8760 hrs)</th>
<th>Cost at $0.065/ kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>T5, 2-lamp</td>
<td>54</td>
<td>25K-36K</td>
<td>5000</td>
<td>4700</td>
<td>9K-10K</td>
<td>946.08</td>
<td>$61.50</td>
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<tr>
<td>T5, 3-lamp</td>
<td>54</td>
<td>25K-36K</td>
<td></td>
<td></td>
<td>13K-15K</td>
<td>1419.12</td>
<td>$92.24</td>
</tr>
<tr>
<td>T5, 4-lamp</td>
<td>54</td>
<td>25K-36K</td>
<td></td>
<td></td>
<td>18K-20K</td>
<td>1892.16</td>
<td>$122.99</td>
</tr>
<tr>
<td>T5, 6-lamp</td>
<td>54</td>
<td>25K-36K</td>
<td></td>
<td></td>
<td>28K-30K</td>
<td>3153.60</td>
<td>$204.98</td>
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<tr>
<td>T8, 2-lamp</td>
<td>28</td>
<td>20K-24K</td>
<td>3100</td>
<td>2567</td>
<td>5.1K-6.2K</td>
<td>490.56</td>
<td>$31.89</td>
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<tr>
<td>T8, 3-lamp</td>
<td>28</td>
<td>20K-24K</td>
<td></td>
<td></td>
<td>7.7K-9.3K</td>
<td>735.84</td>
<td>$47.83</td>
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<tr>
<td>T8, 4-lamp</td>
<td>28</td>
<td>20K-24K</td>
<td></td>
<td></td>
<td>10.3K-12.4K</td>
<td>989.88</td>
<td>$64.34</td>
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<tr>
<td>T8, 6-lamp</td>
<td>28</td>
<td>20K-24K</td>
<td></td>
<td></td>
<td>15K-18.6K</td>
<td>1690.68</td>
<td>$109.89</td>
</tr>
<tr>
<td>T12, 2-lamp</td>
<td>55</td>
<td>20K</td>
<td>2650</td>
<td>2047</td>
<td>4.1</td>
<td>1716.96</td>
<td>$111.60</td>
</tr>
</tbody>
</table>
| Metal Halide    | 400    | 20K        | 40000                | 29000             | 29K             | 4029.60                | $261.92              

Lighting study is a good idea
Fluorescent Retrofits 1

- Existing System: T12 lamps with Magnetic Ballasts
- Retrofit Alternatives:
  1. T12 low wattage lamps (34W) – replace lamps only
     - Less light, less energy consumption
  2. T8 (32W) – replace lamps and ballasts
     - Same light, less energy consumption, better color, rendering, less map flicker, less ballast hum
     - Can operate 4 lamps per ballast
     - Can be tandem wired
     - Electronic ballasts can be parallel wired

Ref: aee CEM training material

Fluorescent Retrofits 2

- Just replace the lamps
  - LED lamps
  - T8 or T12 compatible
  - 14.5 watts vs. 34, 32, 28W
    - 4’ and 8’ lengths
  - Available in double-pin and single-pin styles
  - Some may be rotated to direct light
  - Rated at 40,000 or more hours*
  - Currently pricey—should become more affordable over time
- Several manufacturers

*EPRI has not verified this longevity through testing
Testing of T8 LED (DOE, 2011)

- Efficacy depends on fixture - did not perform well in “basket” fixture
- May be costly at present; most lumens directed downward
- Lamps tested by DOE:
  - $60 to $120 each
  - One shown ~$10

Lighting Considerations

- Lighting technologies have different color temps
  - Better light quality may require fewer lumens

Light Terminology — The eye’s response to color

Basic LED Reference Example

Kelvin Color Temperature Scale Chart
Lighting Considerations

Control Schemes for High Bay Lighting

Entire Aisle Control from Ends

Entire Aisle Control from Ends & Middle

*Individual Fixture Control*

Individual Fixture Control w/ Lights On Ahead

Ref: sensor switch
**Individual Fixture Control**

Ref: sensor switch

**Forklift Enters Aisle – First Light Comes On**

Ref: sensor switch
Each Lights Comes on Directly at Forklift

Ref: sensor switch
Light Comes on Directly at Forklift

Ref: sensor switch
Lights Start Turning Off Behind Forklift

Ref: sensor switch

Forklift Leaves Aisle, Lights Continue to Turn Off

Ref: sensor switch
Forklift Leaves Aisle, Lights Continue to Turn Off

Ref: sensor switch
Lights Finish Turning Off

Ref: sensor switch

Energy Star Lighting Comparison

<table>
<thead>
<tr>
<th>Technology</th>
<th>CRI</th>
<th>Efficacy (lumen/W)</th>
<th>Lifetime (hrs)</th>
<th>Color Temperature (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compact Fluorescent</td>
<td>80-90</td>
<td>60-70</td>
<td>6,000-10,000</td>
<td>2700-6500</td>
</tr>
<tr>
<td>Incandescent</td>
<td>100</td>
<td>12-18</td>
<td>750-1,500</td>
<td>2400-2900</td>
</tr>
<tr>
<td>Linear Fluorescent</td>
<td>70 - 90</td>
<td>80-100+</td>
<td>20,000</td>
<td>2700-6500</td>
</tr>
<tr>
<td>Halogen</td>
<td>100</td>
<td>16-29</td>
<td>2,000-4,000</td>
<td>2850-3200</td>
</tr>
<tr>
<td>White LED</td>
<td>65-90</td>
<td>20-50</td>
<td>Up to 100,000</td>
<td>2700-6500</td>
</tr>
</tbody>
</table>

LIGHTING TECHNOLOGIES: A GUIDE TO ENERGY-EFFICIENT ILLUMINATION
### Energy Comparison

<table>
<thead>
<tr>
<th></th>
<th>Induction</th>
<th>MH</th>
<th>HPS</th>
<th>LED</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Light Color</strong></td>
<td>Cool White</td>
<td>Cool White</td>
<td>Yellow</td>
<td>White to Cool White</td>
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<tr>
<td><strong>Color Rendering Index (CRI)</strong></td>
<td>&gt;80</td>
<td>65-95</td>
<td>21</td>
<td>&gt;70</td>
</tr>
<tr>
<td><strong>Color Correction Temperature (CCT)</strong></td>
<td>5000</td>
<td>4300</td>
<td>2200</td>
<td>2700-7500</td>
</tr>
<tr>
<td><strong>Economic Lamp Life</strong></td>
<td>100,000</td>
<td>10,000-24,000</td>
<td>15,000-24,000</td>
<td>50,000-100,000</td>
</tr>
<tr>
<td><strong>Lamp Longevity (years)</strong></td>
<td>22.83</td>
<td>2.28</td>
<td>4.57</td>
<td>11.42-22.83</td>
</tr>
<tr>
<td><strong>Remaining Life @ 25,000 hrs</strong></td>
<td>75,000</td>
<td>na*</td>
<td>na*</td>
<td>25,000-75,000</td>
</tr>
<tr>
<td><strong>Emission Reduction</strong></td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Restart</strong></td>
<td>Instant</td>
<td>10 - 15 minutes</td>
<td>10 - 15 minutes</td>
<td>Instant</td>
</tr>
</tbody>
</table>

*25,000 hours exceeds lifetime of these lamps

An Illuminating Comparison of Three Commonly Used Lighting Technologies: High Intensity Discharge, Induction and LED


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### Clear Result/FirstEnergy Calculator

- **Excel Lighting Study**
Example Lighting Assessment

- The plant primarily uses Metal Halide Fixtures for lighting in the two main buildings
- Each fixture accounts for ~458W of power, continually on
  - Bldg 1 ~466 units
  - Bldg 2 ~ 337 units
- Median Light Value directly under Metal Halide fixtures ~ 27 fc

<table>
<thead>
<tr>
<th>Fixture Height</th>
<th>Meter Height</th>
<th>Bldg</th>
<th>Area</th>
<th>Location</th>
<th>Measurement (fc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>1.5</td>
<td>1</td>
<td>Warehouse</td>
<td>Under Fixture</td>
<td>28.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>Warehouse</td>
<td>In between two fixtures</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>Warehouse</td>
<td>Under Fixture</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>Storage</td>
<td>Under Fixture</td>
<td>11.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>Mixing Area</td>
<td>Under Fixture</td>
<td>25-12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>at Foyer corner</td>
<td>Under Fixture</td>
<td>27</td>
</tr>
</tbody>
</table>

Example Lighting Assessment

- Lighting on 24x7

- Estimated Lighting Load/Costs
  ~367kW or 3.22MWh/year
  ~$237,000 k/year in power costs
Example Lighting Assessment

- Forty-Eight (48) T12 8 foot fixtures were found in the mezzanine storage area.
- The lights were left on at switch by top of stairs although there was no one present.
  - Approximate cost/day of leaving lights on
    \[48 \times 0.2\text{kW} \times \$0.0736/\text{kW} \times 24\text{hrs/day} = \$16.90/\text{day}, \sim \$6000/\text{year}\]
- The lights could be replaced with more efficient technology and/or add an occupancy sensor.
- Utility may have incentive for occupancy sensors that could be placed where light switch is now –set for long delay.

Example Lighting Assessment

- Potential change out:
  - (4) Bulb T5HO Fluorescent ~234W/fixture
  - (6) Bulb T8 Fluorescent ~222W/fixture
  - (6) Bulb T5HO Fluorescent ~324W/fixture

- Assuming one for one replacement with Metal Halides

- Estimated lighting load/costs (4) Bulb T5 HO Fixture
  - ~187kW or 1.9 MWh/year
  - ~$121k/year in power costs
  - ~$116k/year Savings

Payback including installation expected to be less than 1 year with Utility incentive included.

Ref: accessfixtures.com
New Lighting Technologies – Induction Lamps

- Induction lamps
  - Long Life --- 100,000 hours for lamp and ballasts
  - Philips QL lamps in 55W, 85W, and 165W
  - New application with reflector to replace metal halides as signs lights for road and commercial signs.
  - Lasts four times as long

Ref: see CEM training material

Basic and Advanced LED Lighting Technologies

- Fewer Light Rays Exit the Lens
  - Basic Technology
  - Lower Efficiency

- More Light Rays Exit the Lens
  - Advanced Technology
  - Higher Efficiency

Courtesy: Philips Lighting
Efficacies of Different Common Light Sources
Incandescents, Fluorescents, HIDs, and LEDs

Comparison of LED and HID Lighting

<table>
<thead>
<tr>
<th>HID</th>
<th>LED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>HID Lamp</strong></td>
<td><strong>LED</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Photopic Initial Delivered Lumen</strong></td>
</tr>
<tr>
<td>PS 70 (H)</td>
<td>3,500</td>
</tr>
<tr>
<td>PS 100 (H)</td>
<td>5,650</td>
</tr>
<tr>
<td>PS 150 (V)</td>
<td>9,800</td>
</tr>
<tr>
<td>MH 175 (V)</td>
<td>9,900</td>
</tr>
<tr>
<td>MH 260 (H)</td>
<td>13,250</td>
</tr>
<tr>
<td>PS 320 (H)</td>
<td>21,000</td>
</tr>
<tr>
<td>MH 400 (H)</td>
<td>22,700</td>
</tr>
<tr>
<td>PS 400 (H)</td>
<td>28,000</td>
</tr>
<tr>
<td>HPS 70</td>
<td>4,450</td>
</tr>
<tr>
<td>HPS 100</td>
<td>6,650</td>
</tr>
<tr>
<td>HPS 150</td>
<td>11,150</td>
</tr>
<tr>
<td>HPS 250</td>
<td>19,600</td>
</tr>
<tr>
<td>HPS 400</td>
<td>35,000</td>
</tr>
</tbody>
</table>

Ref: Beta-Kramer
LED* for Street and Area Lighting

Metal Halide

THE EDGE™
30% Energy Savings


LED – Light Emitting Diode, a semiconductor material that when energized emits light.

Light Patterns and Color Vary

LED – Light Emitting Diode, a semiconductor material that when energized emits light.
Example Audit Outdoor Perimeter Lighting Replaced with LED

- The plant has replaced 20 of their 96 outdoor metal halide lights (454W each) with LED units (56W each).
  - Saving $1760/year
- LED units will cost less per year to operate, but payback is over 5 years.
- Replacing all outdoor units with LEDs could save $6.7k/year, but at a current expense of about $38k.

<table>
<thead>
<tr>
<th>Technology</th>
<th>Cost/Fixture</th>
<th>Total Fixtures</th>
<th>kW/Fixture</th>
<th>Hrs/Year</th>
<th>KW Total</th>
<th>kWh Total</th>
<th>Cost/kWH</th>
<th>Cost/Year</th>
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<tbody>
<tr>
<td>Metal Halide</td>
<td>$216</td>
<td>1</td>
<td>0.458</td>
<td>4380</td>
<td>0.458</td>
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<td>LED</td>
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<td>0.056</td>
<td>4380</td>
<td>0.056</td>
<td>245.28</td>
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<tr>
<td>Savings</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$88.04</td>
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<td>Costs</td>
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<td></td>
<td></td>
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<td>$500</td>
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<td>Payback</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5.6 Years</td>
</tr>
</tbody>
</table>

Use of Premium Efficiency Motors

Baskar Vairamohan, PE, CEM  
EPRI Project Manager  
Technical Leader, Energy Utilization
Motors & Motor Driven System

- Motors and Motor driven systems account for nearly 50% of global electricity consumption
- Typically used by various industries and large buildings to drive:
  - Pumps
  - Fans
  - Compressors
  - Traction systems
  - Industrial handling and Process equipment

Motors and Drives – Pumps, Fans and Compressors

Photo Source: http://toritdust.com/parts/fans
http://www.emeraldseedandsupply.com/equipment/pumps_bowie_industrial.html
Global Perspective

- Electric motor-driven systems makes up about 19 percent of the global electricity demand
  - This is more than twice as much as the next-largest user, lighting
- Electricity consumption by motors could double to 13,360TWh per year by 2030
  - Equivalent to emitting 8,570 million tonnes of CO2
- End users are now spending about $565 billion on electricity to power electric motors
  - This could increase to $900 billion by 2030 without improvement
- Use of high-efficiency motors alone could cut energy consumption by 4-5%
- By adopting the best technologies, the world’s electricity demand could be cut by 3,890TWh a year by 2030
  - Equivalent to reducing CO2 emissions by 2,490Mt


Electric Motor Use and Energy Savings in US

- U.S. Installed Base is 90 Million Electric Motors
  - Industrial & Commercial Electric Motors is 40 Million
- According to DOE estimates (1998), potential industrial motor system energy savings using mature, proven, cost-effective technologies range from 11-18 percent of current annual usage or 62 to 104 billion kWh per year in the manufacturing sector alone
  - Savings is valued up to $5.8 billion
  - Reduction of CO2 emissions of about 29.5 million metric tons annually
- DOE (2010) estimates that the new small motor efficiency rule will save 2.46 quads of cumulative energy over 30 years (2015–2045)
  - 2.13 quads of savings result from standards on capacitor-start (single-phase) motors
  - 0.33 quads of savings result from standards on polyphase motors
Global Market Size of Low Voltage Motors & Drives

Globally, the motors & drives market are growing...

Industry Breakdown of Low Voltage Motor Drives Market

Source: IMS Research 2010, Presented at EEMODS 2011
How to increase productivity through motors?

Improving Production Efficiency can be broken down into three main categories:

1. Improving motor efficiency or using advanced motors
2. Correcting for motor over sizing
3. Improving the total process efficiency / eliminating system losses
Energy Independence and Security Act (EISA) 2007 – Electric Motors

Uses NEMA MG1 standard as basis for regulation

- Expected to save 9.8 TWh of energy over next 20 years and reduce peak demand by 1.341 TW - equivalent to three coal plants (ACEEE)
- New electric motors (baring some exceptions) between 1-500 HP covered
- Small electric motors (2-digit frames) exempt – separate legislation planned

EISA 2007 – Penetration

Significant utility prescriptive rebate programs

Worldwide adoption of standard
Impact of EISA 2007 on Motor and System Manufacturers

- Impacts motors sold separately as well as motors integrated into systems (pumps, compressors, ...) – must meet EISA 2007 mandates
- Not expected to pose any serious technological hurdles to motor manufacturers
- Motor system manufacturers must factor in performance differences due to high efficiency motors (namely higher speed and low slip)
- Requires independent-third party certification and detailed record keeping
- Stiff fines for violations

Impact on End-Users

- Premium efficiency motors may cost anywhere from 15-30% more than standard efficiency motors
  - End-users must conduct ROI analysis prior to considering replacement
  - However, significant long-term savings due to longer life and higher efficiency
  - Several electric utility rebate programs also exist that can incentivize end-users to replace old motors with high efficiency Premium motors
Impact on Motor Technology

<table>
<thead>
<tr>
<th>Motor Type</th>
<th>Line-Start</th>
<th>IE1</th>
<th>IE2</th>
<th>IE3</th>
<th>IE4</th>
<th>IE5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three-phase cage-induction motors (ASM)</td>
<td>Yes</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>Difficult</td>
<td>No</td>
</tr>
<tr>
<td>Wound-rotor induction motors</td>
<td>Yes</td>
<td>OK</td>
<td>OK</td>
<td>Difficult</td>
<td>Difficult</td>
<td>No</td>
</tr>
<tr>
<td>Single-phase induction motors (one capacitor)</td>
<td>Yes</td>
<td>OK</td>
<td>Difficult</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Single-phase induction motors (two switchable capacitors)</td>
<td>Yes</td>
<td>OK</td>
<td>Difficult</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Permanent-magnet synchronous motors (PMSM)</td>
<td>No</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>Difficult</td>
</tr>
<tr>
<td>Wound-rotor synchronous motors</td>
<td>Some</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>Difficult</td>
</tr>
<tr>
<td>Line-start permanent-magnet motors (LSPM)</td>
<td>Yes</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>Difficult</td>
</tr>
<tr>
<td>Sinusoidal-field reluctance motors</td>
<td>Some</td>
<td>OK</td>
<td>OK</td>
<td>Difficult</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Source: Dr. Matin Doppellbauer, IEC 60034-30 2nd edition Rotating Electrical Machines Efficiency Classes (IE-Code)

Partial Load Efficiencies of 75 hp, 1800 rpm Motors

Permanent Magnet Motors shows higher efficiency at lighter loads

Source: Baldor Motors presentation at ACEEE 2011
Results – Lower Power Consumption

Source: Baldor Motors presentation at ACEEE 2011

Ind. Motor Power
PM Motor Power
~12% energy savings @ full load

Levels of Motor and Process Efficiency
First Level Improvement
- Better (More Efficient) Motors
  - EPACT Standards
  - International Standard
  - NEMA Premium Efficiency
Levels of Motor and Process Efficiency

- Variable Speed Drives
  - 10%-50% Process Improvement
  - Application Limited
  - Widespread Acceptance

Second Level Improvement

- Vector Control Drives
  - Improvement on ASD Efficiency
  - Opens up New Ap. Opportunities
  - Highest Efficiency at all Loads

Third Level Improvement

ASD – Adjustable Speed Drive
FOC – Field Oriented Control
Example Vector Control Drives

http://www.losungautomation.com/images/mitsubishi-pic.jpg


Motors and Drives - Minimum Energy Performance Standards (MEPS)

- **EF1: High**
- **EF2: Improved (equivalent to EPAct)**
- **EF3: Standard Efficiency Classes**
- **CEMEP (Europe)**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1-200 HP</td>
<td>76.7-93.5%</td>
<td>Pre-EPAct</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-200 HP</td>
<td>82.5-98%</td>
<td>EPAct (USA)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5-100 HP</td>
<td>85-95%</td>
<td>[\text{IE2} \text{Premium Efficiency} ]</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>15-500 HP</td>
<td>95.5%</td>
<td>[\text{IE4} \text{Efficiency} ]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NEMA Premium Efficiency</td>
<td></td>
<td>[\text{IE5} \text{Efficiency} ]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EISA 2007 (USA)</td>
<td></td>
<td>10 CFR Part 431 (USA)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Ultra-Premium Efficiency**
  - 1-2% \[\text{IE3} \text{IE3 premium} \]

- **Super Premium**
  - \[\text{IE5} \text{IE3 premium} \]

- **Induction motors**
- **Copper rotors/superconducting motors**
- **Enhanced magnetic texture steel (EMTX)**

- **Increasing penetration of variable speed motor systems**
  - (SFLC, Switched reluctance, PM/SM motors)

- **PM motors** (SuperSwitch) and other advanced motors (SuperSwitch) needed to meet IE4

- **Direct drive applications to improve system efficiency**
Electric Motor Use

- Process motor systems account for 63% of all electricity used in industry
- Most motors are at least 30% under loaded
- A third of motors are run below 50% load


Motor Decisions Matter website
“Introduction to Premium Efficiency Motors” by the Copper Development Association

Induction Motor Losses (1)

- Induction Motor Losses
  - Power Loss
  - Magnetic Core Loss
  - Friction and Windage Loss
  - Stray Load Loss

<table>
<thead>
<tr>
<th>Type of Loss</th>
<th>Typical % of Losses for 4 Pole Motors</th>
<th>Factors Affecting These Losses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stator winding losses</td>
<td>35 to 40%</td>
<td>Stator conductor size and material</td>
</tr>
<tr>
<td>Rotor losses</td>
<td>15 to 20%</td>
<td>Rotor conductor size and material</td>
</tr>
<tr>
<td>Rotor core losses</td>
<td>15 to 20%</td>
<td>Type and quantity of magnetic material</td>
</tr>
<tr>
<td>Stator core losses</td>
<td>10 to 15%</td>
<td>Type and quantity of magnetic material</td>
</tr>
<tr>
<td>Stator and winding losses</td>
<td>5 to 10%</td>
<td>Selection/design of fans and bearings</td>
</tr>
</tbody>
</table>


The above values show the typical loss distribution for medium induction motors. Speed, size, and load can cause total losses to vary significantly in some of these proportions, particularly the core and friction and windage losses.
Induction Motor Losses (2)

- Power losses (also called I²R losses) and stray load losses appear only when the motor is operating under load.
- Power losses are comprised of stator and rotor I²R losses.
  - They are therefore more important — in terms of energy efficiency.
  - Stator losses may make up to 66% of power losses.
- Magnetic losses can account for up to 20% of total losses.

“Introduction to Premium Efficiency Motors” - by the Copper Development Association

Typical Induction Motor Efficiency

Efficiency Opportunity Through Motor Rewinding

- Traditional fast rewinding can decrease efficiency by 20%
- Since motors are frequently operated for 20 to 30 years, a motor may be repaired 3 to 5 times in its service life
- For every new motor sold, approximately 2.5 motors are repaired
- Improper rewinding can significantly decrease motor efficiency (actual numbers vary from source to source, but in the range of 5-20%)
- Sophisticated rewind can increase efficiency
- Improved methods of rewinding failed motors can contribute an additional 4.8 billion kWh (DOE, 1998)

Guidelines for maintaining motor efficiency during rebuilding, Electrical Apparatus Service Association (EASA), 1999

Good Place to Start – Your Spare Inventory

- It's rarely justifiable to replace a motor before failure.
- Tools like DOE's ITP Motor Master can help you find more efficient replacements.
Example Motor Efficiency Assessment

- Plants keeps many backup motors in spares
- In some cases, plant replaces process motors with like units or rewinds for larger motors if possible.
- Replace failed motors with like units
  - DOE ITP Motormaster+ not being used for determining most efficient motor replacements.
- As plant equipment is not new, “like” motors may not be most efficient.

1 hp, 80% => 85.5% Premium

5 hp, 87.5% => 91.7% Premium

50 hp, 87.5% => 95.0% Premium

125 hp, 94.5% => 95.8% Premium

Example Motor Efficiency Recommendations

- Assessment of motor efficiency of inventory is in progress from nameplate data
  - Spot analysis shows that there are opportunities for energy efficiency savings
  - 50 hp range may represent largest opportunity for this customer
- Recommend detailed inventory against Motor Master + and Motor Master + International
  - Begin procuring more efficient replacement motors
  - Focus on units with highest savings/year versus motor cost
    - (e.g. payback for 50hp premium efficiency motors ~3 years based on list price)

<table>
<thead>
<tr>
<th>ECM No.</th>
<th>Use Premium Efficient Motors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cost/Year $</td>
</tr>
<tr>
<td></td>
<td>Operating Hrs/yr</td>
</tr>
<tr>
<td>Motor Size (hp)</td>
<td>Existing Eff.</td>
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<tr>
<td></td>
<td>Cost/Year ($)</td>
</tr>
<tr>
<td>1</td>
<td>1,300</td>
</tr>
<tr>
<td>5</td>
<td>2,000</td>
</tr>
<tr>
<td>50</td>
<td>37,500</td>
</tr>
<tr>
<td>125</td>
<td>75,000</td>
</tr>
</tbody>
</table>

A. Cost per Year calculated by [Hrs/yr] * [Motor Loading] * [In turb/yr] / [Efficiency]
B. From Motor Master Plus List

Estimated Yearly Savings: $ 86,040
Remember Load Factor (% Loaded)

- Theoretical:
  - kW Saved = 0.746 * hp * \( [(1/\text{eff. Motor 1}) - (1/\text{eff. Motor 2})] \)

- Actually:
  - kW Saved = 0.746 * hp * LF *[\( (1/\text{eff. Motor 1}) - (1/\text{eff. Motor 2}) \)]
  - Where LF = Load Factor (percent of full load)

- If actual load is less than 50% of its nameplate, efficiency nameplate is meaningless.
- Part load efficiency number would be needed to calculate accurately
  - i.e. 75%, 50%, 25% load efficiencies

Watch Out for Direct-Coupled Centrifugal Loads when estimating energy efficiency

- Energy Efficient motors have less slip.
  - Motor will run a few rpm faster
- For direct-coupled centrifugal loads (Pumps and Fans), this can result in an increase in work output
- When the high efficiency motor is expected to save from 3% to 5% of full load hp, this can eat away at savings.

- Example: A new motor runs 10 rpm faster
- Speed Ratio: \( \frac{1760}{1750} = 1.006 \)
- Affinity Laws:
  \[
  \left(\frac{N_2}{N_1}\right)^3 = \frac{HP_2}{HP_1}
  \]
  \[
  HP_2 = HP_1 \cdot \left(\frac{N_1}{N_2}\right)^3
  \]
  Hp increase = \( (1.006)^3 = 1.02 \)
  2% Energy Use Increase
Cogged and Synchronous Belts

- Standard V-belt drives can stretch up to 3% of the original length throughout the life of the belt.
  - If proper tension is not maintained, the required friction can be lost and the belt can slip. When slip occurs, additional heat is generated between the belts and grooves.
- At the time of proper installation, V-belts can run between 95-98% efficiency. The efficiency then falls to an average of approximately 93% during normal operation.
- Cogged V-belt could save about 2% on energy, uses same pulleys as V-belt, ~95% Efficient
- Synchronous belts (also called timing, positive drive or high-torque drive belts) are on average about 5% more efficient than standard V-belts, ~98% Efficient
  - Require installation of mating toothed drive sprockets

Ref: US DOE Energy Tips- Motor Systems, Replaced V-Belts with Cogged or Synchronous Belt Drives

Cogged and Synchronous Belts

<table>
<thead>
<tr>
<th>ECM No.</th>
<th>Replace V-Belt with Cogged or Synchronous Belt</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Cost (Growth)</td>
</tr>
<tr>
<td></td>
<td>Operating Hrs/yr</td>
</tr>
<tr>
<td></td>
<td>V-Belt Efficiency</td>
</tr>
<tr>
<td></td>
<td>Cogged-Belt Efficiency</td>
</tr>
<tr>
<td></td>
<td>Synchronous Belt Efficiency</td>
</tr>
<tr>
<td></td>
<td>Motor Size</td>
</tr>
<tr>
<td></td>
<td>Motor Efficiency</td>
</tr>
<tr>
<td></td>
<td>Motor Power Usage</td>
</tr>
<tr>
<td></td>
<td>Motor Diversity</td>
</tr>
<tr>
<td></td>
<td>Net Hours Btw Loaded</td>
</tr>
<tr>
<td></td>
<td>Power Savings Cogged Belt</td>
</tr>
<tr>
<td></td>
<td>Power Savings Synchronous Belt</td>
</tr>
<tr>
<td></td>
<td>Years Energy Use with V-belt</td>
</tr>
<tr>
<td></td>
<td>Energy Savings Cogged Belt</td>
</tr>
<tr>
<td></td>
<td>Energy Savings Synchronous Belt</td>
</tr>
<tr>
<td></td>
<td>Estimated Yearly Savings Cogged Belt</td>
</tr>
<tr>
<td></td>
<td>Estimated Yearly Savings Synchronous Belt</td>
</tr>
<tr>
<td></td>
<td>Cost/Cogged Belt</td>
</tr>
<tr>
<td></td>
<td>Cost/Synchronous Belt and Sprockets</td>
</tr>
<tr>
<td></td>
<td>Estimated Payback Cogged Belt</td>
</tr>
<tr>
<td></td>
<td>Estimated Payback Synchronous Belt</td>
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<tr>
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<td>$ 1,189</td>
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</tr>
<tr>
<td></td>
<td>$ 1,233</td>
</tr>
<tr>
<td></td>
<td>$ 9,999</td>
</tr>
</tbody>
</table>

Ref: US DOE Energy Tips- Motor Systems, Replaced V-Belts with Cogged or Synchronous Belt Drives

Remember:
For centrifugal fans and pumps, which exhibit a strong relationship between operating speed and power, synchronous belt sprockets must be selected that take into account the absence of slippage.

Operating costs could actually increase if slippage is reduced and a centrifugal load is driven at a slightly higher speed.
Efficient Application of Adjustable Speed Drives

Baskar Vairamohan, PE, CEM
EPRI Project Manager
Technical Leader, Energy Utilization

Adjustable Speed Drive (ASD)

- Other Names of Adjustable Speed Drive (ASD):
  - Variable Speed Drive (VSD)
  - Inverter
  - Voltage Source Inverter (VSI)
  - Adjustable Frequency Drive (AFD)
  - Variable Frequency Drive (VFD)
Types of Adjustable Speed Drives

- DC Motor Drives
- Induction Motor Drives
  - Current Source Inverter
  - Voltage Source Inverter
  - Pulse Width Modulated (PWM) Inverter

Pulse Width Modulated (PWM) ASD

Source Voltage  →  DC Bus Voltage  →  Motor Input Voltage
Constant Speed Control

- Equipment is typically oversized to meet most extreme system requirements
- Motors are upsized to the nearest horsepower about the required for the oversized equipment
- In most cases, full performance is not required by the system
- The motor is usually in continuous full speed operation.

Running a motor at full speed wastes energy ($$$) when full output is not required by the process.

Constant Speed Control Example
Motor Driven Process Using Flow Control Valve

Input kW = HP × 0.746 kW

System Efficiency

Input kW = \(\frac{100 × 0.746}{0.9} = 110.5\ kW\)

Motor Driven Process Using Flow Control Valve

Constant Speed

Required Input Power

110.5 kW (148Hp)

Power Source

Motor

Efficiency 0.90

Pump must overcome pressure losses due to mechanical valve

FCV

Required HP = 100 (74.6kW)

Efficiency 0.75

Input kW = HP × 0.746 kW

System Efficiency

Input kW = \(\frac{100 × 0.746}{0.9} = 110.5\ kW\)
Adjustable Speed Control

- Valves, clutches, brakes, and dampers typically adjust the output of the equipment, wasting energy to varying degrees.
- Variable Speed Drives (a.k.a. Adjustable Speed Drives (ASDs)) save energy by modulating the output of the motor to satisfy the changing system requirements.

ASDs Allow for Energy Efficient Control of Process Outputs

Adjustable Speed Control Example

![Diagram of Adjustable Speed Control System]

- 3Ø, 60 Hz 460 Volt Source
- Flow Element
- FIC
- Motor
- Variable Speed Pump
Adjustable Speed

40.75 kW
(54.6 Hp)

Power Source
Efficiency 0.93

ASD

Motor
Efficiency 0.90

Required HP = 34.4
(25.66 kW)

Input kW = HP x .746 kW
System Efficiency
Input kW = 34.4 x .746 = 40.75 kW

.93 x .9 x .75

Adjustable Speed Power Source Efficiency 0.93 Motor Efficiency 0.90 Required HP = 34.4 (25.66 kW)

Example Losses In System Elements With Mechanical Control Versus ASD Control at four load Levels

<table>
<thead>
<tr>
<th>Loss Type</th>
<th>463/50%</th>
<th>648/70%</th>
<th>832/90%</th>
<th>925/100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>No ASD</td>
<td>8</td>
<td>7</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>With ASD</td>
<td>8</td>
<td>7</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Motor Loss</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Pump and Mechanical Loss</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
ASD Selection Criteria

I) Based on Type of Driven Load:
Do the torque and horsepower requirements of the load decrease with decreasing speed?
- **Good**: Centrifugal fans, pumps, blowers, compressors.
- **Fair**: Other fluid-handling equipment (blenders, screw compressors).
- **Poor**: Conveyor belts, grinders, rollers, winders/un-winders.

II) Based on Variability of Load (Load Duty Cycle):

III) Based on Motor Size:
Larger motors are more likely to be better energy-saving candidates than smaller motors.
- **Good**: Motors rated over 75 HP.
- **Fair**: Motors between 30 HP and 75 HP.
- **Poor**: Motors below 30 HP.

IV) Based on Total Operating Hours:
How many hours does the system operate annually?
- **Good**: More than 6000 hours annually.
- **Fair**: Between 2500 and 6000 hours annually.
- **Poor**: Under 2500 hours annually.
**Decision Tree for Selecting Drives for Application**

1. Are any ratings Poor?
   - Yes: Applications should not be considered for VSD retrofit based on probable energy savings. Consider other benefits.
   - No: Are there more than two ratings of Fair?
     - No: A VSD will likely pay for itself from energy savings alone.
     - Yes: VSD energy analysis is required.

**Screening Methodology**

- Good Candidate for ASD if:
  - High Annual Operating Hours
  - Variable Load Characteristics
  - Moderate To High Horsepower Rating
Example of ASD Application

Required Information

- Motor Horsepower Rating
- Annual Equipment Operating Hours
- Fraction of Time Operate at Less Than Rated Load
- Amount of Flow Variation
**Load Duty Cycle – Excellent Candidate**

Example of an Excellent ASD Candidate

**Load Duty Cycle – Good Candidate**

Example of a Moderate ASD Candidate
Example Findings in Plant

- The combustion blowers on the 5 kilns before the rotating drum dryers all utilize 60hp Motors with a throttling damper.
- Initial tests and measurements show that the operating point for flow, fan is loaded about 50% - therefore a VFD could be more feasible.

Measured Power:
- Voltage: 480 Vac
- Avg Phase Current: 35.6 Amp
- PF (Cos∅): 0.9
- Power (kW) = \(\sqrt{3} \times V \times I \times \text{Cos∅}\) = 26.6kW
Good Drive Candidate: Combustion Blower

\[
\text{ASD Power} = \text{HP} \cdot 0.746 \left( \frac{\text{Flow}}{\text{Max Flow}} \right)^3
\]
ECM – Turn off Blower!

...Combustion blowers are manually controlled via SCADA by operator. Found several instances of hours of “dead heading” a fan with the throttling damper closed.

Turn MOTOR OFF When Damper is Fully Shut!

Candidate 2 – Dryer Blower
Poor Drive Candidate: Dryer Blower

Applications 1 & 2

Application 1
Good deal of time below 70% flow
Good Candidate for AC Drive!

Application 2
Good deal of time above 70% flow
Moderate Candidate for AC Drive

Very little time at or near full flow
Very little time at low flow
Max Flow Vs. ASD Power for Potential Drive Application 1 and 2

Fan is “dead heading”

~ $10,000 to $14,000 per year in savings to apply to all 5 combustion fans.

Payback: 2.43 to 3.47 yrs

Excel Spreadsheet by FE

- Calculate savings for installing a VFD
  - Instructions
  - Project Summary
  - VFD Calculator

VFD Inventory Form (Retrofit & New Construction)
ASD Case Study: Circulating Pump (With and Without ASD)

A) Pump Application with Conventional Throttle Valve

B) Pump Application with Variable Speed Drive (VSD)

ASD Case Study: Circulating Pump (With and Without ASD)
Results of ASD Application

- Criteria evaluation:
  1. Motor Size: 125 hp (Good)
  2. Motor Operating Hours: 5600 hours (Fair)
  3. Type of Load: Pump (Good)
  4. Variability of Load: Operate at 100% (Poor)

Results of ASD Application

- Results:
  - Side by side comparison of identical motors (125 hp)
  - Both motors operate at 100% load
  - NO energy savings
  - Not a correct ASD application

<table>
<thead>
<tr>
<th>Cooling Plant</th>
<th>Rated HP</th>
<th>Voltage (THD%)</th>
<th>Current [A]</th>
<th>Current (THD%)</th>
<th>Power [kW]</th>
<th>Power Factor</th>
<th>Oil Flow (GPM)</th>
<th>ASD Connected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant 1</td>
<td>125</td>
<td>1.3%</td>
<td>105</td>
<td>2.7%</td>
<td>75</td>
<td>0.85</td>
<td>408</td>
<td>No</td>
</tr>
<tr>
<td>Plant 2</td>
<td>125</td>
<td>3.7%</td>
<td>113</td>
<td>67%</td>
<td>76</td>
<td>0.82</td>
<td>346</td>
<td>Yes</td>
</tr>
</tbody>
</table>

No Savings
Innovation in Drives: Common DC Bus Drive Systems

Stand-Alone Drive System (Traditional Approach)
- Fuses
- Line Reactor
- Contactor
- Converter
- Braking Resistor

300 - 400 VAC

Common DC Bus Drive System (Newer Approach)
- Fuses
- Line Reactor
- Contactor
- Rectifier
- Common DC Bus
- Inverters
- Braking Resistor

300 - 400 VAC

Common DC Bus Drive Systems
- Cost effective design:
  - Less cabinet space, less wiring, less assembly time
- Takes advantage of regenerative drive – braking application
  - E.g. Web handling application in paper & pulp industry

185 Amps going through motors

Unwind 45 amps
Idler 15 amps
Nip #1 30 amps
Nip #2 20 amps
Winder 75 amps

Source: Siemens E&A
What are other benefits of ASDs?

Possible other benefits of ASDs are, but not limited to the following:

- Motor life extension
- Reduced motor-starting current
- Increased time between motor rewinds
- Reduced maintenance cost
- Better grade of product or process control
- Regulation and reduction of pollution
- Reduced audible noise (made by mechanical controls)
- Reduced cooling load
- Improved system reliability

Circulator Pump Test: Alpha pump by Grundfos

- Permanent magnet (PM)
- Brushless DC (BLDC) motor
- Micro-processor based, feedback control loop, variable speed operation (suitable for HVAC)
- Price: Comparable to conventional pumps of similar flow rate
Summary

- Advancements in motors and drives help improve productivity by:
  - Reduced energy consumption of existing traditional approach – reduce energy intensity
  - Reduced maintenance times associated with existing systems – e.g. speed reduction through gear Vs. adjustable speed drive
  - Increased reliability of system through reduction of components
  - Solutions available to mitigate harmonics, voltage sags, and other power quality concerns.
Compressed Air Systems

Mark Stephens, PE, CEM, CP EnMS
EPRI Principal Project Manager
Industrial Energy Efficiency & Power Quality Services

Compressed Air System
Compressed Air Systems

- Compressed air is used in many operations and processes and as a source of energy for heating, ventilating, and air conditioning (HVAC) and process actuators and motors.
- It may also be supplied for low pressure systems and used for pneumatic control.
- Air can be compressed in several different ways and supplied at varying pressures and degrees of filtration depending on its use.
- A typical compressed air system is shown in the figure. The example system is capable of producing instrument quality air for pneumatic HVAC controls, tools, conveying systems, and general plant air.
- The system consists of a single motor driven single stage rotary screw compressor with inlet air filter, an after cooler, moisture separator, air receiver, pre-filter, air dryer, after-filter, oil-water traps, and oil-water separator.

Compressed Air Best Practices


  https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/compressed_air_sourcebook.pdf
Appropriate and Inappropriate Use

- **Use** if safety enhancements, significant productivity gains, or labor reductions result (typically 10% to 15% efficient)
  - Pneumatic tools, packaging/automation equipment, conveyors, etc.

- **Inappropriate Uses**
  - Open blowing, sparging, aspirating, atomizing, transporting liquids or light solids, cooling operations, vacuum generation, abandoned equipment
  - Low-pressure blowers may be a more efficient alternative

Ref: EPRI PQ Investigator

Ref: Improving Compressed Air System
Performance: A Sourcebook for Industry, US DOE
Example Inappropriate Use....

- Compressed air found being improperly used to hold open boiler intake damper.
- 90 PSI, ~1/4 dia
  - Estimated Cost ($0.05/kWh)
  - ~$4,500/year in waste

Watch Those Leaks!

- Leaks
  - Keep < 10% of compressor capacity
  - May be calculated as shown
- Establish a Leak Prevention Program
- See [www.eere.energy.gov](http://www.eere.energy.gov)

Leakage (cfm free air) = (V x (P_1-P_2)/T x 14.7) x 1.25

where:
- V is in cubic feet
- P_1 and P_2 are in psig
- T is in minutes

Ref: Improving Compressed Air System Performance: A Sourcebook for Industry, US DOE
Leak Detectors – Ultraprobe 15,000

Example Compressed Air Survey

- Plant has 12 air compressors
  - All Constant Speed
  - 200hp and 125 hp units
    - 94.5% to 95% efficient
  - No trim compressors
- Compressed air used in extensively throughout plant for product positioning in production lines.
Example Compressed Air Survey

- 15 Leaks found in spot survey
  - In compressor rooms
    - At backup compressor connection
    - Around air dryer connections
  - Throughout plant
    - Line "A" (partial walkdown)
    - Adjacent Line (partial walkdown)
  - ~ $7,000-$8,000/year in losses from those identified – likely much higher overall

Pressure and Electricity Costs

- High pressure air costs more to produce than lower pressure air.
- For the example system operating at 100 psig, rule of thumb, every 2 psi equates to a 1% increase in energy costs.

<table>
<thead>
<tr>
<th>Compressor</th>
<th>Annual Operation</th>
<th>Electricity Cost</th>
<th>Motor Efficiency</th>
<th>Annual Electricity Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 hp</td>
<td>8760 hours</td>
<td>0.0734 $/kWh</td>
<td>0.9</td>
<td>$53,296</td>
</tr>
</tbody>
</table>

Annual Electricity Cost $53,296

Bottom Line: Look for opportunities to lower overall system pressure!
Use Outside Air for Compressor Air Make Up

- Air can be compressed more efficiently when the intake air is cooler.
- Rule of Thumb - Power required by air compressor reduces by 1% for every 3°C / 5.4°F drop in inlet air temperature.
- Example: Plant has 200 hp air compressor, 8000 hours/year operation, 95% efficient 
  Average inside air temp = 74 deg F, Average outside air temp = 60 deg F, $0.0734/kWh

<table>
<thead>
<tr>
<th>ECM No.</th>
<th>Bring in Outside Air for Compressor Air Make Up</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Compressed</td>
</tr>
<tr>
<td></td>
<td>Operating Hrs</td>
</tr>
<tr>
<td>Air Compressor Size</td>
<td>Total HP</td>
</tr>
<tr>
<td>Motor Efficiency</td>
<td>0.95</td>
</tr>
<tr>
<td>Compressor Power Usage</td>
<td>kW</td>
</tr>
<tr>
<td>Compressor Diversity</td>
<td>100%</td>
</tr>
<tr>
<td>Load Capacity</td>
<td>75%</td>
</tr>
<tr>
<td>Net Hours Base Loading</td>
<td>5000</td>
</tr>
<tr>
<td>Average Inside Air Temp</td>
<td>74 deg F</td>
</tr>
<tr>
<td>Average Outside Air Temp</td>
<td>60 deg F</td>
</tr>
<tr>
<td>Estimated Electricity Consumption</td>
<td>4.1 kW</td>
</tr>
<tr>
<td>Estimated Yearly Savings</td>
<td>$24,720</td>
</tr>
<tr>
<td># of required intakes</td>
<td>1</td>
</tr>
<tr>
<td>Estimated cost</td>
<td>$1,500</td>
</tr>
<tr>
<td>Utility Incentives</td>
<td>Note if applicable</td>
</tr>
<tr>
<td>Net Estimated Cost</td>
<td>$3,000</td>
</tr>
<tr>
<td>Estimated Payback</td>
<td>1.66 Years</td>
</tr>
<tr>
<td>Estimated Payback</td>
<td>12 Months</td>
</tr>
</tbody>
</table>

Power/Output Relationships by Control Type

- **Blow Off** – To avoid surge, centrifugal compressors may discharge compressed air to the atmosphere to control compressed air output to the system.
  - Blow-off control is the least efficient method of controlling compressed air output, since input power remains constant as the supply compressed air to the system decreases.
- **Modulation Control** – the position of the inlet air valve is modulated from full open to full closed in response to compressor output pressure.
  - Modulation control typically employs PID control with a narrow control range about ± 2 psig. Inlet modulation is a relatively inefficient method of controlling compressed air output.
- **Load/Unload Control** – Load/Unload on control points from 90 psig-100 psig.
  - Power is drawn when unloading (60% to 30%) of full load.
- **Variable-Speed Control** - Rotary-screw air compressors can be equipped with variable frequency drives to vary the speed of the screws and the corresponding compressed air output.
  - As in other fluid flow applications, the variation of speed to vary output is extremely energy efficient.
- **On/Off Control** - The compressor turns on and begins to add compressed air to the system when the system pressure falls to the lower activation pressure. Typical lower and upper activation pressures would be 90 psig and 100 psig.
  - On/off control is the most efficient type of part-load control, since the compressor draws no power when it is not producing compressed air.
Compressed Air Storage

- Stores compressed air until needed
- Use of compressed air storage tanks can
  - Smooth out demand events during peak periods.
    - 2 psi increase in header pressure can lead to 1 to 2 percent higher energy consumption
    - Smoothing out these peaks reduces energy use
  - Control the rate of pressure drop to end use
  - Protect critical pressure applications from other events in the system.
    - Providing some PQ ride-through as well!
    - If plant has storage tanks, PQ issues are normally not an issue with the compressed air

Example Compressed Air Survey

- Air Knifes (many)
  - From main air compressor system
    - ~ $1800+/year
  - From local 1.5kW blower (measured at motors)
    - ~$1,100/Year
- Plant uses air at 100 to 120 psig
  - Potential to lower pressure to reduce energy consumption
  - 10 psig rise in pressure can result in 5% power increase
Chiller Plant Optimization

Energy Saving with BMS/BAS

Chilled Water Systems

- The plant/building Chilled water system can represent a large part of the overall load.
ECM – Reset the Supply Water Temperature

- Increasing the chilled water supply temperature can decrease chiller electricity consumption significantly.

- As a Rule-of-Thumb: **Raise Chilled Water Temp** by 1 deg F for 1.7% decrease in compressor energy consumption.

---

ECM - Reset Chilled Water Temp

<table>
<thead>
<tr>
<th>ECM No.</th>
<th>Raise Chilled Water Temp</th>
<th>(\text{Cost/KWh})</th>
<th>(7.078%) Average With Costs</th>
<th>Operating Temp</th>
<th>(\text{Chiller Tonnage})</th>
<th>(1000) Tons</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0.665</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.6 Based on Type</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chiller Compressor Power Usage</td>
<td>(800) kW</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chiller Efficiency</td>
<td>(100%) Percentage of time chiller on</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Compressor Efficiency</td>
<td>(95%) of time at near full load</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>With/Compressor Usage</td>
<td>(400)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Current Chilled Water Temp</td>
<td>(42) Deg F</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Proposed Chilled Water Temp</td>
<td>(35) Deg F</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Estimated Electricity Consumption Decrease</td>
<td>(228) KW</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>With/Refrigerant</td>
<td>135,708</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Available Capacities:
- Reversing machines are manufactured in capacities from 0.5 to 150 TR.
- Air-cooled **reversing** chillers have an energy usage of 1.2–3.5 W/kWh.
- Air-cooled screw chillers are available with cooling capacities between 70 tons and 500 tons and energy usage between 1.1 and 1.5 W/kWh. Water-cooled screw chillers are available with cooling capacities between 10 tons and 750 tons and energy usage between 0.65 and 1.4 W/kWh.
- Centrifugal chillers are generally manufactured in capacities from 40 to 1,000 tons, with most units falling in the range of 100 to 300 tons. Centrifugal compressor chillers are the most energy-efficient chillers with energy usage between 0.5 and 0.8 W/kWh.
ECM- Reduce Condenser Water Temperature

- Chillers operate more efficiently when the condensers are provided with cooler water.
- As a Rule-of-Thumb, for every 1 deg. F temperature drop in condensing water temp, a 1% savings can be expected.
- This is accomplished by changing the cooling tower water temp set point.

---

ECM- Reduce Condenser Water Temperature

<table>
<thead>
<tr>
<th>ECM No.</th>
<th>Reduce Condenser Water Temp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost/Wh</td>
<td>EPRI/Passage/UP-Cons</td>
</tr>
<tr>
<td>Operating Efficiency</td>
<td>87%</td>
</tr>
<tr>
<td>Chiller Efficiency</td>
<td>100% Total Tons</td>
</tr>
<tr>
<td>kWh/ton</td>
<td>1.5 based on type</td>
</tr>
</tbody>
</table>

- Chiller Compressor Power Usage: 120kW
- Chiller Efficiency: 92%
- Percent of time chiller is on
- Compressor Efficiency: 90% of time or near full load
- kW/Refrigeration Capacity: 48kW
- Current Cooling Tower Setpoint: 85 deg F
- Proposed Cooling Tower Setpoint: 83 deg F
- Estimated Average Temperature Reduction: 2 deg F
- Est. Chiller Electrical Consumption Decrease: 30kW
- kW (pre-survey) 181,480

- Estimated Yearly Savings: $5,515
- Estimated Payback: 6 months

- Plant must check chiller mfr make sure that proposed set point is not below the min recommended condenser water setting.
Use of ASDs on Chillers

From York Optispeed Literature

(1-3 year payback)

U.S. Landscape of Large Commercial Space Conditioning

Total Floorspace of U.S. Commercial Buildings Over 100,000 ft² Containing Cooling Equipment (billion ft²)

- Chilled Water Systems: 16
- Packaged AC: 18
- Split AC: 1.5
- Individual AC: 5

*Source: Commercial Building Energy Consumption Survey 2012.*
Where are Chilled Water Systems?

**Commercial Buildings...**
- Large to Massive
- Multi-Story to High Rise
- Campus Applications

**% Floorspace by Building Size**

<table>
<thead>
<tr>
<th>Building Size (ft²)</th>
<th>U.S. Floorspace</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,001 to 10,000</td>
<td>0%</td>
</tr>
<tr>
<td>10,001 to 25,000</td>
<td>5%</td>
</tr>
<tr>
<td>25,001 to 50,000</td>
<td>10%</td>
</tr>
<tr>
<td>50,001 to 100,000</td>
<td>21%</td>
</tr>
<tr>
<td>100,001 to 200,000</td>
<td>26%</td>
</tr>
<tr>
<td>200,001 to 500,000</td>
<td>49%</td>
</tr>
<tr>
<td>Over 500,000</td>
<td>60%</td>
</tr>
</tbody>
</table>

*Source: CBEC 2015 Data for Central Chillers

**% Floorspace by Floors**

<table>
<thead>
<tr>
<th>Number of Floors</th>
<th>U.S. Floorspace</th>
</tr>
</thead>
<tbody>
<tr>
<td>One</td>
<td>6%</td>
</tr>
<tr>
<td>Two</td>
<td>16%</td>
</tr>
<tr>
<td>Three</td>
<td>27%</td>
</tr>
<tr>
<td>Four to nine</td>
<td>45%</td>
</tr>
<tr>
<td>Ten or more</td>
<td>73%</td>
</tr>
</tbody>
</table>

**% Floorspace by Building Use**

<table>
<thead>
<tr>
<th>Building Use</th>
<th>U.S. Floorspace</th>
</tr>
</thead>
<tbody>
<tr>
<td>Education</td>
<td>35%</td>
</tr>
<tr>
<td>Health care</td>
<td>59%</td>
</tr>
<tr>
<td>Inpatient</td>
<td>79%</td>
</tr>
<tr>
<td>Outpatient</td>
<td>33%</td>
</tr>
<tr>
<td>Lodging</td>
<td>29%</td>
</tr>
<tr>
<td>Office</td>
<td>32%</td>
</tr>
<tr>
<td>Public order</td>
<td>30%</td>
</tr>
</tbody>
</table>

Typical Air-Cooled Chilled Water System

**Outside**
- Heat Rejection
- Chiller ABC
- Chiller XYZ

**Occupied Space**
- Chilled Water
  - Chilled Water Pumps
- Fan Coil
- Space Cooling

**Electricity Consumers**
- Compressors in Chillers
- Fans in Chillers
- Water Pumps
- Blowers in Fan Coils
Typical Water-Cooled Chilled Water System

Electricity Consumers:
- Compressors in Chillers
- Water Pumps
- Fans in Cooling Tower
- Blowers in Fan Coils

Utility Programs for Chilled Water Systems

- Utilities commonly have programs for:
  - Variable Speed Drives (VSDs) on Chilled Water Components
  - Air-Cooled and Water-Cooled Chillers
- Programs are mix of deemed and custom

Requirement or Option of Variable Speed Drives (VSDs) on Chilled Water Components in ASHRAE 90.1

<table>
<thead>
<tr>
<th>ASHRAE 90.1</th>
<th>Chilled Water System Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>1989</td>
<td>Chilled Water Pump</td>
</tr>
<tr>
<td>1999</td>
<td>Cooling Tower Fan</td>
</tr>
<tr>
<td>2010</td>
<td>Chillers</td>
</tr>
<tr>
<td>2013</td>
<td>Condenser Water Pump</td>
</tr>
</tbody>
</table>

Source: Trane All Variable Speed Chiller Plants Newsletter
## Example of Custom Utility Program for Chillers

### Starting Place: Chiller above ASHRAE 90.1 Level

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Size Category</th>
<th>Units</th>
<th>Path A</th>
<th>Path B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Full load</td>
<td>IPLV</td>
</tr>
<tr>
<td>Air cooled, with condenser, electrically operated</td>
<td>&lt;150 tons</td>
<td>EER</td>
<td>≥9.562</td>
<td>≥12.50</td>
</tr>
<tr>
<td></td>
<td>≥150 tons</td>
<td>EER</td>
<td>≥9.582</td>
<td>≥12.75</td>
</tr>
<tr>
<td>Water cooled, elec. operated, positive displacement,</td>
<td>&lt;75 tons</td>
<td>kW/ton</td>
<td>≤0.780</td>
<td>≤0.630</td>
</tr>
<tr>
<td>or reciprocating</td>
<td>75-150 tons</td>
<td>kW/ton</td>
<td>≤0.775</td>
<td>≤0.615</td>
</tr>
<tr>
<td></td>
<td>150-300 tons</td>
<td>kW/ton</td>
<td>≤0.680</td>
<td>≤0.580</td>
</tr>
<tr>
<td></td>
<td>≥300 tons</td>
<td>kW/ton</td>
<td>≤0.620</td>
<td>≤0.540</td>
</tr>
</tbody>
</table>

**Source:** ConEdison Green Team 2014

EER = Energy Efficiency Ratio  
IPLV = Integrated Part-Load Value  
kW/ton = kW (electrical) per ton (cooling)

## Advanced Technologies

- All Variable Speed Air-Cooled Chiller
- Water-Cooled, Magnetic Bearing Chiller
- Low Global Warming Refrigerant Chiller
- Advanced Designs for Cooling Towers
- Real-Time, Relational Chiller Optimization
- Induction Chilled Beam
Water-Cooled Magnetic Bearing Chillers

- Magnetic Bearings
  - Levitate the shaft and impeller within a compressor
  - Eliminate resistance and thereby increase efficiency
  - Eliminate oil, oil accessories, and potential degradation
- Currently, magnetic bearings are applied to centrifugal compressors in water-cooled equipment

Low GWP Refrigerant Chillers

- Chillers utilize refrigerant with either a higher Global Warming Potential (GWP) or Ozone Depletion Potential (ODP)
- One commonly used refrigerant R123 is set to be banned in 2030, however alternatives are in place

<table>
<thead>
<tr>
<th>Refrigerant</th>
<th>R123</th>
<th>R1233zd</th>
<th>R134a</th>
<th>R1234ze</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application for Chillers</td>
<td>In Use</td>
<td>Alternative to R123</td>
<td>Widely Used</td>
<td>Alternative to R134a</td>
</tr>
<tr>
<td>Global Warming Potential</td>
<td>77</td>
<td>6</td>
<td>1370</td>
<td>6</td>
</tr>
<tr>
<td>Ozone Depletion Potential</td>
<td>0.01</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Banned Production</td>
<td>2030</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>
Real-Time, Relational Chiller Plant Optimization

- All variable speed chiller plants not uncommon. Each component has flexibility – what’s the optimal point of operation?

- Traditional chiller plant control may seek to maximize each component independently.

- Real-time, relational optimization seeks to optimize entire plant efficiency.

Building Management System (BMS) / Building Automation System (BAS)

- Beyond thermostat adjustments
  - Control heating and cooling parameters by time of day, building occupation, etc.
  - Modify operation of chilled water systems, HVAC systems, etc.
  - Increased effectiveness with VFD-controlled motors
    - Adjust motor speed according to set parameters or changing conditions
Example: Building Management Software from Johnson Controls (two varieties)

- **Central Plant Optimization™ 10 - Metasys**
  - Claims 5-15% compared to bldg. with standard automation
  - Set point adjustments made programmatically

- **Central Plant Optimization™ 30 – Optimum Energy**
  - Claims 15-20% with software only
  - Set point adjustments made continuously, in real time

---

**Induction Chilled Beams**

- Integrates ventilation and space conditioning system

- Outdoor Air System provides the induction of the room over the chilled water coil

- Improvements in nozzle design allow for improved efficiency over older induction systems
PC Power Management

Mark Stephens, PE, CEM, CP EnMS
EPRI Principal Project Manager
Industrial Energy Efficiency & Power Quality Services

Products

• PC Power Management
  – Put Computers in Stand-by/Sleep/Hibernate/Shut Down, etc
  – Claims savings of $40-$60 per desktop per year
  – Claims ROI within 3 Months, “savings pay for product”

• Patch and Application Manager
  – Microsoft
  – 3rd party (Adobe, Java, Chrome, etc.)
  – Custom application patches

• End Point Manager
  – Software and Hardware Asset Management
  – Software license compliance
  – White and Black Listing
  – Remote Desktop access
  – Imaging

For More Info:
Alexa Rodrigues
Alexa@autonomic-software.com
WHO IS AUTONOMIC SOFTWARE?

McAfee SIA – “SIA Partner of the Year, 2011” and “SIA Most Valuable Partner of the Year, 2013”
Entergy – Autonomic Software wins “Exceptional Partner of the Year”

Arkansas School Districts PC Power Management Program

The following took place over a 12-month period:
• 70 Schools, Gov’t buildings and Corps have Signed Up for PC Power Manager and Were Installed
• Arkansas will save over 4.5 Million Dollars over the next year just on PC Power Usage
• Reduction of over 30,000,000 kWh for the Utility Companies Entergy and SWEPCO
• Savings in Other States include... Oregon, California, Nevada, Missouri, Ohio, and Utah
Typical School District PC Power Management Program Results

- Drive Down Cost Per Node
- Reduce Power Costs $40-$60 Per Node Per Year
- Control when computers are on, in standby, or shutdown

878 Computers - Monthly kWh Consumption

Example of First Energy's Program Website
Example of First Energy’s Program Website
Possible Savings

- Available for offices, schools, hospitals, other commercial buildings (FirstEnergy's Pennsylvania utilities)
- Automatically places computer in low-power sleep mode
- Tracks PC energy costs over time

<table>
<thead>
<tr>
<th>Number of Workstations</th>
<th>Potential Rebate Amount*</th>
<th>Estimated Annual Energy Savings (kWh)</th>
<th>Estimated Annual Energy Cost Savings††</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>$1,250</td>
<td>25,000</td>
<td>$2,000</td>
</tr>
<tr>
<td>500</td>
<td>$5,250</td>
<td>$125,000</td>
<td>$10,000</td>
</tr>
<tr>
<td>1,000</td>
<td>$12,500</td>
<td>250,000</td>
<td>$20,000</td>
</tr>
</tbody>
</table>

- Based on PC power management software rebate available to FirstEnergy's Pennsylvania utilities, non-residential customers
  - Assumes the average energy savings to be 250 kWh/year for a single PC workstation (including computer and monitor) at $0.08/Kwh

80 Plus Program
What is 80 PLUS?

80 PLUS: is a brand designed to be an integral building block in the creation of best-in-class energy efficient electronic systems.
## What is 80 PLUS Badge Level Certified?

<table>
<thead>
<tr>
<th>80 PLUS Certification</th>
<th>115V Internal</th>
<th>230V Internal</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of Rated Load</td>
<td>10% 20% 50% 100%</td>
<td>10% 20% 50% 100%</td>
</tr>
<tr>
<td>80 PLUS</td>
<td>80% 80% 80% / PFC.90</td>
<td>--- --- ---</td>
</tr>
<tr>
<td>80 PLUS Bronze</td>
<td>82% 85% / PFC.90</td>
<td>82% 81% 85% / PFC.90</td>
</tr>
<tr>
<td>80 PLUS Silver</td>
<td>85% 88% / PFC.90</td>
<td>85% 85% 89% / PFC.90</td>
</tr>
<tr>
<td>80 PLUS Gold</td>
<td>87% 90% / PFC.90</td>
<td>87% 88% 92% / PFC.90</td>
</tr>
<tr>
<td>80 PLUS Platinum</td>
<td>90% 92% / PFC.95</td>
<td>90% 90% 94% / PFC.95</td>
</tr>
<tr>
<td>80 PLUS Titanium</td>
<td>90% 92% / PFC.95</td>
<td>94% 90% 94% / PFC.95</td>
</tr>
</tbody>
</table>

## What is 80 PLUS Badge Level Certified – New

<table>
<thead>
<tr>
<th>80 PLUS Certification</th>
<th>115V Industrial</th>
<th>230V EU</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of Rated Load</td>
<td>10% 20% 50% 100%</td>
<td>10% 20% 50% 100%</td>
</tr>
<tr>
<td>80 PLUS</td>
<td>--- --- --- ---</td>
<td>82% 85% / PFC.90 82%</td>
</tr>
<tr>
<td>80 PLUS Bronze</td>
<td>--- --- --- ---</td>
<td>85% 88% / PFC.90 85%</td>
</tr>
<tr>
<td>80 PLUS Silver</td>
<td>80% 85% / PFC.90 88% 85%</td>
<td>87% 90% / PFC.90 87%</td>
</tr>
<tr>
<td>80 PLUS Gold</td>
<td>82% 87% / PFC.90 90% 87%</td>
<td>90% 92% / PFC.90 89%</td>
</tr>
<tr>
<td>80 PLUS Platinum</td>
<td>85% 90% / PFC.95 92% 90%</td>
<td>92% 94% / PFC.95 90%</td>
</tr>
</tbody>
</table>
| 80 PLUS Titanium      | --- --- --- --- | 90% 94% / PFC.95 96%
**EPRI Laboratory Role**

A. It is a test area for measuring the electrical efficiency of all types of power supplies used in residential, commercial, and industrial applications.

Expanded list: computer, server, storage, secondary, gaming, set top box, industrial, ballasts, battery charging, televisions, external, uninterruptible, European computers, LED street lights, redundant, DC, workstation, slot machine, kiosk, home audio.

**Test Facilities**

A. Within EPRI’s facility in Knoxville, TN.

Test stand for multi-output power supplies

Test stand for single-output power supplies
Testing Methods

1. The laboratory for efficient power supplies has as a reoccurring client, the company Ecova, which manages the 80PLUS program.
2. The laboratory provides the testing results and Ecova provides the certification.
3. The laboratory manages and updates the generalized test procedure, builds and maintains two customized test stands and a quality procedure as well as partners with others within EPRI for supplemental projects.

EPRI Involvement

A. EPRI has been involved in power supply testing since 2002.

- 2002
- 2003
- 2004
- 2005
- 2006
- 2007
- 2008
- 2009

- External Power Supplies
- Efficiency Challenge
- Internal Power Supplies
- 80 Plus
- Ongoing
- Battery Chargers
- Secondary Power Supplies
- UPS
- Server Power Supplies
- Ongoing
- DC Data Centers
- Industrial Power Supplies
- Ongoing

EPRI Power Supply Research
Why is EPRI Involved?

- **Initial Need**
  - In the early 2000s, EPRI helped discover that power supplies were differentiated by price, not by performance. Moreover, the initial efficiency was low (<70%) and for an incremental cost manufacturers could supply a product that exceeded 80% efficiency.

- **Startup Need**
  - In 2003, Ecova approached EPRI and asked for help in launching a program to certify power supplies based on performance with the hope of transforming the market from one of inefficiency to one of high efficiency.
  - EPRI possessed the technical expertise and recognized a need for a world-class laboratory to champion the cause of market transformation.

- **Ongoing Need**
  - New models are developed almost every day and manufacturers continue to compete to rank among the best-in-class for efficiency. Also, building upon its success in transforming the market for computers and servers, EPRI has targeted additional use areas for power supplies that are in various stages of transformation.
Seminar Review

**10:00 AM Kickoff**
- Making Energy Management Part of Your Culture
- Upgrading Lighting and Controls
- Premium Efficiency Motors and Application of Adjustable Speed Drives

**12:00-12:45 PM Lunch**
- Compressed Air Best Practices
- Chiller Plant Optimization
- PC Power Management
- MetEd Program Description (30 Minutes)

**Adjourn 3:00 PM**
Together…Shaping the Future of Electricity
“Racing to the Finish Line”
Energy Efficiency Rebates Under Phase 2

FirstEnergy’s Pennsylvania Utilities
PA Act 129

PHASES I, II, III

PA Law
Incentives for Eligible Measures

PA Law : Act 129 ?

- 2008 PUC mandates Energy Efficiency Programs

- State legislation requiring permanently reduce electricity demand over time across residential, commercial & industrial sectors
PA Law: How Does it Work?

- **PA Public Utility Commission (PA PUC) sets energy efficiency goals**, rules & penalties for non-compliance
  - Spending Cap Set at 2% of 2006 Annual Revenues
  - Utilities Develop and Submit Plans to PUC
  - Plan Submission States Developed Budget for Each Program in Plan
  - PUC Reviews and Approves Plans

PA Law: How is it Funded?

- **Funded by Surcharges on Electricity Bill**
  - Surcharges are set by Rate Class
  - **Utilities re-distribute** surcharges as **rebates** to support customer energy efficiency projects
  - Program Budgets are Finite
**PA Act 129: Timeline**

- **Phase I**: Nov 2009 -- May 31, 2013
- **Phase II**: June 1, 2013 -- May 31, 2016
- **Phase III**: June 1, 2016 -- May 31, 2021

---

**PA Act 129 Phase II Incentives**

- **Variable Rebates**
  - Rebates of **5¢ per kWh saved**
  - **EXCEPTION**: Penn Power large C&I equipment rebate reduced to **3¢ per kWh** as of June 1, 2015
  - Combined Heat & Power (CHP) projects: **3.5¢ per kWh saved**

- **Prescriptive Rebates**
  - HVAC / Specialty Equipment / LED Exit Signs
  - LED Traffic Signals / Lighting Controls

- **Incentive caps**:
  - Lighting: Projects Capped at cost of materials
  - Custom Projects: Capped at 50% of total project cost

---

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PA Act 129 Phase II Energy - Efficient Projects Eligible

- **Interior Lighting Equipment & Controls**
  (occupancy sensors, timer controls, replacing T12 with T8, or metal halides with T5, etc.... LED)

- **Exterior Lighting Equipment & Controls**
  (retrofitting to LED lighting, occupancy-based controls, etc.)

- **Lighting Updates:**
  - T12 – Phase out on June 1, 2016 (Phase III)
  - SSL – PA State Requirement

- **HVAC Systems & Controls**
  (i.e. heat pumps, PTAC unit, hotel room HVAC controls, dual enthalpy economizers, building automation systems, etc.)

- **Kitchen Equipment**
  (i.e. convention ovens, pre-rinse sprayers, ENERGY STAR® steam cookers, fryers, etc.)

---

PA Act 129 Phase II Energy - Efficient Projects Eligible

- **PC Power Management**
  (energy management features for PCs in an idle state)

- **Refrigeration**
  (i.e. ECM motors, ENERGY STAR® doors, refrigerators, freezers & anti-sweat controls)

- **Buildings Program**
  - Renovations
  - New Construction
  - Buildings Automation & Controls

- **Custom Program**
  - Industrial Process
  - Chiller Replacement
  - Variable Frequency Drives (non HVAC Applications)
  - Compressed Air Systems

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Phase II Program Availability Status

- Small C&I
  - Buildings Program : Funds Available
  - Equipment Program : Funds Available

- Large C&I
  - Buildings Program : Funds Available
  - Equipment Program : Funds Available

- Governmental Program : Funds Available

Met-Ed Governmental, Non-profit & Institutional Customers (GNI)

SPECIAL PROGRAMS

- Met-Ed Customer BONUS Program for GNI Projects
- Met-Ed Program Ally BONUS Program for GNI Projects
- Met-Ed Direct Install Program for GNI Projects
New BONUS for Met-Ed Customers

For Governmental, Non-Profit and Institutional Projects

Beginning August 1, 2015, the incentive for lighting and custom measures1 will change to the amounts shown in the table below:

<table>
<thead>
<tr>
<th>Period</th>
<th>Current Incentive</th>
<th>Customer Bonus</th>
<th>Total Incentive</th>
</tr>
</thead>
<tbody>
<tr>
<td>August 1 – September 30, 2015</td>
<td>5¢ / kWh</td>
<td>4¢ / kWh</td>
<td>9¢ / kWh</td>
</tr>
<tr>
<td>October 1 - November 30, 2015</td>
<td>5¢ / kWh</td>
<td>3¢ / kWh</td>
<td>8¢ / kWh</td>
</tr>
<tr>
<td>December 1 – January 31, 2016</td>
<td>5¢ / kWh</td>
<td>2¢ / kWh</td>
<td>7¢ / kWh</td>
</tr>
</tbody>
</table>

1 Prescriptive measures and Direct Install measures are NOT eligible for bonus incentive.
2 This is a limited time offer starting August 1, 2015, and may be withdrawn or modified at any time.

For Governmental, Non-Profit and Institutional Projects

- **Projects** must be pre-approved starting October 1, 2015, and meet all necessary program requirements according to the letter of pre-approval.

- **Customers** have 90 days from the pre-approval date to complete installation and submit paperwork in order to qualify for this bonus incentive program. It is important to note the bonus incentive is based on pre-approval date, not the application submitted date.

- If the application is not complete in 90-days, the bonus will drop to the active bonus incentive level, which may be zero.
Met-Ed Customer BONUS Requirements

For Governmental, Non-Profit and Institutional Projects

- All applications must be submitted via FirstEnergy’s Pennsylvania utilities’ online application portal.
- New applications for completed projects that fall within the 180-day look-back period may also qualify for this bonus incentive program.
- Only non-prescriptive measures qualify for this bonus.
- Recommend submit applications before the 15th of the month to allow time for processing and approval.

New BONUS for Met-Ed Program Allies

For Governmental, Non-Profit and Institutional Projects

Met-Ed is offering a bonus incentive to program allies for governmental, institutional (includes schools, institutions of higher education and hospitals), and non-profit (GNI) projects only. Beginning August 1, 2015, the program ally bonus incentive for non-prescriptive measures is shown in the table below:

<table>
<thead>
<tr>
<th>Pre-approval Period</th>
<th>Program Ally Bonus</th>
</tr>
</thead>
<tbody>
<tr>
<td>August 1 – August 31, 2015</td>
<td>4 ¢ / kWh</td>
</tr>
<tr>
<td>September 1 - September 30, 2015</td>
<td>3 ¢ / kWh</td>
</tr>
<tr>
<td>October 1 – October 31, 2015</td>
<td>2 ¢ / kWh</td>
</tr>
</tbody>
</table>

1 Prescriptive measures and Direct Install measures are NOT eligible for bonus incentive.
2 This is a limited time offer starting August 1, 2015, and may be withdrawn or modified at any time.
Note: Total of Customer incentive plus Program Ally incentive cannot exceed the material cost for lighting or 50% of the project cost for custom measures.
For Governmental, Non-Profit and Institutional Projects

- All applications must be submitted via FirstEnergy’s Pennsylvania utilities’ online application portal. Note, bonus incentive is based on pre-approval date, not the application submitted date. Recommend submit applications before the 15th of the month to allow time for processing and approval.

- New applications for completed projects that fall within the 180-day look-back period may also qualify for this bonus incentive program. Only non-prescriptive measures qualify for this bonus and maximum program ally bonus incentive for any customer site is $20,000. Program incentive limits apply.

For Governmental, Non-Profit and Institutional Customers

- Surveys at no additional cost to identify and prioritize energy efficiency opportunities specific to your facility
- Reduced monthly utility costs – long term savings
- Program covers up to 80% of the cost to install energy savings measures, up to $6,000
- Increased efficiency of facility and improved comfort
Met-Ed Direct Install Program cont.

For Governmental, Non-Profit and Institutional Customers

Opportunities include:

- PC power management
- Lighting and lighting controls
- Refrigeration: auto closers, evaporator fan controllers, strip curtains, etc.
- High-efficiency evaporator fan motors
- VSDs on kitchen exhaust fan
- ECM circulating fan
- Low flow pre-rinse sprayers
- Smart strip plug outlets

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<table>
<thead>
<tr>
<th>Measure</th>
<th>Unit</th>
<th>Estimated Annual Energy Savings (kWh)*</th>
<th>Estimated Annual Energy Cost Savings**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto closers for walk-in coolers</td>
<td>per cooler/freezer</td>
<td>981 kWh (cooler) 2,348 kWh (freezer)</td>
<td>$74 (cooler) $176 (freezer)</td>
</tr>
<tr>
<td>Door gasket replacement for walk-in cooler</td>
<td>per door</td>
<td>360 kWh (cooler) 1,280 kWh (freezer)</td>
<td>$22 (cooler) $96 (freezer)</td>
</tr>
<tr>
<td>EC evaporator fan motor replacement for walk-in refrigerators</td>
<td>per fan</td>
<td>1,105 kWh</td>
<td>$83</td>
</tr>
<tr>
<td>Anti-sweat heater controls for refrigerated glass display cases</td>
<td>per door</td>
<td>981 kWh</td>
<td>$74</td>
</tr>
<tr>
<td>Insulation for refrigeration compressor suction pipes</td>
<td>per 10' of pipe</td>
<td>200 kWh</td>
<td>$15</td>
</tr>
</tbody>
</table>

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### Met-Ed Direct Install Program cont.

<table>
<thead>
<tr>
<th>Lighting Measures</th>
<th>Estimated Annual Energy Savings (kWh)*</th>
<th>Estimated Annual Energy Cost Savings**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replacing T12 lamps with T8 linear fluorescent lamps</td>
<td>Per 4-lamp 424 kWh</td>
<td>$32</td>
</tr>
<tr>
<td>Replacing 250-watt metal halide canopy lights with 86-watt LED lamps</td>
<td>Per fixture 900 kWh</td>
<td>$68</td>
</tr>
<tr>
<td>Replacing 60- to 100-watt recessed incandescent or halogen bulbs with 15- to 26-watt fluorescent bulbs</td>
<td>Per bulb 160–230 kWh</td>
<td>$12–$17</td>
</tr>
<tr>
<td>Replacing incandescent exit signs with LED exit signs</td>
<td>Per sign 75 kWh</td>
<td>$6</td>
</tr>
<tr>
<td>Installing occupancy sensors in low-usage areas such as bathrooms</td>
<td>Per sensor 280 kWh</td>
<td>$21</td>
</tr>
</tbody>
</table>

---

### Funds to help pay for energy efficiency projects

**REBATES & GRANTS**

- **PA Small Business Administration Grants**
- **Sustainable Energy Fund**
- **Other Sources of Funding**

www.energysavePA-business.com
PA DEP Small Business Grants

• PA Department of Environmental Protection offers Small Business Advantage Grants
• 2015 Small Business Advantage Grant Program
  ▪ Less than 100 employees, for-profit company
  ▪ 50% matching grant, up to $9,500
  ▪ Energy efficient equipment or processes
  ▪ 2015 SBAG applications for project costs incurred on or after July 27, 2015
  ▪ [www.portal.state.pa.us/portal/server.pt/community/small_business_ombudsman/10493](http://www.portal.state.pa.us/portal/server.pt/community/small_business_ombudsman/10493)

PA DEP Small Business Loan

• Pollution Prevention Assistance Account (PPAA) Loan Program
  ▪ [www.portal.state.pa.us/portal/server.pt/community/financial_assistance/10495/ppaa_loan/553247](http://www.portal.state.pa.us/portal/server.pt/community/financial_assistance/10495/ppaa_loan/553247)
  ▪ Low interest loans to small businesses undertaking projects that reduce waste, pollution or energy use.
    ▪ Loans fund up to 75 percent of the total eligible project cost.
    ▪ Maximum loan amount is $100,000 within any 12-month period.
    ▪ Small businesses with 100 or fewer full-time employees are eligible.
    ▪ The interest rate for the loan will be 2% and remain fixed for the duration of the repayment term. Maximum loan term is 10 years.
Other Funding Opportunities - DSIRE

- Database of State Incentives for Renewables & Efficiency (DSIRE)
  - www.dsireusa.org
  - DSIRE is the most comprehensive source of information on incentives and policies that support renewable energy and energy efficiency in the United States. Established in 1995, DSIRE is operated by the N.C. Clean Energy Technology Center at N.C. State University and is funded by the U.S. Department of Energy.

Other Funding Opportunities - HPB

- PA Department of Community and Economic Development (DCED) Loan or Grant
- High Performance Building Program (HPB)
  - Requires LEED Certification or National Green Buildings Standards to be met
  - Loans: Loans for high performance building projects shall not exceed $2 million. Loans for individual residence projects shall not exceed $100,000.
  - Grants: Grants for high performance building projects shall not exceed $500,000 or 10% of the total eligible building construction/renovation costs, whichever is less.
  - www.community/newpa.com/programs/high-performance-building-program-hpb
Other Funding Opportunities - FCVAS

- Volunteer Fire Company Grants (FCVAS)
  - Available to all fire companies, volunteer ambulance services and volunteer rescue squads
  - Eligible projects include facilities construction or renovation, equipment, debt reduction and training
  - Grant application available online in September of each year the week following Labor Day
  - Grant Award: $2,500 - $15,000
  - [www.portal.state.pa.us/portal/server.pt/community/volunteer_fire_company_and_volunteer_ambulance_service_grant_program/9188](http://www.portal.state.pa.us/portal/server.pt/community/volunteer_fire_company_and_volunteer_ambulance_service_grant_program/9188)

Sustainable Energy Funds

- Four funds were created as a result of the restructuring plans of five electric companies.
- The funds are designed to promote the development of sustainable and renewable energy programs and clean-air technologies on both a regional and statewide basis.
- The funds have provided more than $20 million in loans and $1.8 million in grants to over 100 projects.
- A Statewide Sustainable Energy Board was formed in 1999 to enhance communications among the four funds and state agencies.
- The board includes representatives from the Commission; the Department of Environmental Protection; the Department of Community and Economic Development; the Office of Consumer Advocate; the Pennsylvania Environmental Council; and each regional board.
### Sustainable Energy Funds

- The four renewable and sustainable energy funds include:
  - Sustainable Energy Fund PPL
    - [http://www.thesef.org](http://www.thesef.org)
  - The Reinvestment Fund Sustainable Development Fund PECO
    - [http://www.trfund.com/](http://www.trfund.com/)
  - Met-Ed/Penelec Sustainable Energy Fund Met Ed / Penelec Penn Power
    - [www.metedpenelecsef.org](http://www.metedpenelecsef.org)
  - West Penn Power Sustainable Energy Fund West Penn Power
    - [www.wppsef.org](http://www.wppsef.org)

---

### Program Resources

**WE’RE HERE TO HELP**

www.energysavePA-business.com
Application Requirements

- Apply online at https://first-energy.clearesult.com
- Pre-approval
- Submit within 180-days of Installation & Operability
- Signed letter of attestation
- Documentation
- Measure & verification

Post-Installation Data Monitoring for:
- Lighting Projects greater than 500 MWh
- All other projects greater than 250 MWh

Program Resources

- Website = www.energysavepa-business.com
- Calculators and Application
- Solutions by Facility Type
- Program Ally Resources
- Eligibility and Documentation Requirements
Help Through the Application Process

CLEAResult Team

Lancaster: Mid-Atlantic Operations
Reading: Met-Ed
Johnstown: Penelec
Greensburg: Penn Power & West Penn Power

Each office provides access to:
• Program Manager
• Energy Engineers
• Program Support Staff
• Outreach Consultants
• Access to CLEAResult’s experts

Website: energysavePA-business.com
Email: energysavepa@clearesult.com
Phone: 866-554-4430
Fax: 888-838-4193

Phase III – What to Expect?

PA PUC issued a final implementation order June 2015

<table>
<thead>
<tr>
<th>Process</th>
<th>Due Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plan Filing Due</td>
<td>November 30, 2015</td>
</tr>
<tr>
<td>Evidentiary Hearing</td>
<td>January / February 2016</td>
</tr>
<tr>
<td>Commission Rules on Plan</td>
<td>March 2016</td>
</tr>
<tr>
<td>EE&amp;C Programs Begin</td>
<td>June 1, 2016</td>
</tr>
</tbody>
</table>
Questions?