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US Department of Energy Federal Energy Management Program Energy Treasure Hunt Toolkit

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March 2024

OAK RIDGE National Laboratory

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Manufacturing Science Division

US DEPARTMENT OF ENERGY FEDERAL ENERGY MANAGEMENT PROGRAM ENERGY TREASURE HUNT TOOLKIT

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ABSTRACT

The US Department of Energy's Federal Energy Management Program (FEMP) aims to assist federal agencies and their stakeholders with their energy-focused goals, opportunities, and barriers. The program offers various technical trainings and resources to its stakeholders. One of these resources is an energy treasure hunt program. This report presents the FEMP energy treasure hunt toolkit, a technical resource designed for systematic application for federal facilities seeking to optimize their energy and carbon usage. The toolkit was designed to help facilitate energy-focused kaizen events, identify energy-saving recommendations, analyze identified opportunities, and provide the tools needed to detect actionable projects to advance federal facilities. Through a collaboration with the Oak Ridge National Laboratory team that executed the industrial-focused Better Plants energy treasure hunt program, a similar treasure hunt toolkit was designed for FEMP. The purpose of this report is to provide an overview of the treasure hunt process and FEMP toolkit capabilities.

1. INTRODUCTION

The US Department of Energy's (DOE's) Federal Energy Management Program (FEMP) aims to assist federal agencies and their stakeholders with their energy-focused goals, opportunities, and barriers. The program offers various technical trainings and resources to its stakeholders. One of these resources is an energy treasure hunt (TH) program [1].

Energy THs, or energy kaizens, refer to continuous-improvement events specifically focused on energy-reduction project identification, analysis, and communication. An energy TH is a 2- or 3-day event that focuses on operational improvements that can improve energy efficiency, including recommendations such as turning off motors when not in use and replacing lights with more efficient options. A TH typically finds 'low-hanging fruit' that tend to have low capital cost and a quick payback. A TH should be considered not an energy audit but rather a continuous cycle conducted by those closest to the process. A site should consider having a TH multiple times a year.

The FEMP team has recognized another federal program that has had great success with a TH program, the Better Plants (BP) program. The BP program partners with industrial companies within the United States to set long-term strategic energy efficiency goals. Part of this partnership includes technical assistance such as workforce development [2]. The BP program has been conducting TH trainings since its inception. To help their industrial partners, the BP program has selectively conducted THs to train site personnel with the goal of preparing company representatives to continue as facilitators at future events.

The FEMP team saw an opportunity to apply the same principles to federal buildings by slightly augmenting the BP approach and resources. The FEMP and BP program began TH collaboration in 2021 to help FEMP design a TH program to support federal agencies. The goal was to kick-start a FEMP TH program with resources similar to those that have been successful for the BP trainings. Through a collaboration with the Oak Ridge National Laboratory team that executed the BP TH program, the existing BP toolkit was evaluated, rebranded, updated, and improved to meet the needs of the FEMP TH program [3]. The resultant FEMP TH toolkit is a technical resource developed to guide facilitators through TH training at federal facilities, from preparation to closeout.

2. TREASURE HUNT AND TOOLKIT OVERVIEW

A TH is an extremely dynamic event that requires preparation weeks in advance, training, and time for the event itself. A TH is typically only a 2- or 3-day activity, and gathering information beforehand is a crucial preparation step that saves time during the actual event. To help the FEMP TH program, resources were designed for the TH toolkit to reduce the effort needed before and during an event. The resources were designed to improve event consistency and to provide a systematic approach to each event. The resources can be divided into two major categories, preparation resources and event resources:

- Preparation resources
    - Treasure hunt flyer (Appendix A)
    - Pretraining presentation for stakeholders (Appendix B)
    - Pretraining data collection sheet (Appendix C)
    - Save-the-date template (Appendix D)
    - Agenda template (Appendix E)
    - Suggested treasure hunt diagnostic tools (Appendix F)
    - Final event logistic and confirmation questionnaire (Appendix G)

- Event resources
    - Training kickoff presentation (Appendix H)
    - Checklist – industrial focused (Appendix I)
    - Data collection sheets (Appendix J)
    - Reference sheets (Appendix K)
    - Manufacturing Energy Assessment Software for Utility Reduction (MEASUR) software

2.1 PREPARATION RESOURCES

Preparation resources are used while planning the event to gather the basic information about the host site's operational practices and details needed the day of the TH event. The resources include promotional flyers, key communication material, and data-gathering sheets. Data gathered beforehand will better prepare facilitators for the event, involve stakeholders prior to the event, and ensure proper diagnostic equipment is available during the event.

2.1.1 Treasure Hunt Flyer

The TH flyer was designed for the FEMP team as promotional material. The flyer should be used to recruit host sites and interested parties. The two-page flyer was designed to be printed in color, front and back. The flyer explains the basics of what a TH is, why it would be beneficial, how the FEMP team can help with the activity, and short success stories from the field. The success stories are sources from the BP program. The bottom of the flyer also contains information about who to contact to schedule an event and where to find more information.

2.1.2 Pretraining Presentation for Stakeholders

This presentation was designed for stakeholders after a site has agreed to participate but prior to the event. This presentation is given several weeks or months before the TH, while the event is still being planned. It should be used to explain the TH process to the main points of contact at the host site and to the personnel who are learning to be facilitators. The presentation discusses the basic outline of a TH and sets expectations for the site. After reviewing the basics of a TH, the call concludes with next steps for the host site, including logistics planning, IT prep work, and preliminary data requirements.

2.1.3 Pretraining Collection Sheets

During the pretraining presentation, the stakeholders are informed of the pretraining data collection sheets. These sheets are an Excel-based form with data requests needed for the training. The first sheet of the Excel form is the essential information. These data points are required prior to the event; without this information, the TH savings analysis cannot be completed. The information on this sheet includes points of contact, the operating schedule, and the unit cost for energy. The second sheet is for helpful data. These are data points that are useful to have before the event but are not required. Participants are strongly encouraged to fill out this form to help facilitators understand operation prior to the event. The form asks for the team breakdown for the event, plant data, and facility-equipment and process-equipment specifications. This information is needed to ensure effective use of data loggers if they are being used prior to the event.

2.1.4 Save-the-Date Template

The save-the-date template is used after a date, time, location, and facilitator have been chosen. The host site or main contact should send the save the date to potential attendees, anyone else they would like to know about the event ahead of time, or anyone they would like to invite to the event, internal or external. The save the date should share the hosting organization, the training organization (FEMP), the facilitator, what the participants should expect to learn, and the goal of the training. The save the date in the toolkit is only a template. Details of the template should be updated, modified, and checked before each event.

2.1.5 Agenda Template

The agenda template should be used after the save the date has been sent. The agenda should include information about the date and time of the event. The number of days dedicated to the event and the start and end times each day will be dependent on the size of the facility, availability of the site, and operating procedures. A smaller site may need 1 or 2 days, whereas a larger site may take 3 full days. This should be left to the discretion of the facilitator, when possible, during the planning phase of the event. The agenda should also include a rough outline of expected tasks during the event. Tasks that should be on the agenda include orientation from the host site, a kickoff with participants, tour times, software training, scheduled breaks and lunch, and a wrap-up presentation to management. Given that THs are dynamic events, these tasks may be moved around to meet the needs of the facility during the event.

2.1.6 Suggested Treasure Hunt Diagnostic Toolkit Contents

During a TH, gathering data is an essential part of the process. Data are needed to evaluate recommendations. A list of recommended diagnostic tools was compiled to help with this process. Tools on this list were carefully selected to be applicable to a wide variety of host sites, including office buildings, hospitals, and industrial settings. For each tool, the list includes a description of the tool, the manufacturer, the model, and the recommended quantity. The list is not all-encompassing and may need to be adjusted slightly based on the site but should be seen as a recommendation for a kit that would be usable at many types of facilities for a basic TH. Depending on the organization hosting the training, a kit may be available for loan; this or the availability of other diagnostic tools should be discussed during the pretraining presentation for stakeholders.

2.1.7 Final Event Logistics and Confirmation Questionnaire

A week or so before the event, the main stakeholders, facilitators, and host organization should review the final event logistics and confirmation questionnaire. The questionnaire helps ensure all parties are communicating efficiently and that the minor details of a visit will not interrupt the TH event. The 20 questions may not cover all topics needed for the visit but should be a good start to encourage logistics conversations. Mainly, the logistics portion is used to confirm external facilitators know what to expect when they arrive and understand the operating procedures of the host site (what personal protective equipment is needed, what documentation is needed for badging, where attendees should park in the morning, etc.). The confirmation portion of the questionnaire is focused more on the event itself (participant count, whether Wi-Fi will be available, whether the training software was downloaded, etc.). The goal of the questionnaire is to reduce nonevent time needed the day of the TH.

2.2 TREASURE HUNT EVENT RESOURCES

The TH event resources are mainly used during the event. This information should be shared with the participants the day of the TH. These resources should be left to the facilitator in training to use in future events at the site.

2.2.1 Training Kickoff Presentation

This presentation is given by the event facilitator. The audience should include upper management and the participants for the event. This presentation occurs at the beginning of the event to express the goals of the TH, identify the expected outcomes, set expectations for participation, and introduce the participants to the software. The presentation also informs participants of typical energy efficiency opportunities in different systems. The facilitator should ensure that technical personnel needed for data measurements and upper management are present. At this time, the facilitator reviews the event agenda and sets the tone for the event. This presentation is similar to the stakeholder presentation but focuses more on data gathering and less on logistics.

2.2.2 MEASUR

The MEASUR suite is a free, open-source software available through DOE. It is a collection of over 70 quick calculators, 6 assessment modules, 1 TH module, 2 equipment inventory options, and 1 data exploration module. The quick calculators were designed for simple inputs and quick spot calculations based on engineering principles. The assessment modules use a much more robust approach, digging deeper into energy systems operations. The TH module is a blend of the quick calculators and assessment modules [4]. The TH module was designed to be paired with the TH toolkit previously mentioned. The module uses a systematic approach to compile, assess, and present recommendations during a TH. During the TH event, the facilitator trains participants on quantifying energy and cost savings using the MEASUR software. Then the software is used to compile and evaluate recommendations found by the teams. Once the event ends, the software can be used to prepare the closeout presentation to management [5].

2.2.3 Checklist – Industrial Focused

A checklist was created to help participants look for opportunities as they tour the site. The list that is included in this toolkit is industrial focused, but sections can be removed as needed to meet the needs of the host site. The checklist walks through the major energy-consuming systems found in most TH events, including general-building, steam systems, chiller systems, process heating, compressed air, pump and fan systems, and lighting. As participants walk through the site, they can check off possible recommendations or take notes about what they are observing. The checklist is ideal for participants who may not be knowledgeable in a particular system. Checklists have also been proved to be useful for even the most experienced assessor. It is recommended to share the checklist (digital or hard copy) with all participants. It is suggested that each team have at least one hard copy for note taking.

2.2.4 Data Collection Sheets

Data collection sheets are used while gathering system information for analysis. These sheets are an Excel form with questions for the major energy-consuming systems. For each system, the sheets describe what is being measured, what data need to be collected, and how to collect the data. The sheets also provide space to write the collected data. In some scenarios, a soft copy will suffice, but a hard copy may be needed for the event. These sheets should be paired with the diagnostic tools to measure data; then the sheets can be used to enter data into the MEASUR software.

2.2.5 Reference Sheets

A reference sheet is similar to a cheat sheet for a system. Each sheet is filled with references or heuristics that can be useful during the TH event. These are used to do quick off-sheet calculations, to train participants about a system, or to help with general system education. These sheets can also be used for calculations if a needed calculator is not included in the MEASUR suite. There is a one-page reference sheet for each major system: chilled-water, compressed air, lighting, pump and fans, and steam systems.

3. SUMMARY

DOE's FEMP provides various technical trainings and resources to federal agencies and their stakeholders. The FEMP team saw an opportunity to create a TH program for federal facilities. By partnering with Oak Ridge National Laboratory and the BP team, resources were adapted, updated, and improved for FEMP. The FEMP TH toolkit is a technical resource developed to guide facilitators through TH training at federal facilities, from preparation to closeout. The existing BP toolkit was evaluated, rebranded, updated, and improved to meet the needs of the FEMP TH program. The toolkit presented in this report was designed to help facilitate energy-focused kaizen events, identify energy-saving recommendations, analyze identified opportunities, and provide the tools needed to detect actionable projects to advance federal facilities. With the resources provided in this document, an energy TH event can be organized and deployed.

4. REFERENCES

[1] Federal Energy Management Program. n.d. "About the Federal Energy Management Program." US Department of Energy. https://www.energy.gov/femp/about-federal-energy-management-program.

[2] W. Guo, T. Wenning, S. Nimbalkar, J. Travis, J. O'Neill, and B. Lung. 2023. "US Department of Energy Better Plants Program's Approach to Manufacturing Workforce Development." *ACEEE Summer Study on Energy Efficiency in Industry*, Detroit, MI, July 11–13, 2023.

[3] W. Guo, T. Wenning, K. Thirumaran, S. Nimbalkar, and E. Levine. 2019. *US DOE Better Plants Program Energy Treasure Hunt Exchange Toolkit*. ORNL/TM-2019/1081. Oak Ridge, TN: Oak Ridge National Laboratory.

[4] G. Accawi, et al. 2022. "MEASUR - Manufacturing Energy Assessment Software for Utility Reduction." DOE Office of Energy Efficiency and Renewable Energy, Energy Efficiency Office, Advanced Manufacturing Office.

[5] K. Armstrong, A. Botts, and T. Wenning. 2023. "MEASUR Up: Identifying Opportunities in a Facility." *Facility Management Journal* 33(2), 59–62.

APPENDIX A. TREASURE HUNT FLYER

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FEMP
Federal Energy Management Program

Energy Treasure Hunts

Cross Functional Teams Identify Energy Efficiency Improvements

What are Energy Treasure Hunts?

An Energy Treasure Hunt is an onsite three-day event utilizing cross-functional teams of employees identify energy efficiency improvements within a facility. Treasure Hunts also enable employees to build a culture of continuous improvement for implementing energy control measures that reduce use, costs, and associated greenhouse gas emissions.

The U.S. Department of Energy's Treasure Hunt program is providing free technical assistance to groups (cohorts) of energy team members from U.S.-based industrial, commercial, and institutional sites that would like to implement an Energy Treasure Hunt to reduce their facilities' energy use by up to 15%.

What are the Benefits of a FEMP Treasure Hunt?

- Reduce energy, operating, and maintenance costs
- Help build a culture of continuous improvement
- Identify inefficiency and unnecessary equipment in a facility
- Align with requirements of EISA 432

Step-by-Step Support and Training

During the Treasure Hunt process, an experienced facilitator helps coordinate participants at the site to identify energy reduction opportunities and quantify the value and validity. Participants typically represent many disciplines (engineering, maintenance, operations, etc.). Participants are trained to identify potential energy saving recommendations in a classroom setting, then tour the site and apply their training, searching for opportunities.

Potential projects are identified by participants. Time is spent training participants to utilize diagnostic equipment and to collect data. The data is then used with software tools, such as DOE's MEASUR tool, to calculate the savings potential of the identified opportunities. At the end of the event, participants prepare and present a close-out presentation for the host facility's management to review. If recommendations are viable, opportunities are pursued at the discretion of the local facility.

Treasure Hunts Align with Federal Statutes

Section 432 of the Energy Independence and Security Act of 2007 (EISA 432) requires federal agencies to conduct energy and water evaluations at each covered facility every four years to identify potential conservation measures. EISA requires agencies to report progress towards these requirements using the Federal Energy Management Programs' (FEMP) EISA 432 Compliance Tracking System. Treasure hunts can support your facility's efforts meeting this federal statute.

betterbuildingssolutioncenter.energy.gov/better-plants/energy-treasure-hunts

FEMP Federal Energy Management Program Energy Treasure Hunts

Success Stories

TOYOTA Since FY08, 40 Toyota suppliers have hosted Treasure Hunt training events. Employees from 180 Tier 1 suppliers have participated and been trained on the Treasure Hunt process. There has been $4.4 M in total annual energy reduction opportunities identified, the equivalent of 43.5 million kilowatt-hours or 15,200 metric tons of CO_2 per year.

At the New River Valley (NRV) truck assembly plant, during a Treasure Hunt event, three teams identified a total potential annual energy cost savings of $538,000 across building envelope, cross-cutting systems, e.g. compressed air, and process equipment.

For Volvo's Mack Truck Macungie, Pennsylvania, plant, three Treasure Hunt teams identified total annual energy cost savings of over $134,000, which included more than 60% of the identified opportunities with paybacks of less than one year.

During a Treasure Hunt at Magic Hat Brewing Company, a potential electric and natural gas usage reductions of 40% were identified with a total potential annual cost savings of $320,000. Total potential kilowatt-hours saved annually were roughly 1.6M kWh. The total potential MMBTUs saved per year were 15,344 MMBTUs. This was roughly enough to power and heat 170 Vermont homes for a whole year.

Summary

- Treasure Hunts are an effective means to quickly identify low- and no-cost energy reduction opportunities
- Dedicated participation and true engagement of facility employees and operational staff is the key to identifying achievable actions
- Early involvement and facility leadership sponsorship is critical to ensure Treasure Hunts are successful
- Training participants on the process and easy-to-use tools will enable the Treasure Hunts to be quickly replicated at other facilities
- Treasure Hunts offer professional training on project identification, use of diagnostic tools, and evaluating project estimated cost savings and validity.

How to Join or Learn More

To join, site leadership will commit staff and resources to complete the Treasure Hunt for their site.

Please contact Kendall Kam to hear more about the technical assistance and how to join.

202-586-9644

Kendall.Kam@ee.doe.gov

betterbuildingssolutioncenter.energy.gov/better-plants/energy-treasure-hunts

APPENDIX B. PRETRAINING PRESENTATION FOR STAKEHOLDERS

APPENDIX B. PRETRAINING PRESENTATION FOR STAKEHOLDERS

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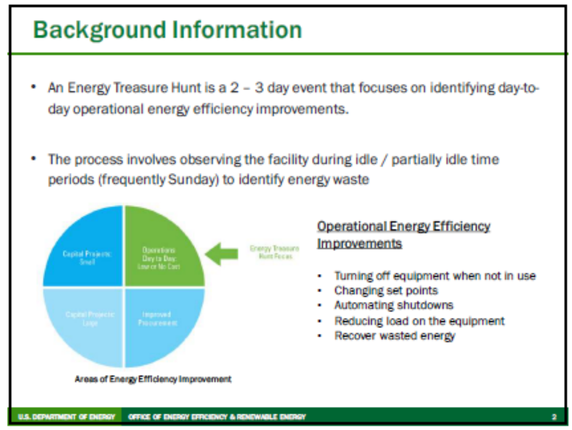

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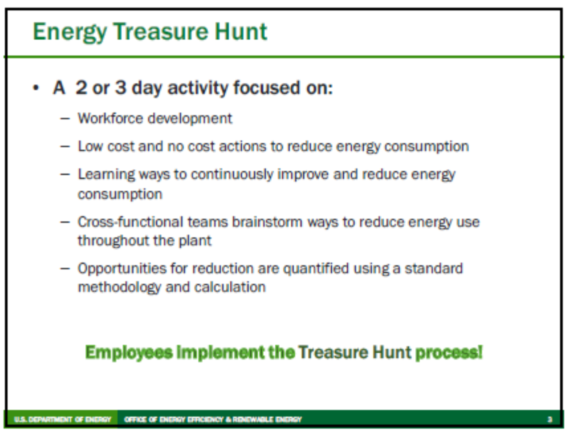

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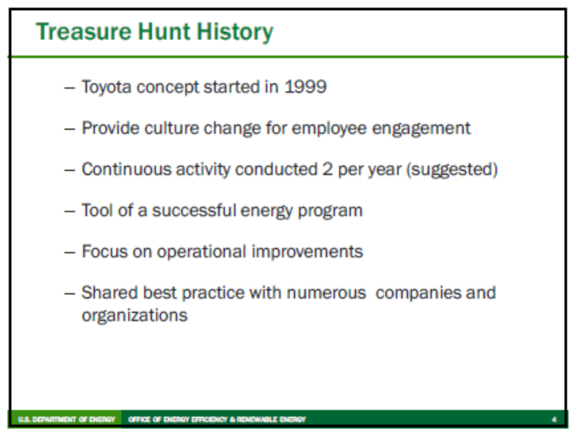

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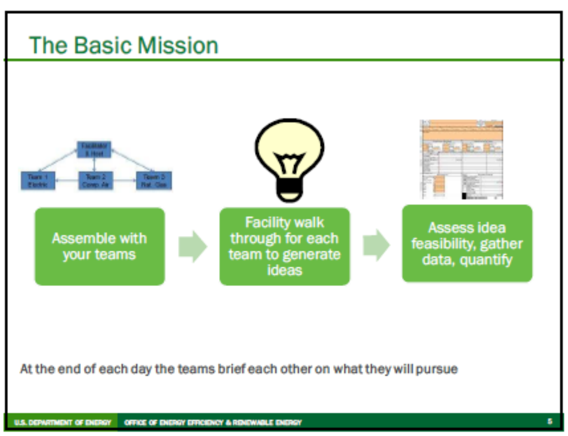

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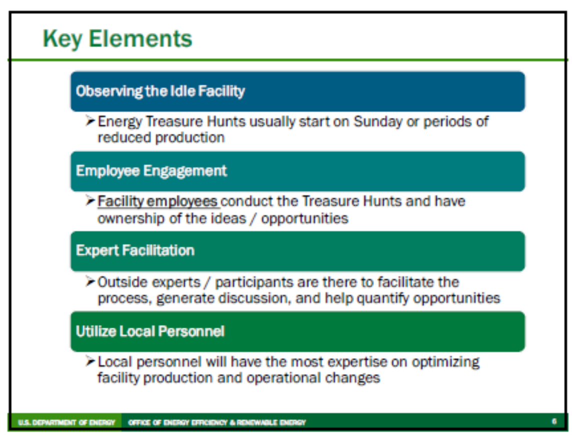

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Team Leaders

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Selecting Team Leaders

Qualities / Attributes

- Strong leadership skills
- Strong experience or technical background in focus area
- Capable of running the laptop / excel calculators
- Knows where to get information, and who makes decisions in their area of focus

Consider These Roles

- Process owners / decision makers / managers
- Engineers, supervisors, area leads
- Subject matter experts, tenure and experience in operations

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Core Team Makeup

The team must be able to validate ideas, understand existing process, and evaluate technical issues

Maintenance
- shift mechanic
- electrician

Production
- operators
- supervisors
- leads

Target 3 participants from these categories

Engineering
- area engineer
- process engineer

Subject Matter Experts
- HVAC
- Compressed Air
- Electrical, etc.

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Additional Participants

Pull on people with outside perspective to identify opportunity that may be overlooked by day to day operations

Internal Participants
(fresh sets of eyes)

- Admin / Office – buyers, planners, management, etc.
- EHS / Engineering / Project Management
- Crafts – mechanics, electricians, hourly, salary
- Anybody enthusiastic to participate

External Participants

- Consultants – compressed air, process heat, energy specialist, etc.
- Facilitators –Energy Efficiency Team, previous hosts, internal host
- nearby facilities, similar facilities, BU participants, internal experts, future Treasure Hunt hosts
- Suppliers, vendors

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Data Gathering

- Data gathering can be done before the Treasure Hunt
  - During the event teams can focus on "floor time" identifying opportunity
- Identify significant energy users, annual cost / consumption, and plant operating parameters
- Additional information such as project lists and major upgrades that will affect the plant energy profile should be included
  - Plant energy profile – meter or utility data
  - Lighting count
  - Proposals for upgrades / projects
  - Existing projects / upgrades
  - Previous energy assessments
  - Utility rate structure / contracts

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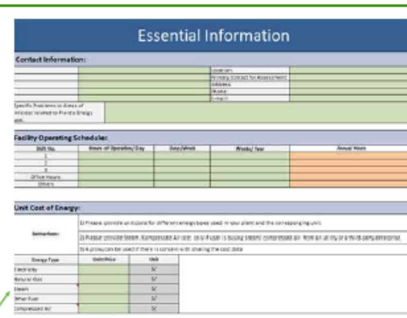
Preliminary Data



This information must be determined before the event starts
Typically an average over 12 months is used unless rates vary greatly

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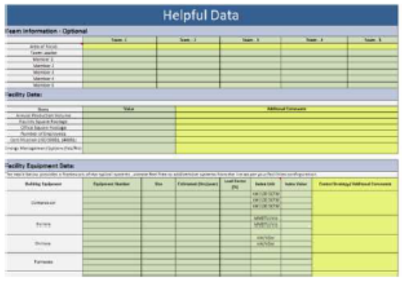
Preliminary Data



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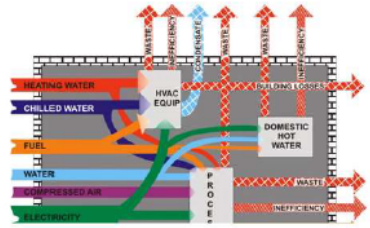
Building Energy Flow



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Logistics

- What locations will we look at?
- How many attendees?
- Start and end time?
- Management participation at kickoff and close out?
- Close out at the end of day 2?
- Projection screen – a means to see presentations
- Tools?
- Arrangements for lunch

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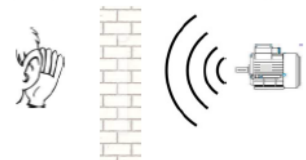
Observing The Idle Facility

- Most important day for generating ideas
- Rarely is production activity 24 hrs / 7 days a week
  - Take note of maintenance downtime / shift changes / off shifts
- Use your eyes and ears to find wasted energy!



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Software Tools

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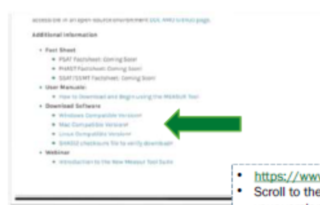
Download via DOE-EERE-AMO website



- https://www.energy.gov/eere/amo/measur
- Scroll to the bottom to find and download your version

Do this before the event!

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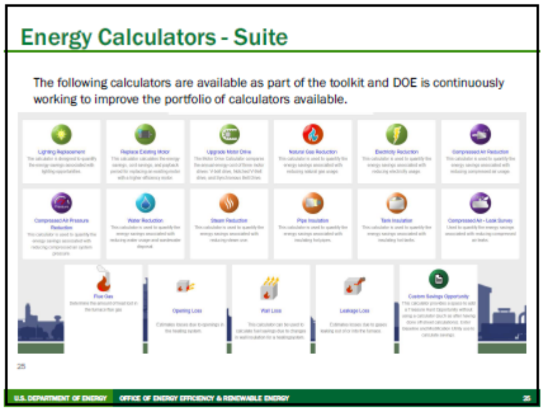

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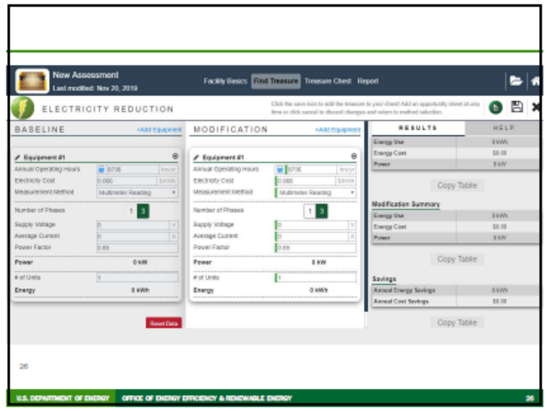

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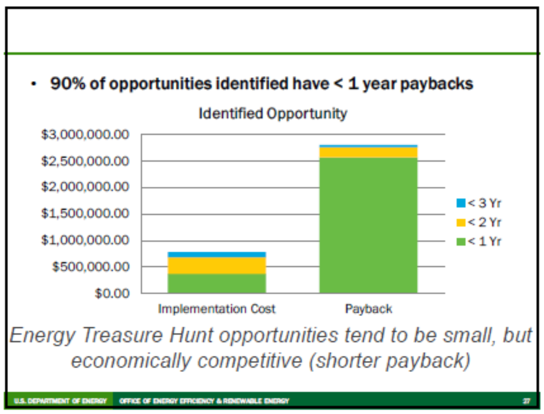

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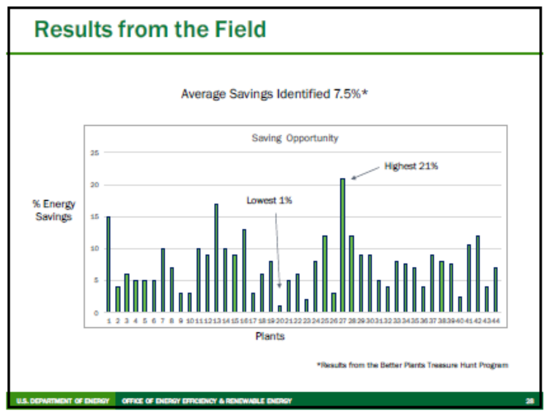

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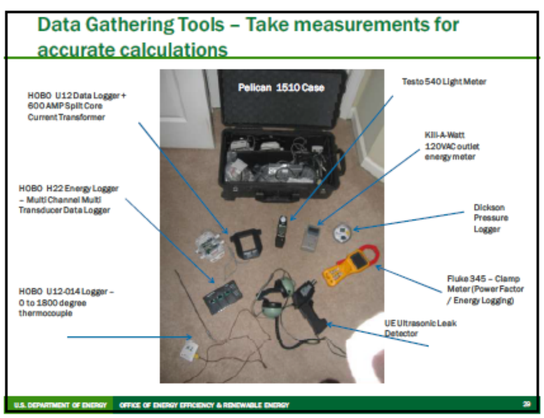

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Questions / Comments

Thank You!

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APPENDIX C. PRETRAINING DATA COLLECTION SHEET

APPENDIX C. PRETRAINING DATA COLLECTION SHEET

Energy Treasure Hunt In-Plant Training

Advanced Information Request

FEMP Federal Energy Management Program

Oak Ridge National Laboratory

This document is requested to be completed at least 2 weeks prior to the energy treasure hunt

The document is broken down into three section (Three tabs of the Excel workbook)

1.) **Essential Data** - All fields listed in this sheet are key to running a successful treasure hunt and is to be filled by the user.

2.) **Helpful Data** - The fields listed in this session are helpful to have in advance and make it easier to effectively plan for the treasure hunt event. It is recommended that the user goes through the various sections in this sheet and complete it based on information readily available.

The **Plant Energy Profiler Excel (PEPEx)** is recommend for users who would like to provide the treasure hunt facilitator with more infomation about the facility. In addition to providing the facilitator with the knowledge required to tailor the treasure hunt event, the PEPEx will also help the user better understand the energy usage and the existing oppurtunities in the facility.

It takes an user with a understanding of the various systems in the plant an average of 20 minutes to complete the tool. Interested users are encouraged to seek the help of the facilitator to complete PEPEx document. PEPEx is included in the treasure hunt toolkit and can also be downloaded from the DOE website.

Essential Information

Plant Contact Information:

Corporation Name:		Location:	
Plant Name:		Primary Contact for Assessment:	
Primary Product:		Address	
Industry Type:		Phone:	
Specify if other:		E-mail:	
Specific Problems or Areas of Interest related to Plant's Energy use:			

Plant's Operating Schedule:

Shift No.	Hours of Operation/ Day	Days/Week	Weeks/ Year	Annual Hours
1				
2				
3				
Office Hours				
Others				

Unit Cost of Energy:

Instructions:

1) Please provide unit costs for different energy types used in your plant and the corresponging unit.

2) Please provide Steam /Compressed Air cost only if user is buying steam/ compressed air from an utility or a third-party enterprise.

3) A proxy can be used if there is concern with sharing the cost data

Energy Type	Unit Price	Unit
Electricity		$/
Natural Gas		$/
Steam		$/
Other Fuel		$/
Compressed Air		$/

Helpful Data

Team Information - Optional

	Team -1	Team - 2	Team - 3	Team - 4	Team - 5
Area of Focus					
Team Leader					
Member 1					
Member 2					
Member 3					
Member 4					
Member 5					
Member 6					

Plant Data:

Items	Value	Additonal Comments
Annual Production Volume		
Plant Square Footage		
Office Square Footage		
Number of Employees		
Certififcation (ISO 50001, 140001)		
Energy Management System (Yes/No)		

Facility Equipment Data:

The table below provides a framework of the typical systems in a manufacturing plant, please feel free to add/remove systems from the list as per your facilities confirguration.

Building Equipment	Equipment Number	Size	Estimated (Hrs/year)	Load Factor (%)	Index Unit	Index Value	Control Strategy/ Additonal Comments
Compressor					kW/100 SCFM		
					kW/100 SCFM		
					kW/100 SCFM		
Boilers					MMBTU/klb		
					MMBTU/klb		
Chillers					kW/kGal		
					kW/kGal		
Furnaces							
etc							

Process Equipment Data:

The table below provides a framework of the typical processes in a manufacturing plant, please feel free to add/remove processes from the list as per your facilities confirguration.

Process Equipment	Total Size	Estimated (Hrs/year)	Load Factor (%)	Additonal Comments/information on the process
Incinerators				
Furnace 1				
Furnace 2				
Press 1				
Press 2				

APPENDIX D. SAVE-THE-DATE TEMPLATE

APPENDIX D. SAVE-THE-DATE TEMPLATE

FEMP
Federal Energy Management Program

Your Logo

SAVE THE DATE

FEMP Energy Treasure Hunt

Company Name
Facility Address

May 1 to 3, 202X

Host Company Name, FEMP, and U.S. DOE's Advanced Manufacturing Office are organizing an Energy Treasure Hunt to identify day-to-day operational energy efficiency improvements in the facility processes and associated systems. The in-plant training will prepare facility personnel with hands-on experience on how an Energy treasure hunt is conducted in addition to identifying and evaluating energy efficiency projects. Participants will be provided with practical information to identify energy saving projects and the necessary tools to quantify the associated savings. The focus will be on identifying low-cost operational opportunities for energy optimization and documenting them.

Participants will learn:

- The value/benefits of a treasure hunt
- Identifying and profiling equipment energy use
- Identifying energy opportunities
- Methods for collecting energy data and common data collection tools
- Effective presentation of outcomes
- Understanding calculation tools and ROI methodologies
- Operation of relevant diagnostic tools
- Selection of processes, facilities, and departments for treasure hunts
- The importance of Team makeup – processes and people
- Prioritizing energy-saving opportunities
- Replicating across facilities, departments, and units

Additionally:

At least one employee will learn how to be a facilitator to conduct internal treasure hunts.

The training will focus on four fundamental elements that every treasure hunt needs to have in order to be effective. These four elements are:

1. A profile of the equipment/systems to be analyzed and an equipment checklist
2. Data collection protocols and tools
3. Calculators and calculation methodologies (baselines & ROI metrics)
4. Relevant energy diagnostic equipment and how to use them

betterbuildingssolutioncenter.energy.gov/better-plants/energy-treasure-hunts

FEMP Federal Energy Management Program

Energy Treasure Hunt

Contacts

- Designation, Name , contact@company.com
- Designation, Name , facilitator@company.com

Get to Know the Presenters:

Presenter 1: Short bio

Presenter 2 : Short bio

betterbuildingssolutioncenter.energy.gov/better-plants/energy-treasure-hunts

APPENDIX E. AGENDA TEMPLATE

APPENDIX E. AGENDA TEMPLATE

FEMP Federal Energy Management Program

Your Logo

Energy Treasure Hunt

Dates: Sunday, May XX, 201X – Tuesday, May XX, 202X

Partner Site: Your Name, TN facility - 1 ABC Drive. Tonawanda, TN 37919

Facility Name, FEMP, and U.S. DOE's Advanced Manufacturing Office is organizing an Energy Treasure Hunt to identify day-to-day operational energy efficiency improvements in the facility's processes and associated systems. The event will be led by Presenter 1 at the ABC Ltd. facility is located in Tonawanda, Tennessee. The facility **insert short description of facility and what they are/do** In addition to identifying projects for the host facility, the event will equip the participants with the knowledge and tools required to take the treasure hunt concept and apply it in their other facilities.

Pre-Training Webinar XX/XX/XXXX at 9:30 AM ET	**In preparation for the Treasure Hunt, join us for a pre-training webinar.** **More Info and to Register –** ****Registration Website or who to contact****

	10:00 AM - 12:00 PM	12PM to 1P	1:00 PM – 5:30 PM
Day 1 **Sunday XX/XX/XXXX** **(Observing the idle facility)**	Safety / Facility Orientation Opening Remarks Kick off Objectives and Overview of the Treasure Hunt Assign teams and leaders	Lunch	Gather into Teams Tour the facility and look for opportunities Discuss initial findings/ideas Plan for Monday morning

	8:00 AM - 12:00 PM	12PM to 1P	1:00 PM – 5:30 PM
Day 2 **Monday XX/XX/XXXX** **(Observing the operating facility)**	Welcome from Management Layout plan for the day Detail Sheet Training Observe facility and operations	Lunch	Begin detail sheets Additional data collection in the facility Identify top ideas

	8:00 AM - 12:00 PM	12PM to 1P	1:00 PM – 4:00 PM
Day 3 **Tuesday XX/XX/XXXX**	Recap top ideas Wrap up detail sheets and field observations Roll up data sheets	Lunch	Dry run management presentation Present to management

Get to Know the Presenters:

Presenter 1: Short bio

Presenter 2 : Short bio

Important Information and Requirements

Use this section to instruct participants on sign-in procedure, photo ID requirements, policy on electronics, PPE requirements, parking etc.

APPENDIX F. SUGGESTED TREASURE HUNT DIAGNOSTIC TOOLKIT CONTENTS

Treasure Hunt Kit Instrument List

Description	Manufacturer	Model	Qty
Infrared camera	Flir	E5	1
Infrared thermometer	Fluke	566	1
Ultrasonic leak detector	Bacharach	Tru-Pointe 1100	1
Light meter	Testo	540	1
Digital thermometer	Omega	HH506RA	1
Thermocouple	Omega	KHXL-18G-RSC-12	1
Laser distance meter	Fluke	414D	1
Conductivity meter	Reed Instruments	SD-4307	1
Clamp-on power meter	Fluke	345	1
Data loggers	HOBO	UX120-006M	6
Adapter cable	HOBO	CABLE-ADAP5	2
Battery box for PT	DigiKey	BK-030-ND	2
Battery connector	Newark	43AC1932	2
PT connector 1	Newark	11X7239	2
PT connector 2	Newark	11X7203	2
Pressure transducer	Ashcroft	G2	2
Plug load logger	Onset	UX120-018	2
Current transformer	Onset	CTV-A	2
Current transformer	Onset	CTV-C	2
Current transformer	Onset	CTV-D	2
Current transformer	Onset	CTV-E	2
Anemometer	Dwyer	9671	1
Mechanical counters	Grainger	2PAU4	3
25′ tape measure	Stanley	33-425	1
LED flashlight	Pelican	2360	1

Treasure Hunt Instruments and Their Uses for Identifying Energy Saving Opportunities

Analog Data logger	Record output from sensors to quantify operational parameters including electric current, water, or compressed air pressure. When combined with the appropriate transducer, or sensor, the data logger is used to determine trends in non-steady state systems, such as motor current or system pressure. The loggers can also be used to record an output signal from permanently installed instrumentation at a facility.
Anemometer	Measure airflow. Used to quantify leakage around seals (process heat, building envelope) or airflow in HVAC ducts or exhaust.
Conductivity meter	Measures the electrical conductivity in a solution. Commonly used in treasure hunts to quantify the number of undissolved solids in the boiler blowdown water. Too little undissolved solids in the blowdown may indicate that the blowdown is occurring too frequently, and thus wasting energy.
Current transformer (CT)	Used to measure electric current being consumed by operating equipment as an approximation of the actual power being consumed. When combined with other operating parameters, input power may be used to determine if equipment is optimally operated.
Laser Distance Meter	Used to measure distances. Commonly used when it is either not possible or practical to do so with standard measuring devices, such as a tape measure. Such measurements can be critical to proper setup of other instruments, or determine distance, area, or volume for use in software tools or other calculations.
Pressure transducer	Used to measure pressure in systems with quick disconnects, normally compressed air. Pressure data provides insight into both how well equipment is functioning, but also whether system setpoints are correct to prevent waste.
Plug-load logger	Records the operation of standard 115V plug loads to identify equipment operation.
Temperature/RH logger	Records building environmental conditions (temperature and relative humidity) to identify opportunities to reduce HVAC operations, improve occupant comfort, or confirm system controls accurately align with what is expected.
Thermocouple and logger	Used to record temperature changes over time in a process media to establish correct process temperatures or identify potential energy waste.
Ultrasonic leak detector	Used to identify leaks in compressed air or steam systems.
3 Phase power meter	Used for logging power in low voltage (<600 V) 1-Phase or 3-Phase electrical components such as pumps, fans, and compressors.
IR Camera	Has a camera function to take photos, used to read temperature on surfaces. Data is used for evaluating structures, door seals, insulation, oven hot spots, etc.
IR Thermometer	Used for non-contact temperature measurements for both manufacturing processes and building envelope applications.
Light Meter	Used to measure lighting levels (intensity) to match work tasks for the area with appropriate lighting levels.

APPENDIX G. FINAL EVENT LOGISTICS AND CONFIRMATION QUESTIONNAIRE

APPENDIX G. FINAL EVENT LOGISTICS AND CONFIRMATION QUESTIONNAIRE

FEMP
Federal Energy Management Program

Logistics and Final Confirmation Questionnaire

Logistics

1. What is the projected start and stop times for each day? (This may be affected by other participants flight times the final day)
2. Will upper management be joining us? If yes, which days?
3. What time can upper management join us for close out?
4. Do you have a ppt template you would like us to utilize for the closeout presentation?
5. How early do ORNL and FEMP visitors need to arrive for badging?
6. Is there any documentation required for visitor passes?
7. Where should ORNL and FEMP visitors park?
8. Is there a plan for lunch? (Will it be provided, will it be offsite, are visitors responsible for their own)
9. What PPE is required?
10. Do teams need to have an escort?
11. What is your COVID policy? (Masks, vaccine cards, etc)

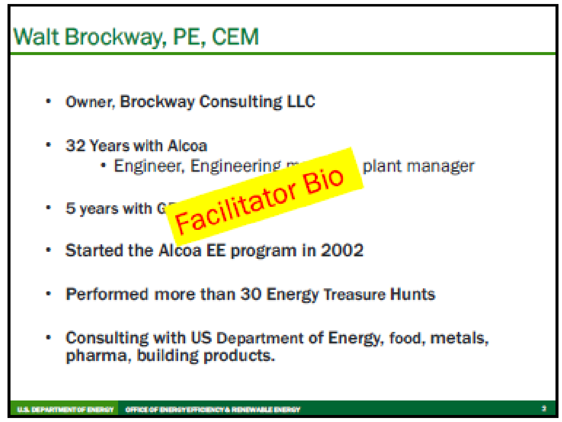
Confirmation

1. Is there a conference room available for us?
2. Will we be able to use Wi-Fi?
3. Were you able to download MEASUR?
4. Is there a projector available?
5. Is there an estimated participant count?
6. What are the main focus areas?
7. Will a technician be available to install and remove logging equipment? Are they able to participate during the event, or do they have selected hours they can assist?
8. Are there general technicians that can answer questions about the systems on the teams?
9. Do you have an annual total volume and cost for your utilities?

APPENDIX H. TRAINING KICKOFF PRESENTATION

APPENDIX H. TRAINING KICKOFF PRESENTATION

1



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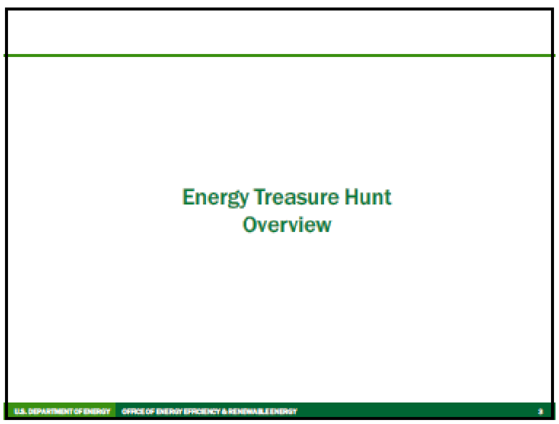

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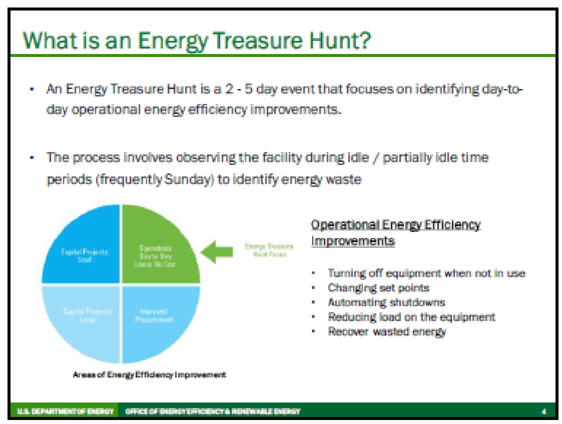

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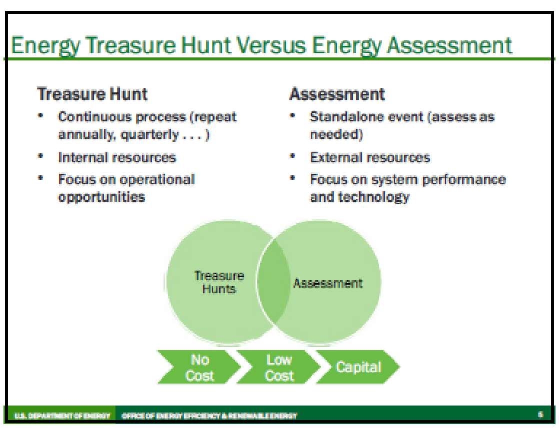

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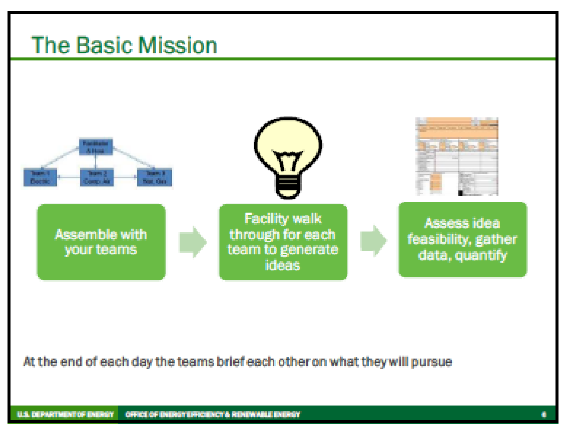

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Learning Objectives – All Participants

The event aims to educate all the participants on,

- What an energy treasure hunt exchange is, its value and benefits
- How to evaluate equipment energy use (both idle and non-idle times)
- How to identify equipment and process opportunities
- Methods for collecting energy data and common data collection tools
- How to effectively present outcomes of the treasure hunt

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Advantages of a Treasure Hunt

- **A Treasure Hunt Exchange encompasses both training and a "hunt"**
  - Does not require sophisticated technical analysis
  - Calculations are (relatively) simple
  - Can be applied by employees of varying disciplines
  - Train selected participants to facilitate future treasure hunts
- **A three day activity – at completion, the facility has sufficient information to execute identified opportunities and an employee who can facilitate future treasure hunts within the organization**
- **Opportunities/ideas are solicited from many disciplines and can be replicated across similar processes and businesses**
- **The Treasure Hunt process can be replicated and repeated (through this training)**

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Some Stats on Energy Treasure Hunts

Include Stats from Better Plants?

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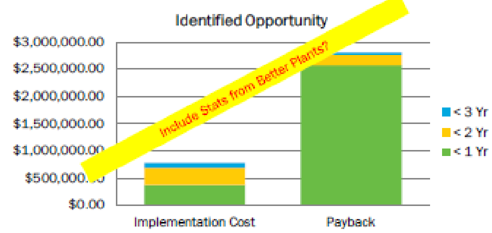
- **90% of opportunities identified have < 1 year paybacks**



Energy Treasure Hunt opportunities tend to be small, but economically competitive (shorter payback)

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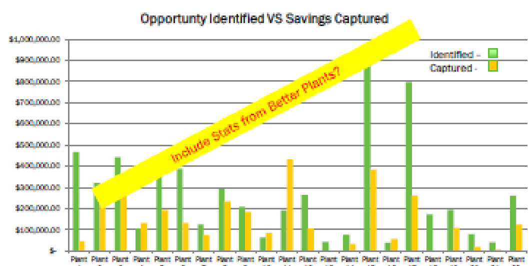

55% of ideas generated are implemented

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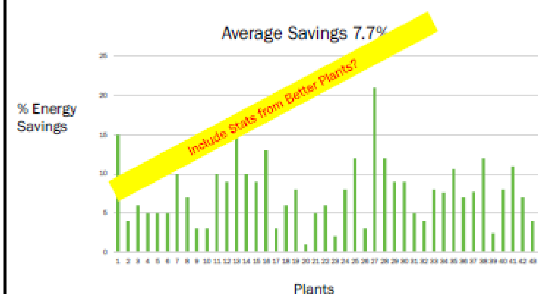
Results from the Field



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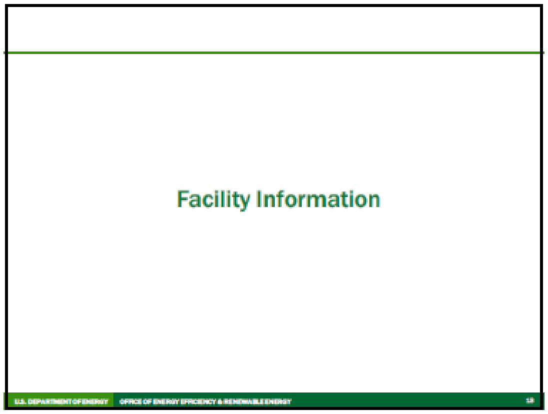

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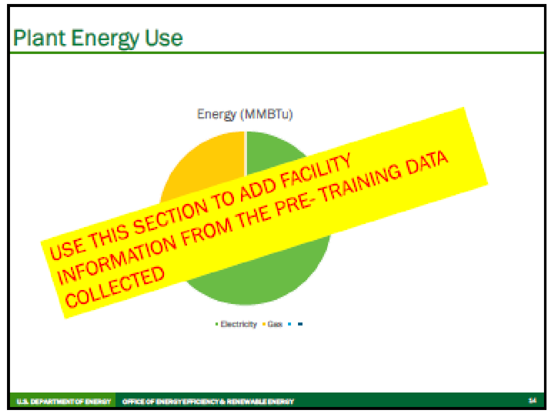

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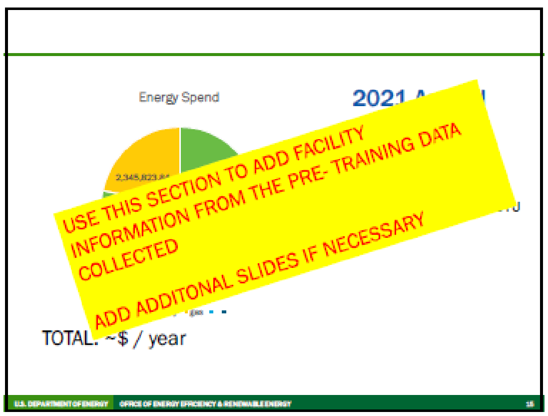

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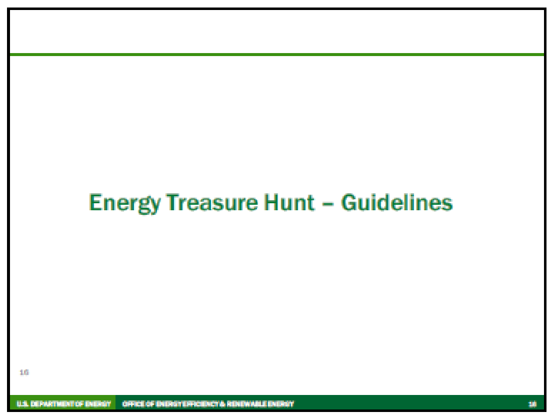

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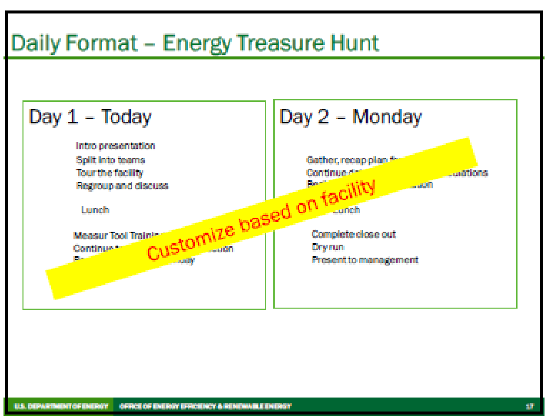

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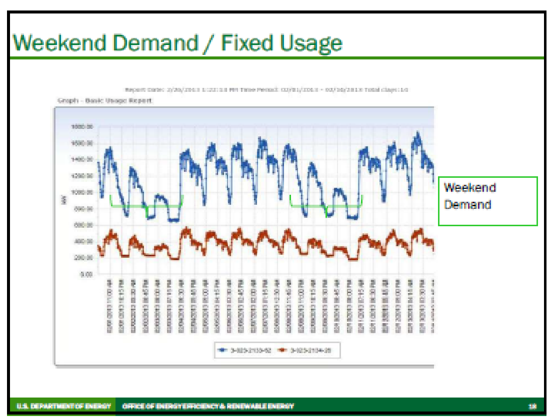

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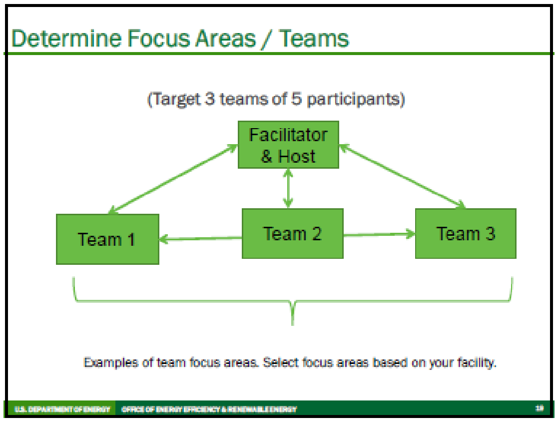

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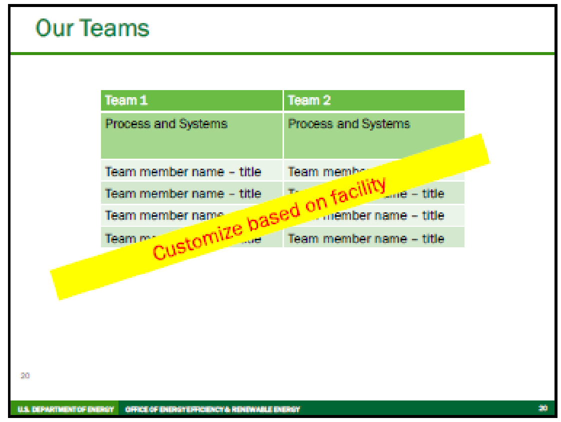

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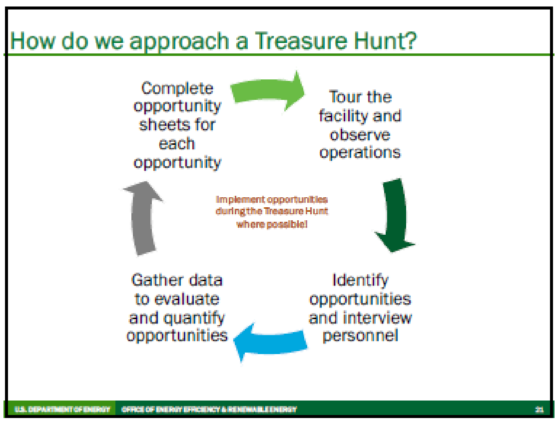

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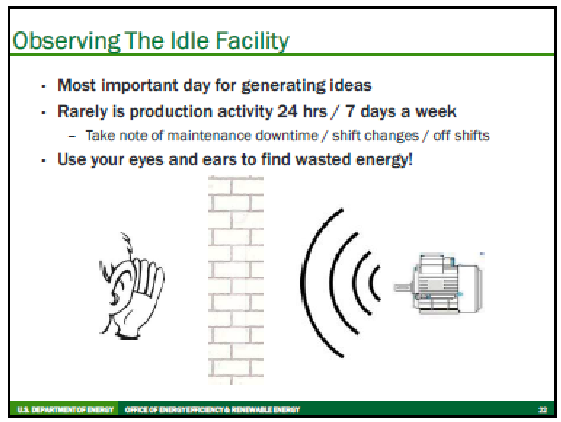

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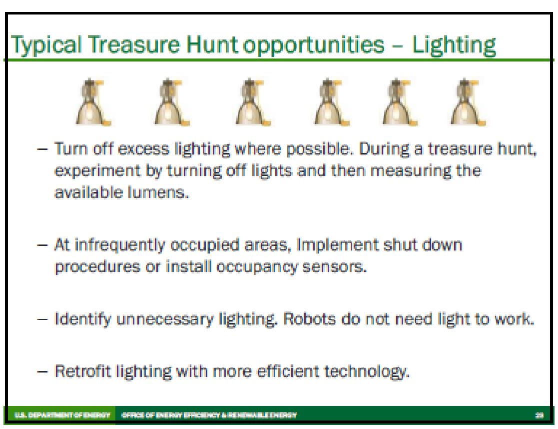

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Typical Treasure Hunt Opportunities –Compressed Air

- Operate at the lowest practical pressure set point
- Replace pneumatic energy with electrical energy where practical
- Evaluate high efficiency nozzles
- Eliminate inappropriate end use applications
- Optimize control strategy
- Perform a leak survey
- Install solenoid valves on open blowing
- No loss condensate drains

bag test on compressed air leaks!

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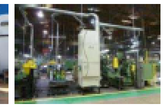
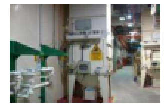
Typical Treasure Hunt opportunities - Exhaust

Exhaust systems frequently operate regardless of production requirements. Implement shut down procedures or automate shut down based on production processes.

- Fume hoods
- Scrubbers
- Dust collectors
- Extraction systems
- Chip collectors





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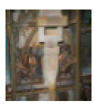
Typical Treasure Hunt opportunities – Process Heating

- Combustion tuning
- Combustion efficiency – burner upgrades, recuperators
- Poor furnace insulation
- Furnace shutdowns /non-production management
  - Temperature set points
  - Recirculation fans / blowers
  - Minimize ramp up time
  - Excessive soak time



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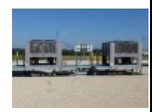
Typical Treasure Hunt opportunities – Cooling / HVAC

- **Cooling Towers**
  - Match tower capacity with process requirements
    - Less active cooling may be needed during night, colder seasons, and nonproduction
  - Check for throttled pumps / opportunities for VFD
- **HVAC / Makeup Air / Comfort Cooling**
  - Use programmable thermostats to optimize cooling schedule
    - Particularly in non 24/7 areas such as offices, warehouses, partial production areas
  - Challenge temperature set points
  - Less makeup air may be needed during nonproduction, if possible, shut down a few units



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Typical Treasure Hunt opportunities – Process Equipment

- Ensure auxiliary energy is minimized during nonproduction
  - Shut down lubrication pumps, valve off compressed air, consoles, lighting panels
- Production cells should have a shut down procedure during idle time
- If the process is not a bottleneck in plant production, consider batch processing and avoid constant idle time waiting for product
- Optimize throughput
  - parts washers
  - cooling tables / fans
  - die heaters
  - Extrusion machines

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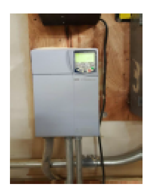
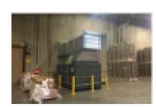
One More Thing

- **Look for best practices**





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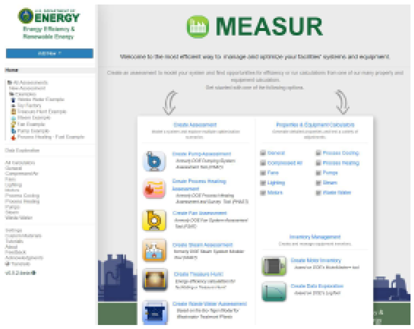
A New Tool



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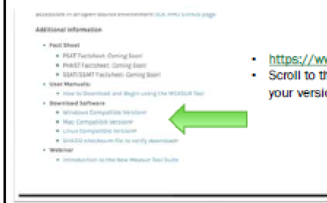
Download via DOE-EERE-AMO website



- https://www.energy.gov/eere/amo/measur
- Scroll to the bottom to find and download your version

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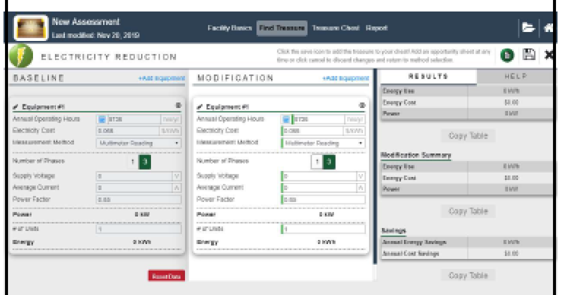
MEASUR Calculators



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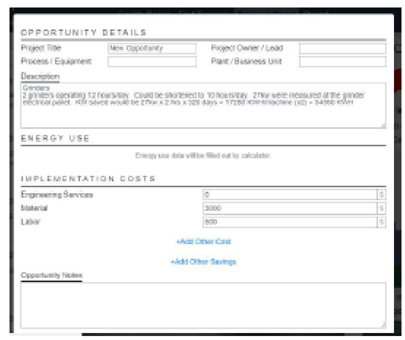
MEASUR Opportunity Sheet



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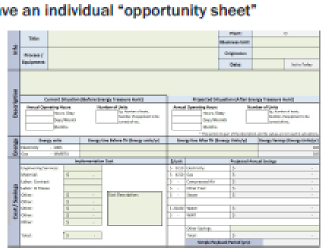
Documentation using Opportunity Sheet

- **An opportunity detail sheet is a tool that helps organize and document information about identified opportunities**
- **Each opportunity should have an individual "opportunity sheet"**

Information captured
- Description
- Implementation costs
- Energy Saved
- Cost Savings
- Payback Metrics



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Useful Resources

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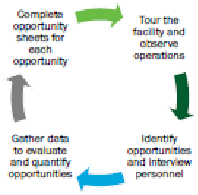
Useful Resources

The following resources are made available to help participants with each step of the treasure hunt process

- **Energy Calculators**
  - To find "Energy Saved" for opportunity sheet
- **Handouts**
  - To help identify opportunity
- **Diagnostic Equipment**
  - To help collect accurate data



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Energy Calculators

- To quantify the energy savings associated with an identified opportunity
- The results from the calculator are used to populate the opportunity sheets.

Two types of Energy Efficiency Calculators are available

I. **Treasure Hunt Calculators**
   - To estimate the savings associated with typical operational opportunities, e.g. Scheduling the equipment, reducing the load on the equipment etc.

II. **Opportunity Specific Calculators**
   - Available for some common opportunities that cant be easily quantified using the treasure hunt calculator e.g. Insulation, lighting replacement etc.

Participants can use their own method or tool to quantify savings, however, the result of the calculation and description still needs to be captured in the standard opportunity sheet provided.

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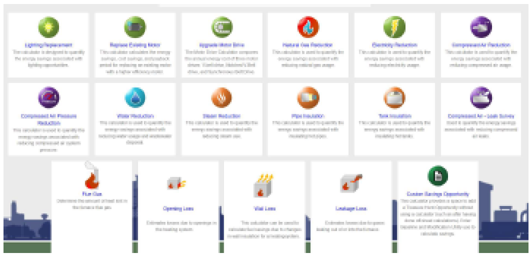
Energy Calculators - Suite

The following calculators are available as part of the toolkit and DOE is continuously working to improve the portfolio of calculators available.



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Data Gathering Tools

- DOE provides energy diagnostic equipment and teaches the participants how to use them
- Helps participants evaluate equipment performance and quantify energy performance improvement more accurately

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Handouts

- System specific handout sheets are provided by DOE to help participants identify and quantify energy savings opportunities.
- Three sets of handouts for each system type is available;
  - System Checklist
  - Data Collection Sheet
  - System Cheat Sheet
- The handouts are not meant to be all encompassing
- Participants should only use the handouts as a tool to get started and not solely rely on it

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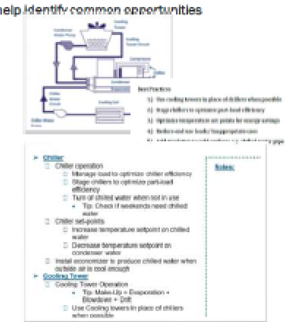
Handout 1 – System Checklist

Checklist (things to look for sheet) help identify common opportunities

- The handout provide a list of best practices
- Typical system schematic is provided wherever applicable
- A list of "things to check" is provided by system area

Checklist are available for
- General Building systems
- Compressed air system
- Steam system
- Process heating system
- Chilled water system
- Pump and Fan system
- Lighting and



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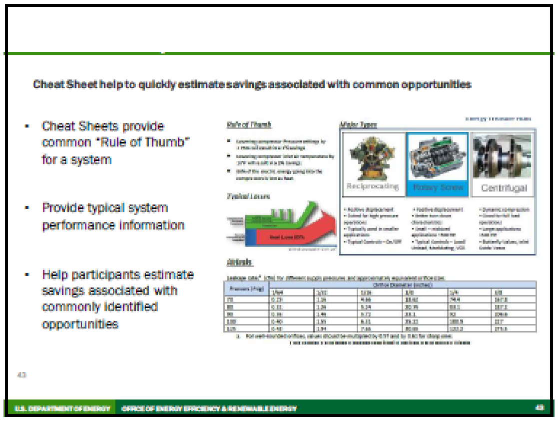
Cheat Sheet help to quickly estimate savings associated with common opportunities
Cheat Sheets provide common "Rule of Thumb" for a system
Provide typical system performance information
Help participants estimate savings associated with commonly identified opportunities
Reciprocating
Rotary Screw
Centrifugal
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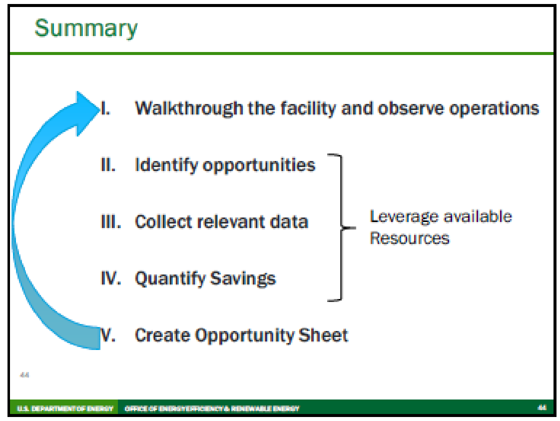
Summary
I. Walkthrough the facility and observe operations
II. Identify opportunities
III. Collect relevant data
IV. Quantify Savings
V. Create Opportunity Sheet
Leverage available Resources
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Questions / Comments
question
good
answers
answer
really
ask
knowledge
Quora
something
want
one
know
people
just
assumptions
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Gather your teammates and head out !
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APPENDIX I. CHECKLIST – INDUSTRIAL FOCUSED

APPENDIX I. CHECKLIST – INDUSTRIAL FOCUSED

FEMP Energy Treasure Hunt

FEMP
Federal Energy Management Program

Treasure Hunt Guide For:

Industrial Buildings

FEMP
Federal Energy Management Program

Industrial Checklist
Energy Treasure Hunt

Contents

Overview

An Energy Treasure Hunt is an event involves cross-functional teams of employees who identify energy efficiency improvements within a facility. The U.S. Department of Energy's Treasure Hunt program is providing free technical assistance to groups of energy team members from U.S.-based industrial, commercial, and institutional sites that would like to implement an Energy Treasure Hunt to reduce their facilities' energy use.

During the Treasure Hunt process, an experienced facilitator helps coordinate participants at the site to identify energy reduction opportunities and quantify the value and validity. Participants are trained to identify potential energy saving recommendations in a classroom setting, then tour the site and apply their training, searching for opportunities. The following systems checklists should be utilized by participants to identify these cost savings measures. The opportunities found using these checklists will later be evaluated for potential implementation.

betterbuildingssolutioncenter.energy.gov/better-plants/energy-treasure-hunts

1

General Building Checklist

Best Practices

1.) Optimize control set points
2.) Shut off idle equipment
3.) Recover waste heat to reuse
4.) Slow equipment during low demand
5.) Utilize economizers on equipment

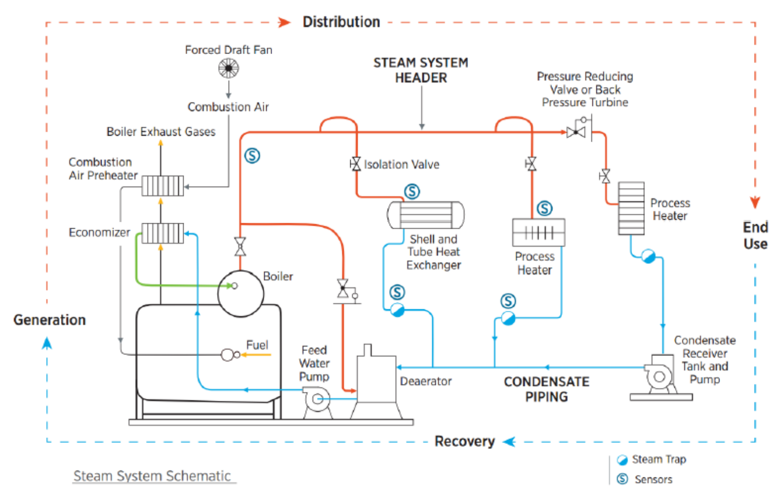
- **Building Envelope**
  - ☐ Identify gaps and cracks in the building envelope that lead to unintended indoor/outdoor air exchange
  - ☐ Check if windows are double pane windows are installed
  - ☐ Consider installing a reflective roof covering if applicable
  - ☐ Keep doors and garage bays closed when inside air is conditioned
    - ☐ Consider installing vinyl curtains if appropriate
  - ☐ Consider installing window tint in areas with high solar exposure to reduce heat transfer
  - ☐ Confirm building and roof insulation is adequate
- **HVAC**
  - ☐ Set controls to avoid simultaneous heating and cooling
  - ☐ Install economizers on air intake so mechanical cooling can be avoided on cool days
  - ☐ Utilize waste heat recovery where possible
  - ☐ Install destratification fans in open areas
  - ☐ Install personal cooling fans for dedicated cooling
  - ☐ Install zone controls to avoid conditioning unoccupied areas
  - ☐ Install demand-controlled ventilation variable occupancy areas
    - Tip: Check auditoriums, conference rooms, etc.
  - ☐ Optimize control setpoint to not over condition air
  - ☐ Establish a temperature setback policy for unoccupied hours
    - ☐ Consider smart thermostats with logic control where applicable
      - Tip: consider after-hours and weekends
- **Plug Loads**
  - ☐ Turn off unused equipment after hours
    - Tip: consider printers, computers, rechargeable devices
  - ☐ Turn off or put vending machines on sleep-mode when not in use
    - ☐ Consider motion sensor on vending machines
  - ☐ Turn off large screen-TVs and monitors when not in use

Notes:

Steam System Checklist

Best Practices

1.) Reduce Steam demand and pressure
2.) Preheat boiler feed water
3.) Optimize Fuel/Air Ratio
4.) Install automated blowdown controls
5.) Fix Steam Traps
6.) Optimize deaerator vent rate
7.) Insulate Pipes and Tanks
8.) Adjust steam system based on production
9.) Recover condensate/ flash steam and capture water & heat
10.) Identify and close off dead legs (unused to sections of steam header)



Steam System Schematic

Boilers

- ☐ Perform regular boiler tune-ups
  - ☐ A tune-up should include minimizing excess air, cleaning boiler heat transfer surfaces, and improving fuel/air ratio control
- ☐ Improve feedwater treatment to avoid excessive blowdown
- ☐ Automate boiler blowdown
- ☐ Use boiler blowdown for heat recovery
- ☐ Turn boiler off or reduce pressure during non-operating hours

➢ **Boiler System**

- ☐ Sequence boilers to avoid part-loading
- ☐ Automate stack dampers to reduce losses
- ☐ Direct warm air to combustion intake
- ☐ Preheat feed water
  - Try to utilize blow-down or exhaust heat

➢ **Distribution System**

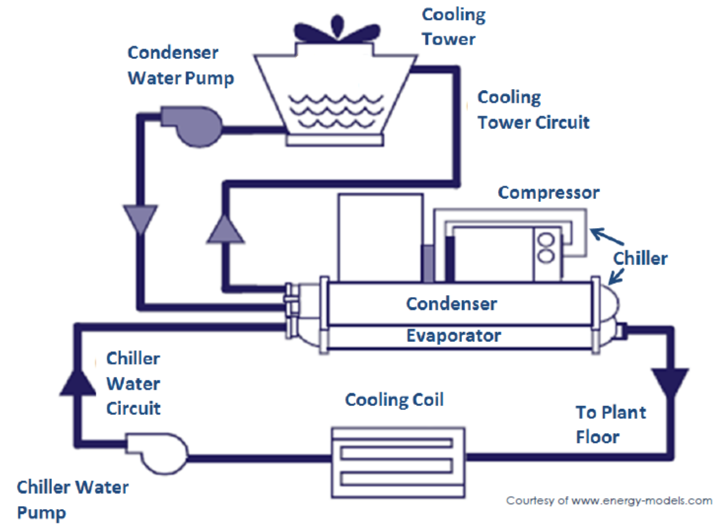
- ☐ Reduce boiler pressure to minimum required
- ☐ Close off dead legs
- ☐ Recover steam for low-pressure applications
  - ☐ Install back pressure turbines instead of pressure reducing valves (PRV)
- ☐ Repair steam leaks
- ☐ Use Insulation throughout system
  - ☐ Steam lines
  - ☐ Condensate lines
  - ☐ Flash tanks
- ☐ Repair steam traps

Notes:

Chiller System Checklist

Best Practices

1.) Use cooling towers in place of chillers when possible
2.) Stage chillers to optimize part-load efficiency
3.) Improve heat exchanger effectiveness
4.) Install VFDs on Cooling Tower Fans
5.) Reduce end use loads/ Inappropriate uses
6.) Optimize temperature set points for energy savings
7.) Add insulation to cold surfaces e.g. chilled water pipe
8.) Employ Floating Head Pressure Control
9.) Stage operation of cooling tower fan
10.) Employ variable-speed pumping



- **Chiller**
  - ☐ Chiller operation
    - ☐ Manage load to optimize chiller efficiency
    - ☐ Stage chillers to optimize part-load efficiency
    - ☐ Turn of chilled water when not in use
      - Tip: Check if weekends need chilled water
  - ☐ Chiller set-points
    - ☐ Increase temperature setpoint on chilled water
    - ☐ Decrease temperature setpoint on condenser water
  - ☐ Install economizer to produce chilled water when outside air is cool enough
- **Cooling Tower**
  - ☐ Cooling Tower Operation
    - Tip: Make-Up = Evaporation + Blowdown + Drift
    - ☐ Use Cooling towers in place of chillers when possible
    - ☐ Install Controls to Stage Cooling Tower Fans On/Off
    - ☐ Install VFDs on Cooling Tower Fans
  - ☐ Tower Make-up water
    - ☐ Decrease blowdown of cooling towers
    - ☐ Conductivity controller to automatically control blowdown
    - ☐ Water treatment opportunities
    - ☐ Opportunities with evaporation
- **Distribution and End Uses**
  - ☐ Sequence distribution pumps using appropriate controls
  - ☐ Interface chilled water with production or process use (control water based on demand)
  - ☐ Reduce end use loads
  - ☐ Reduce setpoints during non-operational hours
  - ☐ Add heat exchangers were relevant
  - ☐ Add or repair insulation
  - ☐ Eliminate inappropriate uses of chilled water

Notes:

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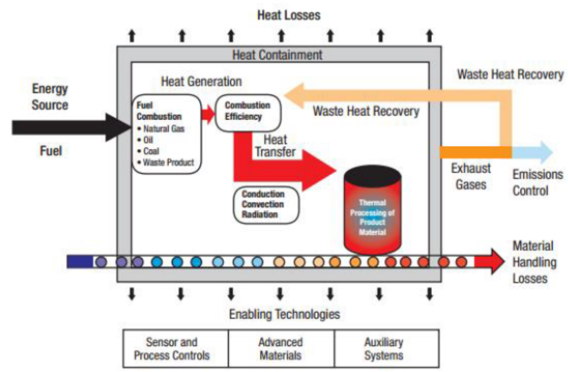
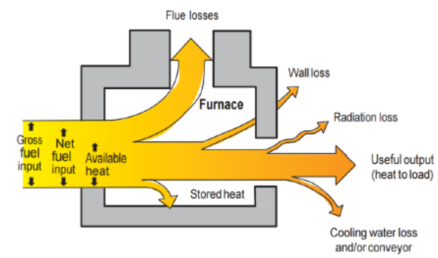
Federal Energy Management Program
Industrial Checklist
Energy Treasure Hunt

Process Heating Checklist

Best Practices

1.) Optimize oxygen level in flue (exhaust) gases or optimize combustion burner air-fuel ratio
2.) Reduce/eliminate openings and air leakage in furnaces
3.) Furnace scheduling, loading, shut down - avoiding delays, waits, cooling between operations etc.
4.) Clean heat transfer surfaces - radiant tubes, heat exchangers, heater tubes, etc.
5.) Use of flue or exhaust gas heat for combustion air preheating or waste heat recycling





- **Heat Generation**
  - ☐ Check for combustion air leak downstream of the control valve
  - ☐ Check the air to fuel ratio
    - ☐ Too much oxygen signals unburned fuel in the flue
- **Heat Containment**
  - ☐ Reduce Heat Loss
    - ☐ Lower operating Temperature
    - ☐ Eliminate openings and air leakage to burner
    - ☐ Clean heat transfer surfaces
  - ☐ Check for holes furnace insulation
  - ☐ Insulate associated piping
  - ☐ Recover waste heat where possible
    - Tip: Check temperature of the exhaust
- **Enabling Technology**
  - ☐ Furnace Operation/scheduling
    - ☐ Avoid frequent furnace starts and stops
    - ☐ Avoid idle time between batches
    - ☐ Avoid extended periods of low-capacity furnace operation
      - ☐ Is batch production possible?
  - ☐ Material Handling
    - ☐ Stop conveyors during non-production
    - ☐ Can the weight of the fixtures be reduced/ alternate fixtures removed?
    - ☐ Recover heat from components
      - Tip: Check temperature of the components going out

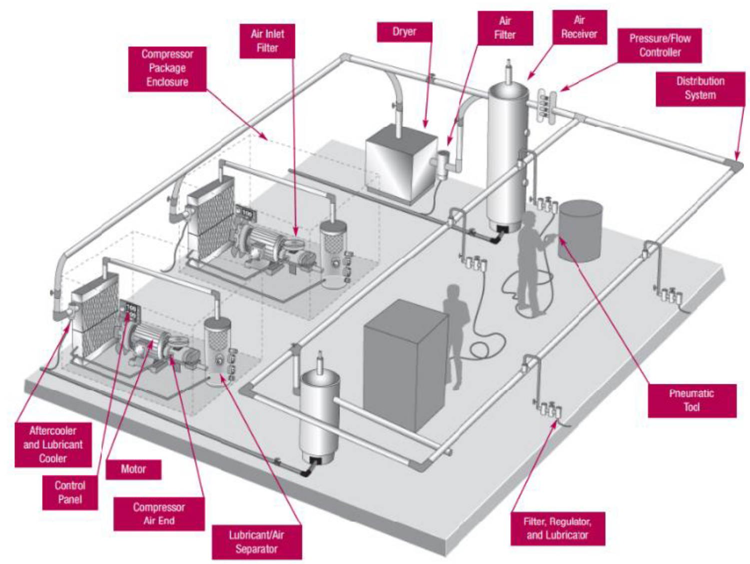
For more info – Improving Process Heating System Performance – A Sourcebook for Industry, 3rd Edition.

Notes:

Compressed Air Checklist

Best Practices

1.) Fix Air Leaks
2.) Reduce Compressor Discharge Pressure
3.) Restrict compressed air flow on weekends
4.) Remove Inappropriate Uses
5.) Switch pneumatic tools to electric mechanical tools
6.) Automate compressor shut off when not needed
7.) Install sufficient Storage & stabilize system
8.) Use VFD machine for trimming
9.) Use no loss condensate drain
10.) Reduce Blow-off in centrifugal compressors



Components of a Typical Industrial Compressed Air System.

- **Compressor Room**
  - ☐ Compressor Controls
    - ☐ Turned off/ down compressor during weekend/ between shifts
    - ☐ Automatic turnoff based on timer
    - ☐ Use control scheme optimized for given load
  - ☐ Optimize Compressor discharge
    - ☐ Confirm pressure drop across the filters/ dryer acceptable
      - Tip: Typical 3-5 PSI
    - ☐ Minimize pressure drop & reduce compressor discharge pressure
    - ☐ Reduce system pressure to the minimum
      - Tip: Save 1% energy for every 2-3 PSI discharge pressure decrease
  - ☐ Recover heat from the compressor to use elsewhere
      - Tip: 80% of the energy is lost as heat
  - ☐ Multi-compressor systems
    - ☐ Use a VFD on the trim compressor
    - ☐ Use a programmable Logic Control (PLC)-based multi-compressor control to sequence based on demand
    - ☐ Avoid multiple compressors at part load
- **Compressed Air System**
  - ☐ Confirm that there is adequate storage for the system
      - Tip: Rule of thumb - 5 gal of storage per cfm
  - ☐ Use dedicated storage for intermittent heavy flow equipment
  - ☐ Use zero loss condensate drains where possible
  - ☐ Check for compressed air leaks and establish leak program
  - ☐ Close off old headers that are no longer in use
  - ☐ Confirm dryer type is adequate
      - Tip: Desiccant dryers should only be used when higher air quality is a requirement
- **End Use**
  - ☐ Turn off compressors when there is no demand
  - ☐ Replace pneumatic equipment with electric
  - ☐ Use solenoid valves to shut off unnecessary air
  - ☐ Use vortex nozzles or FRLs on unregulated end uses
  - ☐ Remove any inappropriate uses of compressed air
      - Tip: Check for personnel cooling, open blowing, mixing, etc

Notes:

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Industrial Checklist
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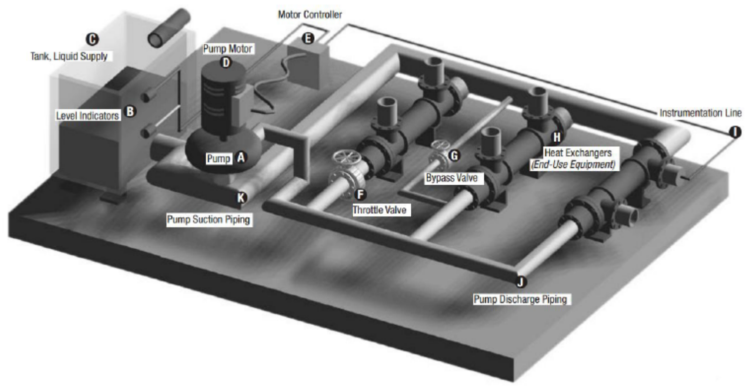
Pump and Fan Checklist

Best Practices

1.) Turn off motors when not in use
2.) Use low head-loss fitting
3.) Size the motors correctly
4.) Reduce pipe/duct length and turns
5.) Use energy efficient motors
6.) Reduce entrance/exit head loss
7.) Use cogged V belts or synchronous belt drives
8.) Install variable speed drive (VSD)
9.) Trim impellers or use a VSD instead of using bypass or valves throttling (in cases of excess flow/oversized pumps)
10.) In intermittent operations, run motor slower and longer



- **Pumps and Fans**
  - ☐ Resize oversized motors
  - ☐ Apply variable speed drives
  - ☐ Use NEMA premium efficiency motors
  - ☐ Control equipment for flow or pressure
  - ☐ Is there more flow than required to meet system requirements?
    - ☐ Higher flow requires more energy
  - ☐ Turn off/ down the fan / blower during low production times
  - ☐ Cycle fan/pump with production throughput
  - ☐ Repair or replace motors that are worn out/ eroded
  - ☐ Avoid pumps being run dead headed
  - ☐ Repair suction problems
    - Tip: look for inadequate suction head, poor geometry, obstructions
  - ☐ Reduce head where possible
  - ☐ Is re-circulation used instead of pump control?
- **System**
  - ☐ Identify and fix air and water leaks
  - ☐ Shut down redundant units
  - ☐ Remove unneeded flow paths
  - ☐ Check for sufficient distance between the fan and first elbow
    - Tip: Fans need piping to be 3 x diameter of the fan blade before the first elbow tee to avoid system effect.

Notes:

Lighting Checklist

Best Practices

1.) Use motion sensors in low-traffic areas
2.) Turn off fixtures blocked by obstructions
3.) Turn off/dim lights near windows/ skylights
4.) Use photo sensors for outdoor lighting
5.) Determine required light level and de-lamp
6.) Clean dirty and yellowed lenses
7.) Lower lights beneath scaffolding
8.) Add reflectors to fluorescent lights
9.) Look at LED replacement options
10.) Add task lighting over critical areas

- **Indoor Areas – Lighting**
  - ☐ Examine lighting levels
    - ☐ Removing or de-lamping existing fixtures
    - ☐ Add task lighting over critical areas and reduce surrounding light levels
  - ☐ Lighting Replacement
    - ☐ Incandescent lamps replaced with LED or CFL
      - Tip: Check Exit signs and stairway lighting
    - ☐ Metal Halide and HPS lamps replaced with LED
    - ☐ T12 & T8 fluorescents lamps replaced with LED
  - ☐ Unplug unused ballasts
    - Tip: Remove magnetic ballasts throughout facility
  - ☐ Remove or replace burnt out lamps
- **Indoor Areas – Controls**
  - ☐ Occupancy sensors in low-traffic areas
  - ☐ Timed switches in areas with scheduled occupancy
  - ☐ Photosensors in areas with adequate daylight during operating hours
  - ☐ Dimming controls on areas with appropriate daylight or where lights cannot be shut off completely
- **Outdoor Areas – Lighting**
  - ☐ Lighting Replacement
    - ☐ Incandescent lamps replaced with LED or CFL
      - Tip: Check Exit signs
    - ☐ Metal Halide and High-Pressure Sodium lamps replaced with LED
      - Tip: Check pole lamps
    - ☐ T12 and T8 lamps replaced with LED
      - Tip: check parking structures
- **Outdoor Areas – Controls**
  - ☐ Occupancy sensors in low-traffic areas
  - ☐ Timed switches on outdoor lighting
  - ☐ Photosensors on outdoor lighting
    - Tip: check parking structures

Notes:

Additional Notes:

APPENDIX J. DATA COLLECTION SHEETS

APPENDIX J. DATA COLLECTION SHEETS

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Pumps / Fans System - Data Collection Sheet

Energy Treasure Hunt

Measure	Data to Collect	Data	How to Collect
Pumps - Common System Data	Condition of seals & impeller		Visual inspection
	Condition of piping (leaks, friction & cavitation)		Visual inspection
	Amount of static and dynamic head		Name Plate / Interview operators
	Suction pressure & discharge pressure		Pump gauges
	Size of pumps relative to load		
	Pumping system controls		Interview operators
Turn off fan/pump motor when possible 1	Motor Location / System its used in		
	Motor Rating		Name Plate
	Percent Load (%)		Interview the operators
	Nameplate Efficiency		Name Plate
	Current operating hours per year		Interview the operators
	Proposed operating hours per year		Determined based on proposed operations
Turn off fan/pump motor when possible 2	Motor Location / System its used in		
	Motor Rating		Name Plate
	Percent Load (%)		Interview the operators
	Nameplate Efficiency		Name Plate
	Current operating hours per year		Interview the operators
	Proposed operating hours per year		Determined based on proposed operations
Belt Replacement (notched belt)	Motor Location / System its used in		
	Motor Rating		Name Plate
	Nameplate Efficiency		Name Plate
	Current operating hours per year		Interview the operators

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Steam System - Data Collection Sheet

Energy Treasure Hunt

Measure	Data to Collect	Data	How to Collect
Common System Data	How many boilers?		
	How many boilers are running?		Interview the operators
	Boiler capacity(s) (BTU or lbs./hour)		From panel
	Total generation capacity (lbs./hour)		From panel
	Average steam generation rate (lbs./hour)		From panel
	Average boiler blowdown rate		Interview the operators
	Current System Pressure		From pressure gauge in header line
	Highest Pressure on header		Interview the operators
	Highest Pressure Required at floor		Interview manager/ personnel on the floor
	Stack Temperature		
Steam Leaks	How many leaks/ defective traps		Approximation based on the ones found
	Diameter of the leak		Ultrasonic Leak Detector / visual determination
	Pressure on line		From nearby pressure gauge
	Hours of operation of the leak(or boiler)		
Reduce System Pressure/ Pressure Setback	Current System Pressure		From pressure gauge in header line
	Proposed system pressure		Determined from existing and needed pressure at end use
	Hours when pressure could be reduced		Determined based on proposed operations
Waste heat recovery	Boiler size		Name Plate
	Area of waste heat use		Combustion Air? At process?
	Average stack temperature		Digital panels , data logging , spot measurement
	Average hours of operation of the boiler		Digital panels , data logging , spot measurement

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Lighting System - Data Collection Sheet

Energy Treasure Hunt

Measure	Data to Collect	Data	How to Collect
Common System Data	Average hours of office Lighting		From Schedule if automated / Interview
	Average hours of floor Lighting		From Schedule if automated / Interview
	Average Lumens level in Office Spaces		From light meter
	Average Lumens level in manufacturing floor		From light meter
	Exsisting Control Strategy in Offices		From light meter
	Exsisting Control Strategy on the Floor		From light meter
Lighting Replacements 1 (Location -_____________)	Existing type of lights		Fixture label / See Cheat Sheet
	Number of Fixture		Physical counting/ From lighting plans
	Wattage of Fixture (including ballast)		Fixture label/ Reference table online
	Hours of Operation		From Schedule if automated / Interview
	Wattage of Proposed fixture		Specification Sheets - Available Online
Turn Off Lights (Location - _____________)	Existing Type of lights		Fixture label/ See Cheat Sheet
	Number of Fixture to be turned off		Physical Counting/ From lighting plans
	Wattage of Fixture (including ballast)		Fixture label/ Reference table online
	Existing Hours of Operation		From schedule if automated / Interview
	Proposed Hours of Operation		Specification Sheets - Available Online
Delamp Lights (Location -_____________)	Existing Type of lights		Fixture label/ See Cheat Sheet
	Number of Fixtures		Physical Counting/ From lighting plans
	Number of lamps per fixture		Physical Counting
	Number of lamps to be delamped per fixture		Based on the amount of excess lighting levels
	Exisiting Wattage of Fixture (including ballast)		Fixture label/ Reference table online
	Wattage of Fixture (including ballast) upon delamping		Calculate from percent delamped
	Existing Hours of Operation		Interview with plant personnel
Occupancy Sensors (Location -_____________)	Existing Type of lights		Fixture label/ See Cheat Sheet
	Number of Fixture to be on Sensor		Physical Counting/ From lighting plans
	Wattage of Fixture (including ballast)		Fixture label/ Reference table online
	Existing Hours of Operation		From Schedule if automated / Interview
	Proposed Hours of Operation		Interview with plant personnel
	Number of Occupancy sensor		Good judgement

FEMP Federal Energy Management Program

Chilled Water System - Data Collection Sheet

Energy Treasure Hunt

Measure	Data to Collect	Data	How to Collect
Common System Data	How many Chillers?		
	How many Chillers are running?		Interview the operators
	Chillers Capacity(s) HP or kW		From panel/ Nameplate
	Cooling Tower Size		From panel/ Nameplate
	Current Chilled Water Temperature Pressure		From temperature Gauge on chilled water side
	Current Condenser Water Temperature Pressure		From temperature Gauge on condenser water side
	Lowest Temperature Required at floor		Interview operators who run equipments that use chilled water
	Is the system closed or open loop?		Interview operators who run equipments that use chilled water
Reduce/Setback Chilled water Temperature	Current setpoint Temperature		From temperature Gauge on chilled water side
	Proposed setpoint Temperature		Determined from existing and needed temperature at end use
	Hours when pressure could be reduced		Determined based on proposed operations
Increase Condenser Temperature	Current setpoint Temperature		From temperature Gauge on condenser water side
	Proposed setpoint Temperature		Determined from existing and needed temperature at end use
	Hours when pressure could be reduced		Determined based on proposed operations

FEMP Federal Energy Management Program

Compressed Air System - Data Collection Sheet

Energy Treasure Hunt

Measure	Data to Collect	Data	How to Collect
Common System Data	How many compressors?		
	How many compressors are running?		Interview the operators
	Are the compressors running fully loaded?		Interview the operators/ from panel
	Compressor(s) total connected BHP or kW		From panel
	Current System Pressure		From Pressure Gauge in Header line
	Highest System Pressure		Interview the operators
	Highest Pressure Required at point of use		Interview manager/ personnel who use compressed air
	Nominal Compressed air Output (CFM)		From panel
Air Leaks	How many leaks		Approximation based on the ones found
	Diameter for the Leak		Ultrasonic Leak Detector / visual determination
	Main header pressure		From nearby pressure gauge
	Hours of operation of the leak		
Reduce System Pressure	Current System Pressure		From Pressure Gauge in header line
	Proposed system pressure		Determined from existing and needed pressure at end use
	Hours when pressure could be reduced		Determined based on proposed operations
Use Blower instead of compressed air	Location		
	Inappropriate operation		Open Blowoff, air motor etc
	Main header pressure		From nearby pressure gauge
	Hours of operation of the blower		Interview manager/ personnel who use compressed air
	Diameter of the blower orifice		Using suitable tool/method
Waste heat recovery	Compressor Size		Name Plate
	Area of waste heat use		Space heating? At process?
	Average power drawn by compressor		Digital Panels on compressor, data logging , spot measurement
	Average hours of operation of the compressor		Digital Panels on compressor, data logging , spot measurement
Lossless Drain	Purge Time		Timer
	Cycle Time		Timer
	Number of Drains		
	Type of existing drain & performance		interview operators
	Pressure		From nearby pressure gauge
	Diameter of drain orifice		Scale/ approximation
	Operating Hours		Operating hours of compressor system

APPENDIX K. REFERENCE SHEETS

Federal Energy Management Program

Chilled Water System Reference Sheet

Energy Treasure Hunt

Rules of Thumb

- Relationship between temperature difference (ΔT) at the chiller, flow through the chiller and energy consumption.
  ΔT of 12°F = 2 gpm/ton; ΔT of 10°F = 2.4 gpm/ton; ΔT of 16°F = 1.5 gpm/ton.
- On a centrifugal chiller, if the chilled water temperature is raised by 2˚F to 3˚F, the system efficiency can increase by 3 - 5%.
- On a centrifugal chiller, if condenser water temperature is decreased by 2˚F to 3˚F, the system efficiency can increase by 2 - 3%.
- For every 10°F of water temperature drop across the cooling tower, there is an evaporative loss of approximately 1%, equating to 2.5 to 4.0 gpm per 100 tons of capacity.

Typical HVAC values (Space cooling)

Ventilation Rate	5 CFM/person
Fan Energy	1000-1500 CFM/hp
Chiller Size	300-400 ft²/ton
Ton	12,000 BTU/ton
Chilled Water	2.4 GPM/ton (10° rise)
Condenser Water	3 GPM/ton (10° rise)
People Load	450 BTU/person/hr
Infiltration	0.5-1.5 ACH without building pressurization
Heat Transmission through envelope	Overall Building – 0.15 to 0.5 BTU/ ft² / F
	See ASHRAE Handbook of Fundamentals for accurate heat loads by envelope type

*These are only typical values which should be verified if appropriate for each case. These values are to be referenced only when accurate values are not available.

Set points for distribution system	Rebuilt Systems Design	55°F supply air
		30°-40° rise reheat coils
	Dual Duct and Multizone design	55° cold deck
		70-105° hot deck – with ODA Reset Schedule
	VAV	55°F cooling
		10% box leakage flow
		40-50% minimum fan volume

Quick Calculations and conversions

$$Q\left(\frac{Btu}{hr}\right) = 499 \times G.P.M. \times Delta - T$$

$$\text{US GPM} = \text{liter/second} \times 15.85$$

$$Ton = 12\ MBH = 12{,}000\ Btuh \text{ (chilled water)}$$

$$Ton = 15\ MBH = 15{,}000\ Btuh \text{ (condenser water)}$$

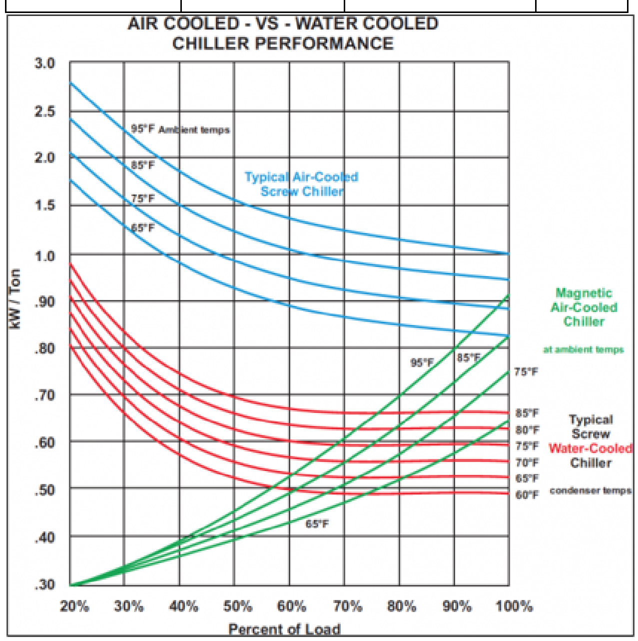
$$COP = 3.516\ /\ (kw\ /\ Ton)$$

$$EER = Tons\ x\ 12\ /\ (Total\ kW\ input)$$

$$Water\ Pressure\ Drop\ (ft.\ wg) = kPa \times 0.335$$

Typical Chiller Efficiencies in kW/ton

Chiller Type\Criteria	ASHRAE Standard 90.1 Minimum	Good	Best
Air- Cooled	1.26	1.21	1.13
Water - Cooled	0.72	0.65	0.45



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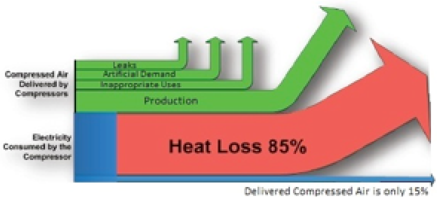
Compressed Air System Reference Sheet

Energy Treasure Hunt

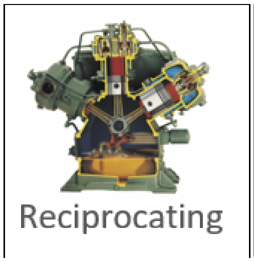
Rule of Thumb

- Lowering compressor pressure settings by 2 PSIG will result in a 1% savings.
- Lowering compressor inlet air temperature by 10°F will result in a 2% savings.
- 80% of the electric energy going into the compressors is lost as heat.

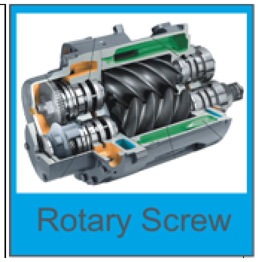
Typical Losses



Major Types



- Positive displacement
- Suited for high pressure operations
- Typically used in smaller applications
- Typical Controls – On/Off



- Positive displacement
- Better turn down characteristics
- Small – midsized applications <500 HP
- Typical Controls – Load/ Unload, Modulating, VSD.

- Dynamic compression
- Good for full load operations
- Large applications >500 HP
- Butterfly Valves, Inlet Guide Vanes

Air leaks

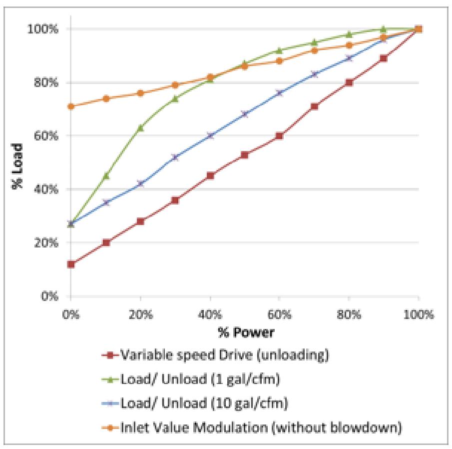
Leakage rates[a] (cfm) for different supply pressures and approximately equivalent orifice sizes

Pressure (Psig)	Orifice Diameter (inches)					
	1/64	1/32	1/16	1/8	1/4	3/8
70	0.29	1.16	4.66	18.62	74.4	167.8
80	0.32	1.26	5.24	20.76	83.1	187.2
90	0.36	1.46	5.72	23.1	92	206.6
100	0.40	1.55	6.31	25.22	100.9	227
125	0.48	1.94	7.66	30.65	122.2	275.5

a. For well-rounded orifices, values should be multiplied by 0.97 and by 0.61 for sharp ones.

Cost savings = # of leaks x leakage rate (cfm) x kW/cfm x # of hours x $/kWh

Power drawn @ Part Load



Calculating Efficiency Index – kW/CFM

-Compressor data sheet (CAGI) usually provides kW/CFM at the rated capacity and the full load pressure

- Average kw/cfm can be found by logging the energy consumption by the compressor.

Inappropriate Uses

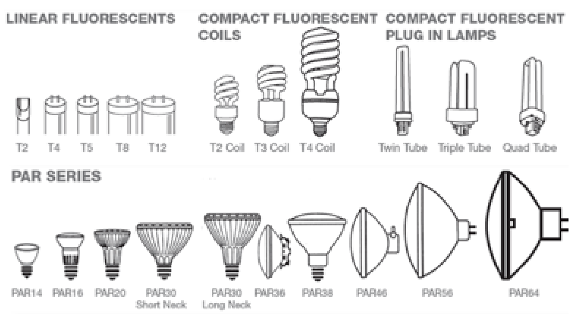
Potential Inappropriate Uses	Alternatives
Clean up, Drying, Process Cooling	Low pressure blowers, electric fans brooms
Sparging	Blowers and mixers
Aspirating, Atomizing	Low pressure blower
Vacuum Generator	Dedicated Vacuum pump
Air operated diagram pumps/motor	Electric pump with proper regulator
Air motor	Electric motor
Idle equipment	Air stop valve at the inlet
Abandoned equipment	Disconnect air supply

Federal Energy Management Program

Lighting Systems Reference Sheet

Energy Treasure Hunt

Identifying Lighting Type



Identifying Lighting Source

Lighting Level Recommendation- Illuminating Engineering Society (IES)

For more details refer to the IES handbook.

Assembly	Footcandle
Rough Easy seeing	25-50
Rough difficult seeing	50-100
Medium	100-200
Fine	200-500
Extra Fine	500-1000

Electronic Manufacturing	
Impregnating	20-50
Insulating coil windings	50-100

Sheet Metal Works General	100
Galvanized, inspection	100-200

Offices	Footcandle
Drafting	50-200
General /private offices	50-100
Conference Areas	20-70
Corridors, Stairways	20
Lobbies, lounges	0-20

Automobile Manufacturing	
Final assembly, finishing	200
Body assembly	100
Body manufacturing	100
Frame assembly	50

Warehousing/ Storage	
Inactive	5-10
Active – Rough bulky	10-20
Active – Medium	20
Active – Fine	20-50

Machine Shop	Footcandle
Medium bench, rough grinding, buffing	50-100
Rough bench	20-50
Fine bench and work	200-500
Welding	20-50

Lighting Controls

Dimmers	Dimmer controls provide variable indoor lighting.
Occupancy	To turn on /off lights based on activity in light levels.
Photo sensors	To turn on /off lights based on ambient light levels.
Timers	To turn on and off lights at specific times.

* Typical energy savings with occupancy sensors is 30%.

LED Options

1.) LED Fixtures – Lamp + Fixture

2.) LED Retrofits – Lamp to fit into existing fixture

Tips

- Make use of lighting plans to get the count of lights
- De-lamping is an easy way to reduce lighting levels and energy use
- LED retrofits (available are all applications) are cheaper than LED fixtures.
- Leverage sky lighting

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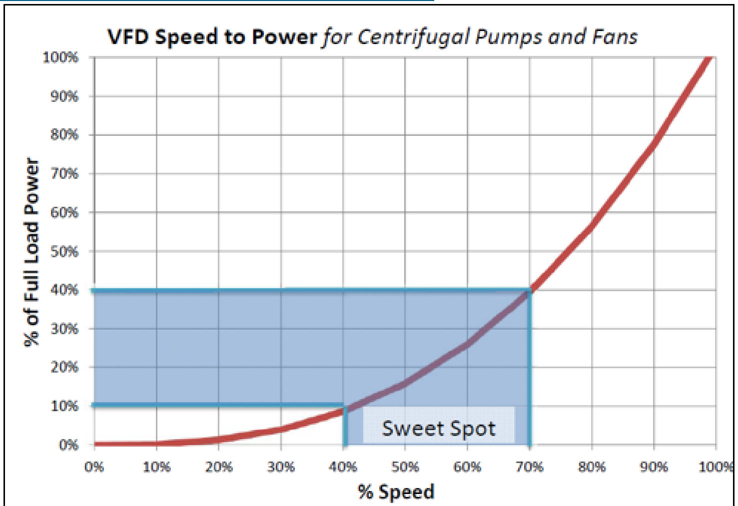
Pump and Fan Systems Reference Sheet

Energy Treasure Hunt

Centrifugal Fan and Pump VFD power relationship

% Loading	Cycling % Power	VFD % Power
110%	100%	133%
100%	100%	103%
90%	90%	78%
80%	80%	56%
70%	70%	39%
60%	60%	26%
50%	50%	16%
40%	40%	9%
30%	30%	4%
20%	20%	1%
10%	10%	0%
0%	0%	0%
VFD inverter efficiency ~ 97%		
Affinity Laws	Flow ∝ Speed Pressure ∝ $Speed^2$ Power ∝ $Speed^3$	
Real World	%Power = (%Speed)^2.7	



* Avoid running VFDs fully loaded by setting maximum speed to ≤90%.

Calculating kWh

from Brake horsepower (BHP)

$$BHP = \text{Motor Nameplate HP} \times 80\% \times \%\text{of full load power}$$

*Percent of full load power can be obtained from the table above.

$$kWh = \frac{Brake\ Horsepower \times 0.746}{Motor\ Efficiency}$$

For three phase power use:

$$kWh = \frac{Amps \times Volts \times 1.73 \times power\ factor \times\ operating\ hours}{1000}$$

Motor Efficiency and Power Factor

Motor Name Plate (HP)	Standard Efficiency	Premium Efficiency	Approx. Power Factor
1	74	82	0.62
5	84	90	0.70
10	87	91	0.73
25	90	93	0.77
50	91	94	0.80
100	92.2	94.7	0.82
250	93.3	95.2	0.85
500	94.0	95.5	0.91
1000	94.5	95.7	0.92

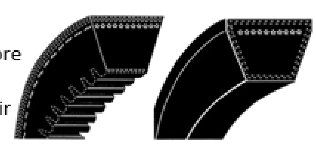
Consideration Criteria's for VFD

- Higher Horsepower the better (>15 hp)
- Loads with variable torque requirements.
- Operating Hours (>2000 hrs)
- Loads that could benefit from soft start/shut-off capability

Replace Belts

- Standard V-belts have nominal efficiency of 93%.
- Notched belts are about 2% more efficient than standard V-belts.
- Synchronous belts maintain their efficiency (98%)

Cogged Belt Standard V belt



Power vs Flow (Approximations)

$$Pump\ H.P = \frac{G.P.M. \times Head}{3960 \times Efficiency}$$

$$Fan\ H.P = \frac{C.F.M. \times SP}{6355 \times Efficiency}$$

*Typical Fan energy – 1000 – 1500 CFM/hp

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Steam System Reference Sheet

Energy Treasure Hunt

Rules of Thumb

- Average efficiency of a steam boiler is 80%.
- 10PSI drop in header pressure is 1% energy reduction
- Every 10.7 F rise in boiler feedwater temperature yields ~1% steam energy savings
- Unmaintained steam system - 15% to 30% of traps failed.
- Ideal, maintained steam system – 5% of traps failed.

Improve Boiler Combustion Efficiency

Excess, %		*Combustion Efficiency — Flue gas Temperature minus combustion air Temperature, F*				
Air	*Oxygen*	*200*	*300*	*400*	*500*	*600*
9.5	*2.0*	*85.4*	*83.1*	*80.8*	*78.4*	*76.0*
15.0	*3.0*	*85.2*	*82.8*	*80.4*	*77.9*	*75.4*
28.1	*5.0*	*84.7*	*82.1*	*79.5*	*76.7*	*74.0*
44.9	*7.0*	*84.1*	*81.2*	*782.2*	*75.2*	*72.1*
81.6	*10.0*	*82.8*	*79.3*	*75.6*	*71.9*	*68.2*

Calculating Steam Cost

Energy required to produce one pound of saturated steam, BTU

Operating Pressure, psig	*Feed water Temperature, F*				
	50	***100***	***150***	***200***	***250***
150	*1178*	*1128*	*1078*	*1028*	*977*
450	*1187*	*1137*	*1087*	*1037*	*986*
600	*1184*	*1134*	*1084*	*1034*	*984*

$$\$/1000\ lbs\ of\ steam\ = \frac{\$/MMBTU \times 1000\ lbs \times Btu/lb}{Combustion\ Efficiency\ x\ 10\text{^}6}$$

Insulate Steam and Condensate Lines

Heat Loss per 100 feet of Uninsulated steam, line, MMBTU/yr

Line Diameter, Inches	*Steam Pressure, psig*			
	15	***150***	***300***	***600***
1	*140*	*285*	*375*	*495*
2	*235*	*480*	*630*	*840*
4	*415*	*850*	*1120*	*1500*
8	*740*	*1540*	*2030*	*2725*
12	*1055*	*2200*	*2910*	*3920*

Heating Value of Fuels

	Units	**LHV**	**HHV**
Natural Gas	Btu/CF	1,050	1,050
#2 Fuel Oil	BTU/Gal	138,300	138,300
#6 Fuel Oil	BTU/Gal	150,500	150,500
Propane	BTU/CF	92,000	92,000
Coal - Bituminous	BTU/lbs	14,100	14,100

- Higher Heating Value (HHV): Total energy from combustion process
- Lower Heating Value (LHV): Assumes heat of condensation cannot be recovered

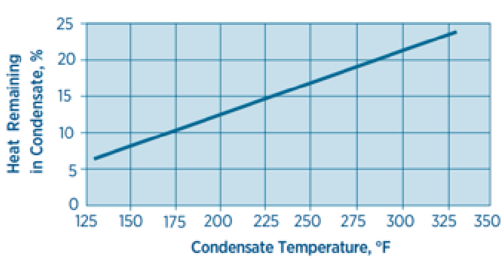
Steam Trap Failure

Obvious Signs	Less Obvious signs
•Steam flashing	•Higher than necessary pressure
•Water Hammer	•Excessive condensate & Chemical losses
• Pump cavitation	•Condensate water too hot
	•Boilers running continuously

Losses with steam Trap Failure

Trap Orifice Diameter (inches)	**Steam Loss, lb/hr**			
	15 psig	**100 psig**	**150 psig**	**300 psig**
1/32	0.85	3.3	4.8	-
1/16	3.4	13.2	18.9	36.2
1/8	13.7	52.8	75.8	145
3/16	30.7	119	170	326
1/4	54.7	211	303	579
3/8	123	475	682	1,303

Return Condensate to Boiler



*A steam system operating at 100 pounds per-square-inch-gauge (psig), with makeup water at 55°F. For other conditions use formula to the right.

Calculating %Heat Remaining in condensate using formula

$$Heat\ remaining\ in\ condensate\ (\%) = \frac{h_{condensate} - h_{makeup\ water}}{h_{steam} - h_{makeup\ water}} \times 100$$

*h - enthalpy

Example

$$h_{condensate}\ at\ 180\ F = 148\ Btu/lb\ ;\ h_{makeup\ water} = 23\ Btu/lb$$

$$h_{steam} at\ 100\ psig = 1{,}189\ Btu/lb$$

$$Heat\ remaining\ in\ condensate\ (\%) = \frac{148-23}{1189-23} = 11\%\ (as\ in\ graph)$$