U.S. DOE's Energy Treasure Hunt Exchange In-Plant Trainings – DOE Resources, Early Results and Lessons Learned

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ABSTRACT

The primary objective of the Department of Energy's (DOE) Energy Treasure Hunt In-Plant Training (INPLT) is to train Better Plants partner employees to lead and conduct future energy efficiency Treasure Hunts within their facilities without DOE assistance. By taking a "learning-by-doing" approach, this INPLT, like other DOE INPLT trainings, has the added benefit of uncovering real energy and cost-saving opportunities. This INPLT leverages DOE and Better Plants technical staff, resources and tools and the EPA "Energy Treasure Hunt Guide: Simple Steps to Finding Energy Savings" process. While Treasure Hunts are a relatively well-known approach to identifying energy-savings in manufacturing plants, DOE is adding several additional elements in its Treasure Hunt Exchanges. The first element is technical assistance and methodology. DOE provides high-quality technical resources, such as energy efficiency calculators, fact sheets, sourcebooks etc., to facilitate the Treasure Hunt process and teaches four fundamentals: 1) how to profile equipment, 2) how to collect data, and 3), data & ROI calculation methodologies. Another element is the "train the trainer" approach wherein the training facilitator will train at least one partner employee to facilitate future treasure hunts. Another element is that DOE provides energy diagnostic equipment and teaches the participants how to use them. Finally, DOE also offers partners the opportunity to exchange teams of employees either within a partners' enterprise or with other partners to conduct the treasure hunt in each other's facilities. This exchange of teams is important because each team can bring different insights and uncover energy-saving opportunities that would otherwise be missed. This paper will discuss DOE methodology and the early results and lessons learned from DOE'S Energy Treasure Hunt In-Plant Trainings at Better Plants Partner facilities.

INTRODUCTION

The Treasure Hunt Exchange is an adaptation of the Kaizen methodology for energy efficiency. The term "kaizen" is a Japanese word that signifies "change for the better" and for more than 70 years, this concept has been adopted as a mechanism to facilitate continuous improvement within manufacturing, not only in Japan, but in the United States as well. Kaizen events are temporary (3-5 day) projects in which groups of employees led by a facilitator focus on improving a specific area or topic within their facilities or workstations [1]. The point of performing Kaizen events is to involve a plant's employees in the improvement of a company's processes based on the idea that cost containment/improving productivity is a shared responsibility by all employees across an enterprise. Companies perform these events periodically to generate new ideas and process optimization projects continuously.

In the U.S., the introduction of Kaizen events was originally applied to enhance productivity and quality. By the late 1990s it started being used as a tool to facilitate improvements in industrial energy efficiency when Toyota introduced it in its U.S. plants as part of the Toyota Production System (TPS) [2]. The company began organizing energy Kaizens that were also called energy treasure hunts. Soon after, other industrial companies began applying the Kaizen methodology for energy efficiency and achieved positive results. In 2014 the U.S. Environmental Protection Agency's (EPA) Energy Star for Industry program published a guidance document (Energy Treasure Hunt Guide: Simple Steps to Finding Energy Savings) to share this established methodology with the industrial sector [3].

The EPA guidance document outlined the methodology for energy treasure hunts in a simple framework and coupled it with many, succinct sector-specific case study examples to show how the treasure hunt model applies across industry. The document also included appendices with pre- and post-event checklists and links to software calculators for a variety of energy-using applications. As a result, the current energy treasure hunt model is a multi-day event in which teams of employees spend time "hunting" through a specific facility looking for opportunities to save energy. Usually, these teams are cross-functional, and include members from operations, engineering, maintenance, and potentially

other employee groups. Energy treasure hunts usually target low- or no-cost measures to save energy, though large capital projects can be included if the teams can identify and develop the business/technical cases for them.

THE U.S. DOE ENERGY TREASURE HUNT EXCHANGE

The U.S. Department of Energy's (DOE's) Advanced Manufacturing Office's (AMO) Better Plants program [4] offers training on industrial energy efficiency as part of its portfolio of technical assistance resources. These trainings, known as In-Plant trainings, are 3-4 day events in which a subject matter expert provides hands-on training in a real-world manufacturing plant on how to identify, implement, and replicate energy-saving projects on a given industrial system. The technical expertise gained in these trainings help manufacturers overcome common, critical barriers to adopting energy efficiency practices and technologies. Since 2011, Better Plants has conducted more than 70 In-Plant trainings to approximately 850 participants.

In an effort to expand the portfolio of training topics, the Better Plants program decided to develop and offer an In-Plant training around energy treasure hunt model. To accomplish this task, it was decided that the existing literature and technical material around energy treasure hunts should be leveraged to the greatest extent possible. As a result, the training builds on the methodology that was established by Toyota and documented in the EPA's guidance document on energy treasure hunts.

A close examination of the treasure hunt model was performed to determine if any changes should be made. This examination uncovered the following conclusions:

- To be an effective training more technical background is needed for the participants. Because some participating staffs have little knowledge of industrial systems a briefing on such systems is warranted. Such a briefing would include a history of past energy efficiency efforts at the host location including what was/was not implemented.
- To be persistent the training needs to develop at least one employee from the host site/organization to serve as a facilitator. This will enable the organization to conduct energy treasure hunts across their enterprise without needing outside assistance.
- Instruction needs to be offered on the data collection and analysis tools to ensure that all participants are able to operate and utilize these tools effectively.

Another mechanism to enhance the training was to offer a peer-based approach. This was done by creating three training options:

- A conventional In-Plant training in which the event is hosted by one plant and the host plant can involve outside stakeholders.
- An internal exchange in which two plants belonging to the same organization trade teams of employees. The training is organized in two parts with part A occurring at one plant and part B at a second plant. A delegation from plant #2 participates in part A and a delegation from plant #1 then goes to plant B, usually a couple weeks later, to participate in the second part.
- An external exchange in which teams of employees belonging to separate companies participate in a two-part training. In this case, part A occurs at a plant belonging to company #1 with employees from company #2. Later, employees from company #1 attend part B at a plant belonging to company #2.

TRAIN THE TRAINER AND HANDS ON TRAINING COMPONENT

The intent of the DOE In-Plant training is to not only help industrial facilities identify energy savings opportunities but to leave the facility employees and others in attendance (similar facilities and other industries) with enough information, knowledge and tools to perform similar events on their own.

The intent of DOE Treasure Hunt Exchange training is to facilitate at one facility having a designated person(s) "shadow" the facilitator from planning stages to process facilitation to generating a summary presentation.

Planning for the Treasure Hunt Exchange includes:

- Selecting a location
- Inviting participants
- Gathering plant energy data
- Presenting pre-hunt training for select participants

During the event at least one of the trainees shadow the trainer as he or she presents an opening training on how the hunt works, followed by training on software tools including opportunity sheets and calculators. Throughout the three-day event the facilitator leads participants through identification of opportunities and then calculating the value (in

monetary units) of them. This is critical to help participants make the business cases for the projects they identify. This often includes coaching on use of tools and identification of feasible opportunities. Finally, the facilitator assists in preparing a "close out" presentation that summarizes findings. The facilitator also identifies and coaches select participants to present and discuss energy-saving opportunities.

In addition, four fundamental elements were determined that are essential for every energy treasure hunt. These four elements include:

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

These four fundamental elements are discussed in the following sections in detail.

ENERGY TREASURE HUNT EXCHANGE TOOLKIT

DOE has developed the necessary tools and materials, collectively known as the Energy Treasure Hunt Exchange Toolkit, to help with each individual phase of the treasure hunt process. The toolkit provides the treasure hunt facilitator with the right tools to effectively plan for the event, successfully run it and track the results.

The different phases of the treasure hunt process and the associated tools are listed below.

Phase 1 – Treasure Hunt Preparation

- Agenda - Template
- Pre-Training Data Collection form
- Plant Energy Profiler (PEP) Tool

Phase 2 –Treasure Hunt Event

- Kick off Presentation
- Handouts
- Energy Efficiency Calculators
- Opportunity Sheet
- Summary Report Generator

Phase 3 – Treasure Hunt Follow-up

- Participation Certification - Template
- In-Plant Training Evaluation Form – Template
- Project implementation tracker

Tools for Phase 1 – Treasure Hunt Preparation

Proper preparation helps the facilitator to setup more effective teams, identify and target high potential operations and avoid surprises on the day of the event. Crucial to proper planning is gathering relevant information and analyzing it to get a better understanding of the facility and its operations. The Pre-Training Data Collection Form is developed to serve this purpose.

The form provides a structured approach to collecting relevant information without missing out on required data. Depending on the level of time and effort the facilitator is looking to put into the preparation, the tool provides three levels of data collection and analyzing options. The "Essential data" section of the form contains items crucial to run the event like the energy sources used, operating shifts, annual energy consumption and utility costs. The "Helpful data" section contains information that is useful to plan an effective event, this include information on process equipment including its specifications, efficiency and operating hours.

For a more detailed analysis, the user can make use of the excel version of the Plant Energy Profiler (PEPEx) [5] which is included in the toolkit. The PEPEx tool helps identify how energy is being consumed at a plant in addition to pointing out the potential for improvement in each system.

Tools for Phase 2 – Treasure Hunt Event

The treasure hunt event involves the participating teams investigating specific systems to identify possible energy savings opportunities, for collecting relevant data, quantifying the savings and summarizing the results. The tools for phase 2 are developed to help the participants and the facilitator at each step of this process. While the toolkit provides the necessary information for anyone to start identifying opportunities and gathering data, it is designed to be used only as a guide to help the participants get started and not meant to be an all encompass checklist.

Handouts - The handouts provide appropriate guidance to help participants identify opportunities and collect relevant data to quantify savings. The toolkit contains three separate set of handouts for each system type including compressed air, steam, process heating, chilled water, pumps & fans, lighting and production line. The three sets of handouts are,

- Checklists or Things to look for Sheets
- Data Collection Sheets

- Cheat Sheets

Checklists - The checklists provide a breakdown of the systems and their various components which are assessed by the treasure hunt participants along with the typical parameters to investigate for identifying opportunities. The main page of the sheet also lists out the most common low cost no cost opportunities associated with the system. A sketch of a system along with its components are provided on the second page for better understanding.

Data Collection Sheet - The data collection sheet lists out the minimum amount of information that is required to quantify the savings associated with some of the most common opportunities identified in a treasure hunt event. In addition, the sheet also provides tips on where and how to collect the required data. Space is provided in the sheet for participants to populate the readings from the field.

Cheat sheets – The system specific cheat sheets are a repository of system charts, default tables, rules of thumb etc. The cheat sheets serve multiple purposes: they help participants understand the system's operation better, they help to make back of the envelope estimates and provide quick references to check the feasibility of some opportunities.

Opportunity Sheet - Properly documenting the identified energy savings opportunity is essential to make sure information is not lost from project identification to its implementation. The opportunity sheets streamline the information transfer between these stages by providing a standard format to capture and summarize the specifics of a potential energy-saving measure. Each opportunity identified during an energy treasure hunt exchange gets its own opportunity sheet.

The opportunity sheet has four sections. General information and the description sections are used to define a project and its specifics including project title, system type, person responsible for the measure, current and proposed operating hours etc. Energy savings associated with the project are defined in the next section of the opportunity sheet (refer to the "Treasure hunt Calculators" section to see how DOE resources could be used to calculate saving) while the final section of the sheet lays out the economic metrics. Once the overall implementation cost is defined, the cost savings and the simple payback are populated based on the energy savings associated with the opportunity.

Summary Report Generator - Post the identification and the quantitative analysis of individual opportunities, the numbers are usually rolled-up and summarized to create a report and presented to management. This is made easy with the use of the summary report generator which automatically rolls up the individual opportunity sheets and creates appropriate summary tables and charts.

Treasure Hunt Calculators - Energy Treasure Hunt calculators are developed to consistently calculate the energy savings from opportunities or best practices identified during the Energy Treasure Hunt Exchanges. In addition to opportunity specific calculators (air leaks, insulation etc.), each energy or utility type (also includes water) has its respective "Treasure Hunt Calculator". The treasure hunt calculators are used to estimate the savings associated with typical treasure hunt opportunities like scheduling or turning equipment on or off, reducing the load on the equipment etc. The calculators use industry accepted methodologies to calculate the savings for specific energy efficiency measures or projects. The results from the calculators are used to populate the opportunity sheets.

The use of these DOE calculators is optional and could be by-passed when the energy savings are estimated using other calculators or methods familiar to the user.

Tools for Phase 3 – Treasure hunt exchange Follow up

The energy treasure hunt exchange follow-up involves prioritizing the identified energy savings opportunities and determining the next steps for project implementation. The **Project Implementation Tracker** helps with this task and is used to check the status of energy projects against the implementation schedule and monitor project results.

Additional Toolkit Components - Communication Materials

In addition to the tools discussed above, the toolkit also has some supplementary templates that the facilitator can make use of at each phase of the treasure hunt process. The templates for the **agenda** and the **save-the-data** document can be used during the planning phase to communicate the event to the participants. The template for the **kickoff presentation** can be used on the first day of the event to get the participants accustomed to the treasure hunt process and provide an overview of the facility and its systems.

Templates for **training certificates** and sample **evaluation form** are also available that could be leveraged for the post event activities. These materials are to be tailored specific to the event and be used on as deemed necessary.

ENERGY EFFICIENCY DIAGNOSTIC EQUIPMENT

Accurate and reliable on-site measurement data is the very basis of evaluating the performance of various energy equipment/systems and quantifying the savings magnitude of energy conservation measures. However, many times plant operation personnel may not have access to the required instruments to gather energy systems' operation data. During the Treasure Hunt Exchange, DOE loans out energy efficiency diagnostic equipment to help participants spot energy savings opportunities.

RESULTS FROM DOE TREASURE HUNT EXCHANGES SINCE 2016

As of May 2017, the DOE has performed seven Treasure Hunt exchanges since 2016, with results as shown below.

Table 1 – Summary of Results from 7 Treasure Hunt Exchanges since 2016.

Plant ID	NAICS (3D)	No. of People Parti-cipated	No. of Opportu-nities Identified	%Energy Cost Saving for the plant	Average aggregate Payback (Yr)
Plant A	325	25	21	9%	0.5
Plant B	331	16	21	3%	0.9
Plant C	332	19	6	13%	1.8
Plant D	336	17	25	3%	0.9
Plant E	334	21	29	10%	0.7
Plant F	336	14	25	7%	0.9
Plant G	336	18	19	17%	1.1

Typical (not limited to) energy efficiency opportunities or best practices identified during these seven energy treasure hunt exchanges are shown in Table 2.

Table 2 - Typical (not limited to) EE Opportunities or Best Practices Identified during Energy Treasure Hunt Exchange Events

Energy System	Typical EE Opportunities or Best Practices Identified
Steam	1. Reduce Steam Demand 2. Reduce Steam Pressure 3. Fix Steam Traps 4. Insulate Pipes and Tanks 5. Setback steam system 6. Preheat Boiler Feed-Water 7. Run Boiler in modulating Mode 8. Adjust Fuel/Air Ratio 9. Install O2 Time based on production 10. Install Automate Blowdown Controls
Process Heating	1. Optimize oxygen level in flue (exhaust) gases or optimize combustion burner air-fuel ratio 2. Reduce-eliminate openings and air leakage in the furnace 3. Furnace scheduling, loading, shut down - avoiding delays, waits, cooling between operations etc. 4. Clean heat transfer surfaces - radiant tubes, heat exchangers, heater tubes, electrical heating elements 5. Use of flue or Exhaust gas heat for combustion air preheating or waste heat recycling
Compressed Air	1. Fix Air Leaks 2. Reduce Excess Pressure 3. Restrict compressed air flow on weekends 4. Remove Inappropriate Uses 5. Reduce Blow off in centrifugal compressors 6. Automatic Turn off 7. Install sufficient Storage and pressure/flow controller 8. Use VFD machine for trimming 9. Use no-loss condensate drains 10. Reduce Compressed Air Demand
Chillers	1. Use cooling towers in place of chillers when possible 2. Stage chillers to optimize part-load efficiency 3. Optimize system set points for energy savings 4. Employ variable-speed pumping 5. Add insulation to cold surfaces
HVAC	1. Lower temperature during the winter season & vice versa 2. Weekend and weeknight setback temperature set points 3. Install timers and/or thermostats 4. Install partitions to reduce size of conditioned space 5. Clean and maintain refrigerant condensers and towers
Pumping and Fan	1. Use cogged belts 2. Size the motors correctly 3. Use Energy efficient motors 4. Turn off motors when not in use 5. In Intermittent Operations, run motor slower and longer 6. Use Low Head-Loss Fitting 7. Reduce Pipe/Duct Length and Turns 8. Reduce Entrance/Exit Head Loss 9. Increase Pipe/Duct Diameter 10. Install VSD or VFD
Lighting	1. Turn off Blocked Lights and Lights in Unoccupied Areas 2. Use Motion Sensors in seldom used areas. 3. Turn off 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 and decrease general area Lighting.

Process & Other	1. Slow process equipment during low production 2. Switch off Auxiliary process equipment during idle time 3. 4. Optimize control set points 5. Waste Heat recovery

Figures 1 and 2 provide opportunity level data by system type. For example, Figure 1 shows percent of total opportunities identified during 7 DOE energy treasure hunt exchanges by system type. Lighting and compressed air related opportunities represent approximately 60% of the total number of identified opportunities. Figure 2 shows percent of total identified cost savings by system type. Although compressed air opportunities represent only 29% based on number of identified opportunities, in terms of percent of total cost savings, they represent almost 50%.

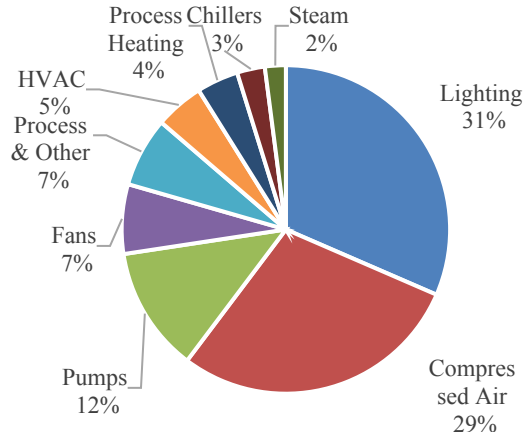

Figure 1 – Percent of total identified opportunities by system type

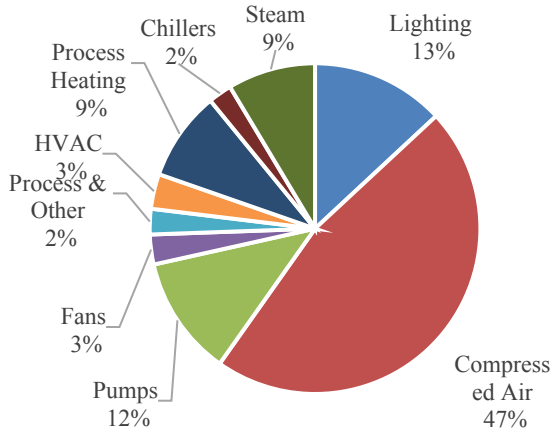

Figure 2 – Percent of Total Identified Cost Savings by System Type

Table 3 – Average energy cost savings and payback data by system type

System Type	No. of EE Opportunities Identified	Average of Total Energy Cost Savings ($/Year)	Average of Payback (Yr)
Steam	3	$79,762	0.2
Process Heating	6	$40,584	0.7
Compressed Air	42	$30,939	0.4
Pumping	18	$18,122	1.2
Chillers	4	$16,048	0.9
HVAC	7	$13,563	0.2
Fans	10	$8,123	0.1
Lighting	46	$7,911	4.7
Process & Other	10	$6,942	0.5

Beyond the results shown above several of the companies involved have replicated the process at other locations. For example - TE Connectivity has performed an additional three events with good results, Charter Steel has also performed three treasure hunt events following the treasure hunt exchange they were awarded. During these events, the Charter Steel Energy Team trained two facilitators, two team leaders, and 18 employees from all three of their locations. UTC has held a second event and AbbVie is planning a next event. These events have relied on initial training from DOE followed by replication facilitated by the trainees. Through the energy treasure hunt exchanges, the companies have improved the level of energy efficiency awareness and gathered some good ideas for energy savings from plant personnel.

CONCLUSION

With companies intending to integrate energy treasure hunts into their energy management practices, DOE's INPLT training help the Better Plants Partners successfully learn the craft and spread it across their manufacturing portfolio. Further, the lessons learned during the initial set of events run by DOE prove to be valuable to anyone looking to host a treasure hunt event. Energy-saving opportunities are more diverse if solicited from many different business units, hence inviting the right people and setting up a diverse energy team is recognized to be necessary. DOE encourages the "External Exchange" for this purpose and mixing external participants with internal personnel in each team has actually maximized collaboration and generation of energy-saving opportunities. Selecting the appropriate calculators/tools to be used based on the competency

of the participants help them to be more effective; the DOE built tools are designed for ease of use and can be picked up by non-technical participants with minimum upfront training. The training of the partner's internal facilitator using the "Train the Trainer" approach is a key DOE objective and it is seen that to be effective. The personnel would will be trained should be identified in the early phases of the event planning. It is also helpful if they are from a technical background. Events are successful when they strike a balance between classroom sessions and field time. The pre-event webinars can be used to effectively train the participants prior to the event. Also, leveraging people at the local facility in order to understand the process and scout for opportunities has been shown to maximize the time spent on the manufacturing floor. Given the breadth of the manufacturing industry new challenges continue to arise with each event and DOE is constantly working on developing additional materials and guidelines to overcome the challenges and effectively run Energy Treasure Hunt Exchanges.

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