US DOE In-Plant Trainings to Develop Expertise and Replicate Success

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ABSTRACT

In-Plant Trainings (INPLTs) offered by the US Department of Energy Better Buildings, Better Plants (Better Plants) program are multi-day workshops performed by industry-recognized experts. INPLTs include both classroom- and field-based sessions that train attendees to identify energy conservation opportunities, quantify savings from these opportunities, and implement projects to realize the savings. These training workshops enhance the attendees' understanding of working principles, knowledge of best practices, and capability to analyze the energy performance of industrial energy systems.

INPLTs are competitively awarded and focus on a wide range of topics, including traditional industrial systems such as steam, process heating and motor-driven systems, and processes such as energy treasure hunts and municipal water and wastewater treatment. Partners that are awarded INPLTs can invite external stakeholders, such as employees of other manufacturers, utility representatives, and vendors. The Better Plants program had delivered 123 INPLTs as of spring 2019, trained more than 2,000 participants, and identified more than $37 million in energy cost savings.

This paper provides an overview of INPLTs, some key statistics, the top identified energy savings opportunities, and success stories from INPLTs delivered from 2011 to 2018. Finally, the vision for future INPLTs is discussed based on participants' feedback and the long-term and strategic goals of the Better Plants program.

Introduction

In the United States, since 2010, industrial facilities have consumed more than 31 quads of energy or 32% of the total domestic energy used per year (EIA 2018). The US Department of Energy (DOE) Better Plants program is a voluntary program initiated by DOE in 2011 to improve the energy efficiency of industrial facilities and water and wastewater utilities (DOE 2011). As of May 2019, 190 manufacturing companies and 25 public water and wastewater treatment plants were partnering with the Better Plants program to improve the energy efficiency of their facilities.

Because ambitious energy efficiency goals (Christoffersen, Larsen and Togeby 2006; Rezessy and Bertoldi 2011) and subsidized technical assistance (Price 2005; Rezessy and Bertoldi 2011; Kimura and Noda 2014; Thollander 2015) are important for successful voluntary energy efficiency programs, the Better Plants program includes both as key components. Companies who join the Better Plants program commit to long-term energy savings goals, typically 25% over 10 years. The technical assistance offered by the program includes subsidized In-Plant Trainings (INPLTs), no-cost energy assessments from university-based industrial assessment centers, and technical support from assigned technical account managers. The Better

Plants program also offers national recognition to encourage innovation, and peer networking opportunities to enhance knowledge sharing.

INPLTs were created to help Better Plants partners overcome one of the major barriers to industrial energy efficiency, lack of in-house energy efficiency expertise (Alkadi et al. 2013; DOE 2015 and 2016a). The purpose of the training events is to provide hands-on training in real-world manufacturing settings to any staff who may impact energy consumption at a facility. Trainings last from 2 to 4 days (depending on system type, plant size, and process complexity) and are led by industry-recognized experts. Participants are trained to conduct assessments, utilize DOE-developed energy-analysis software tools, develop energy management systems, and implement and replicate energy projects. INPLTs are also intended to expand the level of attendance from one single facility to include (1) multiple facilities of the host companies, (2) participants from other companies within the Better Plants program, and (3) other stakeholders, including state agencies, utility companies, vendors, and suppliers. Appropriate external attendees are identified by the host companies.

Since 2011, Better Plants has delivered 123 INPLTs as of March 2019, trained more than 2,000 participants, and identified more than $37 million in energy cost savings. This paper provides an overview of INPLTs and then discusses some key statistics and top identified energy savings opportunities from INPLTs delivered from 2011 to 2018. A vision for future INPLTs is presented based on participant feedback and the Better Plants program's long-term goals.

Overview of In-Plant Trainings

Application and Awarding Processes

The Better Plants program holds two rounds of INPLT application solicitations each year, which usually open in April and October. Partners have 3–4 weeks to complete and submit the application forms. The application form collects information on:

- Contact information and location of the host company and plant
- Planned number of attendees
- Willingness to invite and allow external attendees
- Recent annual total source energy consumption for the host plant
- Amount of cost sharing

The applications are reviewed, scored, and selected by a committee of DOE program management. The committee gives preferences to the following types of applications:

- Companies that have not previously hosted an INPLT
- Applications with higher scores
- Partners who have submitted their latest annual energy reports
- Events that are open to external attendees
- Applications that include cost sharing by the partner

The application results typically are announced 4 weeks after the application deadline. DOE typically awards 6 to 12 INPLTs per solicitation based on funding availability.

Pre-training Data Collection

Reliable and accurate operational data are critical for evaluating the energy performance of energy systems and manufacturing processes. Training experts typically request 2–3 weeks of operational data for the energy systems to be assessed. The data are used to teach participants how to identify energy savings opportunities and use DOE software tools to quantify potential energy savings.

Some plants have very sophisticated metering and submetering systems and can easily obtain the operational data. However, many facilities experience challenges in obtaining data at acceptable sampling rates for the equipment and systems to be accessed. To address this issue, Better Plants developed a field validation and diagnostic equipment program that allows partners to borrow various types of equipment and instruments to enable the measurement of key energy data points (DOE 2017). Partners have short-term access to more than 20 types of diagnostic equipment, including anemometers, combustion analyzers, pressure and temperature sensors, data loggers, and flow meters. Partners can use the equipment for up to 4 weeks and can receive technical assistance to help with the selection and use of these tools. Over the past 2 years, the field validation and diagnostic equipment program has been used by 26 Better Plants partners in support of 24 INPLTs and 18 one-off measurement activities.

Classroom-based Training Sessions

The DOE Better Plants Program Energy Treasure Hunt Exchange Toolkit (Guo et al. 2019) includes a sample INPLT agenda. INPLTs provide both classroom- and field-based sessions. The classroom-based training sessions covers the following topics:

- Background and fundamental knowledge of the energy systems being studied
- Best practices for maintenance and energy efficiency
- Top energy conservation opportunities
- How to identify energy conservation opportunities using diagnostic equipment and collected operational data
- How to use DOE software tools to quantify energy savings from identified opportunities

The software tools used for each INPLT type are listed in Table 1. DOE is currently developing the MEASUR Tool Suite as a comprehensive software suite containing numerous calculators and energy analysis modeling capabilities for multiple facility-support systems. MEASUR is open-source, compatible across multiple platforms, and technology- and vendor-agnostic. When complete, MEASUR will include all the software tools listed in Table 1. The pump, fan, process heating, and steam systems modules in the MEASUR Tool Suite are currently implemented.

Table 1. DOE Software Tools Used in In-Plant Trainings

INPLT System Type	Software Tools
Pump systems	MEASUR Tool Suite Pump System Assessment Tool (PSAT)
Fan systems	MEASUR Tool Suite Fan System Assessment Tool (FSAT)

INPLT System Type	Software Tools
Compressed air systems	AIRMaster+ LogTool
Steam systems	MEASUR Tool Suite Steam System Modeler Tool (SSMT) Steam System Scoping Tool (SSST) Insulation Evaluation Software – 3E Plus
Process heating systems	MEASUR Tool Suite Process Heating Assessment and Survey Tool (PHAST)
50001 Ready	50001 Ready Navigator
Energy treasure hunts	US Department of Energy Better Plants Program Energy Treasure Hunt Exchange Toolkit

Field Training

During the first afternoon of an INPLT, participants tour the whole host facility to understand the manufacturing processes. During the second afternoon, participants are split into three to four groups to identify energy conservation opportunities for designated processes and areas. Attendees have opportunities to apply what they have learned from the in-class training sessions. On the third day, attendees return to the field to collect more data to quantify energy savings from the identified energy conservation opportunities. On the final day, all findings (energy conservation opportunities and estimated savings) are presented to the plant management team.

Feedback Collection

On the final day of each training event, evaluation forms are distributed to collect feedback. The evaluation forms gather feedback on the effectiveness of INPLTs and collect suggestions for improving future INPLTs.

Statistics of Delivered In-Plant Trainings

Geographical Distribution

From January 2011 to March 2019, the Better Plants program delivered 123 INPLTs. The geographical distribution of the delivered INPLTs is shown in Fig. 1. It can be seen that the South (45; 37%) and Midwest (43; 35%) hosted the most INPLTs and the West hosted the fewest. Ohio (11; 8.9%), Texas (8; 6.5%), California (7; 5.7%) and Michigan (7; 5.7%) hosted the most INPLTs among all the states. The regions and states that hosted the most INPLTs were those that contain the most partner facilities (DOE 2016b).

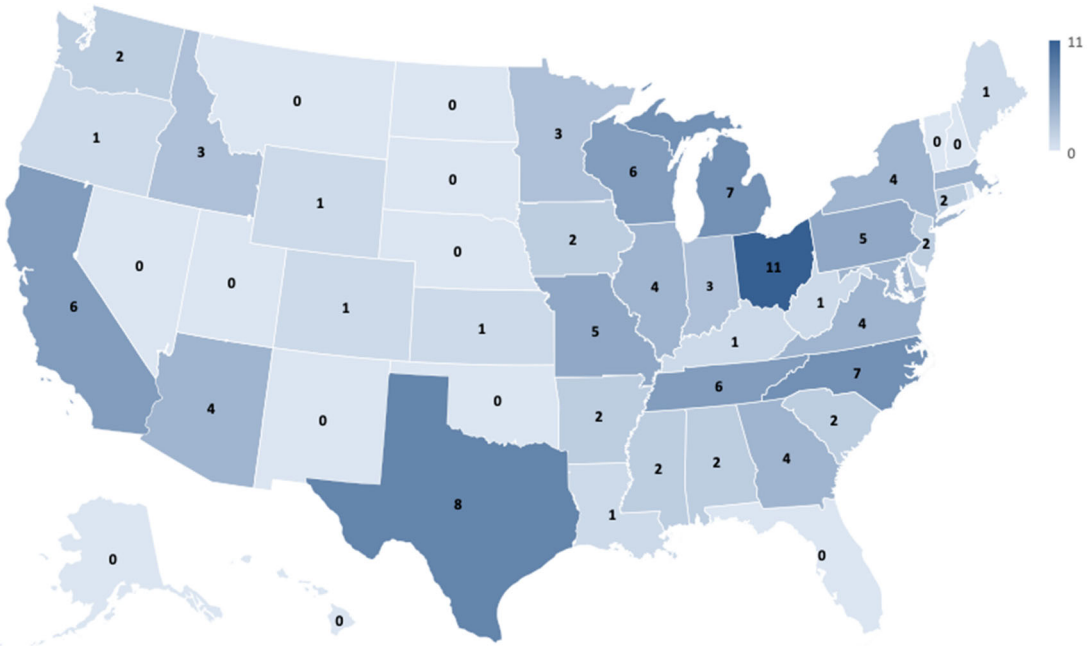

Figure 1. Geographical Distribution of Delivered INPLTs.

Sector Distribution

Figure 2 shows the distribution of delivered INPLTs among the various manufacturing sectors. More INPLTs had been hosted at plants of Sectors 336 (transportation equipment manufacturing), 325 (chemical), and 331 (primary metal manufacturing), to which most partner facilities belong to (DOE 2019).

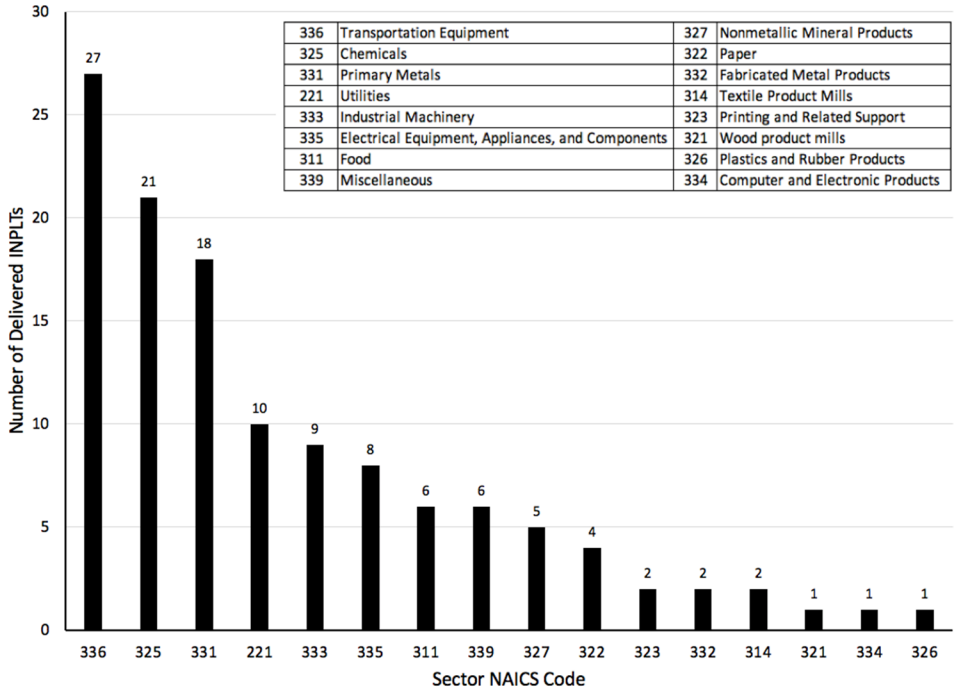

Figure 2. Sector Distribution of Delivered INPLTs.

Energy Systems Distribution

Table 2 shows the numbers of INPLTs delivered for different types of energy systems. The highest numbers of INPLTs were delivered for compressed air systems (33; 27%), energy treasure hunts (23;19%), and steam systems (18;13%). The reasons might be that compressed air (Saidur, Rahim and Hasanuzzaman 2010) and steam systems (DOE and NREL 2012) are fairly complex and energy intensive, and sites often lack internal expertise for optimizing these systems (DOE and Compressed Air Challenge 2016). Energy treasure hunts focus more on low-hanging fruit for energy conservation and are a good way to engage more employees and increase energy efficiency awareness.

Table 2. Number of Delivered INPLTs by System Type.

Energy Systems	Delivered INPLTs (#)	Delivered INPLTs (%)
Compressed Air Systems	33	27%
Treasure Hunt Exchange	23	19%
Steam Systems	18	15%
Process Heating Systems	15	12%
Multi-Systems	12	10%
Fan Systems	7	6%
Pump Systems	6	5%
Water/Wastewater	5	4%
50001 Ready and Energy Management Systems	3	2%
Industrial Refrigeration	1	1%
Total	**123**	**100%**

Top Identified Energy Conservation Opportunities

Tables 3–5 present the average annual cost savings and simple payback periods for the top identified energy conservation opportunities for compressed air systems, steam systems, and pump systems, respectively.

Table 3. Most Frequently Identified Energy Conservation Opportunities for Compressed Air Systems

Energy Conservation Measures	Average of Annual Cost Savings	Average of Simple Payback (years)
Eliminate or reduce compressed air used for cooling, agitating liquids, moving product, or drying	$ 52,380	1.3
Eliminate leaks in compressed air lines/valves	$ 60,489	0.6
Upgrade controls on compressors	$ 73,969	0.9
Reduce the pressure of compressed air to the minimum required	$ 38,428	0.3

Table 4. Top Frequently Identified Energy Conservation Opportunities for Steam Systems

Energy Conservation Measures	Average of Annual Cost Savings	Average of Simple Payback (years)
Insulate steam/hot water lines	$8,799	0.5
Install economizer	$59,580	2.9
Optimize boiler controls strategy	$53,635	0.9
Install steam turbine	$190,686	1.8
Repair or replace steam traps	$38,140	0.2
Flash condensate to produce lower-pressure steam	$38,800	0.9
Repair or replace steam traps	$38,140	0.2

Table 5. Top Frequently Identified Energy Conservation Opportunities for Pump Systems

Energy Conservation Measures	Average of Annual Cost Savings	Average of Simple Payback (years)
Install variable frequency drive	$83,488	2.6
Replace existing pumps	$9,080	2.0
Remove throttle valves	$41,163	0.0

Participant Feedback

As mentioned previously, standardized feedback forms are utilized to collect qualitative feedback from event participants. The overall feedback regarding INPLT effectiveness has been highly positive. Based on the evaluation feedback, 94% of participants responded that they would recommend the INPLT to other plants in their organization (Figure 3) and 73% responded that they felt comfortable utilizing the DOE system assessment tools and software as a result of the training (Figure 4).

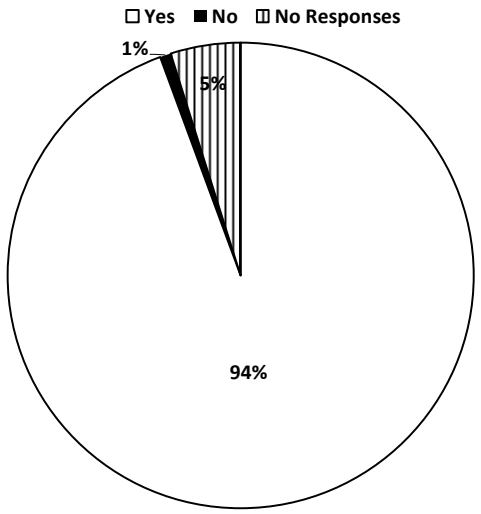

Figure 3. Responses to "Would you recommend this In-Plant Training to other plants in your organization?"

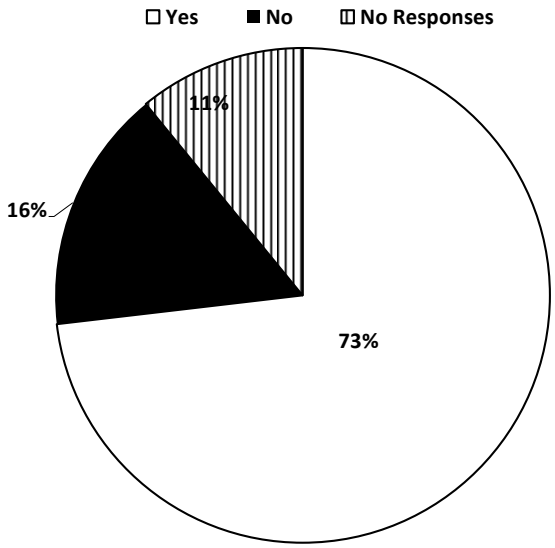

Figure 4. Responses to "As a result of this training, do you feel comfortable using the DOE System Assessment Tools & Software?"

The evaluation survey forms collect feedback on a variety of INPLT objectives. Specifically, participants are asked to provide quantitative responses on how effectively the INPLT provided information on 5 various subjects. Over 75% of respondents rated the INPLTs as effective or very effective across all 5 learning criteria (Figure 5).

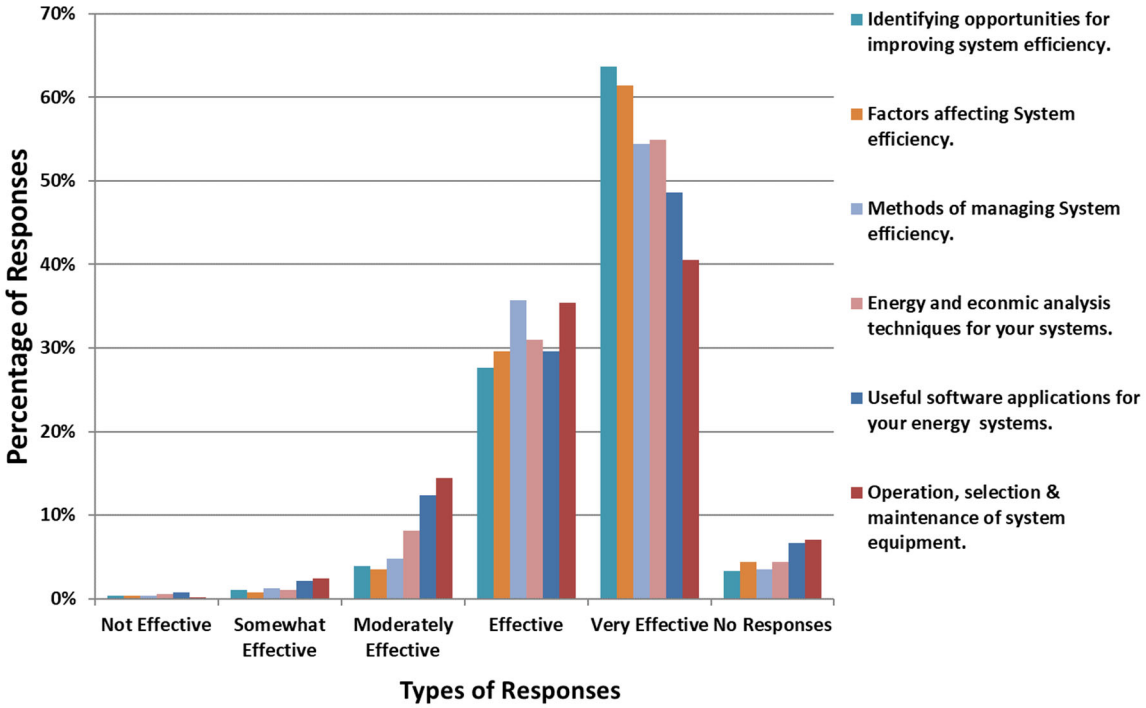

Figure 5. Responses to "How effective was the INPLT at providing information on:"

Finally, as part of the evaluation feedback, participants are asked an open-ended question on how the INPLT could be improved. The top five recommendations for improvements to the INPLT events can be classified as:

1. Arrange more time for diagnostic tool hands-on training and demonstration
2. Plan more time for plant tour to enable better understanding of the manufacturing processes
3. Provide more detail on energy savings calculation and more time on software training
4. Provide training on water conservation
5. Provide more information focusing on new design projects

Success Stories

INPLTs help partners identify energy conservation measures and quantify savings; and more important, they equip partners with the capabilities, expertise, and resources to identify and implement energy efficiency projects on their own.

Using DOE's INPLT approach and resources, TE Connectivity (TE) piloted energy treasure hunts at other sites and demonstrated that it could be done without an external facilitator and without significant corporate resources (Levine and Lung 2018). TE also adopted the energy treasure hunt as a "Ready to Deploy" project in its Energy Centers of Excellence (COE) (Levine and Lung 2018). Nissan and Volvo Group (2018) had applied what they have learned from hosting INPLTs to perform energy treasure hunts at other facilities and achieved significant energy savings.

In regard to implementing energy management systems, 3M, AbbVie (DOE 2018a), and ArcelorMittal (DOE 2018b) had each hosted a 50001 Ready–focused INPLT. Each of these partners has facilities that have achieved DOE's 50001 Ready recognition or ISO 50001 certification.

Future In-Plant Trainings

INPLTs have been the most popular form of technical assistance from the Better Plants program since the program began. Partners have provided valuable feedback and comments for past and future INPLTs. The Better Plants program keeps providing new topics of interest, improving the effectiveness by modifying the training structure, and adding new components to the training events.

New Training Topics and Structure

A new training topic, best practices for water savings, is currently being developed by the Better Plants program with the intention of accepting applications in the fall of 2019. Through Better Plants partner engagement events, several additional subject areas have been identified for possible INPLT development. These topics include process cooling (chillers and cooling tower systems), cyber security, and smart manufacturing. If these are developed, they would be launched sometime in late 2020 or thereafter.

As a response to past INPLT feedback, future INPLTs will feature more time for hands-on training with diagnostic equipment, plant tours, and performing savings calculations using software tools.

Certifications

The Better Plants program currently offers attendance certificates that can be applied toward participants' individual requirements for professional development hours. The Department of Environmental Quality of Michigan accepts the continuing education hours from INPLTs for the renewal of water and wastewater operator licenses.

DOE has been revising and evaluating its role in the training space. Although DOE no longer supports its Qualified Specialist trainings, several other organizations provide various levels of training that complement the INPLT process (Guo et al. 2017). Two examples are the Compressed Air Challenge and Hydraulics Institute, which are developing Certified Practitioner certifications in the areas of compressed air and pump system assessments, respectively.

Implementation Follow-up

Partners have reported that most energy conservation measures identified in the INPLTs had been implemented. However, more detailed information about achieved savings, implementation costs, and barriers is unavailable. A formal 2 year-post-training follow up will be performed to gather this information.

Identifying implementation barriers will provide opportunities for the Better Plants program to develop new forms of technical assistance and provide new resources to support partners. The Better Plants program already encourages partners to coordinate their INPLTs with their local utility companies, but greater opportunities exist to strengthen that connection to better ensure access to utility rebates and incentive programs and further support in implementing energy conservation measures.

Conclusions

The Better Plants program currently provides INPLTs on ten topics: pump systems, fan systems, compressed air systems, industrial refrigeration systems, steam systems, process heating systems, multi-systems (combination of the preceding systems), water and wastewater treatment processes, energy treasure hunt exchange, and 50001 Ready.

Since 2011, 123 INPLTs have been performed for Better Plants partners. More than 2,000 people have attended these training events, and the identified energy and cost savings were 4.4 TBtu and $37 M, respectively. More INPLTs were performed in the South (45; 37%) and Midwest (43; 35%). Ohio (11; 8.9%), Texas (8; 6.5%), Michigan (7; 5.7%), and North Carolina (7; 5.7%) hosted the most INPLTs among all states. The reason is that those geographical areas have more Better Plants partners manufacturing plants. Compressed air systems (33; 27%), energy treasure hunt exchange (23;19%), and steam systems (16;13%) were the more popular INPLT topics.

The most frequently identified energy conservation measures for compressed air systems are to eliminate or reduce inappropriate compressed air uses, eliminate leaks, upgrade controls on compressors, and reduce the pressure of compressed air to the minimum required. The most frequently identified energy conservation measures for steam systems are to improve the insulation on steam/hot water lines, install economizers, optimize boiler controls strategies, install steam turbines, and repair or replace steam traps. The most frequently identified energy conservation measures for pump systems are to install variable frequency drive, replace existing

pumps, remove throttle valves. Most of these energy conservation measures have a simple payback of less than 1 year.

Over three partners have customized the energy treasure hunt processes for their companies after hosting and attending a Better Plants energy treasure hunt INPLT. More than three partners hosted 50001 Ready INPLTs and later, several of the facilities have received DOE's 50001 Ready recognition and ISO 50001 certification.

Based on the collected evaluation feedback forms, 94% of INPLT respondents indicated that they would recommend the INPLT to other plants in their organization; in addition, 73% responded that they felt comfortable utilizing the DOE system assessment tools and software as a result of the training. Over 75% of respondents rated the INPLTs as effective or very effective at providing participants with energy assessment and system efficiency information.

A new training topic, best practices for water savings, will accept applications in the fall of 2019. INPLTs on process cooling, cyber security, and smart manufacturing will be launched in late 2020. Future INPLTs will also feature significantly increased time for hands-on equipment training, plant tours, and savings calculations.

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