EERE Award # DE-EE0007702
Public – Private Partnership to Promote Efficient Manufacturing and Workforce Development
Tennessee 3-Star Industrial Assessment Center
Tennessee Tech University
University of Memphis Satellite Center
Principal Investigator / Project Director: Glenn Cunningham (2016 – June 2021),
Ethan Languri (July 2021 – November 2021)

FINAL TECHNICAL REPORT

Executive Summary

Through delivering ninety (90) energy assessments to small- and medium-sized manufacturing facilities in and around Tennessee, significant understandings were gained through providing detailed energy assessment reports to manufacturers and training seventy-seven (77) engineering students in which thirty-five (35) certified IAC students were recognized by DOE. The robust involvement of Tennessee Valley Authority (TVA), local utility and Tennessee Tech's Cybersecurity Education, Research, and Outreach Center (CEROC) in majority of assessments made the technical operation very effective where leaded to 40.5% implementation rate of energy recommendations. Other benefits of the award to the public are a dynamic modeling tool capable of analyzing existing cooling towers for energy use optimization was developed and presented to DOE IAC, providing technical assistance to non-participating manufacturers in the form of workshop and training, publishing fifteen (15) peer-reviewed conference and journal papers as well as a book chapter in the area of industrial energy efficiency field, assisting the TVA Magnolia Combined Cycle Power Plant to become the First *50001 Ready Certified* Power Plant in the U.S. through briefing them on ISO 50001 and 50001 Ready as well as providing an energy assessment to the plant, assisted the new IAC center at Clemson University with on-site and remote support, and provided assessment and training in unique areas of water, waste water, cyber security and smart manufacturing to our clients, students and community.

Goals and Objectives

There were two overarching goals guiding the operation of the TN 3-Star IAC: 1) Providing top quality educational and training experiences to all IAC students, and 2) Delivering high quality energy assessments for industrial clients.

Expected Outcomes (per SOPO)	Actual Outcomes
Conduct 90 energy assessments including expanded services in areas of: Cybersecurity, Smart Manufacturing, Water & Wastewater Treatment, and ISO 50001 Energy Management System	Conducted 90 days of energy assessments including expanded services in the areas of: Cybersecurity, Smart Manufacturing, Water & Wastewater Treatment, and ISO 50001 Energy Management System.
Train 50 students through the IAC	Trained 77 students through the IAC

Issue 25 certificates of achievement to IAC students	Issued 35 certificates of achievement to IAC students
Develop 4 technical resources designed to assist non-participating companies	Provided technical assistance to non-participating companies in the form of greater than 12 workshops and published articles.

Summary of Project Activities

A. Conduct industrial assessments, to include a variety of plant types, sizes, and commercial/school facilities, as well as coverage of the geographic area defined

1. Ninety assessment days were conducted at plants ranging from small energy users (~$100,000/yr in energy costs) to large energy users (>$4 million/yr in energy costs).

2. The geographic area covered included all three major divisions of Tennessee: West, Middle, and East. Clients were also assessed in Alabama, Mississippi, Kentucky, Indiana, and Illinois.

3. Most plants assessed were manufacturers from a variety of industries; however, assessments were also conducted for water and wastewater treatment plants, a TVA power plant, and a NASA campus.

B. Provide training, educational opportunities, other related activities for IAC students

1. Seventy-seven students were trained at Tennessee Tech University and the University of Memphis. Thirty-five of those students received IAC certificates.
2. Students received training on numerous energy-related topics including:
   - Wastewater treatment plant assessment. Training provided by industry expert Dr. Larry Moore.
   - Pumping systems assessment, including using PSAT
   - Steam systems assessment, including using SSAT and touring a TVA steam plant
   - Compressed air system assessment utilizing AIRMaster+ software
   - Chillers and cooling tower assessment, including using the in-house developed cooling tower model, the TTU Cool Tool
   - Process cooling and heat recovery
   - Electrical measurement and safety
   - Utility rate structures
   - Use of variable frequency drives (VFDs) on electric motors
   - Industrial fans
   - Electric motors
   - Energy efficient belts
   - Cogeneration/ combined heat and power, including tours of CHP systems in the region
3. Students received training on the additional offerings the IAC provides, including:
   - Smart manufacturing
   - Additive manufacturing

- ISO 50001 and other energy management systems and programs
- Industrial cybersecurity

4. Female students participated in Women in the IAC program
5. Students attended energy-related conferences
    - Association for Energy Engineers (AEE) World Energy Conference & Expo
    - Best Practices Expo

C. Promote and increase the implementation of assessment recommendations and employ innovative methods to assist in accomplishing these goals

1. The Tennessee Valley Authority (TVA) receives copies of the reports (with the permission of the client) and advises on available financial and technical incentives.
2. An "Energy Hotline" was established and advertised for IAC clients and non-participating plants to contact us with their questions regarding energy.
3. A supportive relationship is maintained after the assessment and after the report is issued, providing technical assistance and guidance relating to implementation of recommendations.
4. When appropriate, information is given to the clients on the USDA Rural Energy for America Program (REAP) and sources of funding for implementation
5. When appropriate, information is given to the clients on applying for tax incentives on energy purchases.
6. Clients are given information on the state's Manufacturing Extension Partnership (MEP) to assist with implementation.

D. Promote the IAC program and enhance recruitment efforts for new clients, expanded geographic coverage, and reaching non-participating small and medium enterprises in the region

1. Participated in the Tennessee Municipal Electric Power Association (TMEPA) conference.
2. Published pieces on energy efficiency in the Tennessee Energy Education's monthly newsletter.
3. Presented on various energy efficiency topics for numerous organizations and associations, including:
    - Tennessee Chamber of Commerce's Energy and Environment Conference
    - Tennessee Office of Energy Programs
    - Tennessee Office of Sustainability
    - American Society of Mechanical Engineers (ASME)
    - Middle Tennessee Association of Energy Engineers
    - TVA Industrial and Commercial Forum
    - TVA Building Science Conference and Expo
    - Manufacturing Extension Partnerships, including UTCIS (TN), KMAC (KY), and InnovateMS (MS)
    - International Energy Technology Conference (IETC)
    - Green Solutions Small Business Expo

- Associated Valley Industries
- City of Maryville Industrial and Commercial Forum
- Memphis Light, Gas & Water Key Accounts Team
- Oak Ridge National Laboratory (ORNL)
- Nano Boston Conference
- East Carolina University Center for Sustainable Energy and Environmental Engineering

4. Maintained Facebook and LinkedIn pages informing the public of IAC activities
5. Recorded radio interviews
6. Published article about TN IAC in the Compressed Air Best Practices industry magazine

E. Approaches to deliver IAC services in the areas of Smart Manufacturing, Cybersecurity, Energy Management Systems and Wastewater and Water Facilities

1. Information on smart manufacturing, cybersecurity, and ISO 50001 given at each client kickoff meeting and in the final report.
2. Conducted an Industrial Cybersecurity Workshop in collaboration with Tennessee Tech's Cybersecurity Education, Research, and Outreach Center (CEROC).
3. Two cybersecurity risk assessments were performed in collaboration with CEROC.
4. Two assessments were conducted at municipal water treatment plants: First Utility District in Knoxville, TN and the City of Cleveland, TN.
5. One wastewater treatment plant assessment was conducted for the City of Lebanon, TN.
6. Presented on wastewater treatment plant assessments at the 4th Annual Better Buildings Summit.
7. Presented on wastewater treatment plant assessments for the Tennessee Water & Wastewater Utility Partnership at their Energy Management Initiative meeting.
8. Presented at the DOE Wastewater Biogas Combustion and Cogeneration Workshop.
9. Technical assistance was given to TVA's Magnolia Plant in Ashland, Mississippi to help them become the first power plant in the US to receive ISO 50001 certification.
10. Presented to the Middle Tennessee Association of Energy Engineers and the Tennessee Valley Industrial Committee about ISO 50001 and Superior Energy Performance.
11. The director and associate director became 50001 Certified Energy Practitioners and the coordinator attended a course on 50001 Lead Auditing.
12. Facilitated conversations between a client and ORNL on a potential smart manufacturing project.

F. Coordinate and integrate Center activities with other Center and IAC Program activities, DOE's Advanced Manufacturing programs and other EERE programs, as well as with any other specific partners/collaborations identified in the Statement of Project Objectives

1. Provided data for DOE's Lighting Market Characterization Study
2. Provided on-site and remote assistance to the new IAC at Clemson University.
3. Presented at the DOE Better Building Summit.

4. Presented on DOE's Superior Energy Performance and the 50001 Ready tool to numerous industrial groups
5. Conducted a workshop on the DOE PSAT tool.
6. Consulted with ORNL on their Measur Suite of Programs
7. Following our assessment of SL Tennessee, they joined the Better Plants program.
8. Provided information to all clients on Combined Heat and Power and referred several clients to the DOE CHP Technical Assistance Partnership.
9. Developed the Cool Tool cooling tower modeling software for DOE.
10. The partnership with TVA is robust. A TVA representative joins and contributes to most assessments and TVA often requests that we give presentations to their industrial groups on energy topics.
11. The partnership with the Tennessee Department of Environment and Conservation provides leads, marketing and publicity opportunities, and speaking engagements.
12. Partnership with state Manufacturing Extension Partnerships provides leads and opportunities for speaking engagements.

G. Other Achievements
1. Tennessee Tech was awarded the DOE IAC Center of Excellence in 2018.
2. TTU lead student Anthony Taylor was awarded IAC Lead Student of the Year in 2017.
3. TTU lead student Ian Swagerty was awarded IAC Alumnus of the Year in 2017.
4. TTU IAC student Austin Estes was awarded the Donal E. Nichols Scholarship for "outstanding scholastic and leadership abilities, character, and potential service to the HVAC profession".

Products Developed

A. DOE "Cool Tool" cooling tower modeling software

B. Publications

Peer-Reviewed Papers:

1. Hooper J., Languri E., Cunningham G., Guo W., A Modeling Tool to Analyze the Performance of Industrial Cooling Towers, Proceedings of the ASME IMECE 2021 International Mechanical Engineering Congress and Exposition IMECE 2021, November 1 – 5, 2021, Virtual Conference, Online.
2. Jaladi D., Languri E., Cunningham G., A Preliminary Study of Combined Heat and Power in a Facility, Proceedings of the ASME 2020 International Mechanical Engineering Congress and Exposition IMECE 2020, November 16-19, 2020, Portland, OR, USA.
3. Taylor A., Cunningham G., Languri E., Nonintrusive Compressed Air Flow Meter to Aid in Compressor Analysis, The Industrial Energy Technology Conference (IETC), June 20-22, 2017, New Orleans, LA, USA.
4. Patil P., Languri E., Cunningham G., Welch A., Loftis A., Role of Variable Frequency Drives on Cooling Tower's Energy Saving, Proceedings of the 2nd Thermal and Fluid Engineering Conference, TFEC2017, 4th International Workshop on Heat Transfer, IWHT2017, April 2-5, 2017, Las Vegas, NV, USA.

5. Languri E., Patil P., Cunningham G., Welch A., Loftis A., Dynamic Modeling and Experimental Analysis of Induced Draft Cooling Tower, Technical Paper Publication, ASME, Power and Energy Conference, June 2016, Charlotte, North Carolina, USA.

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