Final Technical Report

Report Date: July 30, 2012

Project Title:	Ohio Advanced Energy Manufacturing Center (OAEMC)
Award Number:	DE-EE0000265
Project Period:	01/2010 to 12/2011
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This material is based upon work supported by the Department of Energy under Award Number(s) DE-EE0000265.

Acknowledgment

This report is based upon work supported by the U.S. Department of Energy under Award No. DE-EE0000265.

Document Availability

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List of Acronyms

AEP	American Electric Power
ANS	American Nuclear Society
JCI	Johnson Controls Incorporated
SAE	Society of Automotive Engineers
ARPA E	Advanced Research Projects Administration-Energy
OSU	The Ohio State University
OSU CAR	The Ohio State University Center for Automotive Research
DOE	U.S. Department of Energy
EPA	Environmental Protection Agency
PEV	Plug-in Electric Vehicle
AEE Ohio	Advanced Energy Economy Ohio
EERE	Department of Energy-Energy Efficiency and Renewable Energy
OBCCE	Ohio Business Council for a Clean Economy
OFCC	Ohio Fuel Cell Corridor
AWEA	American Wind Energy Association
MORPC	Mid-Ohio Regional Planning Commission
UCEAO	University Clean Energy Alliance of Ohio
NFC	Nuclear Fabrication Consortium
GAMC	Global Automotive Management Council
ICOSSE	International Congress on Sustainability Science and Engineering
MEDC	Michigan Economic Development Corporation
NIST	National Institute of Standards and Technology
EDA	Economic Development Authority
DOT	Department of Transportation
NASA	National Aeronautics and Space Administration
NSF	National Science Foundation
OEM	Original Equipment Manufacturer
NAM	National Association of Manufacturers
FY	Fiscal Year
EV	Electric Vehicle
AMTech	Advanced Manufacturing Technology

Executive Summary

The program goal of the Ohio Advanced Energy Manufacturing Center (OAEMC) is to support advanced energy manufacturing and to create responsive manufacturing clusters that will support the production of advanced energy and energy-efficient products to help ensure the nation's energy and environmental security. This goal cuts across a number of existing industry segments critical to the nation's future.

Many of the advanced energy businesses are starting to make the transition from technology development to commercial production. Historically, this transition from laboratory prototypes through initial production for early adopters to full production for mass markets has taken several years. Developing and implementing manufacturing technology to enable production at a price point the market will accept is a key step. Since these start-up operations are configured to advance the technology readiness of the core energy technology, they have neither the expertise nor the resources to address manufacturing readiness issues they encounter as the technology advances toward market entry. Given the economic realities of today's business environment, finding ways to accelerate this transition can make the difference between success and failure for a new product or business.

The advanced energy industry touches a wide range of industry segments that are not accustomed to working together in complex supply chains to serve large markets such as automotive and construction. During its first three years, the Center has catalyzed the communication between companies and industry groups that serve the wide range of advanced energy markets. The Center has also found areas of common concern, and worked to help companies address these concerns on a segment or industry basis rather than having each company work to solve common problems individually.

EWI worked with three industries through public-private partnerships to sew together disparate segments helping to promote overall industry health. To aid the overall advanced energy industry, EWI developed and launched an Ohio chapter of the non-profit Advanced Energy Economy. In this venture, Ohio joins with six other states including Colorado, Connecticut, Illinois, Maine, Massachusetts, New Hampshire, Rhode Island and Vermont to help promote technologies that deliver energy that is affordable, abundant and secure. In a more specific arena, EWI's advanced energy group collaborated with the EWI-run Nuclear Fabrication Consortium to promote the nuclear supply chain. Through this project EWI has helped bring the supply chain up to date for the upcoming period of construction, and assisted them in understanding the demands for the next generation of facilities now being designed.

In a more targeted manner, EWI worked with 115 individual advanced energy companies that are attempting to bring new technology to market. First, these interactions helped EWI develop an awareness of issues common to companies in different advanced energy sectors. By identifying and addressing common issues, EWI helps companies bring technology to market sooner and at a lower cost. These visits also helped EWI develop a picture of industry capability. This helped EWI provide companies with contacts that can supply commercial solutions to their new product development challenges. By providing assistance in developing supply chain partnerships, EWI helped companies bring their technology to market faster and at a lower cost than they might have been able to do by themselves.

Finally, at the most granular level EWI performed dedicated research and development on new manufacturing processes for advanced energy. During discussions with companies participating in advanced energy markets, several technology issues that cut across market segments were identified. To address some of these issues, three crosscutting technology development projects were initiated and completed with Center support. This included reversible welds for batteries and high temperature heat exchangers. It also included a novel advanced weld trainer that EWI has recently commercialized.

1.0 Introduction

1.1 Background

The State of Ohio's alternative energy developers face the profound challenge of manufacturing their products at a cost the market will accept. To do this they must compete economically with the incumbent technologies that have been optimized for several decades. Today, advanced energy sources are typically more expensive than the incumbent technologies. While the cost of process inputs (wind, sunlight, biomass) for alternative generation are comparable to, or cheaper than, conventional sources, advanced energy technologies are less well developed and the hardware for energy conversion is more complex. The hardware also relies on more expensive materials of construction to achieve a competitive level of performance. These new technologies also lack the economies of scale that petroleum refineries and utility-scale power generation achieve. This scale allows oil companies and electric utilities to produce their product very efficiently – bigger is better. On the other hand, the distributed nature of the energy inputs and the cost of feedstock transportation for bio-fuels means new technology developers must achieve "economics at smaller scale". If they are successful, these new energy technologies can compete with and effectively supplement conventional sources of energy, and transform award-winning technology into financially successful job-creating businesses.

Many of the advanced energy businesses are starting to make the transition from technology development to commercial production. Historically, this transition from laboratory prototypes through initial production for early adopters to full production for mass markets has taken several years. Developing and implementing manufacturing technology to enable production at a price point the market will accept is a key step. Since these start-up operations are configured to advance the technology readiness of the core energy technology, they have neither the expertise nor the resources to address manufacturing readiness issues they encounter as the technology advances toward market entry. Given the economic realities of today's business environment, finding ways to accelerate this transition can make the difference between success and failure for a new product or business.

The program goal of the Center is to support advanced energy manufacturing, and to create responsive manufacturing clusters that will support the production of advanced energy and energy-efficient products to help ensure the nation's energy and environmental security. This goal cuts across a number of existing industry segments critical to the nation's future.

1.2 Approach

In furtherance of our goals, the Center has used several approaches:

- Established contacts with Ohio-based advanced energy companies to develop manufacturing technology needs profiles, and develop company clusters to accelerate the commercialization of new technology.
- Conducted outreach activities to encourage investment in Ohio advanced energy companies, establish policies to support advanced energy manufacturing, and to raise the awareness of the importance of successful advanced energy companies in Ohio.
- Conducted crosscutting technology projects designed to catalyze technology commercialization and job creation in Ohio.

These approaches were divided into several tasks and subtasks.

(1) Industry Support (State/Federal)
   a. Managing the relationship between the local manufacturing community and the Center by coordinating access to the Center network and assuring delivery of services.
   b. Managing industry/technology roadmapping to identify and assess targets of opportunity.
   c. Establishing manufacturing support approaches and tools to connect companies with team members and resources.

(2) Technology assessment and planning
   a. Conduct design reviews.
   b. Conduct onsite visits, technical, and operational reviews.
   c. Manage and support supply chain development.

(3) R&D in Crosscutting Technologies

2.0 Results and Discussion

The industry support program included three separate elements: developing and managing relationships between companies and the Center network to assure delivery of services; managing industry-technology roadmapping to assess targets of opportunity; and establishing manufacturing support approaches to connect companies with resources.

2.1 Industry Support (State/Federal)

The Industry Support task involved many small activities that came together to produce three major outcomes.

2.1.1 Major Accomplishments

<u>Advanced Energy Network</u>

EWI has successfully created a network of Ohio Advanced Energy companies and established foundation funding for ongoing sustainability of this activity. EWI led a consortium that includes the Ohio Business Council for a Clean Economy, and regional business incubators Nortech, the Dayton Development Coalition, TechColumbus, CincyTech, TechGrowth and Rocket Ventures to form the Ohio chapter of a new national organization Advanced Energy Economy. Advanced Energy Economy is an organization of state and regional business groups promoting American companies as suppliers of innovative energy technologies. In this venture, Ohio joins with six other states including Colorado, Connecticut, Illinois, Maine, Massachusetts, New Hampshire, Rhode Island and Vermont to promote technologies that deliver energy that is affordable, abundant and secure. Through the OAEMC's involvement, Ohio is now at the forefront of this effort. As a result of this organization being formed, Ohio advanced energy companies will have access to a national support base to foster innovation, establish public private partnerships and accelerate technology for the new energy economy.

<u>PEV Readiness</u>

Every major automotive manufacturer and several startups have introduced or plan to introduce electrified vehicles to the market by 2015. Many of these vehicles will allow the batteries to be charged from the grid to increase efficiency and decrease gasoline consumption. To attract consumers to these efficient vehicles infrastructure must be installed to provide recharging sites for consumers away from their home base.

Getting communities ready for the next generation of electrified vehicles requires strong leadership and consistency among those who understand the promise as well as the limitations of electrified vehicle technology. The OAEMC began the dialogue in Ohio to bridge the gap between local policy and infrastructure and technology deployment by bringing together stakeholders from state government regulatory bodies, public utilities, clean fuel advocates, state Department of Transportation officials, university researchers, economic development professionals and businesses investing in the supply chain. This dialogue progressed into a statewide coordinated campaign through the Clean Cities Program creating a master plan for acceptance of the new technology in communities and towns throughout Ohio. It is now institutionalized within the purview of several local groups focusing on deployment of recharging stations across the region.

Nuclear Industry Support

The nuclear construction industry in North America has been quiet for the past 30 years. As a result, the supply chain for supporting maintenance and construction of facilities has declined. When the OAEMC began its activities in 2009, it supported the formation of the Nuclear Fabrication Consortium (NFC) at EWI. This Consortium was designed to help reinvigorate the nuclear supply chain and aid new companies to bring their skills and capabilities to the industry.

Since 2009, the nuclear industry has witnessed several important changes. In the last year construction has begun on four new reactor facilities. This is the first new construction in North America since the 1980s. This new construction involves new passive safety designs that increase the demands on the nuclear supply chain to help design and deliver high performance modular systems that can be assembled in factories and installed on-site, reducing the costs of facility construction. The industry is also exploring new small-scale modular designs to further reduce the cost of construction. Working with the NFC, the OAEMC has helped to bring the supply chain up to date for this new period of construction and helped them understand the demands for the next generation of facilities now being designed.

The OAEMC also responded to the problems encountered by the nuclear industry in Japan when the earthquake and tsunami damaged the reactors at Fukushima. This incident has changed the public's perception of the importance of nuclear industry safety, so it will have an impact on the construction of the next generation of nuclear power facilities. The OAEMC organized programs to help the industry keep abreast of the changing landscape of requirements. During the Fukushima accident, EWI was able to quickly assemble a team of experts for an educational conference call. Numerous EWI clients had requested information on the accident. EWI held a conference call with over 250 attendees wherein leading U.S. nuclear scientist explained the accident and the implications for the U.S. nuclear industry.

2.1.2 Managing Relationships and Coordinating Access

- Developed list of service providers for providing business assistance, capital funding, Six-Sigma analysis, design for manufacturability analysis, carbon footprinting, and energy audits. A list of contacts is provided in Appendix A.
- Investigated manufacturing sustainability with The Ohio State University Center for Resilience, Executive Director, Professor Joseph Fiksel.
- Worked with advanced battery component suppliers and researchers to broaden the battery cluster in central Ohio.

- In 2011, we sponsored a booth at the Advanced Research Projects Administration-Energy (ARPA-E) Innovation Summit in Washington, D.C. during which we met with several small advanced energy companies, and networked on issues related to rare earth materials and battery production.
- Met with DOE Office of Environmental Management about future plans for an Energy Park.
- Supported an Areva Supplier Event in Jefferson City, MO.
- Presented at the Youngstown State University "Sustainable Technologies Forum".
- Attended a scoping meeting for Regional Energy Planning in Philadelphia, PA.
- Presented at the "SMART at CAR" consortium meeting. This organization includes utilities and smart grid companies from around Ohio and the Great Lakes region.
- Hosted Senator Sherrod Brown's staff to discuss advances in nuclear technology.
- Worked with the Ohio Department of Transportation on a PEV Readiness Plan.
- Hosted the demonstration of a new high performance anti-corrosion coating material developed by EonCoat.
- Attended an introductory event at Toxco to understand battery recycling issues.
- Met with OSU Center of Automotive Research (OSU CAR) to discuss battery recycling technology and plans to establish a center of excellence.
- Visited Areva, Fiamm, and Venturi European offices using private funds to discuss energy projects and overlap with the North American operations of these European companies.
- Visited Washington, D.C. to discuss energy issues with the following U.S. DOE groups:
    - Office of Nuclear Energy
    - Wind and Water Program
    - Energy Storage Research & Development
    - Industrial Technologies Programs
    - Energy Efficiency and Renewable Energy (EERE) Program Management Office
- Participated in discussions with the battery and electric vehicle group from HeFei China on collaboration efforts including HeFei Forklifts and JAC Automotive.
- Worked with national foundations and the Ohio Business Council for a Clean Economy (OBCCE) to form Advanced Energy Economy Ohio (AEE Ohio), a statewide network with eight regional partners, led by the EWI Energy Center. The core mission of AEE Ohio is to connect, attract and grow advanced energy and clean technologies across Ohio by ensuring access to capital and seeking public policies favorable to long-term positive economic impact.
- Drawing upon the experience, expertise, and networks of its members, AEE Ohio is poised to be the leading voice for the collective interests of clean technology businesses in Ohio and linking them to the national network of energy technology manufacturers. AEE Ohio will leverage the organizational capabilities of two well established and active organizations in Ohio. EWI Energy Center will operate the cluster development aspect of the Council's mission. OBCCE will be responsible for the advocacy mission.
- Served on a panel at Nortech Business to Business conference to explore barriers to energy technology deployment.
- Hosted the "Manufacturing Innovation Summit: Strengthening U.S. Manufacturing Competitiveness" in collaboration with The Manufacturing Institute on October 27, 2011.

The objective of the Summit was to create a plan for innovation and application of manufacturing technology that will be embraced by industry and facilitate State and Federal government policy changes to encourage innovation and deployment of new manufacturing technologies.

- Met with Zane State to discuss workforce training needs for Ohio's new shale gas resources, and other advanced energy industries.
- Presented in partnership with the Appalachian Regional Committee and the Ohio Department of Development to Appalachia Ohio on how to transition to the advanced energy economy and develop opportunities in Ohio for shale gas.
- Visited Ohio University to discuss opportunities in Advanced Energy.
- Visited the University of Toledo and Bowling Green State University to discuss statewide collaboration to assist Ohio energy companies.
- Co-sponsored a State Science and Technology Institute conference in Columbus, OH.
- Attended OBCCE meeting.
- Met with delegation of Chinese energy manufacturers from HeFei, China.
- Met with DOE loan guarantee program representatives, Barry Fromm and Rich Aikens.

2.1.3 Managing Industry/Technology Roadmapping to Identify Targets

- Participated in Battelle "Energy Futures" workshop in January 2010. Battelle is helping to develop a roadmap for U.S. energy policy in conjunction with the DOE national labs.
- Worked with Blue Water Wind and Ohio businesses to help develop business case for offshore wind on Lake Erie.
- Hosted Senator Sherrod Brown and Ron Bloom, Senior Advisor to the President, for an advanced energy manufacturing roundtable on April 7, 2010.
- Attended lunch with DOE Secretary Chu and Senator Sherrod Brown on energy topics November 16, 2010.
- Attended Ohio State University's "Moving Ahead 2010" conference on sustainable transportation.
- Developed an EV roadmap in cooperation with the State of Ohio Department of Transportation.
- Attended AWEA Wind Power Conference.
- Attended EaglePicher Battery Workshop.
- Attended Ohio Fuel Cell Corridor (OFCC) Event in Cleveland April 2010.
- Hosted Senator Voinovich roundtable on nuclear power April 23, 2010.
- Attended OSU Sustainability Forum.
- Co-sponsored a meeting on "The Future of Nuclear Energy in the U.S." in Cleveland on September 21, 2010 with over 100 attendees from both the industry and public. The keynote addresses were given by Dr. Patrick Moore, cofounder of Greenpeace and Karen Alderman Harbert, President of the U.S. Chamber Institute for the 21st Century Energy.
- Co-sponsored a conference on "Battery Manufacturing" in Detroit on September 8, 2010 with over 100 attendees.
- Started development of a battery technology roadmap for publication in the fourth quarter of 2010.

- Participated in OFCC meetings.
- Wrote a PEV readiness framework for the State of Ohio including outreach, infrastructure, and supply base components.
- Hosted Ohio EPA “Economy, Energy, and Environment” quarterly meeting at EWI.
- Participated in Mid-Ohio Regional Planning Commission (MORPC) planning for EV infrastructure in Ohio.
- Participated in “Plug-in Vehicle and Infrastructure Workshop” at DOE in Washington, D.C.
- Participated in OSU round table with Department of Commerce Secretary Locke on manufacturing and the clean economy.
- Participated in University Clean Energy Alliance of Ohio (UCEAO) meetings.
- Hosted Senator Voinovich at EWI on September 27, 2010 for a roundtable to discuss Ohio nuclear workforce issues.
- Worked with partner organizations TechColumbus, Battelle, Ohio State University, and the City of Columbus to create the “Central Ohio Hub of Advanced Manufacturing and Power Storage” to help develop business in central Ohio for batteries and energy storage.
- Helped to develop the “Ohio Transportation Futures Plan”.
- Worked with State of Ohio officials to apply for $14M of U.S. DOT funding to deploy 864 electric vehicle charging stations.
- Project Manager, Mark Norfolk, accepted a position on the industrial advisory board for the Clemson Large Wind Turbine Drivetrain Testing Facility, a national facility funded by the Department of Energy to build a test facility for 15MW wind turbines. As part of the first advisory board meeting, Mark reviewed the Clemson team’s facility designs and attended the facility ground breaking.
- Assisted Clemson in finding a technical resource for high-power electronics to serve the needs of the Large Wind Turbine Drivetrain Testing Facility.
- Hosted Ohio EPA Deputy Director, Drew Bergman at EWI to train EWI staff on U.S. EPA carbon regulations and their effect on manufacturing.
- Attended “The Role of Combined Heat & Power and Waste Heat Recovery” meeting in Columbus, OH.
- Attended “Delivering the Next Economy” in Chicago, IL.
- Attended a national policy forum on renewable energy in America in Washington, D.C.
- Attended the UCEAO board meeting in Dayton, OH.
- Attended “The Business of Plugging In” in Detroit, MI.
- Helped develop an Ohio EV readiness policy.
- EWI hosted Senator Sherrod Brown for a 25-person roundtable discussion on issues with procuring rare-earth materials. A summary report was assembled for manufacturers with an interest in this topic. A summary of this discussion is provided in Appendix B.
- Co-sponsored a public forum on current issues with rare-earth materials and E-waste recycling with 40 attendees from government, industry and the public.
- Hosted a one-hour webinar with nuclear experts to explain the situation at the Fukushima Daichi nuclear power plants. The more than 250 participants heard from the following speakers:

- David Blee, Former U.S. Deputy Assistant Secretary of Energy
  - Lake Barrett, Former Deputy Director Office of Radioactive Waste Management
  - Edward Davis, Former President American Nuclear Energy Council
  - Dan Yurman, American Nuclear Society (ANS)
  - Nate Ames, Director of the Nuclear Fabrication Consortium (NFC)

- Started work on a comprehensive energy plan for the State of Ohio.
- Presented a paper on "Energy Issues in Manufacturing" at a conference hosted by the Global Automotive Management Council (GAMC) in Las Vegas, NV.
- Attended International Congress on Sustainability Science and Engineering (ICOSSE)" conference in Tucson, AZ.
- Attended training on improving industrial energy efficiency in Columbus, OH.
- Attended the Detroit Auto Show.
- Met with Michigan Economic Development Council (MEDC) about extending the energy center concept.
- Participated on the board of UCEAO.
- Attended a "Restoring Prosperity" event on sustainability in Cleveland OH.
- Attended Ohio Combined Heat and Power Meeting in Ohio.
- Met with Director Arun Majumdar of ARPA-E to discuss commercialization of ARPA E funded technologies. As a result of this discussion, the Center interviewed companies to find a fit between the technologies offered and commercial opportunities.
- Hosted Senator Rob Portman for a policy roundtable for large industrial energy users on June 1, 2011 at EWI. Attendees included a representative of Governor Kasich's Office, the Ohio Farm Bureau, Ohio Chamber of Commerce, BASF, Timken, Lubrizol, V&M Star, Ohio Chemistry Technology Council, Arcelor Mittal, Ohio Steel Group, Porter, Wright, and The Ohio State University.
- Hosted six stakeholder groups to discuss EPA greenhouse regulations aimed at understanding the impact these regulations on Ohio business.
- Attended "Regional Reshoring: Bringing Manufacturing Back to the U.S.".
- Attended the board meeting of UCEAO. Activities of the Alliance included attending the 5th Annual UCEAO Conference held in April 2011 in Columbus. The Center Director served as the Moderator for the "Energy Policy in Ohio" panel session.
- Participated in Ohio Third Frontier cluster development meetings
- Attended "PEV Infrastructure Readiness Meeting" hosted by Ohio House of Representatives member Anne Gonzales on April 20, 2011.
- Convened a meeting of plug-in electric vehicle readiness group at TechColumbus to create priorities for Ohio's readiness strategy.
- Moderated a panel on Ohio manufacturing issues at the Ohio Governor's 21st Century Energy & Economic Development Summit.
- Attended a National Association of Regional Councils event on shale gas in Pittsburgh, PA.
- Attended Ohio Clean Air Coalition meetings in Columbus, OH.
- Co-sponsored an event in Columbus, OH, on "Shale Gas Implications for Energy and the Environment" at the Columbus Metropolitan Club.

- Submitted a response to the National Institute of Standards and Technology (NIST) request for information on the Structure for Proposed Advanced Manufacturing Technology Consortia (AMTech) Program.
- Hosted NIST Associate Director for Innovation, Phil Singerman, to discuss advanced energy manufacturing.
- Met with Department of Commerce Economic Development Agency representative, John Fernandez, to discuss financial models for advanced energy companies and EDA's role in expansion of the advanced energy industry.
- Hosted NIST Engineering Laboratory Director, S. Shyam Sunder, on November 28, 2011 to discuss energy manufacturing.
- Convened a coalition of advanced energy trade groups to analyze the impact of the State of Ohio renewable portfolio standard including energy efficiency and combined heat and power generation.
- Continued collaboration with Clean Fuels Ohio and the Ohio Department of Transportation for a plug-in electric vehicle stakeholder's discussion and strategic planning for Ohio plug-in electric vehicle readiness.
- Met with Rich Frederick, State of Ohio workforce development manager, to discuss training the next generation of welders for advanced energy sector.
- Attended Advanced Manufacturing Partnership regional meetings in Boston, MA and Detroit, MI to provide commentary and feedback on the committees' recommendations to the White House Office of Science and Technology.
- Attended NASA Glenn automotive industry workshop to discuss how to transfer technology from NASA to the advanced energy sector.

2.1.4 Establishing Manufacturing Support Approaches and Tools

- Developed the Energy Center website and social media strategy that includes blogs and Facebook (www.ewienergycenter.org).
- Implemented a resource library tool on the Center website to link companies with regional resources.
- Performed an energy audit of EWI's facility to learn the necessary steps for providing this service to other companies.
- Implemented the Energy Center blog (www.ewienergycenter.org)
- Attended Massachusetts Institute of Technology 4-day course on "Clean Energy Ventures − Developing Innovative New Businesses in Energy".

2.2 Technology Assessment and Planning

During the last three years, the OAEMC has visited more than 115 companies in a wide range of industry segments. This tabulation shows the diversity of the companies in the advanced energy sector.

Segment	No. of Visits
Wind	5
Solar	7
Fuel Cell	5

Segment	No. of Visits
Battery	9
Biofuels/Biomaterials	5
Waste to Energy	3
Energy Efficiency	9
Nuclear	10
Electric Vehicles	10
Utilities	3
Other	16

These visits served several purposes. First, they helped the OAEMC develop an awareness of issues common to companies in different advanced energy sectors. By identifying and addressing common issues, the OAEMC assists companies in bringing technology to market earlier, and at a lower cost. These visits also help the OAEMC develop a picture of industry capability. This helps the OAEMC provide companies with contacts that can supply commercial solutions to their new product development challenges. By providing this assistance to develop supply chain partnerships, the OAEMC helps companies bring their technology to market faster, and at a lower cost than they might have been able to do by themselves. Some examples include:

(1) Worked with Momentive to secure funding from the State of Ohio to commercialize a new high performance thermal management material.

(2) Worked with AlgaeVentures to improve the efficiency of algae drying equipment using high power ultrasonic vibrations.

Additionally, EWI helped to foster a growing supplier network. One of the most difficult things for a company to do in a new technology area is to identify suppliers who can provide solutions to the challenges that arise in development of a new product or technology. The advanced energy market is new to most of the companies the OAEMC has contacted. While these companies are very familiar with the issues in their core business sectors, the challenges of advanced energy markets are new, so companies may not know what the critical performance issues are. They also do not know who has commercial solutions to the challenges they discover while developing their product or technology. If they cannot identify a solution provider locally, many advanced energy companies embark on an internal search for solutions. This can lead to schedule delays and cost overruns.

The OAEMC sought to help companies avoid reinventing solutions by developing supply chain options in two ways. The first was through company onsite visits. These visits helped the OAEMC develop an understanding of each company's capabilities. This allowed the OAEMC to make connections between technology needs and available technology suppliers. The OAEMC also identified broader supply chain options through discussions with trade associations to help build a consensus on ways to access national or global solution suppliers. This will help advanced energy companies bring their technology to market faster and at a lower price point.

2.2.1 Design Reviews

Design reviews are an approach that many large companies use to review designs and products at an early stage. These reviews are intended to identify key challenges or barriers to commercial success before designs and production methods are finalized. This allows companies to avoid late stage issues that delay commercial product launch and increase production costs.

To start this process the Center developed a formal design review process. This process required participating companies to provide information to the review team in writing in advance of the review. Once that information was received, members of the review team were selected to ensure that experts in key issues identified in this information were participants in the review process.

The following information was requested from the companies to provide a firm base for the review:

- Description of the opportunity or challenge
- Description of the product or application
- Description of the business drivers and financial impact of the opportunity or challenge
- Description of the improvement required for the design, product, or process to achieve success
- Description of previous attempts to address the opportunity or challenge including the results of those activities
- Description of the product and process requirements and parameters
    - Quality
    - Capital
    - Performance
    - Reliability
    - Manufacturability
    - Productivity
    - Production cost
    - Material costs
- Description of the timeline required for success

After the review team had the opportunity to study the information provided, a meeting was scheduled to review the details with company representatives.

The first part of the review meeting involves a presentation of the product opportunity or challenge to the review committee. After a discussion of the issues, the committee inspects the products and processes that were described during the meeting. This direct contact with the product and manufacturing process allows the committee to identify issues that the company may have overlooked or dismissed during their description of the product or process of interest. At the end of the meeting, the review committee supplies the company with a confidential list of suggestions to address the key issues identified during the review.

During the past two years, four formal design reviews were completed:

- AcuTemp − review of process to manufacture insulated panels for high efficiency refrigerators
- Owens Illinois − review of glass making facility to identify areas for energy reduction
- Concentrated Solar Collector manufacturer − review of collector design for portable applications
- Thin Film Solar Company − root cause analysis of thin film product failure

Candidate companies were reluctant to invest the preparation time this formal review process requires. Many were either too early in the development process to warrant this activity, or so far along that a redesign would not be economically feasible. Therefore, timing is critical. The company needs to perceive value for solving problems with their technology, product design, or manufacturing process before the value proposition of the review is met.

2.2.2 On-site Visits, Technical and Operational Reviews

Over the past two years, the Center contacted more than 118 companies in industry segments that range across the advanced energy continuum. These visits were made to introduce the Center's programs and capabilities to the companies, and help the companies create avenues of collaboration to catalyze their success. During these visits, the Center staff also developed an understanding of the technology and business challenges these companies face. Center staff was also able to transfer solutions from sector to sector within the advanced energy industry. On-site technical reviews and introductions were conducted at the following companies. The company's interests and focus in the advanced energy marketplace is listed after their name.

- Faraday Technology − Electrochemical processing including catalysts
- StrateNexus − Nanotechnology
- Willard & Kelsey Solar − Solar cell manufacturing
- NexTech Materials − Solid oxide fuel cells
- Tech Sonic − Manufacturer of battery welding equipment
- Didion Mechanical − Maker of pressure vessels for bio-reactors
- Blue Water Wind − Developer of offshore wind
- Nexergy − Battery pack manufacturer
- Greenfield Solar − Concentrated solar power
- Webcore − Maker of composite wind towers
- Echogen Power − Producing energy from waste heat
- AcuTemp − Vacuum insulated panels for high efficiency appliances
- Xunlight − Solar cells
- Action Group − Nuclear component supplier
- AlgaeVentures − Oil from algae
- Rol Fab − Nuclear component supplier
- GrafTech International − Nuclear component supplier
- Ultracell − Fuel cell manufacturer
- Great Lakes Wind Network − Nonprofit wind technology and supply chain developer
- Superior Roll Forming − Nuclear component manufacture
- Smashray − LED lighting equipment
- Sunpower − Turbine generators
- Areva − Nuclear OEM
- Babcock & Wilcox − Nuclear OEM
- Westinghouse − Nuclear OEM
- IP Technologies − Energy efficient manufacturing equipment
- First Energy − Power production
- Nautica Wind − Floating wind towers
- HC Stark (heavy manufacturing) − Talked about carbon footprint and energy reduction projects
- Calyxo − Thin film solar
- Replex Plastics − Custom plastic mirrors
- SPSI − Nuclear supplier
- Rolls Royce Fuel Cells − Fuel cell manufacturer
- CODA Automotive − Electric car manufacturer

- Fiamm − Italian battery manufacturer
- Quasar Energy − Waste to energy
- AEP − Power production and distribution
- Echogen − Makers of energy equipment from waste heat
- Owens Illinois − Glass manufacturer
- Iosil − Recycling of silicon for semiconductor industry
- General Motors − Electric vehicles
- U.S. Chamber of Commerce
- Idaho National Lab − Nuclear energy
- GrafTech International − Carbon products for heat exchangers and fuel cells
- Clean and Safe Energy Coalition
- American Nuclear Society − Nuclear energy
- Westinghouse − Nuclear energy
- Custom Alloy Corp
- Keyence − Process control and automation
- Ford
- Society of Automotive Engineers (SAE)
- Center for Automotive Research (CAR)
- Ohio State University (OSU)
- Northern Manufacturing – Contract machine shop making parts for bioreactors
- MLPC − Contract manufacturer making wind inspection sensors
- Polyflow − Municipal waste to oil conversion technology
- Velocys − Maker of bioreactors
- AMP Electric Vehicles − Electric vehicles
- Magna E-Car − Car batteries
- Staber Industries − High efficiency washing machines
- DTE Energy − Residential and commercial electricity provider
- Terracal − Geothermal cooling using energy stored in aquifers
- Venturi − Manufacturer of batteries and EV's
- Myers Motors − Electric vehicle manufacturer
- Entrotech − Electronics manufacturer
- RW Beckett Corp − Manufacturer of home electricity storage units
- Toxco − Lithium battery recycling
- Dura Magnetics − Custom magnet manufacturer
- Sheetak − Semiconductor cooling devices
- Cool Energy − Sterling engines
- NSF Media Office − Advanced manufacturing videos
- Global Automotive Management Council – Benchmarking
- JCI − Many advanced energy initiatives
- Traycer Diagnostics − Terahertz inspection systems
- Syscom Advanced Materials – Metalized plastic fibers
- MAGNA-E Car – Electric vehicles
- AMP Electric Vehicles – Electric vehicles
- Northern Manufacturing – Supplier to wind industry
- Zyvex – Nanomaterials
- Abengoa Solar – Concentrated solar
- Momentive Performance Materials – Heat conducting films
- Algaeventures – Bio plastics
- First Solar – Solar cell and panel manufacturer
- Bloom Energy – Automation for manufacturing

- Banner Metals Group – Aerospace and automotive
- Tipping Point – Solar module financing
- Engen – Lithium battery producer
- The Andersons – Environmentally responsible paint stripping

2.2.3 Supply Chain Management and Support

The following technology impact analysis activities were completed:

- Purchased one year license for online advanced energy database.
- Mined the database for advanced energy suppliers and OEM's in Midwest.
- Participated in Supplier days for nuclear OEM's Areva and Babcock & Wilcox.
- Surveyed over 500 companies from the Ohio manufacturing base to look for potential new entries into the advanced energy supply chain.
- Met with the National Association of Manufacturers (NAM).
- Met with the American Iron & Steel Institute.
- Met with the Manufacturing Institute.
- Collaborated with Areva and Westinghouse on supplier day activities.
- Participated in State of Ohio clean coal / nuclear supply chain development meetings.
- Met with sustainability advisor to EPA Region 5, Joseph Fiksel, regarding commercialization of environmental technologies in collaboration with the EPA R&D lab in Cincinnati, OH.

2.3 Research & Development in Crosscutting Technologies

2.3.1 Crosscutting Technology Development

During discussions with companies participating in advanced energy markets, several technology issues that cut across market segments were identified. To address some of these issues, three crosscutting technology development projects were initiated and completed with Center support. Summaries of these projects are provided below:

Welder Training

Currently in the U.S. welders are in short supply. They are needed for many energy industries such as nuclear, oil/gas, as well as general construction for other large energy structures. In FY11, EWI worked to develop a beta version of a proprietary welder training system suitable for implementation at educational and industrial training facilities. This system allows training centers to train welders to a high level of skill faster than traditional approaches. As a result of this project, EWI has formed a new subsidiary RealWeld Systems to commercialize the weld trainer. The new subsidiary has already hired its first employee and it is working to raise money and establish manufacturing alliances. The goal is to place the production models of the trainer at technical schools and community colleges to begin the next phase of beta testing and commercialization.

Reversible Welding Technology for Battery Bus Bars

Through efforts with CAR Technologies, Toxco, and The Ohio State University the OAEMC has began a discussion of issues related to the secondary use of advanced lithium batteries once their service life for transportation has been exceeded. As a part of this effort, the OAEMC sponsored a project to develop a reversible joining approach for vehicle battery module assembly. This technology would allow manufacturers to repair modules during service, and to readily recondition batteries after their vehicle service life has been completed.

High Temperature Thermal Management

To improve thermal efficiency power generators are developing generating systems that operate at higher and higher temperatures. Generating power at high temperatures also allows power companies to use combined heat and power technologies to further improve efficiency. In this situation, waste heat from power generation is used to provide lower temperature process heating for other industrial applications like food processing and space heating. The key to this new level of energy efficiency is the development of cost effective high temperature heat exchangers to capture energy in high temperature, high pressure systems.

To support this evolution to higher temperature power generation, the OAEMC sponsored the development of a refractory metal microchannel heat exchanger designed for solar thermal applications. Assembly of this system required the development of several new welding protocols to produce a system that can be assembled rapidly from simple stamped refractory metal parts. This generic part has needs for many future energy applications such as high temperature solar, next generation nuclear reactors, and waste energy recovery systems.

High temperature heat exchangers are the future of industrial energy efficiency. Adoption of this technology is both a manufacturing and a public policy challenge. The OAEMC is well situated to work on both elements of the problem through its technical and managerial staffs.

2.3.1.1 Advanced Weld Trainer

Introduction and Background

Fabrication of energy systems requires a skilled workforce. In conversations with advanced energy companies, one area that consistently comes up as a problem is a nationwide shortage of skilled welders. Industries such as nuclear, bio-fuels, solar, and wind all require skilled manual welders for construction and repair projects. The emerging shale gas industry also needs welders to assemble collection and transmission systems to capture new gas and liquids from the shale wells now being drilled in Eastern Ohio, Western Pennsylvania and elsewhere in the country. For these projects to be completed on time and on budget, new welders need to be trained efficiently. This will require new technology because the number of welding instructors is also declining.

In FY11, EWI worked to develop a beta version of a proprietary welder training system suitable for implementation at educational and industrial training facilities. This system allows training centers to train welders to a high level of skill faster than traditional approaches. The system uses advanced computer motion tracking in combination with weld process monitoring to assess compliance with the preferred welding procedure. Computer feedback is provided to trainees in real time to help them understand how to improve their performance. Field tests have shown that this multi-media computer feedback mechanism has proven to be attractive to young trainees.

Objective

The objective of this project was to complete development of the key aspects of the weld trainer and to make it available as a commercial product for the advanced energy market. This will allow advanced energy companies to train welders faster and with a greater degree of consistency.

Approach

Feedback from field testing was incorporated into the beta system to develop a market ready system to deliver improved workforce training for advanced energy companies. The functionality of the core measurement system was improved and a prototype system was assembled for field testing. This second generation system required improvements in four categories:

- Software refinement
- Hardware refinement
- Testing and Validation
- Documentation

Results

Task 1 − Software Refinement

The initial version of the welder training software was designed for laboratory use. As a result, the software required the input of an experienced welding engineer. Set up of the system for the correct welding procedure was convoluted and evaluation of trainee performance required interpretation of the performance data by a skilled instructor. Key welding processes were also missing from the system's repertoire. To address these issues the following software enhancements were made.

- Calibration videos for the system were generated to walk the user through the set up process step-by-step.
- Feedback to the user was shifted from a graphical format (plots as a function of time) to real-time pictorial meters with target ranges. The option to see the graphical output was maintained to provide information for instructors and advanced trainees.
- Numerical scores were added to allow the trainee to both easily view those torch manipulation variables which needed improvement, and to provide a baseline for improvement.
- Expansion of the range of welding processes in the trainer's repertoire − mathematical algorithms were developed and tested for tracking the manipulation of a shielded metal arc welding (SMAW) electrode holder during welding.
- Progress tracking feature was added to allow the user to track progress over time.
- Curriculum page was added to allow the user to track progress through the welding curriculum. This page can be customized to any specific welding curriculum by the instructor.

Task 2 − Hardware Refinement

The initial version of the Weld Trainer also had hardware deficiencies that made the system difficult to use. The following enhancements addressed these issues:

- Universal calibration block was designed. This decreased the number of calibration blocks required for system calibration from five to one.
- Target shape and design was restructured to improve measurement accuracy.
- Target holder was designed and tested for SMAW electrode holders.
- Universal calibration accessory was designed to integrate with the calibration block to simplify the calibration process.
- Carriage assembly was designed to allow for the camera mount and welding fixtures to be manipulated together allowing for easier set up and more accurate readings.

Task 3 − Testing and Validation

Upon completion of the hardware and software refinement tasks a working prototype was built and tested. All combinations of welding process (GMAW, FCAW, SMAW), joint design (fillet, lap, butt, groove), and torch position (flat, horizontal, vertical) were tested. In addition, the working envelope for the monitoring camera's field of view and depth of focus were identified so that the system can keep the training specimen in the optimum position for accurate monitoring.

Task 4 − Product Documentation

An operational manual was written to aid in the set up and use of the tool. Each user screen was described in detail, from both an instructor and trainee perspective.

<u>Accomplishments</u>

As a result of this project, EWI has formed a new subsidiary, RealWeld Systems, Inc., to commercialize the weld trainer. The new subsidiary has already hired its first employee and it is working to raise money and establish manufacturing alliances. The goal is to place the production models of the trainer at technical schools and community colleges to begin the next phase of beta testing and commercialization.

2.3.1.2 Reversible Assembly of Aluminum Tabs to Copper Bus Bars

<u>Introduction and Background</u>

Advanced batteries are becoming important components of vehicle power systems as the automotive industry starts to make the transition from internal combustion engines to hybrid or electric powertrains. Advanced batteries are also being considered for grid storage applications to help stabilize the voltage and frequency of the grid and to help buffer energy supplies as intermittent sources like solar and wind are added to the supply side of the system. Since each battery cell has a limited voltage and capacity, cells must be assembled into groups to provide the storage and power these applications require. These packs and modules are assembled by attaching the copper and aluminum cell tabs to bus bars in module and pack assemblies. Similar joints are used in photovoltaic panel assemblies. Since the cell units in both battery modules and solar panels are expensive, it would be advantageous to use a repeatable, cost effective connection process that would also allow for replacement of cells that are damaged or otherwise compromised. This study investigated the use of a solder joint to make a reversible connection between cell tabs and module bus bars.

Attachment of aluminum tabs to copper bus bars is an important step in the assembly of battery modules and packs for electrified vehicles and grid storage applications. A wide range of technologies have been demonstrated for this application including percussion welding, ultrasonic welding, laser welding, and deformation welding. Although these technologies provide low resistance, mechanically secure connections can only be applied once to a specific joint. Thus, there is the potential to create a defective assembly of many cells when only a single cell or joint is defective.

One technology that offers potential for creating metallurgical and reversible attachments is the use of soldering with the appropriate filler alloy. In this process, ultrasonic energy is used to facilitate wetting and flow of the filler onto the substrate without the use of flux. Typically, this is done as a pre-tinning operation. Ultrasonic energy has been used to pre-tin substrates ranging from copper, titanium, and aluminum to ceramics and glass. Once the solder has been pre-applied to the substrates, it can be re-flowed in any heating operation to create a joint. In this study, resistance heating will be used to reflow the pre-applied solder. Resistance heating is fast and can focus the heat in a highly localized area leaving nearby heat-sensitive areas unaffected. It can also be used to heat an existing joint sufficiently to allow it to be disassembled. The focus of this study was on developing techniques to disassemble a stack.

Approach

To model the disassembly of connections in a battery module, four 0.12 mm thick 12 mm wide by 30 mm long aluminum 1100 tabs were pretinned using an ultrasonic soldering process , joined together and then soldered to copper strips.

A specially designed resistance heating tool was assembled to reheat the joint and pull it apart. To decouple the tab stack from the copper strip, a specially designed resistance heating tool was clamped in place with clips attached to a tab stack. After a quick heating cycle the tool was designed to open, separating the tab stack from the copper bus.

Objectives

The objective of this program was to demonstrate each of the following steps:

- Conductive heat spot welding can be used to consolidate aluminum tabs.
- Ultrasonic assisted soldering can apply tin to the consolidated tab-stack.
- Resistance heating reflow of the solder can join the tab stack to a copper buss.
- The combination of mechanical separation and resistance heating can decouple the tab stack from the bus bar.

Results and Discussion

Tab Stack Consolidation

Conductive heat welding was used to consolidate the tab stack. In this process, a cover sheet is resistively heated and the tabs are heated by conduction of heat from the cover sheet into the substrate.

For successful conductive heat welding, it was necessary to use an upslope for each current pulse to reduce expulsion and allow the electrodes and cover sheets to settle completely into the tab stack. To produce a high current density and assist with through thickness heating, the electrodes were given a slight radial convex shape. The best welds were produced with a weld current of 6 kA and weld time of 5-20 cycles to allow for weld nugget diameter growth. The best weld nuggets were produced with a weld force of 1.1 kN. This was sufficient to produce acceptable welds without deforming the tab stack.

Incorporating a downslope in each pulse was also found to be advantageous. This improved the appearance and solder deposition behavior by allowing backfilling of surface cracks on the weld button surface.

Solder Application (Pretinning)

Ultrasonic soldering was successfully used to apply solder to the consolidated stack. SAC 305 solder (96.5% tin, 3.0% silver, and 0.5% copper) was used as the solder in this study. Reflow of the solder across the aluminum tab and copper bus was done at 255°C. Excess solder should be avoided.

Bonding Trials

Standard resistance soldering parameters were used to form the tab to bus joint. A pulsation schedule was used to minimize peak temperature in the joint, while still providing sufficient heat to reflow the solder across the entire contact area. Both the aluminum and the copper substrates should be heated during reflow to produce a good bond. A relatively long hold time was required to allow the solder to solidify.

Disassembly Trials

A custom tool was used for this investigation. It is shown in Figure 1 and Figure 2. This tool allowed the resistance electrodes to be inserted into tight spaces that would be encountered in an assembled battery module or pack. The current pulse for disassembly is longer than that used to form the joint in order to keep the solder soft long enough to pull the joint apart. Results showed that the tool should start pulling the joint apart as soon as the heating current pulse ends so that the joint is dismantled when the solder joint is weakest. During disassembly the current pulse must be off when the pieces are pulled apart to avoid arcing. Excess solder increases the likelihood of producing solder strings between the pieces as they are pulled apart.

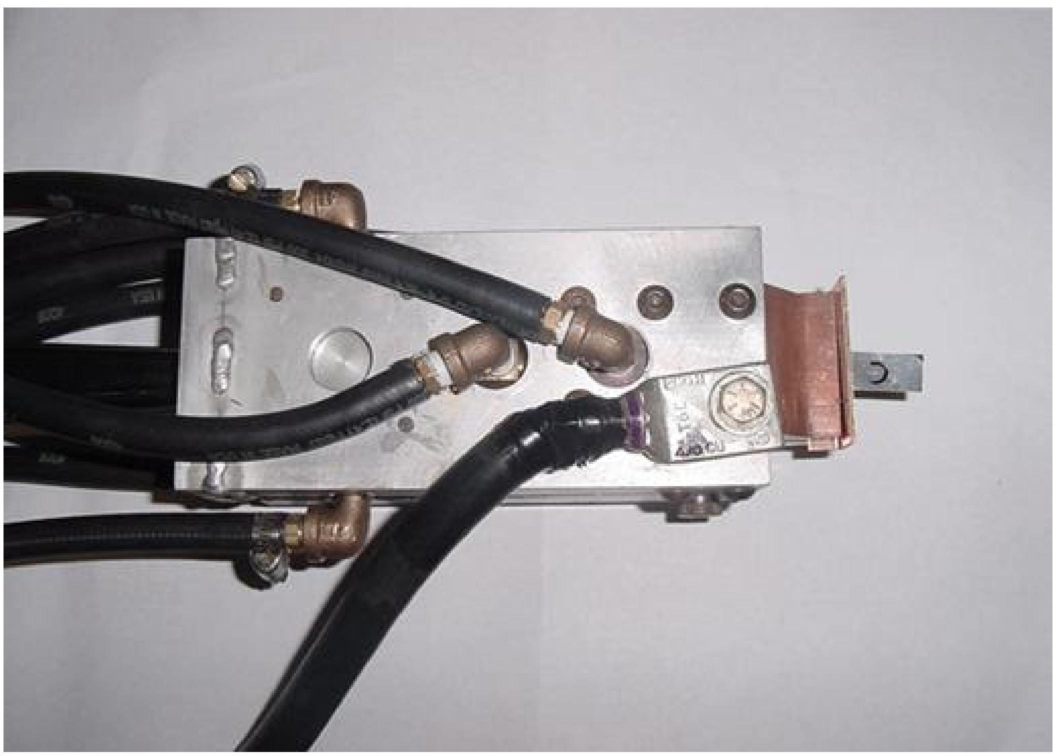

Figure 1. Special Tool for Tab Joint Disassembly

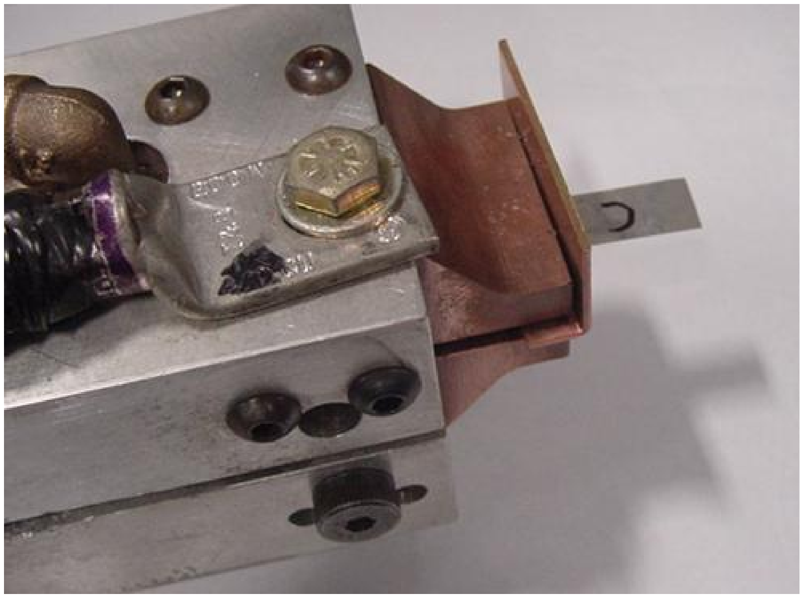

Figure 2. Close-up of Clamping Jaws of Tab Joint Disassembly Tool

The best decoupling cycle was determined to be one second power on pulse at 6KA and about 290-N clamping force. Decoupling trials using this tool were completed. Some trials produced clean separation between the tab stack and the bus. In other cases, separation left solder strings or solder globules that were easily separated by manipulation of the tab-stack.

<u>Conclusions</u>

A system for joining aluminum sheets into a tab stack using conductive heat resistance spot welding was demonstrated. The process can be adjusted to produce a weld the full width of the tab stack without the outer heat generating sheet being welded to the tab stack.

Resistance soldering trials were successful. An ultrasonically pretinned tab stack was joined to the copper bus by reflow of the joint using resistance heating. The disassembly process using a resistively heated desoldering tool was also successful at removing the tab stack from the copper bus. An extended heat cycle during disassembly helped keep the solder soft while the joint was pulled apart.

The complete process shows that it is possible to reversibly create and disassemble joints between aluminum tab stacks and copper bus bars using a solder joint. A custom tool was developed that allowed the dismantling of a 12 mm wide aluminum tab stack from a copper bus.

2.3.1.3 High Temperature Heat Exchanger

<u>Introduction and Background</u>

Solar thermal receiver systems function as high efficiency heat exchangers, converting radiant energy to heat in a working fluid that is used to generate electricity. Heat exchangers typically incorporate large surface areas (for the impinging energy source), short transfer distances (minimizing thermal resistance of the system), and high internal operating pressures (for the working fluids). These requirements have led to new "micro-channel" heat exchanger designs to accomplish these objectives.

Assembling these new designs is difficult. One technique uses thin sheet panels. Thin sheet panel construction involves assembling corrugated internal sheets to create the micro-channels with face sheets that provide the large energy-absorbing surface area. The surface sheets also seal the working fluid inside the system. These thin sheet metal based micro-channel heat exchangers are welding intensive. The joints must seal between the plates, and withstand the resulting pressures inherent in the high temperature applications.

The high temperature of a solar thermal receiver (1000°C operation) requires fabrication from niobium sheet. In this program, manufacturing technologies for assembly of thin sheet niobium based micro-channel heat exchangers were investigated. Technology options include laser welding for device edges, resistance welding for inter-channel attachment, and brazing for header attachment. These techniques were used to assemble prototypes for further testing.

Objective

The objective of this project was to design and build a technology demonstrator for a high temperature, high pressure solar thermal collector.

Approach

The approach to this project will follow five general tasks. These will include:

- Tack 1 − Material selection and acquisition
- Task 2 − Solar collector design
- Task 3 − Material forming
- Task 4 − Development of material joining processes (brazing, resistance spot welding, laser seam welding)
- Task 5 − High pressure and temperature testing

Results

Task 1 − Material selection and acquisition

Due to its formability and weldability, niobium was chosen as the structural material. An analysis of the loading at pressure indicated the need for materials at least 0.2 mm thick. This material was purchased in flat sheet form.

Task 2 − Solar collector design

The collector was designed as a series of parallel micro-channels. Each channel would have a trapezoidal cross section 2 mm high with a 6 mm base and a 2 mm top (Figure 3). A base plate of the same material would be attached to the micro-channel corrugation to complete the closed cell. This particular design was chosen as a compromise between its ability to withstand high pressures (smaller channels are preferred) and ease of manufacturability. Headers for the collector ends have been designed and they will be brazed to the collector providing a hermetic seal.

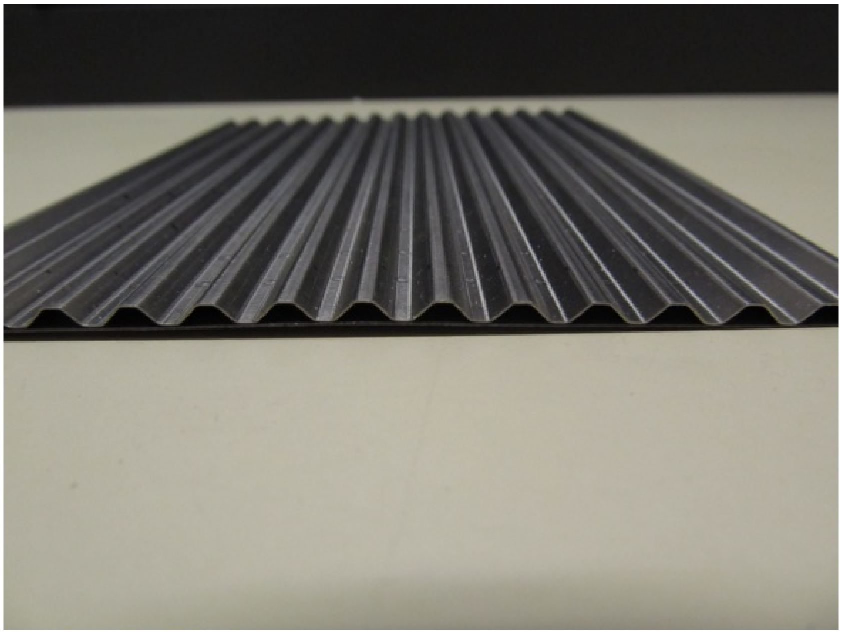

Figure 3. Micro-channel Cross section

Task 3 − Material Forming

A set of dies were designed and built to form the corrugation in the upper sheet of the assembly. This consisted of a male/female die pair to form the corrugation. This die was indexed to another male/female pair that holds the bend while the next corrugation is formed. This process was repeated until the full width of the collector was formed (Figure 4).

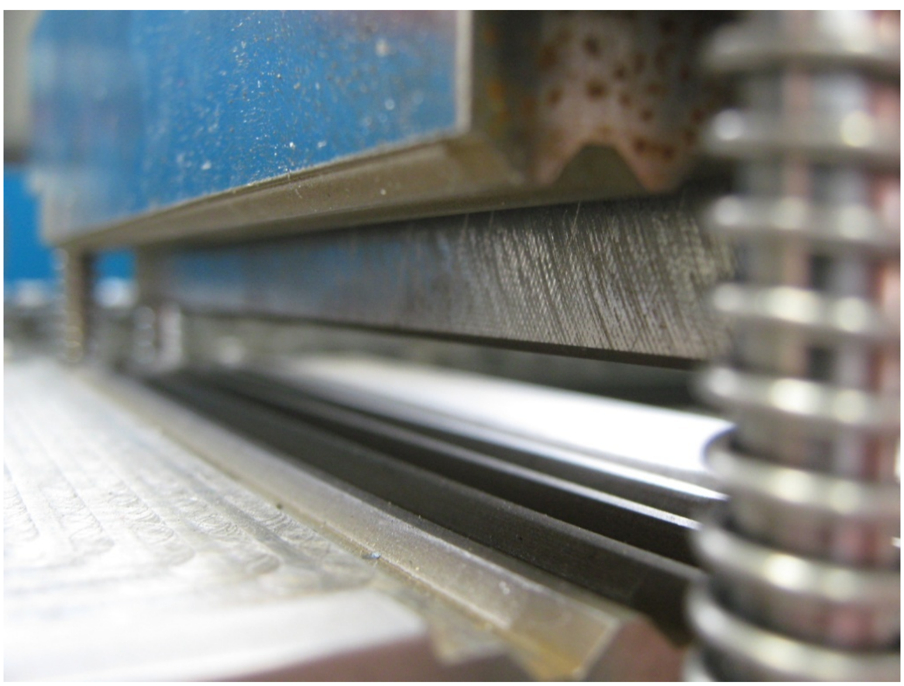

Figure 4. Forming Dies

Task 4 − Development of Material Joining Processes

Three joining processes resistance spot welding, laser welding, and brazing were investigated.

Resistance spot welding was used to join the corrugated face sheet to the flat backer sheet on the solar collector. These welds were made at the root of each corrugation spaced approximately 10 mm on center (Figure 5).

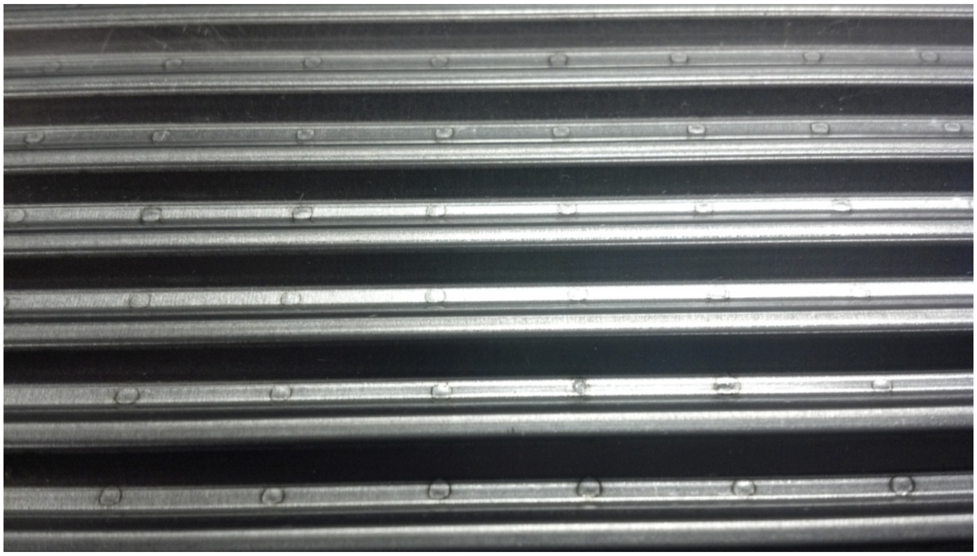

Figure 5. Corrugation to Backer Sheet Spot Welds

Laser welding was used to provide a hermetic seal around the edges of the assembly (Figure 6). In production, this could be accomplished with laser welding or resistance seam welding.

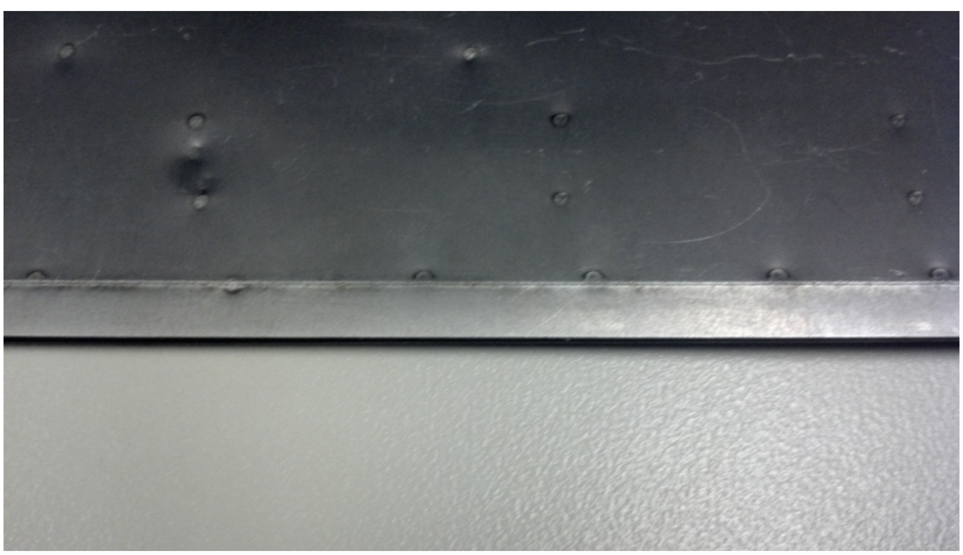

Figure 6. Laser Seam Welding

Vacuum brazing will be used to join the headers to the collector. Preliminary trials using a nickel alloy have shown sufficient wetting of the substrate and the ability to fill small (< 0.5 mm) gaps.

Task 5 − High Pressure and Temperature Testing

The project ran out of money before high pressure testing could be completed. EWI plans to perform this testing using private funding in the future.

3.0 Benefits Assessment

The activities of the Center have created a network of advanced energy companies and capabilities in Ohio. Under the right circumstances, this network can help companies get products and technologies to market faster. This will create jobs for Ohio residents.

The support of the Center has directly contributed to the creation of at least one job. EWI has recently formed a company RealWeld Systems to commercialize the Advanced Weld Trainer equipment developed with the support of the Center. This training software and hardware can be used by companies, technical schools and two year colleges to train welders for opportunities arising from biofuels, shale gas and wind energy. This training system will allow a small number of skilled welding instructors to provide training to a new generation of welders.

4.0 Commercialization

Completion of the crosscutting technology program to develop an advanced weld trainer led to the creation of RealWeld Systems an EWI spin-off organized to produce and market the trainer to support the training of the next generation of welders.

5.0 Accomplishments

- Launched the Advanced Energy Center.
- Developed the methodology for manufacturing design reviews.
- Launched social media based web interface for connecting with advanced energy suppliers and developers.
- Held technical discussions and reviews with more than 110 companies in a wide range of advanced energy businesses.
- Held four formal design reviews to help companies do root cause analysis of challenges and identify paths towards technical solutions.
- Hosted Battery Manufacturing Symposium with more than 100 attendees.
- Co-sponsored meeting “The Future of Nuclear Energy in the U.S.” with over 100 attendees from both the industry and the public. Keynote addresses were given by Dr. Patrick Moore, co-founder of Greenpeace and Karen Alderman Harbert, President of the U.S. Chamber Institute for the 21st Century Energy.

- Hosted Nuclear Safety Webinar after the Fukushima tsunami with more than 250 participants.
- Developed list of service providers for providing business assistance, capital funding, Six-Sigma analysis, design for manufacturability analysis, carbon footprinting, and energy audits. A list of contacts is provided in Appendix A.
- Created the "Central Ohio Hub of Advanced Manufacturing and Power Storage" with partner organizations TechColumbus, Battelle, Ohio State University, and the City of Columbus to help develop business in central Ohio for batteries and energy storage.
- Formed Advanced Energy Economy Ohio a statewide network to attract and grow businesses in advanced energy and clean technologies by providing access to capital, technical assistance and governmental support.
- Hosted Manufacturing Innovation Summit on "Strengthening U.S. Manufacturing Competitiveness" with The Manufacturing Institute.
- Attended more than 90 meeting, conferences and symposia to discuss technologies the advanced energy industry needs and the challenges it faces.
- Sponsored and completed three crosscutting technical development programs on:
  - Advanced Welder Training
  - Reversible Connection between tabs and bus bars
  - Resistance welding

6.0 Conclusions

The range of companies in the advanced energy market is very broad. They range from small to large and from start-ups to well-established nationally-known major manufacturers. These firms use a wide range of technologies to address a very diverse set of markets. Some technologies are completely new, emerging from universities and national laboratories to address new challenges and create totally new industries. Other technologies in these markets are well-established solutions to existing challenges that are now being redeveloped to solve new problems.

Developing relationships with companies across the advanced energy manufacturing spectrum has required substantial effort on the part of the Center. Even though the Center visited more than 110 companies and attended more than 90 meetings, it has not uncovered all of the critical issues and missing capabilities that advanced energy manufacturers need to prosper and grow. The Center needs to continue its efforts to establish and maintain contact with advanced energy companies so that it can provide assistance as the technology at these companies matures, and they begin to transition from technology development to manufacturing and commercialization.

During this initial period the Center contacted a large number of small advanced energy companies. While we anticipated that a design review service would be important for them, we found that many companies were still too early in their technology development cycle to consider design for manufacturing and commercialization issues. They also do not have the resources to undertake commercialization and pre-manufacturing activities without government or venture capital support. The Center's activities are most ideally suited to support companies in transition from technology development to manufacturing, but companies in this stage of development are not easy to find. By casting a wide net, the Center has established a presence in the industries that are involved with advanced energy product, and is poised to provide assistance as these companies reach the key transition to commercialization.

In addition to resource limitations, the Center encountered another barrier to helping advanced energy companies. Small companies in these industries are still mentally in a start-up mode; they want to do everything by themselves, so that they can protect their technology from competitors. As a result, they are wary of asking for help or cooperating with suppliers and partners to bring their technology to market.

Large companies in advanced energy markets are also reluctant to work with partners. Even though the advanced energy markets are new to them and require skills outside their core, they feel they have the knowledge and talent necessary to bring their technology to market. This has often slowed the introduction of new technology into the market.

Developing relationships with advanced energy manufacturing and technology companies takes persistence. The Center has now established its presence with companies across the broad spectrum of technologies that are needed to supply advanced energy markets, and it is poised to help these companies bring new products to market and new jobs to U.S. industry.

7.0 Recommendations

There are several recommendations that can be taken from the this effort:

- Companies are wary of working with external partners to bring new technology to market. Success stories would help reluctant companies envision how the Center can help them bring their technology to market faster and cheaper.

- Companies are wary of cooperating with other companies, preferring to develop technology internally when there are commercially available options at hand. This lengthens the development cycle and increases product costs.

- Many small companies in advanced energy markets are not yet ready for the transition from technology development to manufacturing. Developing a better company screen to identify companies in this transition phase would help the Center focus its efforts where they can product the most benefit.

- The Center needs to be persistent in putting its message in front of potential client companies. It often takes several visits for a client business to understand what role the Center can play in their success.

- The Center would be more effective if it had access to funding for small technology development projects like the three undertaken here. Since many companies lack the resources to fund manufacturing development projects, the Center needs resources to provide this service.

Appendix A

Business Consulting Resources

Business Consulting Resources

Resource	Address	City	State	Zip code	Phone	Email
The Quality Innovation Institute	114 Shawnee Trail	Aurora	OH	44202	330-388-6586	sommersdan@msn.com
Frank S. Gruber and Associates	320 Poplar Grove	Springboro	OH	45066	513-786-4493	sfapgruber@aol.com
Genx Materials	One Neuman Way MD BBC15	Cincinnati	OH	45215	513-786-1654	walt.buttrill@ge.com
Broering Office Solutions		Columbus	OH		513-717-4169	jack.broering@gmail.com
Lean Solutions Group	30996 Walden Drive	Westlake	OH	44154	440-899-1190	chuck@leansolutionsgroup.com
Les Helleman						les.helleman@ae.ge.com
Clark Consulting	1310 Lakeside Place	Worthington	OH	43805	614-888-1746	clark.17@osu.edu
Supplier Six Sigma LLC	729 Autumn Branch Road	Westerville	OH	43081	614-570-2541	bill.soller@suppliersixsigma.com
NCK Consulting	2298 Comet Cr. NW	North Canton	OH	44720	330-499-1340	nick@nckconsulting.com
Andy Paquet	1388 Walnut Ridge Drive	Uniontown	OH	44685	330-517-7084	paquetandy@hotmail.com

Appendix B

Rare Earth Roundtable Discussion Resistance Welding Technology for Refractory Metals

Rare Earth Roundtable Discussion Resistance Welding Technology for Refractory Metals

Rare earth elements are members of the lanthanide group of the periodic table. While they are not really rare, there are only a few locations where they are concentrated enough to be mined economically. These metals and their oxides have useful optical and magnetic properties so, while they are used in small concentrations, they have an important impact on the performance of the products they are in. These products include ultra-strong neodymium-iron-boron magnets that are critical components of many hybrid vehicles, smart phones, laptop computer hard drives and wind turbine generators. They are also important components of advanced nickel metal hydride batteries and phosphors for fluorescent lighting (including new light emitting diodes) and plasma flat panel displays. Rare earth elements are also critical for a number of military applications including missile guidance systems, sonar, radar, laser range finding and targeting, electronic countermeasures and satellite communication systems. They even find uses in commodity metal alloys including high temperature steel super alloys, dispersion strengthened steels and as strengthening and corrosion resistant additives in aluminum. Even arc and resistant welding electrodes depend on small amounts of rare earth elements.

More than 97% of the rare earths in commercial trade are mined and processed in China. Recently the Chinese government has begun to limit exports of these minerals. There are several reasons for this supply restriction:

- Support for China's domestic industry
- Concern about resource depletion
- Concern about environmental damage from illegal mining operations

As the Chinese have begun to restrict supply, other suppliers have begun to investigate reserve locations in other parts of the world. The challenge is that these reserves will cost $500M-$2B to develop and the process will take about 7-10 years because the sites are in remote locations that will require construction of new infrastructure.

The Department of Energy has begun to address this issue by completing its Critical Materials 2010 report which called for:

- Developing an integrated research plan
- Strengthening the DOE capacity for gathering information on rare earth materials and applications
- Working closely with international partners to reduce vulnerability to supply disruptions
- Develop an updated Critical Materials Strategy
- Enable diversified global supply chains for rare earth elements so that there are multiple sources
- Develop environmentally sound alternatives to rare earths in their applications
- Develop economical processes and procedures for recycling and reuse

The priority attention will be directed at finding substitutes for rare earths in magnets, batteries, photovoltaic films and phosphors ion addition to developing environmentally sound mining, processing and recycling procedures.

The Roundtable Discussion highlighted the following questions for companies who use rare earth elements in their products. The questions included both technical and policy issues.

- What are your concerns about the supply of rare earth elements for your products? If there is a shortage, how would it affect your operations?
- Do your suppliers use rare earth elements in the products they supply to your or in their operations to make your parts? Are there situations where a shortage of rare earth materials would interfere with your ability to deliver your products?
- Do you know where your key customers use rare earth materials? If these customers had to eliminate rare earth materials from their products, would this cause problems for you or change the parts you supply?
- Do you have enough information on the rare earth situation? Would more information about how entire industries or products might be affected?
- Are you interested in how your products might be redesigned without rare earth components or with less rare earth content?
- Do you think the U.S. needs to be concerned about sourcing nearly all rare earth materials from China? Is this a strategic threat to the U.S.?
- What national policies might you favor to address this issue?
    - Promotion of domestic production
    - Government sponsored national stockpiles
    - R&D support to develop substitutes for rare earths or recycling processes
- Do we need national and international strategies to deal with this issue?
- How can Government implement policies to help the industry deal with this challenge?
- What other material shortages would create a production problem for you or your industry?
    - Lithium
    - Cobalt
    - Indium
- Are the escalating prices of rare earth elements a concern for you? At what level would high prices lead you to redesign your products or look for alternatives?
- How important are environmental concerns about the production of rare earth elements to you?

Answers to these questions were discussed by industrial attendees at this Roundtable session. These attendees included representatives from:

- AlGalCo
- Air Force Research Lab
- Army Research Lab
- Amp Electric Vehicles
- Case Western Reserve University
- Composite Technical Systems
- Dayton Development Corporation

- U.S. Department of Agriculture
- Electrodyne
- Fiamm Energy
- First Energy Technologies
- GE
- GE Aviation
- IAP research
- Innovative Weld Solutions
- Magna E Car
- Ohio Chamber of Commerce
- Ohio Department of Transportation
- Ohio Manufacturers Association
- Ohio State University
- Ohio State University Center for Automotive Research
- SCI Engineered Materials
- Tipping Point Renewable Energy
- Toxco
- Westinghouse Nuclear
- Zyvex