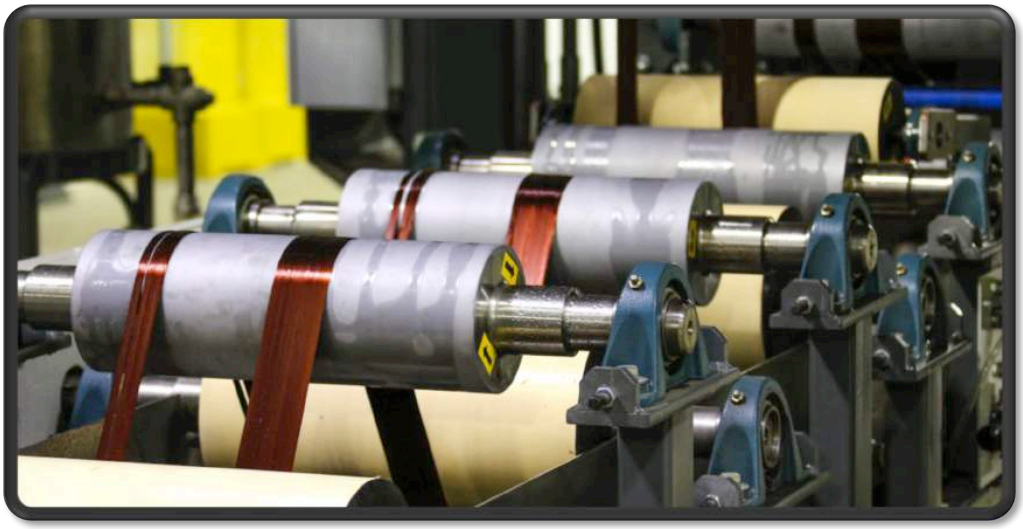
The University of Tennessee, Knoxville

Southeast Regional Energy Innovation Workshop

Chattanooga, TN • May 23, 2016

Southeast Regional Energy Innovation Workshop Report



Carbon Fiber Technology Facility / Photo by ORNL

Hosted by the University of Tennessee, Knoxville and Oak Ridge National Laboratory - May 23, 2016

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THE UNIVERSITY OF TENNESSEE KNOXVILLE

OAK RIDGE National Laboratory

The Southeast Regional Energy Innovation Workshop Report

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WORKSHOP INTRODUCTION

The University of Tennessee, Knoxville (UT), and Oak Ridge National Laboratory (ORNL) hosted the Southeast Regional Energy Innovation Workshop on Monday, May 23, in Chattanooga, Tennessee, at the Chattanoogan Hotel. The workshop focused on the future of energy innovation. Participants explored ways universities, industry, community stakeholders, and the Department of Energy's (DOE) national labs can leverage emerging clean energy technologies to stimulate regional economic development. Representatives from DOE, ORNL, and regional industries as well as nine universities from six states in the southeast participated in panel discussions aimed at advancing clean energy innovation and regional collaborations. This event was an opportunity for participants to share their views on the future of clean energy adoption in the southeast. The purpose of this report is to inform DOE's future planning about clean energy technology innovation in the Southeast Region. It is structured around each session, by framing question. Audience questions are classed by framing questions as well.

WORKSHOP SUMMARY

Dr. Thomas Mason (Director of ORNL) started the Southeast Regional Energy Innovation Workshop with an announcement that ORNL would be opening an office in Chattanooga. Chattanooga Mayor **Andy Berke** later emphasized this as a great partnership and opportunity for increased innovation in the region. **Dr. Elizabeth Sherwood-Randall** (Deputy Secretary of U.S. DOE) then introduced the concept of Regional Energy Innovation Hubs: areas around the U.S. paving the way for energy innovation. **Dr. Joe DiPietr**o (President of the University of Tennessee System) welcomed everyone to Chattanooga and talked about the great synergies that come from collaborating with ORNL. Finally, Congressman **Chuck Fleischman** (3rd District of Tennessee) highlighted how area resources; specifically ORNL capabilities (such as supercomputing, carbon fiber generation, and 3D printing) can be utilized to meet the goals of a Southeast DOE Regional Energy Innovation Hub. Some key themes emerged from each section, summarized below:

1. Energy and industry are already collaborating in a variety of ways, often hosted by the Electric Power Research Institute (EPRI). Additional DOE efforts to support southeast energy and

industry collaboration should start small, build on existing infrastructure, and be allowed to grow and change as innovations develop. (*Roundtable 1: Energy Innovation Industry*)

2. Southeastern universities are increasingly embracing interdisciplinary programs that span departments and integrate students into national labs and industry. Programs like these enable students to be influenced by real-world situations during their studies, so they have a competitive advantage when they graduate, and ideally are already making significant contributions to the advancement of clean energy. (*Roundtable 2: Energy Innovation University*)
3. Graduate students at these universities are already engaging in a wide range of energy-related research through interdisciplinary programs, and some are launching businesses during their graduate studies. Working in national lab environments fosters experience in policy and entrepreneurship. (*Panel 1: Entrepreneurship & Graduate Education to Drive Innovation*)
4. Conventional manufacturing and engineering processes are adapting at an unprecedented rate to improve, reducing production times and increase energy efficiency. Efficient manufacturing techniques and clean energy sources are proving themselves a very strong and ever-increasing economic driver in the region. (*Panel 2: Clean Energy Innovations*)
5. ORNL provides access to advanced scientific tools and expertise not readily available in industry and academia. ORNL welcomes the opportunity to collaborate with industry, and encourages companies to visit and discuss their research challenges. (*Panel 3. Leveraging DOE Capabilities to Deliver Innovation*)
6. Public-private partnerships between national laboratories, universities, and industries act as drivers of innovation and economic development. These partnerships build local ecosystems to strengthen the region in changing innovation landscapes. In a global economy, advanced manufacturing is a strong resource in the southeast. (*Panel 4: Tech to Market Innovations*)

ROUNDTABLE 1: ENERGY INNOVATION INDUSTRY

Joe Hezir (Chief Financial Officer, U.S. DOE) moderated this roundtable, and **Dr. Moe Khaleel** (Director of Planning, ORNL) took notes. Roundtable participants included: **Peter Hoffman** (Vice President, Intellectual Property Management, Boeing Co.); **Dan Stout (**Senior Manager, Small Modular Reactors, TVA); **Jason Swager** (Manager R&D Electrical, VW Americas); and **Nick Irvin** (Program Manager, Advanced Energy Systems, Southern Company). **Joe Hezir** noted that the panel was designed to talk about what regional partnerships are, and to get industry perspectives on them. He read language from a senate appropriation report that encouraged regional work through existing programs. Hezir summarized the energy situation in the southeast as being uniquely known for hydropower generation. He also noted that a regional partnership could be structured as a cross-sector consortium, serving as a federally-funded energy planning hub.

Question 1. Please provide introductions and background. **Jason Swager** said that VW America, headquartered in Chattanooga, is building a new SUV. They are looking ahead to gauge target markets and future products. **Peter Hoffman** said that Boeing is focused on developing and protecting technologies and is a strong believer of collaboration. **Nick Irvin** said that Southern Company is a 4-regional utility that still has an in-house R&D function. They are a contractor and collaborator with DOE, working directly with EPRI. Recently, they have been exploring increased nuclear capabilities. **Dan Stout**

said that TVA continues research of the small modular reactor, and has submitted an application to the Nuclear Regulatory Commission (NRC) to evaluate the suitability of the ORNL small modular reactor site. TVA is pursuing a balanced portfolio of electricity generation, and has a new focus on their three pillars of sustainability: energy generation, environmental health, and economical advantage for the Southeast Region.

Question 2. What are some key priorities for an energy technology innovation agenda in the southeast? **Dan Stout** said that the southeast should have a strengths and weaknesses assessment done, before determining the course of action. He noted that UT and ORNL provide significant nuclear expertise in the region, and that there is a growing need for clean, reliable, sustainable electricity. **Jason Swager** said that from the automotive side, a southeast energy innovation agenda should include lightweight materials, energy storage, smart vehicles, and smart cities. He also said that increasing carbon fiber research and reducing the cost of the manufacturing is important.

Audience Member Q&A. This question is for the energy company representatives. You both come from very innovative companies. Are both companies collaborating to address common issues? **Nick Irvin** said that there are opportunities to collaborate on technology development and regulatory issues. He noted that TVA and Southern Company have worked on carbon capture technologies together. **Dan Stout** said that the whole southeast energy industry is collaborating thru EPRI, sharing resources in a regulatory environment – though, he notes, deregulation makes sharing more difficult.

Audience Member Q&A. This question is for the industry representatives. You both are manufacturing using multiple technologies. Is there one technology you wish for more advancement of? **Jason Swager** said that advancing material affordability, especially carbon fiber, would be good. **Peter Hoffman** agreed. He would like to see scaling with carbon fiber technology, noting that Boeing uses a lot of titanium due to carbon compatibility. Aluminum didn't work as well, so they had to tailor materials for specific functions. **Jason Swager** stressed again the need for smart infrastructure, and the ability to meet customer desire for autonomous vehicles in safe environments.

Question 3. How can industry build on current DOE programs and models to achieve a regional partnership that promotes an innovation ecosystem for the southeast? **The panel** agreed that two members from power and two members from industry should be represented, at a minimum. They acknowledged the need to work with each other, as well as with the communities they inhabit. **Dan Stout** noted that the rate of change in the energy sector is exceptionally high right now, and that how the southeast responds to distributed generation and renewable energy sources is important to be competitive. He noted that partnerships help industries pivot quickly in the face of diverse technologies.

Audience Member Q&A. Are there further opportunities for cross-sector collaborations across technology? **Jason Swager** noted that technology goes thru phases, and that the most time is spent focusing on the practical over the theoretical. Identifying how to speak with the research community is sometimes difficult, because the research community tends to think in terms of what's possible, whereas industry thinks in terms of what's practical. The trick is to solve real-world problems using outstanding innovations in cost- and time-effective ways.

Question 4. Where do you see a need for increased southeast energy investment, and how important are energy supply issues to expanding the manufacturing base in the region? **Peter Hoffman** said that advanced manufacturing and aerospace industry research is a critical investment. He recognized that the Southeast is on a manufacturing upswing. He also noted that while Boeing isn't intense in power usage, increased automation makes their processes able to tolerate less interruption – so, power reliability is very important to them. **Dan Stout** said that innovation in clean safe, reliable, affordable energy is very important. **Nick Irvin** noted that Southern Company has an innovation center in Atlanta, which manages $2 billion in applied research projects.

Question 5. What kinds of things should DOE do to support regional collaboration between energy and industrial manufacturers? **Nick Irvin** said that collaborative efforts tend to start small, and grow with successes. DOE could foster a staged collaboration approach, with the intent to grow over time. He noted that there is a need to be agile in support of collaboration, which can be messy at times. DOE could develop targets for energy and industry sectors, built around a staged approach. This would accommodate a variety of activities throughout the innovation life cycle.

ROUNDTABLE 2. ENERGY INNOVATION UNIVERSITY

Dr. Stacey Patterson (Associate Vice President for Research, University of Tennessee), moderated this roundtable, and **Susanna Sutherland** (PhD Candidate, The Bredesen Center, UT Knoxville) took notes. Roundtable participants included: **Dr. Jimmy G. Cheek** (Chancellor, UT Knoxville); **Dr. Joanne Romagni** (Vice Chancellor for Research and Dean of the Graduate School, UT Chattanooga); **Dr. Timothy Lieuwen** (Executive Director, Strategic Energy Institute, Georgia Institute of Technology); **Dr. Tanju Karanfil** (Vice President for Research, Clemson University); **Dr. Ray Vaughn** (Vice President for Research and Economic Development, University of Alabama, Huntsville); and **Dr. David Kosson** (Cornelius Vanderbilt Professor of Engineering, Department of Civil and Environmental Engineering, Director of CRESP, Vanderbilt University). **Stacey Patterson** had the panel introduce themselves. Then she asked a series of questions:

Question 1. What are the unique or most pressing energy research opportunities in the Southeast Region? **Timothy Lieuwen** noted that nuclear is high on the list, but emphasized hydrocarbon from natural gas as a good opportunity. He thinks this makes a lot of sense for the southeast, because there is an existing research and development (R&D) powerhouse already in existence, as well as carbon capture sequestration sites. He noted that General Electric is experimenting with hydrocarbon from natural gas. **Joanne Romagni** said she would like to develop the workforce and create the next generation of innovators, which is the focus at UT Chattanooga (UTC). She noted that collaboration is key – UTC works with ORNL, TVA, and other partners to explore things like electricity generation from solar and wind. **Jimmy Cheek** agreed: UT Knoxville has benefited tremendously from a relationship with ORNL, which has influenced academic programming. **David Kosson** noted that Vanderbilt tests technology against social, legal, and monetary constraints. He wants to understand market constraints for end users. **Tanju Karanfil** agreed, and said that quicker access to the market is needed – which test beds can provide. **Ray Vaughn** commented that this kind of workshop is a good catalyst. He wants to encourage expansion of the 501c6 Public Private Partnerships (PPPs) in the region.

Audience Member Q&A. Michael Walton said that Green Spaces sees the need for cost-effective storage in the grid connection space, and asked what the panelists have been doing in this area. **David Kosson** said that Vanderbilt is working on embedding energy storage into nanomaterials that can then be placed throughout the electrical grid system. **Timothy Lieuwen** noted that energy grid storage is an enabler, but that it's also essential for cyberspace security. The southeast doesn't yet excel here but he thinks that it should, because the region is home to some of the largest computers in the world. **Ray Vaughn** also wants to focus on cyber security. He notes that though computing infrastructure is easy to attack, there is significant capability to address these attacks. **Stacey Patterson** said that ORNL has energy storage experts, and UT Knoxville is also very active in this area. It is an area of need, and will impact future application of all technologies.

Audience Member Q&A. A person from Vanderbilt noted that smart grid security is a big deal. He said that the right partnerships need to be established to ensure the data is as safe as possible across sectors. **Tanju Karanfil** said that the Dept. of Homeland Security simulates what happens during attacks, and how quickly systems can recover. **Joanne Romagni** said that EPB (Chattanooga's local distributing utility) has opened 15-minute increment data to UTC faculty.

Audience Member Q&A. A private consultant said that as the energy system moves towards distributed energy resources, energy transactions need to communicate with a block chain of software. He wanted to know if any institution is looking at the underpinning software system that supports grid operations. **Ray Vaughn** said that the University of Alabama, Huntsville (UAH) collects data on these systems. **David Kosson** noted that the Vanderbilt Integrated Software Institute is also working on this.

Question 2. What do you see as the way forward to expand and accelerate technology innovation and commercialization? **David Kosson** said that capturing high caliber students and teaching them how to make a difference through industry internships is key. **Jimmy Cheek** noted that both policy and entrepreneurship focuses are available in the Bredesen Center. He hopes this will be a model for other programs: to build entrepreneurship into the fabric of the programs UT Knoxville offers. **Timothy Lieuwen** said Georgia Tech tries to find 1 - 3 universities in each country to partner with southeast-based Fortune 500 companies. They were recently named a Siemens Center of Knowledge Interchange (CKI), in part due to their leverage with local industry. **Tanju Karanfil** noted that Clemson finds access to materials challenging. **Joanne Romagni** said UTC creates interdisciplinary teams to incubate new energy tech ideas.

Audience Member Q&A. A student from UTC asked how the panel considers technology adoption. **Timothy Lieuwen** responded that they consider the social and physical systems surrounding technology.

Question 3. How to better connect resources and capabilities across DOE, universities, and industry in the Southeast Region? **Timothy Lieuwen** said to consider the industrial base, and all the investments in R&D the southeast is making in order to know today what areas are going to require major investment so they can bloom tomorrow. **David Kosson** noted that this as a dialogue: it should be an ongoing engagement between the universities, DOE, and the labs – as well as the communities who will ultimately benefit from the discoveries. **Jimmy Cheek** said that universities around the country are

critical to southeast energy advancement. He stated the need to leverage collective resources. **Ray Vaughn** asked if there could be more workshops. He recalled that an industry panelist said that there are three approaches to innovation: what's possible, what's probable, and what's practical. UAH is more on the probable or practical end of the spectrum, with the very applied work that they do. **Tanju Karanfil** said that innovation needs a catalyst, with supporting infrastructure.

Audience Member Q&A. Jason Swager with VW asked how universities handle having access to the future of buying power. **David Kosson** noted Vanderbilt works hard to leverage student access: they give students a challenge, asking for multi-disciplinary ideas. He said that universities don't want to predict the future, they want students to imagine it and then develop it. **Tanju Karanfil** said that students want to be connected, and that it's the university's job to channel that desire into projects.

Audience Member Q&A. Courtney Piper (TN Advanced Energy Business Council) asked what non-governmental organizations (NGOs) can do to increase the visibility of energy-related work already happening in the region. **Ray Vaughn** said most NGOs are locally functioning, and that trying to build the next generation to work on a regional scale is an endeavor deserving of federal support.

Audience Member Q&A. Lee Riedinger (Director of the UT Knoxville Bredesen Center) observed that this meeting is an exciting opportunity, but wondered how to accomplish next steps. He noted that six universities and four industries were present, and said that if this is the last workshop it won't be enough. He wondered who would convene future conversations, to decide on prominent regional strengths. **Oak Ridge Associated Universities (ORAU)** was asked if they could adopt the role of convener, and said they were suited for it. **Ray Vaughn** observed that some long-term research isn't conducive to the flow of grad students. One thing UAH has started doing is to pay tuition and student salaries if they can be embedded directly in companies. The approach seems to be working. It becomes a long-term relationship that advances new technology.

PANEL 1: ENTREPRENEURSHIP & GRADUATE EDUCATION TO DRIVE INNOVATION

Dr. Franklin (Lynn) Orr (Undersecretary for Science & Energy, U.S. DOE) moderated this session, and **Victoria DiStefano** (PhD Candidate, The Bredesen Center, UT Knoxville), took notes. Panelists included: **Mallory Ladd** (PhD candidate, The Bredesen Center, UT Knoxville); **Jeff Beegle** (PhD Candidate, The Bredesen Center, UT Knoxville); **David Collao** (PhD Candidate, UTC); **Anne Mallow** (PhD Candidate, Georgia Institute of Technology); and **Annette Bodenheimer** (PhD Candidate, North Carolina State University).

Franklin Orr said the purpose of the panel was to understand what energy research graduate students in the southeast are doing, and what more could be done to further graduate work in clean energy fields. He noted that the energy transition is well under way, and there is a continued need for smart people to drive energy innovation in

educational systems and labs. The panel introduced themselves:

Annette Bodenheimer is currently working on her dissertation at ORNL through the Graduate Opportunities (GO!) Program. Her dissertation involves structurally characterizing the enzymes that break down cellulose. **Mallory Ladd** is a National Science Foundation graduate research fellow. Her dissertation research (at ORNL as part of the NGEE-Arctic project), focuses on the soil biogeochemistry and investigates nutrient cycling in the Artic. **Anne Mallow** is working on her dissertation at ORNL through the GO! Program. Her dissertation involves designing advanced heat exchangers for many applications through experimental and computational research. **David Collao** is in the SimCenter (Center of Excellence in Applied Computational Science and Engineering). His work involves using computational models to improve the stability of axial compressors. **Jeff Beegle's** ORNL research involves advancing systems that convert waste to energy. He is also the CFO of a start-up company, Grow Plastics, which utilizes a technology to use renewable plant matter to make plastic.

Question 1. How is your research related to energy? **Jeff Beegle** said his research involves looking at the water energy nexus. Specifically, he is researching how microbes can be used to treat water and generate electricity. **David Collao** said he focuses on improving axial compressors (which are in planes and power plants), by designing them to use less energy. **Anne Mallow** works on increasing energy efficiency by storing waste heat to preheat other waste streams. Her research examines using phase change materials in cyclic latent heat thermal storage systems to store waste heat. She is also researching increasing heat transfer in heat exchangers, to improve the efficiency of mechanical systems. **Mallory Ladd** focuses on the climate energy nexus (understanding how changing climate impacts energy issues, and vice versa). Specifically, she focuses on how warming temperatures in geographically vulnerable areas (such as the Artic) may influence the future energy landscape. **Annette Bodenheimer** researches the transformation of plant cellulose, or organic matter that requires enzymes to be broken down. These enzymes work to modify cellulose into downstream fuels (i.e., biofuel).

Audience Member Q&A. Panelist David Colloa asked if other panelists' research changed when they went to work at ORNL. **Anne Mallow** said definitely. Her initial experience at ORNL – before graduate school – informed her graduate work. **Annette Bodenheimer** said her advisor has a joint faculty appointment with ORNL and NC State, and that this shifted her research focus. **Franklin Orr** asked if this experience caused the panelists to want to work at ORNL or another national lab after graduation. **Mallory Ladd** said yes.

Question 2. How is the ORNL environment different from a university environment? **Anne Mallow** was at GA Tech for three years before coming to ORNL, where she became involved in the startup of a new project involving rotating heat exchangers, which is now part of her research. She notes that in a university setting, she focused on one project. In the lab setting, she has had the opportunity to be involved in many additional side projects, which showed the applicability of her research in many different situations.

Question 3. In a university setting, grad students are often inadvertently responsible for the transfer of information about research activities. Do you find yourselves in that role that at the lab? **Anne Mallow** said her ORNL group is good at information transfer; they have lunch meetings to discuss

research. **Mallory Ladd** says they do a lot of collaborative research at the lab: graduate students are offered the opportunity to develop questions, pursue them, and seek out collaborations. She said that the Bredesen Center is also good at having an interdisciplinary approach, in two ways: 1) students come from all different scientific backgrounds, forcing communication across scientific fields, and 2) students must pursue knowledge breadth curricula such as policy or entrepreneurship, allowing them to gain valuable experience communicating with non-science fields. **Jeff Beegle** agreed. He said the Bredesen Center and ORNL are both interdisciplinary environments, encouraging students to think economically and practically.

Question 4. The Bredesen Center also has a unique design, encouraging students to pursue other interests related to energy including policy and entrepreneurship. What have you been involved in? **Mallory Ladd** said she is interested in the policy track. She had the opportunity to go to Washington, D.C. for an internship at the Wilson Center, which was a great experience. **Jeff Beegle** is interested in entrepreneurship. He notes there is a group of Bredesen Center students that get together to practice pitches for technologies they have developed, and want to bring to industry. **Anne Mallow** said she is also interested in energy policy. While at ORNL, she has been able to see how technology can be applied.

Question 5. National labs commonly work with industry partners. Have your graduate studies allowed you to do so? **David Collao** said he's had the opportunity to do some work with Sandia National Lab, but not much industry experience. **Mallory Ladd** noted that some Bredesen Center students have been studying the U.S. Environmental Protection Agency's (EPA) Clean Power Plan. Through this work, they have interacted with industry stakeholders to assess how this plan will impact them. **Jeff Beegle**'s entrepreneurship work has given him lot of opportunity to work with industry, carving out a niche where his company can succeed. **Anne Mallow** has been able to interact with industry when she presents her work to them.

Question 6. What would be helpful from DOE to maximize your potential? **Jeff Beegle** noted that there is room for improvement in attracting new students. He thought an incubator for student businesses at the lab would be helpful. Also, having access to six-month tech licenses would help streamline the process. **Franklin Orr** stressed the importance of national labs functioning as great educational systems for graduate students, post docs, and scientists, and commended them for taking advantage of this role to train the leaders of tomorrow.

PANEL 2: CLEAN ENERGY INNOVATIONS

Cortney Piper (Tennessee Advanced Energy Business Council) moderated this session. **Guin Shaw** (Ph.D. Candidate, The Bredesen Center, UT Knoxville) took notes. Panelists included: **Tom King** (Director, Energy Efficiency and Electricity Programs, ORNL); **R. Platt Boyd IV (**Founder and CEO, Branch Technologies); and **David Wade** (Executive Vice-President and Chief Operating Officer, EPB). Cortney Piper had the panel introduce themselves, and then asked a series of questions.

Question 1. What do you think is the most pressing clean energy issue in the region? **David Wade** said that one issue is making technologies cohesive and scalable, while guaranteeing they are economically feasible and can be equitably accessed. **Tom King** added to this, saying scalability in energy tech is

critical in three areas: 1) available resources (like natural gas, coal, wind, hydro, solar, and nuclear); 2) resource cost structures; and 3) reliability and resilience. **Platt Boyd** said modification and design of buildings to save energy is a huge opportunity. He said that 3D printing building components can save up to 50% in small scale construction. He also said that 39% of land fill waste is produced by the construction industry.

Audience Member Q&A. Who sets the composition goals for the energy portfolio: is it government led or private sector led, and what is the best mix? **Tom King** said federal policy plays a key role, but that there is much ambiguity in determining the right policies. If the energy portfolio is determined entirely by one sector, the perspective is skewed towards that sector's best interests. A balanced approach is needed. Policy should address more than rates: it should deal with security, sustainability, and affordability.

Audience Member Q&A. What is the largest 3D printed structure in the world today? **Platt Boyd** named a 3D design he produced in Atlanta, GA, and said IDK was the tallest 3-D printed building in Chattanooga.

Audience Member Q&A. What does this next large-scale demonstration 3D printed building project look like for the construction industry - for improved energy efficiency? **Platt Boyd** would like it to come from the winners of his competition design. It should be a simple one-bedroom residential example of the most energy efficient, smart, and resource efficient home possible.

Question 2. How important is grid research becoming for macro/micro grid modernization? **David Wade** said it is extremely important, and that it needs a two-way model. This model would allow communication between different energy sources, storage capacity, and demand. He said that if limited to a one-way system, the grid cannot be fully integrated and has limited interconnectedness, sustainability, and adaptability. **Tom King** noted that two-way communication provides the ability to change demand to fit supply - a huge paradigm shift. Passive loads would be replaced with a more dynamic and changing load.

Question 3. In working with National Labs, and even with research universities, can you share a best practice or challenge? **Platt Boyd** said often small companies don't have capital or reputation to start a relationship with research entities. He noted that the solution proposed needs to be fundamentally game changing (not focused on small incremental changes), to get participation. **David Wade** noted that in-person knowledge transfer was a nice aspect of a lab relationship, but that the challenge is developing a common objective from organizational priorities and agendas. Failure to identify common objectives leads to wasted time and miscommunication. **Tom King** said it is critical for a lab to have industry partners: it enables technology market transfer. He notes a symbiotic relationship: industry encouraging lab research and labs solving industry problems.

Question 4. What are the existing and potential economic impacts from clean energy innovation? **Platt Boyd** said that they are innovating in a $1 trillion dollar industry, working with manufacturing and prefabrication to bring jobs to the region. **David Wade** talked about putting in gigabit fiber optics and working with a UTC professor. His economic impact study estimated $3 million in investments over 10 years. However, unquantifiable but substantial economic benefit outweighed cost. Now, they work to

really define "economic impact" more comprehensively. **Tom King** noted that overcoming the gap between science and reality helps determine value propositions.

Audience Member Q&A. Where is clean energy innovation coming from: industry or academia? **Platt Boyd** said that startups are lean, with low overhead that allows for more trial and error than larger companies can afford. Failure is required for innovation to occur. Academia's perspective is needed to create theory, labs to turn theory into pilots, and industry scales and markets innovations. **Tom King** said the innovation and the creativity come from people in both places. **David Wade** said that large-scale collaborations are the best innovation.

Question 5. What additional support do you need in the region to further clean energy innovation? **Tom King** said that defining a pathway and being able to use data to better inform decisions is a challenge. Honing a single vision is challenging, so good communication and coordination are critical. **Platt Boyd** said support is needed to access technology impacts. He hosted a design competition for the first 3D printed house, and had a diverse set of applications from 97 different countries. The winner of this competition demonstrated the power of 3D printing in energy efficient construction in Chattanooga. **David Wade** agreed that a shared vision is important, but also advocated for large deployments to scale technology.

Audience Member Q&A. Can energy efficient building codes drive innovation in industry? **Platt Boyd** referenced Leadership in Energy and Environmental Design (LEED) certifications, an industry-run program designed to spur energy efficient buildings - which ultimately is impacting state and local building codes.

PANEL 3: LEVERAGING DOE CAPABILITIES TO DELIVER INNOVATION

Dr. Jim Roberto (Associate Lab Director, Science and Technology Partnerships, ORNL) moderated this session, and **Suzy Tichenor** (Director, Industrial Partnerships Program, Computing and Computational Sciences, ORNL) took notes. Panelists included: **Dr. Jeff Nichols** (Associate Laboratory Director, Computing and Computational Sciences, ORNL); **Dr. Michelle Buchanan** (Associate Laboratory Director, Physical Sciences, ORNL); **Dr. Bill Peter** (Director, Manufacturing Demonstration Facility, ORNL); and **Dr. Roderick Jackson**, (Group Leader, Building Envelope Systems, ORNL). **Jim Roberto** opened the panel by saying that ORNL is DOE's largest science and energy lab, and that more than 3,000 guest researchers use the lab's different user facilities annually. The panelists represent five of the largest facilities at the lab. They offer perspectives on how to partner with the lab to accelerate innovation. Each panelist described their facility:

Michelle Buchanan said that ORNL is home to four scientific user facilities funded by the DOE Office of Science (SC), accessed by user proposals. Two center on neutron scattering: 1) the Spallation Neutron Source (SNS), and 2) the High Flux Isotope Reactor (HFIR). These are open to and used by researchers from other labs, academia and industry. Together, SNS and HFIR are leading neutron scattering facilities in the country and are used to characterize a wide variety of materials including structural and functional materials, polymers and even in structural biology. The Center for Nanophase Materials Science (CNMS) is another DOE SC user facility that offers collaborative opportunities with the center's experts in materials synthesis, nano fabrication, materials characterization and theory. Finally, the Oak

Ridge Leadership Computing Facility (OLCF) is the fourth DOE SC user facility that provides world-class leadership high performance computing to the nation's scientific community. ORNL also has other four other user facilities supported by DOE's Office of Energy Efficiency and Renewable Energy (EERE): the National Transportation Research Center (NTRC), the Buildings Technology Research and Integration Center (BTRIC), the Manufacturing Demonstration Facility (MDF), and the Carbon Fiber Technology Facility (CFTF).

Jeff Nichols said that the ORNL OLCF is sponsored by the Office of Science Advanced Scientific and Computing Research (ASCR) office. The currently installed high performance computer (HPC) is Titan and calculates at 27 petaflops (27 quadrillion operations per second). Titan is the most powerful HPC system for open science in the nation and the second most powerful in the world. Access is granted through a peer review proposal process the INCITE (Innovative and Novel Computational Impact on Theory and Experiment) program, the ASCR Leadership Computing Challenge (ALCC) and the OLCF Director's Discretionary program. INCITE allocates 60% of Titan to teams of users for the most complex computing challenges. ALCC allocates 30% of Titan for problems important to DOE. The director's discretionary allocations are for new communities of users: those needing to scale up to compete for ALCC and INCITE, and to further programs that grow applications important to ORNL and DOE.

Bill Peter said that the Manufacturing Demonstration Facility (MDF) is five years old and is a public-private partnership (PPP) sponsored by DOE EERE. Through a cost share program, the MDF provides industry with affordable and convenient access to facilities, tools and expertise to facilitate rapid deployment of advanced manufacturing technologies to enhance the competitiveness of U.S. manufacturing. The MDF hosts approximately 5,000 core R&D visits a year in projects addressing advanced materials, quality of parts and faster printers. In addition, the MDF hosts 60-70 summer interns and helps drive curriculum for professional development. For example, the MDF provided training to help Boeing design for additive manufacturing.

Roderick Jackson said that ORNL supports collaboration and rapid innovation in new building technologies. The Additive Manufacturing Integrated Energy (AMIE) demonstration led the development of a 3D printed house and a car, both capable of sharing power together through bidirectional wireless technology for more energy efficiency. The house, powered through solar energy, is able to draw power from the car when the sun is not shining. This research was only possible through industry collaboration.

Question 1. Michelle, describe ORNL's unique capabilities in neutron scattering and nanoscale science and technology. How can these facilities help industry? How does ORNL assist industry in understanding the capabilities and facilitating access? **Michelle Buchanan** said that both SNS and CNMS work closely to bring companies to facilities and introduce them to capabilities. They have workshops about research activities in catalysis, photovoltaics, polymers, and many other applications. They welcome industry inquiries. Instead of simply sending samples to be characterized by the CNMS, companies will visit, discuss what they want to do, and then write a proposal. For example, a company wanted to characterize holes engineered in sheet graphene, and ORNL helped them with world-leading imaging techniques. They worked with firms to characterize polymers, and even synthesize polymers labeled with deuterium that were subsequently characterized at the SNS. They suggest that potential users reach out to the SNS/HFIR and the CNMS to learn more about capabilities, getting to know the

staff scientists. They also have unique capabilities to examine the structural aspects of materials and alloys. They study them in situ with neutrons, look at them under high temperatures and pressures, and evaluate materials for different applications. They can help predict the lifetime of a new material, which is important to the aerospace industry. They invite companies to come or call the lab.

Question 2. Jeff, computing power has increased by more than a factor of 10 in the past 5 years, and will increase by another factor of 100 by 2022. This is a 1,000-fold increase in 10 years. What impact does this have on the potential for modeling and simulation of complex systems and processes? How does ORNL help companies benefit from this? **Jeff Nichols** said they have gone from the Jaguar supercomputer system at 2 petaflops to Titan at 27 petaflops – and, hopefully in 2022 the first exascale supercomputer (10^{18}, or 1 quintillion, operations per second). They will have 1,000 times more performance – faster than Moore's law predicts. This is a great example of innovation by the computing industry. They are using graphical processing units (GPUs) in supercomputers to get 10X performance increase while using same power. That innovation came from the gaming industry. This 1,000x performance increase at the high end in the supercomputing center will trickle down. For example, a cell phone is 500 MFLOPs of computer capability. A few years ago, that was the power in a leading edge supercomputer. Applications that have to run at scale on large systems will also now run on smaller industry systems. All the tools and applications developed are open source. Extensive training is offered.

Audience Member Q&A. Are the labs driving the computer innovation described, or is industry coming up with it? **Jeff Nichols** responded that their next machine has a power target of 20 MW. They need fundamental scientific breakthroughs to achieve this power window. They need innovation in microelectronics in memory logic, circuit design, etc. They expect a 1,000-fold increase not just in hardware, but also in software performance. They need to program in CUDA to use GPUs, and they need advances in associated languages and tools. Next generation software developers are needed.

Audience Member Q&A. When will there be a 27 petaflop smart phone? **Jeff Nichols** said that cell phones will be at teraflops when there are exascale supercomputers.

Audience Member Q&A. Are there any breakthroughs in quantum computing? **Jeff Nichols** noted it's closer than ever, but that this technology is not like CMOS technologies. The science today won't run wholly on quantum computers. He guesses that when there are quantum computers in 10-15 years, they will run with in-house systems. Moore's law is ending sooner than expected. Expect exascale systems in 2022, but know that the fundamental limits of physics are being reached.

Question 3. Bill, ORNL's Manufacturing Demonstration Facility is the nation's premier facility for additive manufacturing R&D, currently partnering with more than 80 companies to advance this field. What do you see as the emerging opportunities in additive manufacturing, and how can industry get involved? **Bill Peter** said that additive manufacturing has huge potential, but is still embryonic. ORNL is working with industry, but is also pulling putting together a computational framework. They are working with industry to discover new materials for parts. There are terrific opportunities for industry to collaborate. For example, DOE will fund an initial project up to $40,000 with in-kind contribution. If the project is successful, DOE will provide up to an additional $200,000. They have done 50 of these so far. There are also opportunities for firms below 300 people. DOE

provides funding to pay for lab expertise. They also participate in a DOE-funded Technologist-in-Residence program with Alcoa. The lab (ORNL) and Alcoa each assign a technology expert to work at the other's sites. Companies can also fund ORNL to do special projects for them. They did approximately $5 million of this kind work in 2015.

Question 4. Roderick, the Additive Manufacturing Integrated Energy (AMIE) project demonstrated the agility of a national lab/industry partnership to deliver innovation in a prototype integrated transportation, housing, and renewable energy system using additive manufacturing. This was accomplished in less than 9 months through a partnership with 20 companies. How was this done, and what are the implications for future innovation in energy systems? **Roderick Jackson** said that the beauty of this project was that they leveraged convening capability to bring together people from different industries and research areas in ORNL (building technologies, transportation, and power electronics) to collaborate. It worked because they had an innovative project coupled with the lab supporting risk that industry couldn't assume. They reduced by 40% the time to print the house and car and show how they related to the electrical grid. Clayton Homes, one of the participants, has now started their own R&D program as a result. They've helped create an ecosystem with these partners that didn't exist before.

Question 5. Innovation is driven by partnerships. Tell us some other examples of partnership successes. **Bill Peter** said that they work with 650 firms a year. For instance, the die and tool industry lost 375 firms, and manufacturing without companies that make the dies and molds is impossible. Now, ORNL is exploring how they can provide rapid prototyping in this area. It's approximately $250,000 for a new die tool. They hope to reduce this cost with new materials. They are also investigating new materials for equipment manufacturers. **Jim Roberto** said that ORNL is a translational lab: half to engineering, half fundamental science. Applications inform fundamental science and fundamental science informs the applications development. **Michelle Buchanan** noted that many companies don't have the high level tools to do the fundamental science and produce breakthroughs they need. ORNL has unique tools, and experts who know how to use them - such as electron microscopy and scanning probes used in situ to evaluate electrochemical processes involved in batteries and corrosion. Industry typically does not have these state-of-the-art tools to solve problems. Several years ago, ORNL solved a critical issue for a leading auto firm that had a problem with a welded part. The firm shipped the car frame to ORNL, and they were able to determine what was wrong with the weld. **Jeff Nichols** said they provide many applications, from fundamental science to high the applied science. **Roderick Jackson** said that they want industry to know they are approachable. As they learn industry's pain points, they can provide better guidance.

PANEL 4: TECH TO MARKET INNOVATIONS

Dr. Mark Johnson (Director, Advanced Manufacturing Office, U.S. DOE) moderated this session, and **Emily Clark** (PhD Candidate, The Bredesen Center, UT Knoxville), took notes. Panelists included: **Major General Nick Justice** (Executive Director, NNMI Power America at North Carolina State University); **Dr. Craig Blue** (Director, NNMI IACMI at UT/ORNL); **Fred Cartwright** (Director, CU-ICAR); **Dr. Johney Green** (Director, Energy and Transportation Science, ORNL); and **Jay Rogers** (CEO and Co-Founder, Local Motors). **Mark Johnson** opened the panel by noting that regional focus on manufacturing is not a new

thing for the U.S. He said that the founding fathers supported manufacturing, and that the U.S. has tremendous scientific and innovative capacity.

Question 1: Jay, what makes science and technology partnerships for manufacturing work well? **Jay Rogers** answered by saying that doing and engaging are critical precursors to making a strong local industry innovation ecosystem. Local Motors was attracted and inspired by the ORNL Manufacturing Development Facility (MDF). The act of doing was really important to them, and continues to be a driver.

Audience Member Q&A. Pete Hoffman, Boeing, had a comment for Jay. He noted they have had positive experiences working with the MDF at Oak Ridge. He said that Boeing has optimized manufacturing processes to the point where interruption isn't tolerated. Their production rates are very high for aerospace standards and going higher. So, the ability to work in a facility doing high-level work, underpinned by good theory (and de-risking these new processes before they show up on the floor) is highly valuable. Another attractive feature of their partnership is that the labs have the latest equipment. Boeing is able to see what's next, and consider it in terms of buying and leasing. The speed of change is so dramatic that having a place that stays on the cutting edge really changes the business model. **Mark Johnson** added that one of the interesting things to watch is the number of machine and equipment manufacturers that are starting PPPs. The competitive advantage is evident.

Question 2: Fred, share your experience with establishing public-private partnerships between industry and university. **Fred Cartwright** said that he has seen an incredible amount of vision for PPPs in South Carolina. SC was a leader in the textile industry for a long time, but no more. They needed to redefine the state as a whole, so they put money into infrastructure and faculty to reinvigorate the economy. The automotive sector was in the middle of a partnership between government, industry and the university. Over 300 students graduated in automotive engineering in 2015.

Question 3: Johney, what does your organization do, and how are you partnering up with people to drive economic development? **Johney Green** said that ORNL has a collection of mechanical and chemical engineers, and functional materials scientists that work on building energy efficiency, manufacturing efficiency, transportation, and energy systems integration – all working closely with industry. They have four user facilities: 1) National Transportation Research Center; 2) Building Technologies and Research and Integration Center; 3) Manufacturing Demonstration Facility; and 4) the Carbon Fiber Technology facility. This gives them a great set of tools to engage with industry across multiple platforms. For instance, they partnered with Emerson to develop a cold climate heat pump, and with GE to produce an efficient heat pump water heater. It has created over 1,000 jobs in Louisville, KY. Other examples include development of power electronics in the Chevy Volt, 3D printing with invertors for power electronics and wind turbines, and power flow control devices for the grid.

Question 4: Craig, share your experiences in standing up those public-private partnerships and partnering with industry. **Craig Blue** noted he is the former director of MDF. They polled industry and asked what they needed to be successful. They needed infrastructure in close proximity to where they actually manufacture. The best form of tech-transfer is people. Informed by the three top DOE energy priorities: automotive, wind, and compressed gas storage, they went to car manufacturers. They went to

universities. They worked side-by-side with UT and ORNL, and partnered with university, industry, local community colleges and national labs. Then, they started looking further. In order to be competitive, they need an integrated supply chain.

Question 5: Nick, share your experience where you are standing up an institute in an academic environment. **Nick Justice** said that one of the things that was a surprise to him was that the business cycle is so critical as a partnership driver. Oftentimes the government doesn't understand this. Learning the business development cycle was a tremendous asset to him. When the DOE secretary announced the quadrennial energy review, it provided strategic focus to start setting long-term goals. It focused the work. Demystifying and making work accessible is important.

Question 6: Fred, how has ICAR changed Clemson? **Fred Cartwright** said that a lot of university leadership is interested in having a relationship with industry. It has become part of the DNA. Clemson students know they can build professional relationships that will allow them to stay local if they want. They know there are 20 local companies funding over 80% of the university's research.

Question 7: Jay, your company is trying to innovate faster than anyone else by working with a national lab and university. How has that interaction pushed your company forward? **Jay Rogers** said that he and Nick started in the military. The innovation for hardware there is very different from what was seen for 20 years in Silicon Valley. When they considered PPPs, they knew that there were heavy lifts to be done. There is an antiquated image that low technology readiness level items are handled at national labs, and that companies drive market transformation. In the southeast, there is a strong group of people each doing their own things, but all of the work represented on this panel is related. **Nick Justice** noted that PPPs are messy. Oftentimes, people may have started in the lab but then moved into industry. There are different sectors and priorities.

Question 8: Is there an equation for PPPs? What are the key elements that make them work? **Nick Justice** said that it starts with an idea. Then, people have to be able to take the risk. Not everything will be successful. **Craig Blue** agreed. Local Motors agreed to have a printed car in less than a year, and the printer didn't even exist. So, ORNL, Cincinnati Inc. and others developed the printer, the control system, and the materials in support of the Local Motors concept. There were challenges, but the people at the MDF could access tools at ORNL to address them.

Question 9: Johney, do these projects actually change the lab themselves? **Johney Green** answered that the house project was a forcing function: it was a step beyond what they did with the car. These projects have all changed the lab; they opened new innovation and partner models. Traditional work is inside the box. Open Innovation 1.0 is outside the box. Open Innovation 2.0 has no box. That changes the way ORNL works. Getting 20 partners to do something within 9 months is unheard of. It rapidly changed how the lab worked internally as well as with industry. **Nick Justice** noted that sometimes a thing can work in a lab, but there's no connection to marketing it. Innovation centers have to include the public and business sectors. **Mark Johnson** said that applied problems challenge known science.

Question 10: What are the next things to think about? **Fred Cartwright** said that we need to realize a focus on manufacturing in the southeast. Most companies are owned by foreign entities. A challenge to focus on is to make sure there are strong relationships developed with decision makers. Trying to pull

this consortium or pull this region together is incredibly important, but difficult. **Mark Johnson** noted that regional ecosystems can add strength. **Mark Johnson** noted that Chinese companies are moving here because they can be more innovative in the U.S. **Fred Cartwright** said there's more foreign direct investment per capita in SC than any other state, but also more foreign direct investment in total than any other state. **Mark Johnson** asked how to expand that to the entire southeast.

Question 11: Jay, you are talking to people around the world about your model now. What have you learned that is worth doing again? **Jay Rogers** said it's not a win in one place and a lose in another. He notes that for knowledge transfer, a researcher can't always come to industry. Sometimes industry has to go to the researcher. He notes that there's a lot of innovation at UT and ORNL, and that there will be an evolution in how it is tapped over time. **Mark Johnson** said that this is a global race, and that there is a cauldron of ideas in the U.S. and a desire to experiment. **Craig Blue's** perspective was that the proper ecosystem and infrastructure determines the speed of innovation. They have set records working with Local Motors. It's important to create an environment where it's easy to work together. **Nick Justice** noted three generations of infrastructure: the bleeding edge, the systems in use, and the legacy systems that aren't yet abandoned. He wants to think about how to improve or remove legacy systems, noting that the ecosystem is a life cycle over time. **Mark Johnson** said that many recent projects at the national labs have to do with legacy industries, such as the pulp/paper and the steel industries. **Johney Green** said that one of the things needed to drive messy, complex innovation environments is not just the win-win, but the win-more. The power of collaboration and shared vision breaks down barriers.

Jay Rogers offered a closing comment: there is a crisis of capital in this country. The government has been a source of last resort capital. Private capital hasn't really stepped in. Some private individuals have, but investment funds need a different structure. There's a respect for long-term capital in other countries, but here in the U.S., investors want to see profit in 3-5 years. Until acknowledging that sometimes innovation takes longer, the discussion can't become robust and empowering. Venture funds need to be able to accept a longer return for something that will be highly competitive and have a large margin. Until then, a critical ingredient is missed.

CONCLUDING OBSERVATIONS

Dr. Taylor Eighmy, Vice Chancellor for Research and Engagement at UT Knoxville provided summary remarks. He thanked the attendees for making time to come to Chattanooga on such short notice. He extended his appreciation to all the panelists for their excellent contributions to the discussion. He thanked staff at the university and at ORNL for organizing the meeting and making it a success. He also thanked Kimberly Rasar, Associate Deputy Under Secretary for Science and Technology, for the critical role that she and her staff and the Secretary's office provided around meeting planning.

Before beginning his remarks, Dr. Eighmy noted that the podium on the dais was printed on the Cincinnati Inc.'s Big Area Additive Manufacturing Machine (BAAM) at ORNL's Manufacturing Demonstration Facility (MDF). The podium was to be used when President Obama announced the award of the Composites Institute—a manufacturing innovation institute member of the National Network for Manufacturing Innovation— to UT Knoxville in January 2015. The podium was made using a carbon fiber composite developed at ORNL with the same BAAM technology that was used to make the Local

Motor's Strati and the ORNL Shelby Cobra. Both vehicles were developed with rapid innovation and this concept—rapid innovation in support of an ecosystem—is proving critical to the East Tennessee advanced manufacturing ecosystem that was attracting companies like Local Motors to the region.

Mark Muro of the Brookings Institution provides context for successful regional ecosystems. He hosted an event in the fall of 2015 at ORNL with regional innovators around how to keep innovation stick within the ecosystem (see this link for the Brookings context). He followed with five specific recommendations about how to enhance stickiness (see this link for more):

1. Local context is critical but first it's essential to maintain, and expand, federal R&D flows.
2. With that said, "making innovation sticky" depends on strengthening local ecosystems.
3. Strengthening local ecosystems won't succeed, though, if the effort doesn't engage industry priorities.
4. Authenticity matters; specificity matters. Multiple participants relatedly stressed that local commercialization around local innovation hubs can only be accelerated by true relevance.
5. Place matters.

Eighmy noted that these five constructs were highly relevant as a model for consideration around a southeast clean energy technology innovation hub. He also noted that the Composites Institute (see this link for more), a $270M, 250 member, DOE NNMI, was an interesting model for the Southeast hub. The Composites Institute is operated by a 501c3 not-for-profit established by the University of Tennessee Research Foundation and it works closely with six states, 180 corporate members (small to very large), and tens of universities to advance the regional composites manufacturing ecosystem in those six states.

Eighmy closed by sharing that a summary report would be prepared and distributed, along with an attendance list. Finally, he offered that a follow-up meeting would be hosted by the University of Tennessee, Knoxville and ORNL to further explore the southeast hub idea.

APPENDIX 1 – Workshop Agenda

Southeast Regional Energy Innovation Workshop
Hosted by the University of Tennessee, Knoxville and Oak Ridge National Laboratory

8:00 a.m. **Arrivals and Registration**

9:00-9:45 a.m. **WELCOME**

Dr. Thom Mason, Director, ORNL, *Convener*
Mayor Andy Berke, City of Chattanooga
Dr. Joe DiPietro, President, University of Tennessee
Dr. Elizabeth Sherwood-Randall, Deputy Secretary, U.S. DOE
Congressman Chuck Fleischmann, 3rd District of Tennessee

9:45-10:45 a.m. **ENERGY INNOVATION INDUSTRY ROUNDTABLE**

Joe Hezir, Chief Financial Officer, U.S. DOE, *Moderator*
Dr. Mo Khaleel, Director of Planning, ORNL, *Rapporteur*

- **Peter Hoffman**, Vice President, Intellectual Property Management, Boeing Co.
- **Dan Stout**, Senior Manager, Small Modular Reactors, TVA
- **Jason Swager**, Manager R&D Electrical, VW Americas
- **Nick Irvin**, Program Manager, Advanced Energy Systems, Southern Company

10:45-11:45 a.m. ENERGY INNOVATION UNIVERSITY ROUNDTABLE

Dr. Stacey Patterson, Associate Vice President for Research, University of Tennessee, *Moderator*
Susanna Sutherland, PhD Candidate, The Bredesen Center, University of Tennessee, Knoxville *Rapporteur*

- **Dr. Jimmy Cheek**, Chancellor, University of Tennessee, Knoxville
- **Dr. Joanne Romagni**, Vice Chancellor for Research and Dean of the Graduate School, University of Tennessee, Chattanooga
- **Dr. Timothy Lieuwen**, Executive Director, Strategic Energy Insitite, Georgia Institute of Technology
- **Dr. Tanju Karanfil**, Vice President for Research, Clemson University
- **Dr. Ray Vaughn**, Vice President for Research and Economic Development, University of Alabama, Huntsville
- **Dr. David Kosson**, Cornelius Vanderbilt Professor of Engineering, Department of Civil and Environmental Engineering, Director of CRESP, Vanderbilt University

11:45-12:30 p.m. LUNCH

12:30-12:45 p.m. BREAK

12:45-1:30 p.m. **PANEL 1: ENTREPRENEURSHIP & GRADUATE EDUCATION TO DRIVE INNOVATION**

Dr. Lee Riedinger, Director, The Bredesen Center, University of Tennessee, Knoxville, *Moderator*
Victoria DiStefano, PhD Candidate, The Bredesen Center, University of Tennessee, Knoxville, *Rapporteur*

- **Dr. Franklin (Lynn) Orr**, Undersecretary for Science & Energy, U.S. DOE
- **Mallory Ladd**, PhD candidate, The Bredesen Center, University of Tennessee, Knoxville

- **Jeff Beegle**, PhD Candidate, The Bredesen Center, University of Tennessee, Knoxville
- **David Colloa**, PhD Candidate, University of Tennessee, Chattanooga
- **Anne Mallow**, PhD Candidate, Georgia Institute of Technology
- **Annette Bodenheimer**, PhD Candidate, North Carolina State University

1:30-2:30 p.m. **PANEL 2: CLEAN ENERGY INNOVATIONS**

Cortney Piper, Tennessee Advanced Energy Business Council, *Moderator*
Guin Shaw, PhD Candidate, The Bredesen Center, University of Tennessee, Knoxville, *Rapporteur*

- **Dr. Tom King**, Director, Energy Efficiency and Electricity Programs, ORNL
- **R. Platt Boyd IV**, Founder and CEO, Branch Technologies
- **David Wade**, Executive Vice-President and Chief Operating Officer

2:30-3:30 p.m. **PANEL 3: LEVERAGING DOE CAPABILITIES TO DELIVER INNOVATION**

Dr. Jim Roberto, Associate Lab Director, Science and Technology Partnerships, ORNL, *Moderator*
Suzy Tichenor, Director, Industrial Partnerships Program, Computing & Computational Sciences, ORNL, *Rapporteur*

- **Dr. Jeff Nichols**, Associate Laboratory Director, Computing and Computational Sciences, ORNL
- **Dr. Michelle Buchanan**, Associate Laboratory Director, Physical Sciences, ORNL
- **Dr. Bill Peter**, Director, Manufacturing Demonstration Facility, ORNL
- **Dr. Roderick Jackson**, Group Leader, Building Envelope Systems, ORNL

3:30-3:45 p.m. **BREAK**

3:45-4:45 p.m. **PANEL 4: TECH TO MARKET INNOVATIONS**

Dr. Mark Johnson, Director, Advanced Manufacturing Office, U.S. DOE, *Moderator*
Emily Clark, PhD Candidate, The Bredesen Center, University of Tennessee, Knoxville, *Rapporteur*

- **Major General Nick Justice**, Executive Director, NNMI Power America at North Carolina State University
- **Dr. Craig Blue**, Director, NNMI IACMI at University of Tennessee/ ORNL
- **Fred Cartwright**, Executive Director, CU-ICAR
- **Dr. Johney Green**, Director, Energy and Transportation Science, ORNL
- **Jay Rogers,** CEO and Co-Founder, Local Motors

4:45-5:15 p.m. **CLOSING REMARKS**

Dr. Taylor Eighmy, Vice Chancellor for Research & Engagement, University of Tennessee, Knoxville

APPENDIX 2 – Workshop Participants

First Name	Last Name	Title	Organization
Christine	Ajinjeru	Bredesen Center Fellow	Bredesen Center for Interdisciplinary Research and Graduate Education, University of Tennessee
Ian	Anderson	Director, Graduate Education and University Partnerships	ORNL
Jon	Barnwell	Vice President	One Scientific Inc.
Jeff	Beegle	PhD Candidate	Bredesen Center for Interdisciplinary Research and Graduate Education, University of Tennessee
Jordan	Bermudez	Intern	The Enterprise Center
Jamie	Blessinger	Development Assistant, Office of Corporate & Foundation Engagement	UT Foundation
Craig	Blue	CEO	IACMI-The Composites Institute
Annette	Bodenheimer	PhD Candidate	North Carolina State University
Mattie	Bono	Intern	green|spaces
Platt	Boyd	Founder - CEO	Branch Technology
Michelle	Buchanan	Associate Laboratory Director for Physical Sciences	Oak Ridge National Laboratory
Cacky	Calderon	Research & Applications Manager	The Enterprise Center
Maria Fernanda	Campa	PhD Candidate, Energy Science and Engineering, Bredesen Center	Bredesen Center for Interdisciplinary Research and Graduate Education, University of Tennessee
Erin K.	Chapin	Director of Research Communications	University of Tennessee, Knoxville
Mark	Christian	PhD Candidate	Bredesen Center for Interdisciplinary Research and Graduate Education, University of Tennessee
Emily	Clark	PhD Candidate	Bredesen Center for Interdisciplinary Research and Graduate Education, University of Tennessee
M. David	Colloa	PhD Candidate	University of Tennessee, Chattanooga, SimCenter
Ann	Coulter	Principal	A. Coulter Consulting
Sabrina	Cowden	Senior Project Manager	Milepost Consulting
Lindsey	Cox	Innovation & Commercialization Manager	LaunchTN
David	Czufin	Sr. Vice President, Engineering & Operations Support (Nuclear)	Tennessee Valley Authority (TVA)
Claus	Daniel	Acting Director, Sustainable Transportation Program	Oak Ridge National Laboratory
Ryan	Daniels	Graduate Research Fellow	Bredesen Center for Interdisciplinary Research and Graduate Education, University of Tennessee
Victoria	DiStefano	Bredesen Center Fellow	Bredesen Center for Interdisciplinary Research and Graduate Education, University of Tennessee
Laura	Doze	Program Manager - Environmental Management Systems	Tennessee Valley Authority (TVA)
Abhishek	Dubey	Application of cyber physical principles for safe operation of tranasactive energy systems	Vanderbilt University
Taylor	Eighmy	Vice Chancellor for Research & Engagement	University of Tennessee, Knoxville
Ahmed	Eltom	Professor and Department Head-Electrical Engineering	University of Tennessee, Chattanooga
Kassie	Ernst	Graduate Student	Bredesen Center for Interdisciplinary Research and Graduate Education, University of Tennessee
Fleming	Farrow	Intern	The JumpFund
Joe	Ferguson	Chairman	EPB
Raymond	Fornes	NC State Liaison to ORNL and interim Associate Dean for Research for the College of Sciences	North Carolina State University
Sam	Fulbright	Empower Chattanooga Program Coordinator	green|spaces
Arlene A.	Garrison	Vice President, University Partnerships	Oak Ridge Associated Universities
Marc	Gibson	Senior Director of Industry & Economic Relations	University of Tennessee, Knoxville
Rachel	Gideon	Research Intern	The Enterprise Center
Beth	Gladden	Manager of Special Events and University Protocol	University of Tennessee, Knoxville
Johney	Green	Director, Energy and Transportation Science Division	Oak Ridge National Laboratory
Carter	Guensler	Research Intern	Edney Innovation Center
Chris	Harris	Director of Licensing	Vanderbilt University
Ken	Hays	President	The Enterprise Center, Inc
Rick	Hitchcock	Attorney	Chambliss, Bahner & Stophel

First Name	Last Name	Title	Organization
Hoi Chun	Ho	Graduate Student	Bredesen Center for Interdisciplinary Research and Graduate Education, University of Tennessee
Peter	Hoffman	Vice President Intellectual Property Management	The Boeing Company
Patrick	Hughes	Director, Building Technologies Program	Oak Ridge National Laboratory
Alan	Icenhour	Associate Laboratory Director for Nuclear Science & Engineering	Oak Ridge National Laboratory
James	Ingraham	Vice President Strategic Research	EPB
Kevin	Ironside	Reindustrialization Regulatory Manager	UCOR
Roderick	Jackson	Group Leader, Building Envelope Systems Research	Oak Ridge National Laboratory
Gary	Jacobs	Interim Associate Laboratory Director, EESD	Oak Ridge National Laboratory
Nannan	Jiang	Bredesen Center Fellow	Bredesen Center for Interdisciplinary Research and Graduate Education, University of Tennessee
Mark	Johnson	Program Director	U.S. Department of Energy - Office of Legacy Management
Nickolas	Justice	Major General Nickolas Justice (Ret.), Executive Director	PowerAmerica/North Carolina State University
David	Keim	Director of Communications	Oak Ridge National Laboratory
Mohammad	Khaleel	Director, Institutional Planning	Oak Ridge National Laboratory
Thomas	King	Director, Sustainable Electricity Programs	Oak Ridge National Laboratory
Justin	Knowles	Graduate Student	Bredesen Center for Interdisciplinary Research and Graduate Education, University of Tennessee
David	Kosson	Professor, Civil and Environmental Engineering	Vanderbilt University
Mallory	Ladd	National Science Foundation Graduate Research Fellow	Oak Ridge National Laboratory
Alan	Liby	Director, Advanced Manufacturing Program	Oak Ridge National Laboratory
Tim	Lieuwen	Professor and Executive Director	Georgia Institute of Technology
Yilu	Liu	Professor, Governor's Chair for Power Electronics	University of Tennessee, Knoxville
Reinhold	Mann	Interim Director	University of Tennessee, Chattanooga SimCenter
Thom	Mason	Director	Oak Ridge National Laboratory
Roger	McGinnis	Director, Center for Advanced Power Systems	Florida State University
David	Millhorn	Executive Vice President	University of Tennessee
Oliver	Mitchell-Boyask	Student	The Enterprise Center
Kristina	Montague	Managing Partner	The JumpFund
Emily	Morris	CEO	Emrgy, Inc.
Robert	Moseley	Graduate Student	Bredesen Center for Interdisciplinary Research and Graduate Education, University of Tennessee
David	Myers	Program Development	U.S. Department of Energy
Jeffrey	Nichols	Associate Laboratory Director	Oak Ridge National Laboratory
Liz	Norred	Graduate Student	Bredesen Center for Interdisciplinary Research and Graduate Education, University of Tennessee
William	Oates	Associate Professor	Florida State University
Kaitlin	Palla	Graduate Research Assistant	Bredesen Center for Interdisciplinary Research and Graduate Education, University of Tennessee
Blake	Palles	Energy Science and Engineering Fellow	Bredesen Center for Interdisciplinary Research and Graduate Education, University of Tennessee
Robin	Pate	Director of Communications & Workforce Development	IACMI-The Composites Institute
Stacey	Patterson	Associate Vice President	University of Tennessee
Alex	Pawlowski	AM in Transportation	Bredesen Center for Interdisciplinary Research and Graduate Education, University of Tennessee
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Tom	Rogers	Director, Industrial and Economic Development Partnerships	Oak Ridge National Laboratory
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