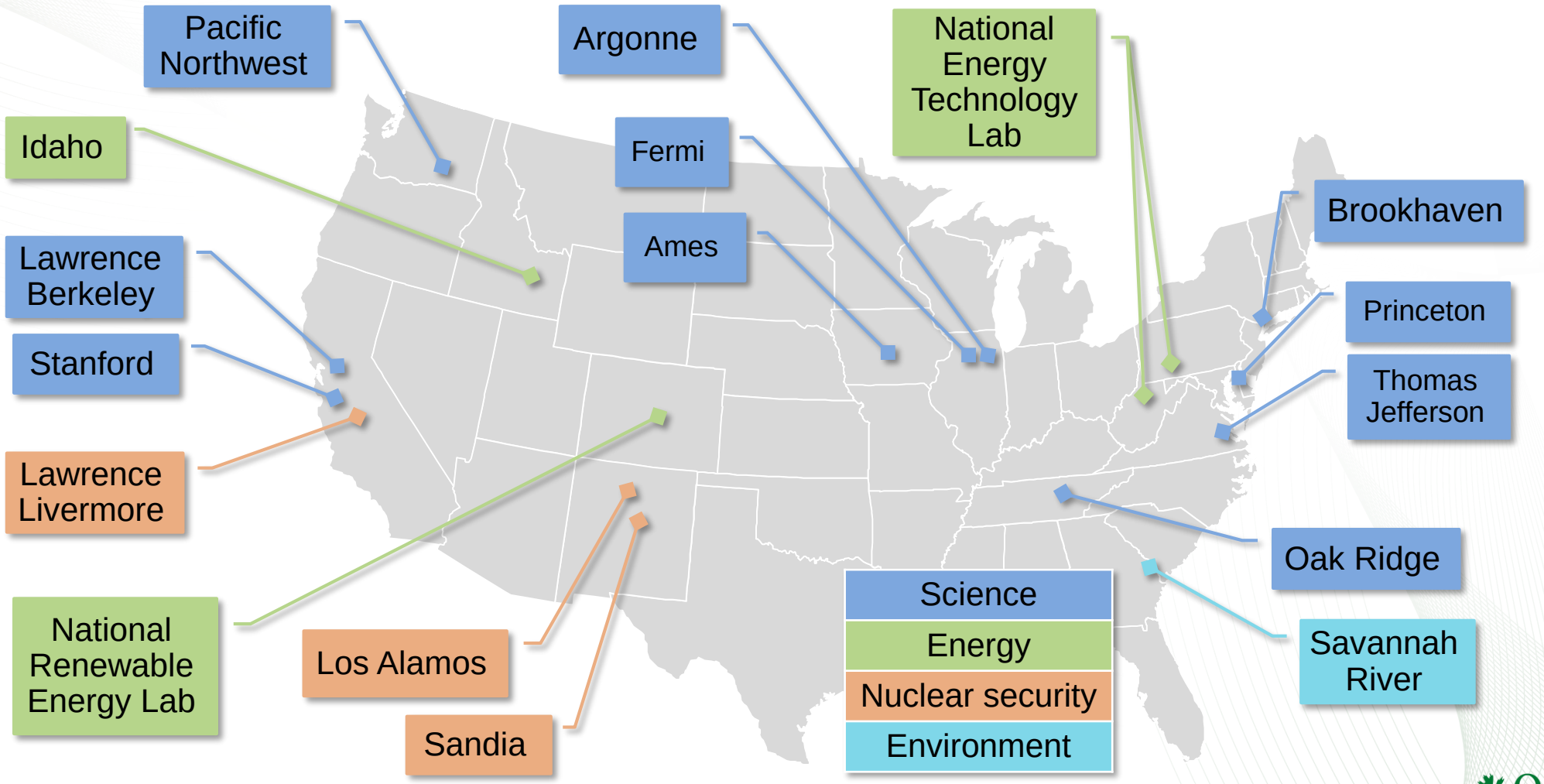
The national laboratories of the U.S. Department of Energy constitute a network for discovery and innovation



OAK RIDGE National Laboratory

Distinguishing characteristics of DOE national laboratories

Mission driven

Sustained support for DOE missions

Science at scale

Large-scale, long-term programs

Multidisciplinary teams

Delivering the talent needed to address the nation's energy, environmental, and nuclear challenges through transformative science and technology

Stewardship of distinctive, powerful research facilities

Designed to meet DOE mission needs

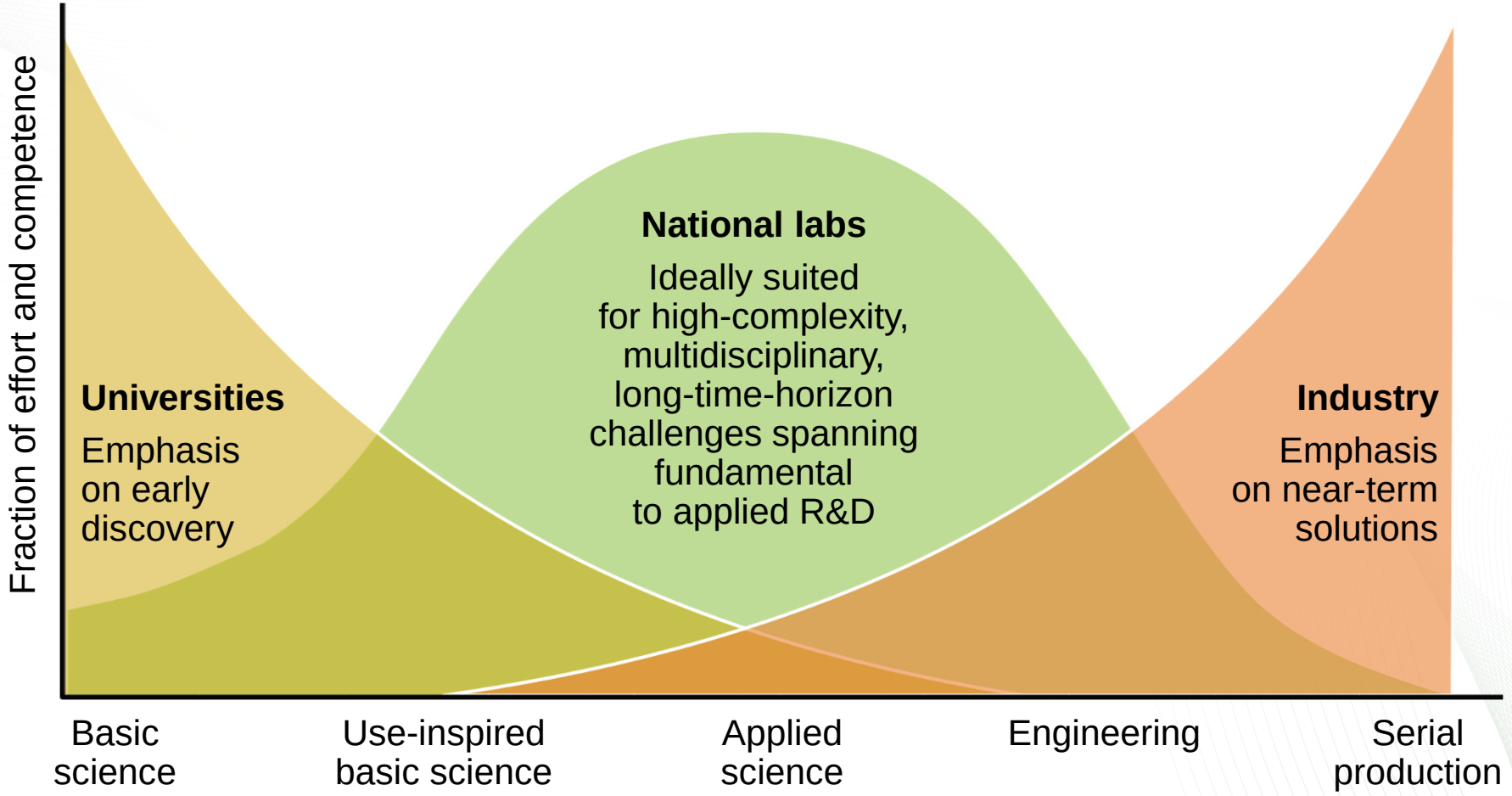
Developed in partnership with the scientific community

Available to users from academia, industry, and other government agencies

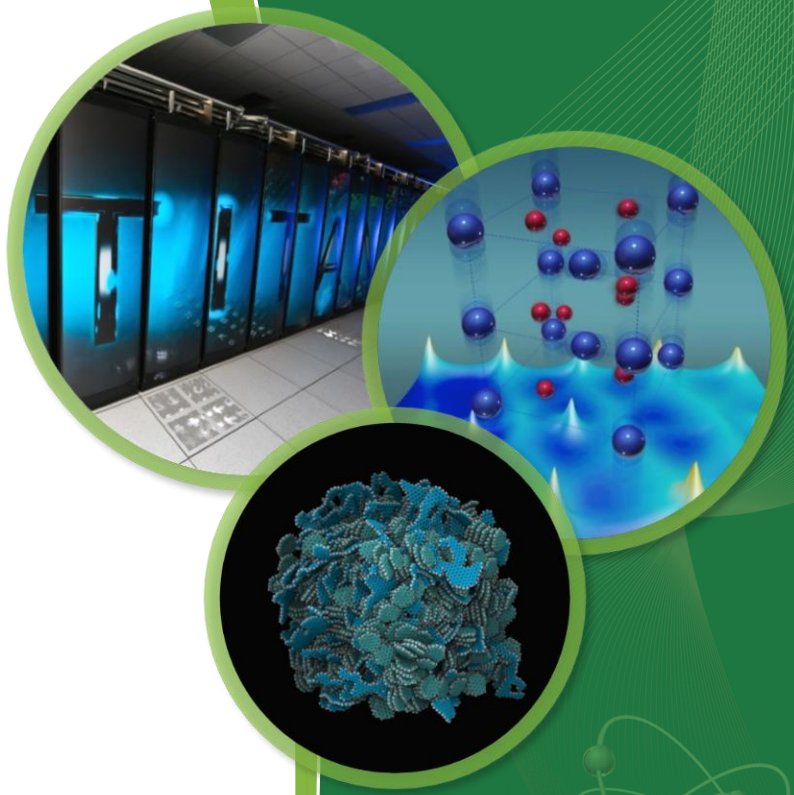
Safe and secure operating environments

Providing for hazardous, sensitive, or classified research essential to national interests

National laboratories occupy a distinctive space in the innovation ecosystem



Oak Ridge National Laboratory



Edgar Lara-Curzio

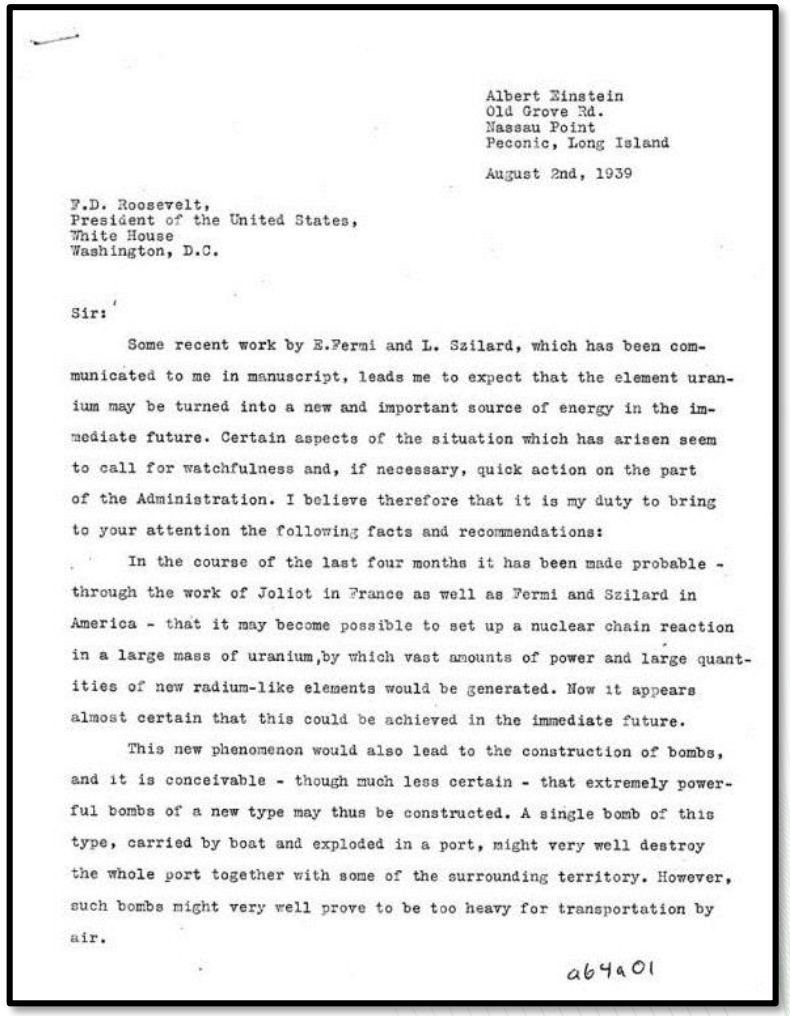
2018 Annual Conference Development District Association of Appalachia

Crystal City, VA
March 19, 2018

OAK RIDGE National Laboratory

The Beginning: Einstein's Letter

August 1939



Albert Einstein
Old Grove Rd.
Nassau Point
Peconic, Long Island

August 2nd, 1939

F.D. Roosevelt,
President of the United States,
White House
Washington, D.C.

Sir:

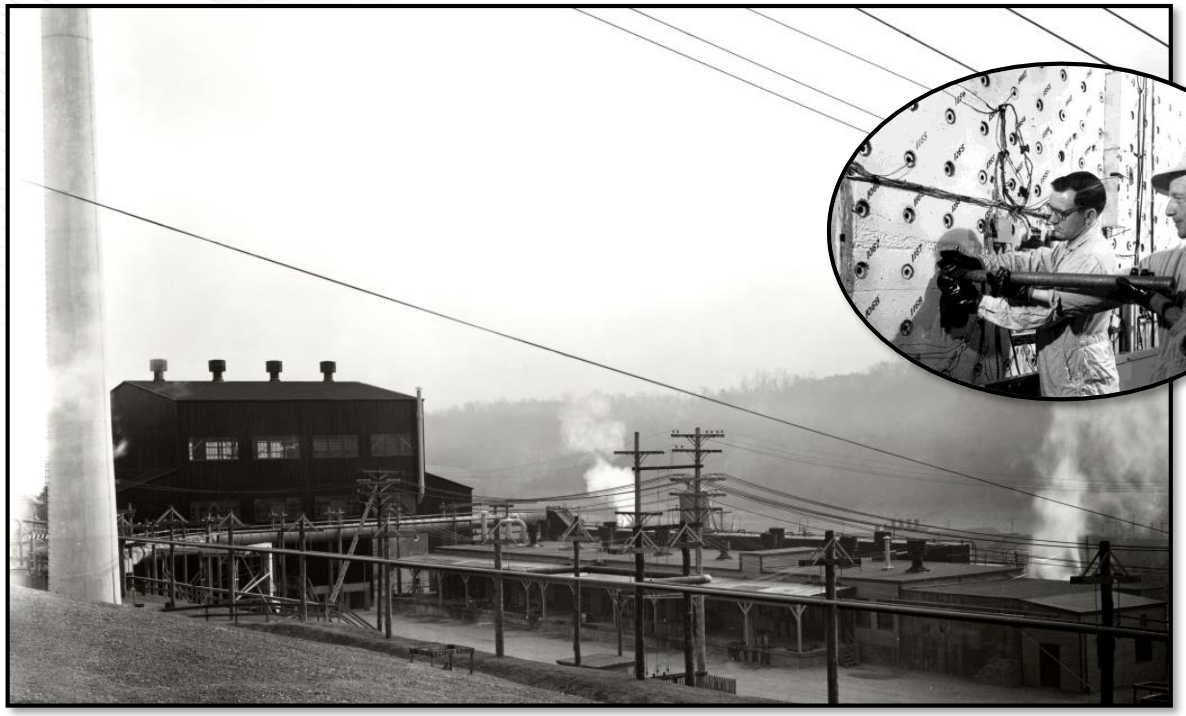
Some recent work by E.Fermi and L. Szilard, which has been communicated to me in manuscript, leads me to expect that the element uranium may be turned into a new and important source of energy in the immediate future. Certain aspects of the situation which has arisen seem to call for watchfulness and, if necessary, quick action on the part of the Administration. I believe therefore that it is my duty to bring to your attention the following facts and recommendations:

In the course of the last four months it has been made probable - through the work of Joliot in France as well as Fermi and Szilard in America - that it may become possible to set up a nuclear chain reaction in a large mass of uranium,by which vast amounts of power and large quantities of new radium-like elements would be generated. Now it appears almost certain that this could be achieved in the immediate future.

This new phenomenon would also lead to the construction of bombs, and it is conceivable - though much less certain - that extremely powerful bombs of a new type may thus be constructed. A single bomb of this type, carried by boat and exploded in a port, might very well destroy the whole port together with some of the surrounding territory. However, such bombs might very well prove to be too heavy for transportation by air.

a64a01

Oak Ridge National Laboratory evolved from the Manhattan Project



The Clinton Pile was the world's first continuously operated nuclear reactor

Chemical processing techniques were developed to separate plutonium from irradiated fuel

ORNL has a distinguished history of making groundbreaking discoveries and meeting national needs

Science and engineering of the nuclear fuel cycle

Reactor technology

Materials and fuels

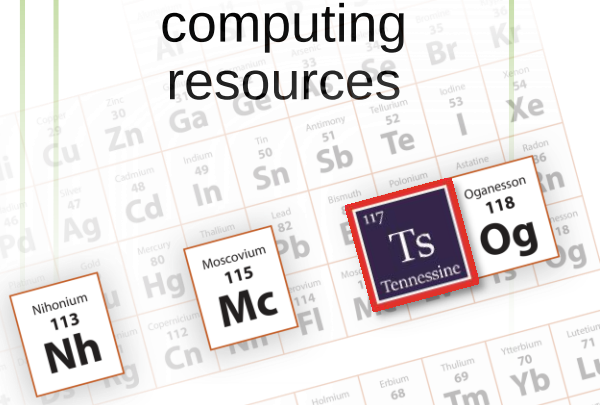
Separations chemistry

Development, production, and distribution of radioisotopes

Development of neutron scattering, neutron activation analysis, and other innovative research tools

Related basic and applied research in the physical and life sciences

Development and application of high-performance computing resources



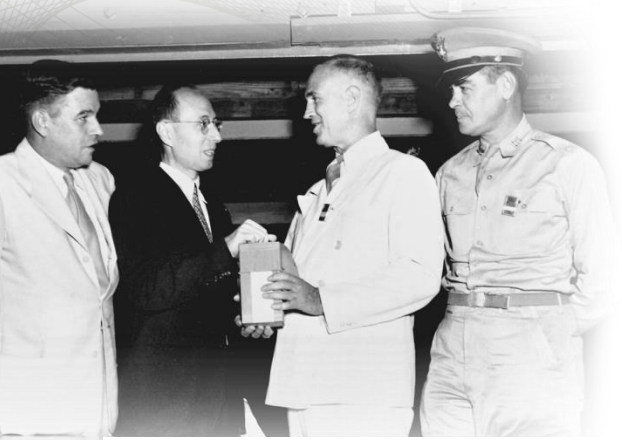
ORNL’s mission

Deliver scientific discoveries and technical breakthroughs that will accelerate the development and deployment of solutions in clean energy and global security, and in doing so create economic opportunity for the nation

Signature strengths

- Computational science and engineering
- Materials science and engineering
- Neutron science and technology
- Nuclear science and technology

ORNL innovations have billion-dollar impacts



- Big-area additive manufacturing: US investment — >$1B
- Fueleconomy.gov: $1B in cost savings — $1B
- Ceramic matrix composites for gas turbines — $150B
- Lab-on-a-chip: Caliper acquired by PerkinElmer — $0.6B
- Cesium extraction: Basis for waste processing plant — $1.3B
- Reactor life extension: $20B cost avoidance — $20B
- Advanced alloys: Chrome-moly steel in widespread use
- Ion implantation: Integrated circuits and medical implants

Coal as a precursor for value-added products

- Centrifuge technology: Basis for vaccine purification and US enrichment industry
- Instrumentation: Products and spinoffs from ORTEC and TENNELEC — >$1B
- Reactor technology: Concept technology for light water, high temperature, and molten salt reactors
- PUREX: Basis for nuclear fuel reprocessing techniques used worldwide
- Radioisotopes: Multibillion dollar industry (>100 million procedures per year) — >$5B/ year

1940s **Today**

Partnerships are vital to accelerating technology transition and engaging with industry and universities

Technology transfer

- Cooperative R&D Agreements (CRADAs)
- Strategic Partnership Projects
- Technology licensing

Industry and economic development partnerships

- Regional industry recruiting and cluster development
- State and local economic development partnerships
- Institute for Advanced Composite Materials Innovation (IACMI)

Graduate/postgraduate education and university partnerships

- Graduate education
  - UT-ORNL Bredesen Center: Entrepreneurial and policy options
  - Graduate Opportunities (GO!) program
  - DOE Office of Science Graduate Student Research program
- ~280 joint faculty appointments

ARC/ORNL summer STEM programs

Hands-on learning at ORNL

Programs

High school math-science-technology institute: 2 week program for students and teachers

Middle school science academy: 1 week program for students

Goals

Encourage students to continue their education and pursue STEM careers

Raise quality of STEM instruction in Appalachian high schools

Activities

Work directly with ORNL scientists and engineers

Learn about real-world applications of STEM

Details

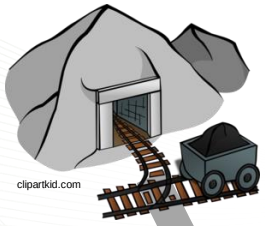
Administered for ARC by ORAU

Applications for 2018 due by March 16

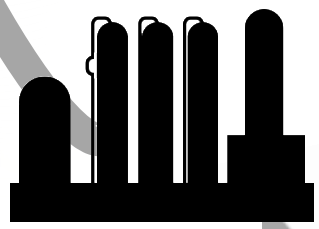
ORNL is working with local community colleges to train the workforce of the future

In collaboration with NETL, ORNL is committed to help establishing an innovation ecosystem in Appalachia

Coal as a Precursor for High Value-Added Products



Coal Mine

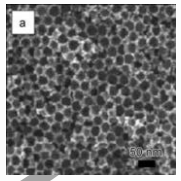


Coal “Refinery”

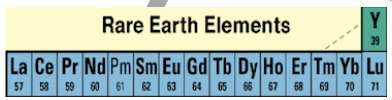
chemicals

water

activated carbon



mesoporous carbon



metallurgical coal

carbon fibers

Lara-Curzio et al. (2016)

Carbon Fiber Composites are widely used in Aerospace Technologies

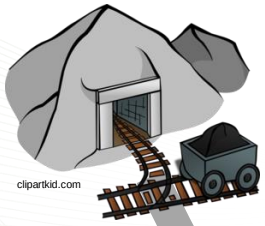
Boeing 787 fuselage

Carbon fiber composites have started to be used in high volume in automobiles: BMW i3: mass-produced carbon fiber cars finally come of age

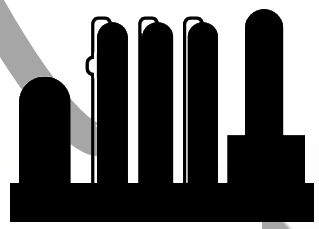
Imagine fiber-reinforced composite panels and components made in Appalachia being shipped to assembly factories across the USA!

Lara-Curzio et al. (2016)

Coal as a Precursor for High Value-Added Products

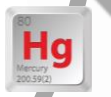


Coal Mine



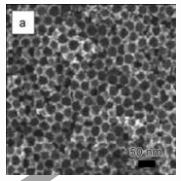
Coal “Refinery”

chemicals

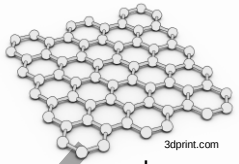


water

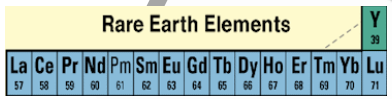
activated carbon



mesoporous carbon

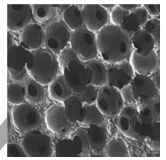


graphene



thermal insulation

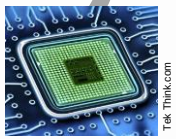
thermal management



thermal conduction

metallurgical coal

carbon fibers

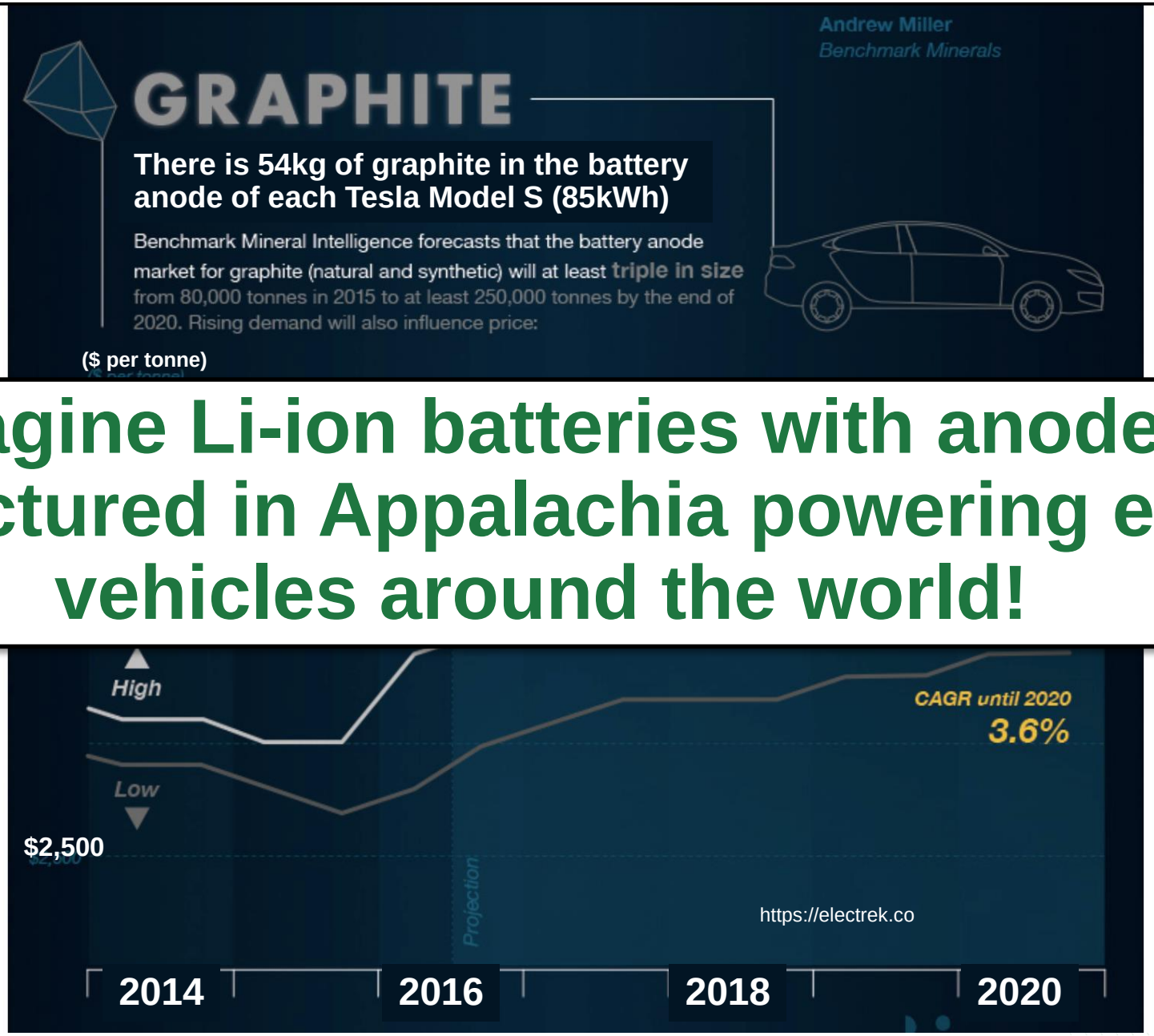


electronic devices including photovoltaics

Electrodes for Li-ion batteries and supercapacitors

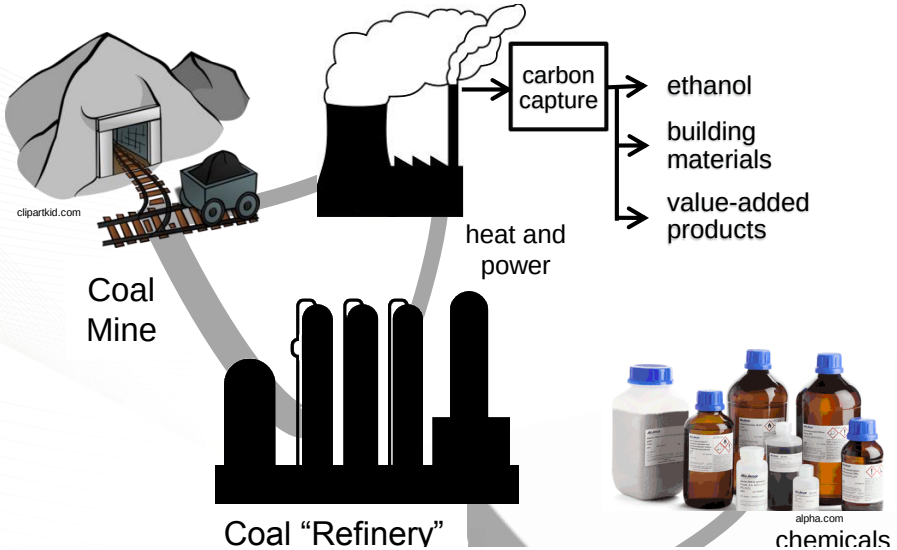
Lara-Curzio et al. (2016)

Carbon is used for anodes of most Li-ion batteries



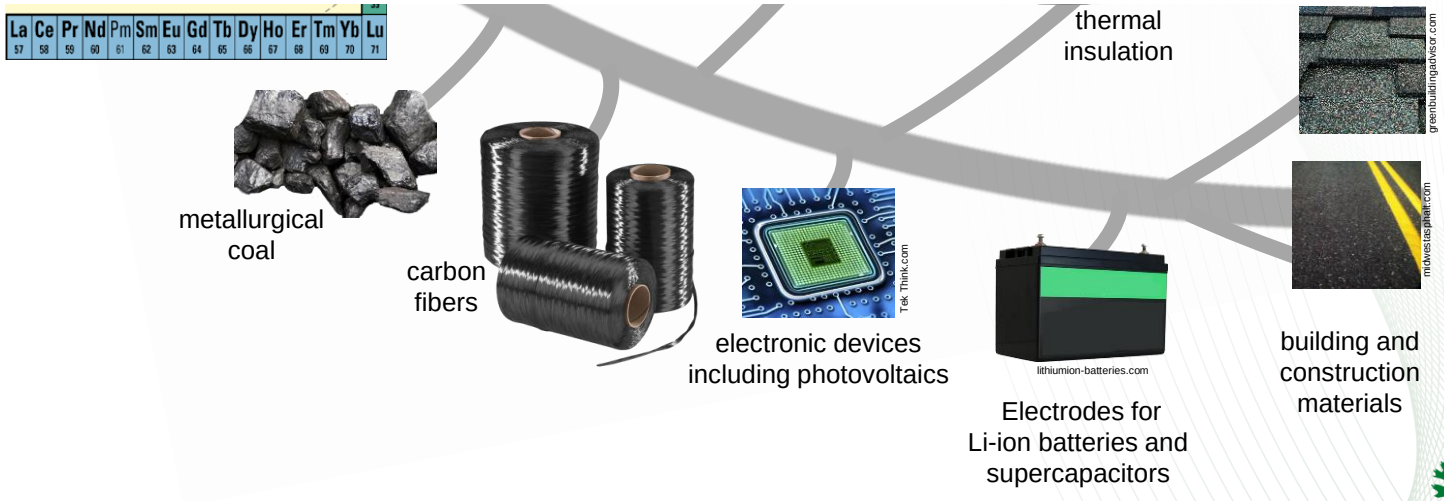
Imagine Li-ion batteries with anodes manufactured in Appalachia powering electric vehicles around the world!

Coal as a Precursor for High Value-Added Products



Finding use for every molecule that is mined.

No molecule left behind!

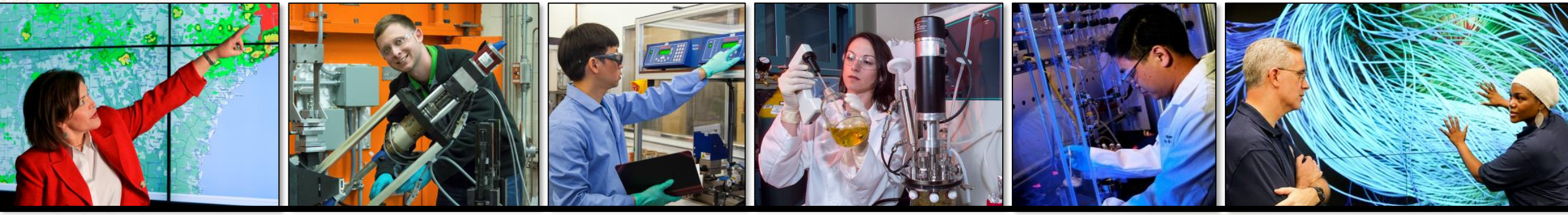


Lara-Curzio et al. (2016)

Discussion

Additional Slides

ORNL's distinctive facilities bring thousands of R&D partners to Tennessee each year

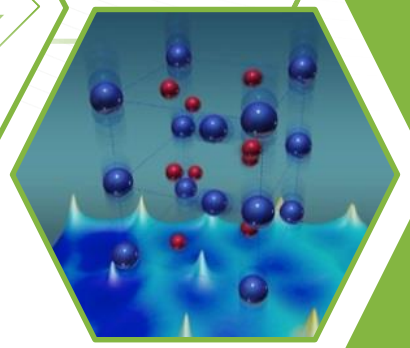


- Building Technologies Research and Integration Center
- Carbon Fiber Technology Facility
- Center for Nanophase Materials Sciences
- High Flux Isotope Reactor
- Manufacturing Demonstration Facility
- National Transportation Research Center
- Oak Ridge Leadership Computing Facility
- Spallation Neutron Source

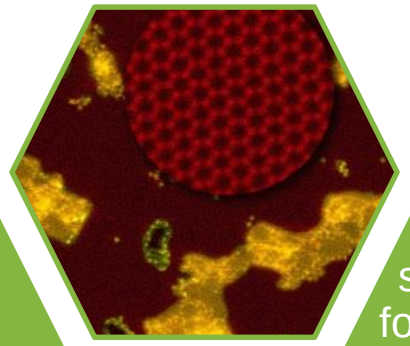
OAK RIDGE National Laboratory

ORNL priorities in science and technology

Advance ORNL's science and Innovation culture



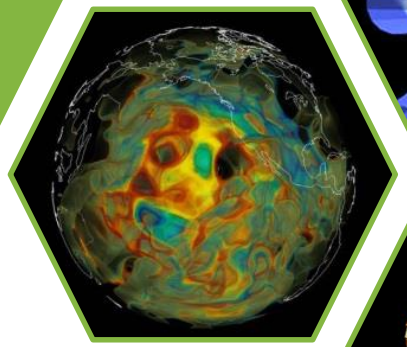
Accelerate the discovery and design of new materials for energy



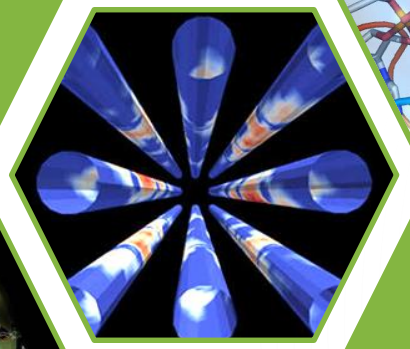
Advance the science and impact of neutrons

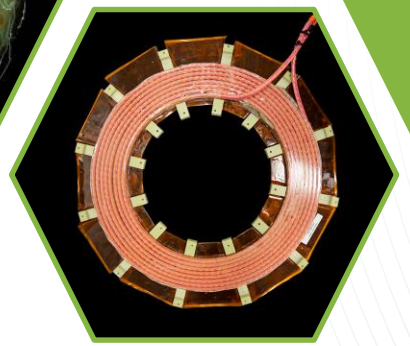
Scale computing and data analytics to exascale and beyond for science and energy

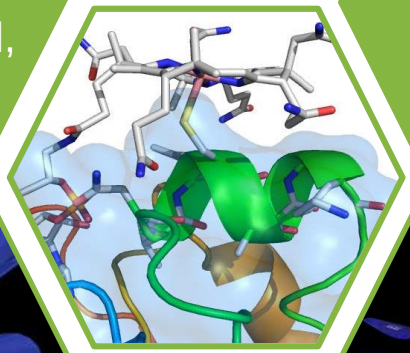
Advance the scientific basis for breakthrough nuclear technologies and systems



Advance understanding of complexity in biological, environmental, and earth systems







Discover and develop sustainable and secure integrated energy systems

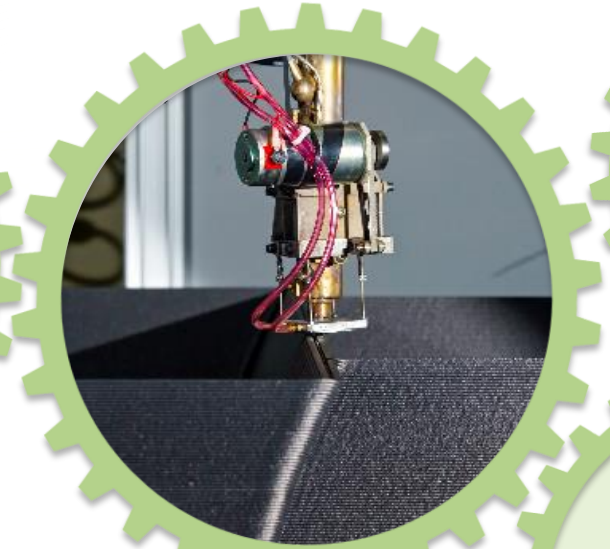
Deliver science and technology to address security challenges

Accelerate deployment of DOE IP and engagement with industry and universities

Today, ORNL is one of the world's leading science and energy laboratories

OAK RIDGE National Laboratory

We are committed to strengthening the regional innovation ecosystem



Local Motors

Contributing to state and local economic development initiatives

Deploying an industry cluster strategy to build regional competitive advantage

- Carbon fiber
- Automotive
- Additive manufacturing

Making our resources available to industry partners

- Technology licenses
- Small business vouchers
- Strategic Partnership Projects
- Cooperative R&D agreements

ORNL is managed for DOE by UT-Battelle, LLC

An ORNL partner since 1946

State-funded Science Alliance started in 1982, to build programs with ORNL

Shared research and joint appointments

Joint institutes: Advanced materials, biological sciences, computational sciences, neutron sciences, nuclear physics

A 75-year relationship with DOE

Develops and deploys technology worldwide

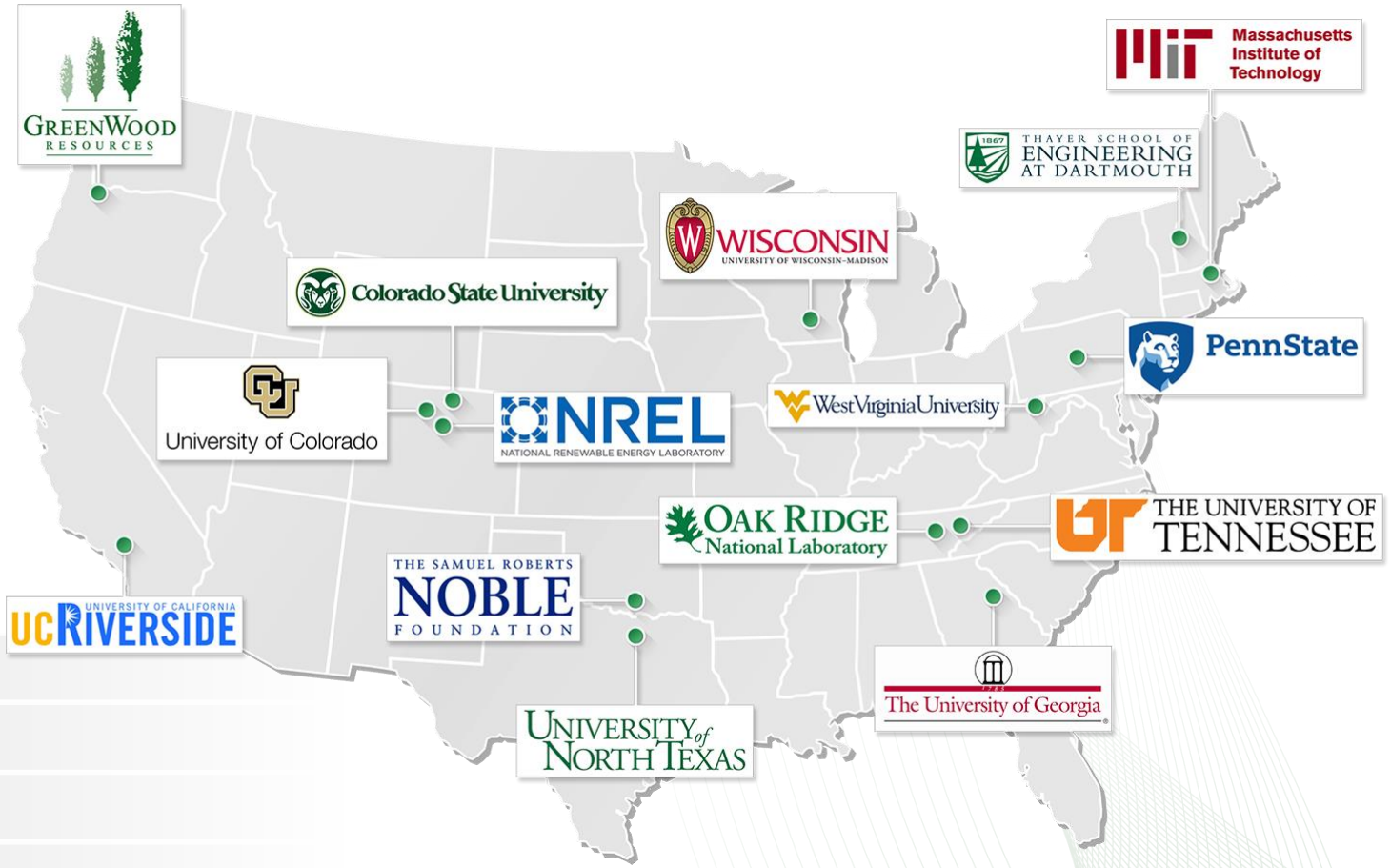
Manages or co-manages 6 national labs: ORNL (with UT), Brookhaven (with SUNY-Stony Brook), Idaho, Lawrence Livermore (with UC and Bechtel), NREL (with MRI), Pacific Northwest

Duke University · Florida State University · Georgia Tech · NC State University · ORAU · Vanderbilt · University of Virginia · Virginia Tech

OAK RIDGE National Laboratory

Leading the Center for Bioenergy Innovation (CBI)

- 1 of 4 DOE-sponsored Bioenergy Research Centers
- Vision: Accelerate domestication of bioenergy-relevant non-model plants and microbes to enable high-impact innovation across the bioenergy supply chain



CBI research partners:

2 national laboratories
11 academic institutions
1 research foundation
1 private company

CBI science focus areas

Sustainability

- Mechanistic understanding of crop interactions with biotic and abiotic environments
- Technoeconomic evaluation of biomass to fuels and products

Deconstruction and Separation

- Feedstock-agnostic deconstruction
- Detailed understanding of plant cell walls during deconstruction
- Improved enzymes and approaches for biomass processing
- Multiscale modeling of plant cell walls

Feedstock Development

- Enhanced feedstocks with improved yield, water use, and nutrient use
- Genetic tools and biosystems design approaches
- High-throughput analytical tools
- Field testing of new bioenergy feedstocks
- Quantitative models to predict feedstock performance

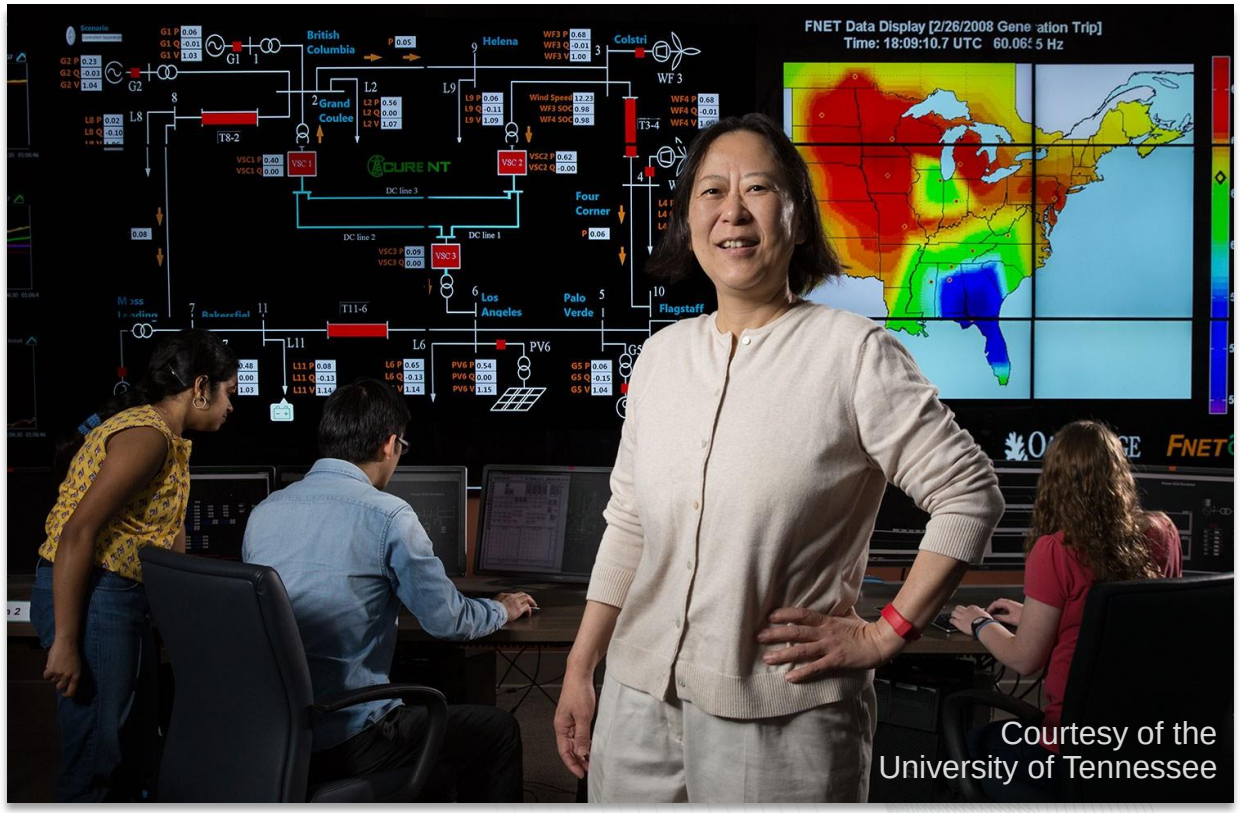
Conversion to Specialty Biofuels and Products

- High-throughput screens of strains and constructs
- Development of a broader set of platform microbes
- Enhanced microbial tolerance to toxins
- Technologies for CBP
- Improved feedstocks for fuels/products

cbi THE CENTER FOR BIOENERGY INNOVATION

Enhancing the reliability and resilience of the electric grid

- Playing a major role in DOE's Grid Modernization Laboratory Consortium
- Supporting CURENT, the Center for Ultra-Wide-Area-Resilient Electric Energy Transmission Networks, at UT Knoxville
- Working with Chattanooga EPB to develop 21st century electric grid
  - Cyber and physical security
  - Advanced materials
  - Low-cost sensors



Courtesy of the University of Tennessee

OAK RIDGE National Laboratory

2017 R&D 100 Awards: 9 ORNL innovations were recognized

ORNL submittals

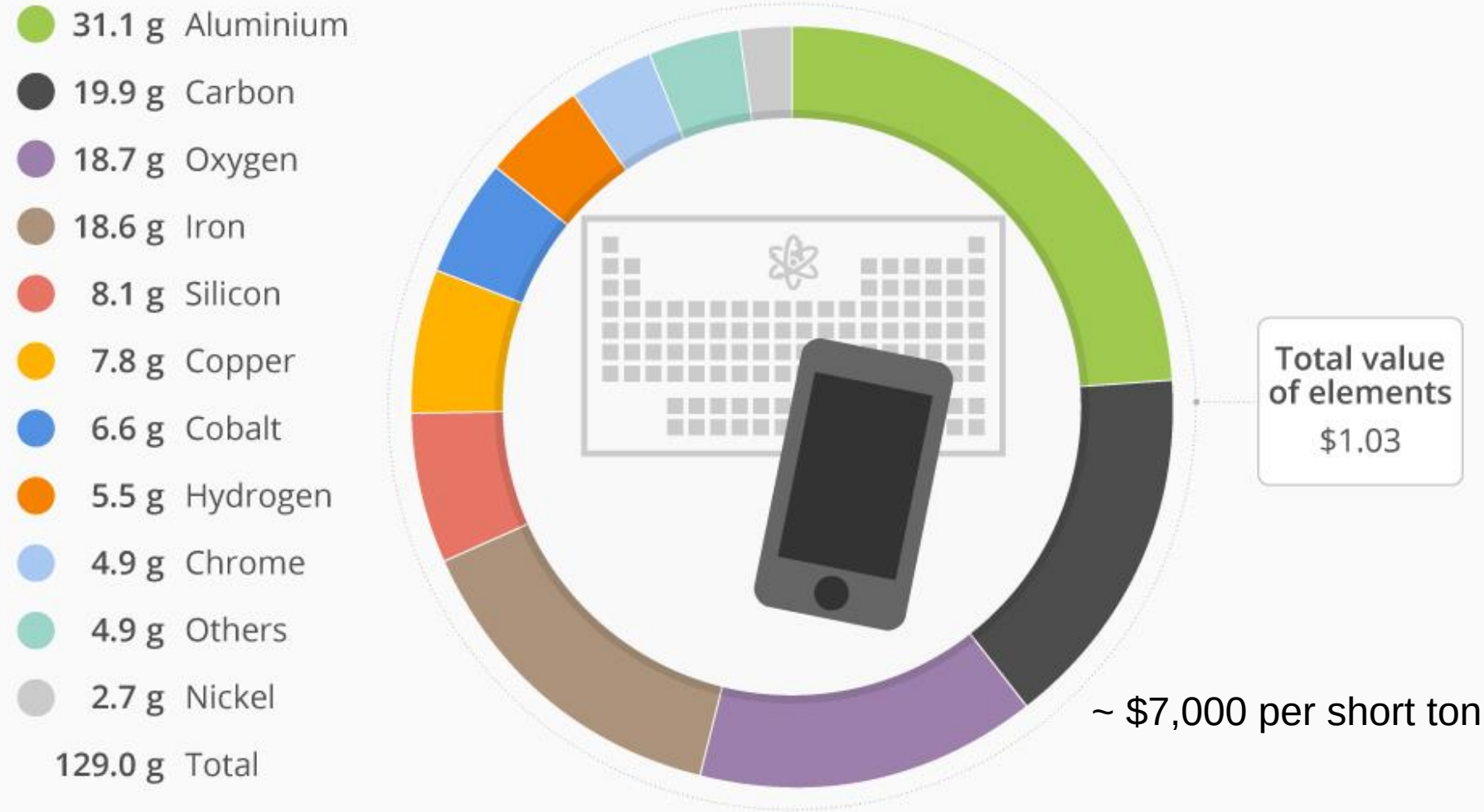
- ACMZ Cast Aluminum Alloys, with Fiat Chrysler Automobile US and Nemak USA
- Additively Printed High Performance Magnets, with DOE Critical Materials Institute, Ames Lab, Magnet Applications Incorporated, Tru-Design, and Momentum Technologies
- Filler Materials for Welding and 3D Printing, with the US Army Tank Automotive Research, Development and Engine Command
- Safe Impact Resistant Electrolyte (SAFIRE), with the University of Rochester
- dropletProbe Surface Sampling System for Mass Spectrometry, with SepQuant

ORNL partner submittals

- DOE Critical Materials Institute, ACE: The Ageless Aluminum Revolution (co-developers: Eck Industries, Ames Lab, LLNL)
- LANL, dfnWorks: A Computational Suite for Flow and Transport in Subsurface Fracture Networks
- Tru-Design, Coating Solutions for Large-Format Additive Manufacturing (co-developer: Polynt Composites)
- Techmer PM, Techmer Engineered Additive Manufacturing Materials (co-developer: BASF)

129 Grams: The Materials That Make Up The iPhone

Materials used in iPhone 6, 16GB model



~ $7,000 per short ton

statista

OAK RIDGE National Laboratory