From NETL's Office of Research & Development

Research news

October 2015, Issue 13

FEATURE STORY:

Centrifugal Force Improves Chemical Looping Reactor Performance

page 2

the ENERGY lab
NATIONAL ENERGY TECHNOLOGY LABORATORY

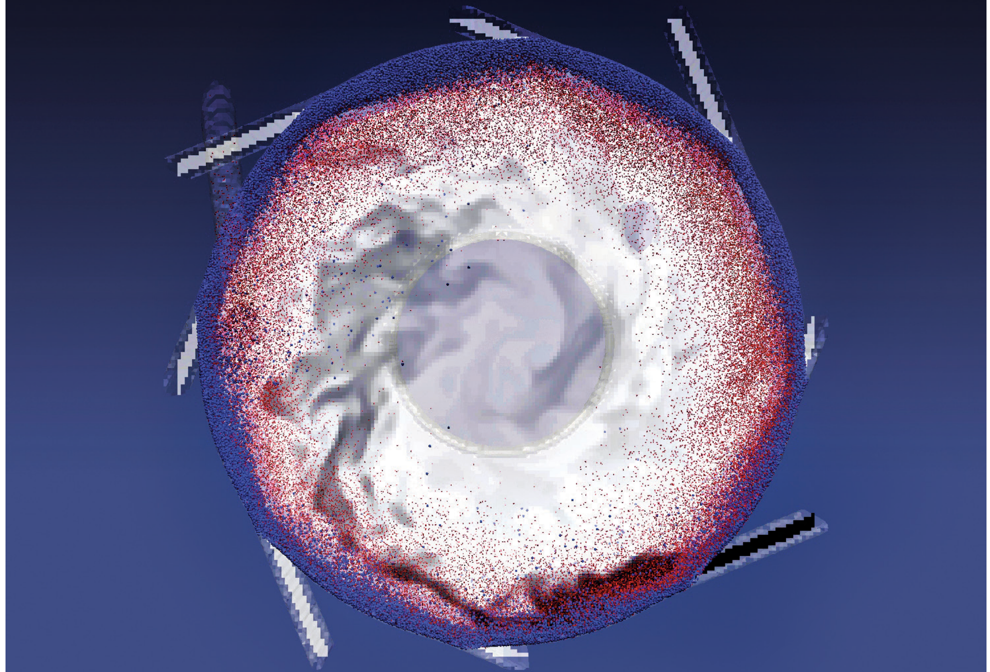
U.S. DEPARTMENT OF ENERGY

Research news
October 2015, Issue 13

Contents

Research News is a monthly publication from the National Energy Technology Laboratory's Office of Research and Development. We focus on the exciting, cutting-edge research done at NETL by our scientists and collaborators to support the DOE Fossil Energy mission.

CENTRIFUGAL FORCE Improves Chemical Looping Reactor Performance



High-G in-situ separation of the larger oxygen carrier particles (in blue) and the smaller ash particles (in red) can be observed in the vortex chamber reactor simulation.

This summer, NETL researcher **Sofiane Benyahia** teamed up with Mickey Leland intern and MIT student **Jessica Torres** on a research mission to improve the efficiency of NETL's chemical looping combustion (CLC) capabilities. The two worked with **Juray De Wilde**, a Louvain-la-Neuve (Belgium) professor on sabbatical at NETL to develop 3D simulations of a unique chamber for use in the Laboratory's CLC. This collaboration provided intriguing first-of-its-kind views of how centrifugal force can efficiently separate coal ash from the metal (-oxide) oxygen carrier in a CLC reactor—an important contribution

Cover image

Artists rendering of a chemical looping reactor.

toward increasing the efficiency of a technology poised to have a positive impact on fossil fuel power generation in the future (read the January 2015 issue of Research News for more about chemical looping reactors).

De Wilde explained, "Essentially, we have a more efficient reactor with in situ separation of carrier and ash."
The team used the NETL Supercomputer to run code that tracks the motion of each individual particle in the chamber. The simulations were based on a vortex chamber that De Wilde and co-workers built in Belgium to coat and dry fine particles. The chamber being simulated was modified for CLC and contained a bed of carrier and ash particles rotating at high speed. The rotation of the chamber is powered by the air and particle stream rushing in from the adjacent fuel combustion reactor and feeding through eight small tangential slots.

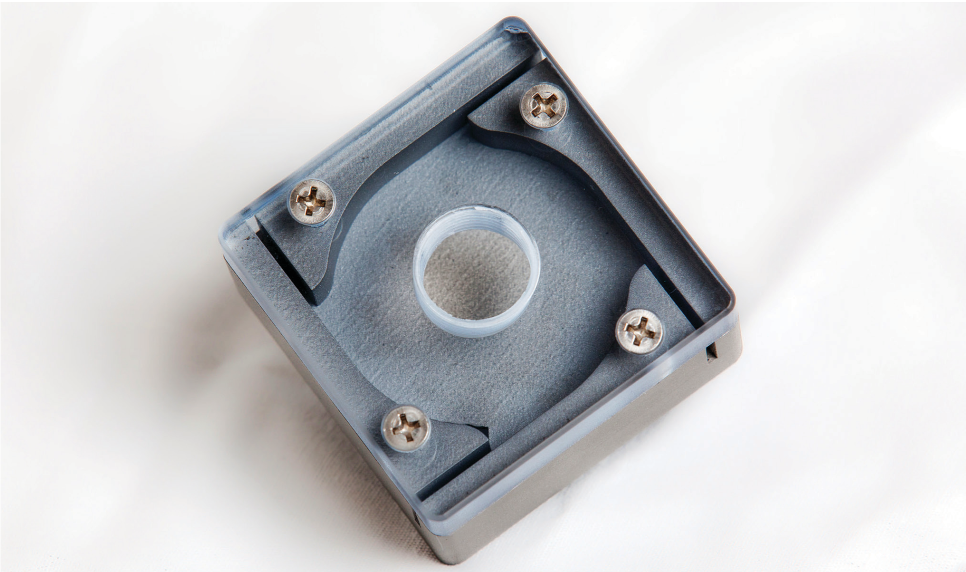
The centrifugal force pushes the ash and carrier particles towards the wall—much like a person is held against the wall of a spinning carnival ride. But the ash and carrier particles will experience much higher centrifugal forces.

"This chamber allows dense and uniform fluidized beds to form at very high gas velocities, improving the efficiency of the reactor. At the same time, it allows efficient separation of the small ash from the larger and heavier carrier particles," Benyahia said. "Once separated, the individual components can be removed through separate outlets."
The successful teamwork has led to the design and construction of a new CLC bench-scale cold-flow unit, which is nearing completion. Prototypes of the new vortex chamber have been constructed with the help of another emerging technology—additive manufacturing (AM), a process of creating objects from 3D model data by adding layer upon layer of material. AM provides a relatively quick, easy, and affordable method of producing these chambers as prototypes, with the ability to create different sizes that can be tested for effectiveness.

Jessica Torres studies the centrifugal forces at play in a vortex chamber simulation.

"The use of additive manufacturing to build vortex chamber devices opens perspectives for a variety of other applications and modular scale-up," **Geo Richards**, NETL's Energy Systems Dynamics focus area lead explained.
"This has been a rewarding collaborative experience," De Wilde said. "NETL has been great, especially Dr. Richards coordinating the important resources that went into making this project a success and Dr. Benyahia running the code with such complex flows."

This team effort highlighted two of NETL's greatest strengths—its valuable educational opportunities through the Mickey Leland Energy Fellowship (MLEF) program and the Lab's ability to form strategic partnerships to leverage resources and conduct world-class research. Torres, as part of her MLEF experience, spent a summer running simulations designed by Benyahia that led to real-world results. De Wilde, on the other hand, brought his existing technology to NETL to be modified for fossil energy research through those very simulations. This mixture of new talent interacting with proven expertise at a cutting edge facility like NETL converged to create a new and potentially game-changing technology for CLC. This collaboration proved that one of NETL's greatest assets is its ability to attract preeminent talent, whether from academia or the private sector, and then enrich the research partnership with state-of-the-art facilities and expertise found at the Laboratory.



The successful simulations of the vortex chamber resulted in a prototype being manufactured through 3D printing for use in a bench-scale reactor.

Contact: Sofiane Benyahia and Juray De Wilde

Medical Alloy Nets Another National Award

NETL researchers are accustomed to teaming up with the private sector to innovate new materials and technologies that improve energy efficiency of power plants and make lives better across a spectrum of applications with little fanfare, but when one particular collaboration led to creation of a landmark medical device material that continues to save lives around the planet, folks took notice in a big way.

NETL's **Paul Jablonski**, **Paul Turner**, **Edward Argetsinger**, and **Jeffrey Hansen** (retired) received a 2015 ASM Engineering Materials Achievement Award for developing a platinum-chromium alloy in collaboration with researchers at Boston Scientific Corporation, Inc. (BSCI). The alloy is now being used in next-generation coronary stents, small, metal mesh tubes that are surgically implanted in heart disease patients to open narrowed arteries and allow blood to flow freely. The NETL–BSCI alloy is the first stainless steel formulation for stents with a significant concentration of platinum, making it easier for coronary specialists to see the stent on x-ray during placement and expansion. The alloy also increases the stents' corrosive resistance, strength, and flexibility.

This novel alloy features an austenitic stainless steel structure that incorporates platinum, a highly "radiopaque" element. Previous stents composed of standard 316 stainless steel were difficult to install due to poor visibility. The high radiopacity of the NETL-developed alloy increases the X-ray visibility of the stent inside a patient, solving this longstanding problem. Better visibility means greater ease and precision of placement of the stent inside the patient's artery. In addition, the greater yield strength of the alloy allowed the stent's designers at Boston Scientific Corporation to make a thinner, more flexible stent that is more easily threaded through the winding path of the artery without doing damage along the way.

Award-winning researchers from left to right—Paul Jablonski, Paul Turner, Edward Argetsinger, and Jeffrey Hansen (retired). They are holding a rolled sheet of the Pt-Cr alloy.

After a lengthy series of clinical trials, BSCI succeeded in having the stents approved for sale on November 2, 2009. They were first marketed in 2010 as the PROMUS® ELEMENT™ in Europe and the rest of the world, selling 206,000 units in Europe, the Middle East, and Africa by December 2010. This represented a 22 percent market share of coronary stents in these regions. On April 25, 2011, the stents were approved for sale in the United States under the TAXUS ION™ label. The total sales since introduction have exceeded $6 billion with a current world market share of 33 percent.

Engineered and manufactured in the United States, the stent series has created 450 sustainable domestic jobs. Carpenter Specialty Alloys, Accellent, and Minitubes Corporation also played roles in the development chain from laboratory to market that made the alloy and subsequent stents a success.

The ASM award joins a crowded trophy case of other recognitions for the technology and its successful commercialization. The NETL- BSCI research team captured a 2011 R&D 100 Award, given by R&D Magazine to recognize the 100 most technologically significant products entering the marketplace each year; a technology transfer award for "Outstanding Commercialization Success" from the Federal Laboratory Consortium; and the U.S. Secretary of Energy's Achievement Award. It was also nominated for the United States Patent Office's Presidential Medal for Innovation in 2013.

Contact: Paul Jablonski

TAPPING THE EARTH'S HEAT—REGIONAL WORKSHOP EXPLORES **GEOTHERMAL POSSIBILITIES**

The potential of geothermal energy was front and center at a workshop hosted recently by the Department of Energy's (DOE) National Energy Technology Laboratory (NETL) and the Office of Energy Efficiency & Renewable Energy's (EERE) Geothermal Technologies Office. Geothermal Direct Use Technology and the Marketplace brought together industry, academia, and government stakeholders to exchange information and make recommendations for the use of geothermal energy in the Appalachian Basin including New York, Pennsylvania, and West Virginia.

NETL's Dr. Geo Richards served as co-organizer of the workshop and provided opening remarks.

The workshop underscored a shared commitment by EERE and NETL to the development of environmental sustainability and secure energy. Geothermal energy is derived from the Earth's heat, which can supply clean, renewable, and continuous energy with very low greenhouse gas emissions. Direct use, low-temperature geothermal energy applications, such as residential heating and cooling, can diversify U.S. energy supplies and contribute to the President's goal of doubling renewable energy generation by 2020.

At the workshop, internationally recognized geothermal experts led discussions on a variety of topics including location and characterization of geothermal resources, low-temperature direct use applications, and the economics and market potential for geothermal energy. An afternoon session focused on opportunities and challenges associated with wider adoption of geothermal energy and what role the Department of Energy could play in meeting applied research needs, project financing, and regulatory hurdles.

The Geothermal Energy Association estimates that less than 7 percent of the world's geothermal capacity has been tapped thus far. Geothermal resources represent an opportunity for a relatively low-cost energy source and for development as an essential part of a more diverse energy portfolio. Geothermal reservoirs are systems of hot rock and water at temperatures that increase – in general – with depth below the Earth's surface. In some cases – geysers and hot springs, for example - high temperatures may be very near the surface. Wells can be drilled into these underground reservoirs to bring steam and very hot water to the surface for a variety of direct use applications, including district heating and cooling systems, greenhouses, fisheries, and industrial and agricultural heating processes. Higher temperature geothermal energy can also be used to generate electricity either directly or through the use of auxiliary technologies.

NETL's **Geo Richards** described the purpose of the workshop, "Geothermal energy is a new idea to many people in the Eastern United States. This workshop helped us take the first step to understanding the potential and challenges of developing geothermal resources in our region."

Contact: Geo Richards

Director of the West Virginia University Energy Institute, Dr. Brian Anderson, gave an overview of the Appalachian Basin region.

Imagination and Persistence:
WORDS TO LIVE BY AND TEACH

Evan Granite finds ways to recover valuable rare earth elements from processes associated with coal-generated power with the same inspirational tools he uses to deliver messages of scientific encouragement to an ever-growing number of children in his community: imagination and persistence.

In the daytime, Granite is the technical lead for NETL's work on rare earth element detection, characterization and recovery from coal-derived products. On his own time, he is a popular interpreter of scientific concepts and career opportunities to eager groups of young people in his community like the Girl Scouts.

"I enjoy giving talks and science demonstrations," he said. "I have two young daughters and I want to show my girls and their friends that science is exciting; that with education, persistence, and imagination they can solve the problems facing humanity like hunger, poverty, war, and disease; that we really know little about the world around us; that natural phenomena like light, chemistry and electricity are beautiful; and that we need girls to help unravel the many unsolved mysteries of the universe."

Granite is a natural for talking to upcoming generations about promising scientific concepts. The valuable lessons he learned in the preparation for and execution of a career in scientific research remain the basis for the lessons he now teaches in community presentations.

"In graduate school, you learn that you do not need expensive equipment and labs to obtain important results, and that imagination and persistence are most critical," he said.

That lesson also serves Granite well at NETL. He cited many successes, such as invention licenses and R&D 100 awards. A prolific principal investigator (PI) or co-PI on many research projects, he has co-authored a book about mercury control, has more than 37 journal articles, eight patents, 221 conference papers and presentations and has 52 DOE reports of invention. He served on Ph.D. thesis committees for students at Stanford and West Virginia Universities and has taught graduate level courses at the University of Pittsburgh. Granite began his career as an ORISE postdoc at NETL in 1996, and told Research News that, "I like to help others through mentoring postdocs and Mickey Leland students and by giving science demonstrations in the community."

Concepts for his community presentations come both from scientific journals and popular science magazines. "They give me many ideas for interesting demonstrations," he said.

Granite maintains that the very best part of his career is working at NETL and the daily interactions he has with his colleagues. But he is quick to add that the chance he gets to be a kid again by doing community demonstrations for young people is "priceless." With a little imagination and persistence, and the encouragement he gives them, young people will find rewarding careers and make scientific advances that serve the greater good.

Contact: Evan Granite

NETL's In-House Research Program: SFIRE

Transitioning the United States' current power-provision structure to one with a greater diversity of power generation resources is a complicated undertaking. Through the Synergies in Fossil-Based Integrations with Renewable Energy (SFIRE) working group, NETL is seeking ways to make that transition as smooth as possible. The researchers and program managers engaged with SFIRE are expert in the intricacies of current, fossil-dominated power generation systems, including how resources are extracted, how electricity is generated and transmitted, how energy systems interact, and how environmental impacts can be mitigated. That expertise makes them ideally suited to devise ways to integrate multiple energy sources and power systems, with high effectiveness.
The primary objective of the SFIRE working group is to seek opportunities to expand NETL's research portfolio in this arena. More specifically, SFIRE strives to identify and conduct research on the changing role of fossil energy power generation in the national transition to a modern grid. To meet this goal, the SFIRE working group identifies and evaluates knowledge gaps in the areas of non-fossil energy and optimal power-systems interactions. The working group also:

- Reviews incoming funding opportunities to NETL, and promotes participation in these opportunities, through educating researchers and supporting their efforts to prepare proposals.
- Hosts collaboration spaces on the Energy Data eXchange (EDX), where researchers and project managers can share information about diverse energy sources and the needs of power networks.
- Supports NETL projects that deal with integrating multiple power sources and systems, including geothermal power, solar power, and optimal grid interactions.

For more information about SFIRE, contact Danylo Oryshchyn.

SFIRE

EDX
A Product of NETL

Geothermal Energy Basics

Geothermal energy is heat energy extracted from beneath the Earth's surface. It is environmentally friendly and produces few emissions and little waste. Temperatures underground generally rise with depth, and the rate of increase (the geothermal gradient) varies with geographic location. New mapping techniques and other novel technologies help locate promising drilling areas.

Geothermal well depths for electricity production vary depending on temperatures required by the production systems. Geothermal sources for power production are generally hydrothermal—natural water reservoirs contained in hot rock. The systems and their temperature requirements include the following:

- Direct dry steam (around 570 °F) — hydrothermal steam turns the turbine directly
- Flash steam (360 °F or more) — high-pressure hydrothermal fluid flashes (vaporizes rapidly) when sprayed into a tank held at lower pressure
- Binary cycle (around 300 °F) — hydrothermal fluid vaporizes a second fluid with a lower boiling point; higher energy output and lower heat requirements make this option attractive for geothermal power plants

Lower-temperature geothermal energy also has other uses. Resources at 100–300 °F provide heat directly to buildings or water at fish farms, help grow plants in greenhouses, dry crops, or pasteurize milk.

To encourage more widespread geothermal energy development, the Department of Energy supports tools and technologies to locate, access, and develop the nation's substantial geothermal resources. It also sponsors research in enhanced geothermal systems: engineered geothermal reservoirs that would otherwise be uneconomical to develop due to lack of water and/or permeability.

Old Faithful, Yellowstone National Park.

America's first geothermally heated campus, Oregon Institute of Technology, adds 3.5 MW of clean, domestic electricity generation capacity.

Image: Bill Goloski, Oregon Institute of Technology

APPLAUSE

Patent Issued

Efficient Electrocatalytic Conversion of CO_2 to CO using Ligand-Protected Au25 Clusters, **Christopher Matranga** (DOE/NETL); **Rongchao Jin** (Carnegie Mellon); **Huifeng Qian** (Carnegie Mellon); **Douglas Kauffman** (Global Energy Services); **Dominic Alfonso** (DOE/NETL), 9,139,920, issued September 22, 2015.

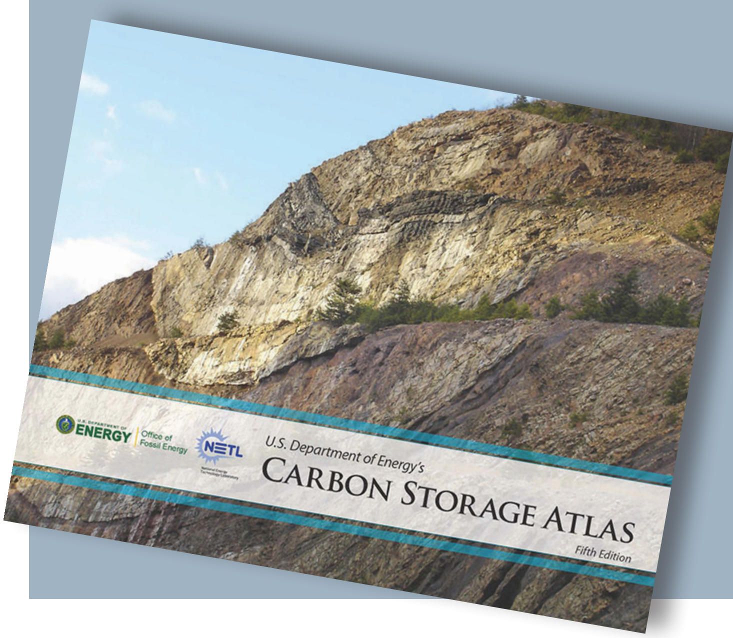
Method for Continuous Synthesis of Pyrochlore Catalyst Powders, **David A. Berry** (DOE/NETL); **Dushyant Shekhawat** (DOE/NETL); **Mark Smith** (URS); **Daniel J. Haynes** (DOE/NETL), 9,126,833, issued September 8, 2015.

EXTRA! EXTRA!

Fifth Edition of the NETL Carbon Storage Atlas Released

The Carbon Storage Atlas (Atlas V) shows prospective carbon dioxide (CO_2) storage resources of at least 2,600 billion metric tons – an increase over the findings of the 2012 Atlas.

Atlas V is a coordinated update of carbon storage resources, activities, and large-scale field projects in the United States. It showcases the progress that NETL scientists and engineers have made with their partners toward wide-scale deployment of carbon storage technologies. It also underscores the importance of the research partnerships and projects that are increasing our understanding of safe, permanent geologic storage of CO_2.



CONTACT

National Energy Technology Laboratory
1450 Queen Avenue SW
Albany, OR 97321-2198
541-967-5892

420 L Street
Suite 305
Anchorage, AK 99501
907-271-3618

3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880
304-285-4764

626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940
412-386-4687

Granite Tower, Suite 225
13131 Dairy Ashford
Sugar Land, TX 77478
281-494-2516

WEBSITE
www.netl.doe.gov

CUSTOMER SERVICE
1-800-553-7681

For more information about NETL's Office of Research and Development and its programs:
www.netl.doe.gov/research/on-site-research

U.S. DEPARTMENT OF ENERGY | NETL

ORD: Science & Engineering To Power Our Future