

Annual Report | November 2019



U.S. DEPARTMENT OF
ENERGY

Office of
TECHNOLOGY TRANSITIONS

Energy I-Corps is a two-month program that trains national lab researchers in evaluating industry needs and potential market applications for their technologies.

An initiative of the U.S. Department of Energy Office of Technology Transitions

Managed by the National Renewable Energy Laboratory



Greetings,

The U.S. Department of Energy (DOE) Office of Technology Transitions (OTT) is pleased to provide you with this update on the Energy I-Corps program.

Over the last year, OTT has worked with National Laboratories across the country to identify and pursue commercialization strategies for some of the most exciting DOE-supported technologies, maximizing taxpayer return on this significant R&D investment.

This program, now in its fifth year, is changing the way our scientists engage with the private sector. Each year has seen the birth of new companies and new licenses for DOE technologies. Energy I-Corps has enabled thousands of interactions that educate and inform not only program participants, but also the entire National Lab community—helping them tackle the most pressing technology challenges facing U.S. industry today.

As we continually explore new ways to fulfill our mission, we invite you to connect with us, get involved, and help energize America's technological leadership and security through DOE's incredible research enterprise for many more years to come.

Sincerely,

A handwritten signature in black ink, appearing to read "Conner Prochaska".

Conner Prochaska

Chief Commercialization Officer
U.S. Department of Energy
Director, Office of Technology Transitions



“Energy I-Corps showed me how I can maximize the benefit of my basic research at Argonne to create technology that has real-world commercial impacts for Americans. That’s a very rewarding feeling.”

Dr. Ralph Muehleisen
Cohort 1 Grad



“I started my first company with a technology from a national lab... If the program had been around when I started my company, I’m sure I would have saved about two and a half years.”

Dr. Peter Fiske
Cohort 3 Instructor



Discovering Market Pathways for National Lab Research

About Energy I-Corps

The U.S. Department of Energy (DOE) invests millions of dollars every year in U.S. national labs, but without industry engagement and a business mindset at the labs, that investment has limited economic return. Energy I-Corps pairs teams of researchers with industry mentors for an intensive two-month training in which the researchers define technology value propositions, conduct customer

discovery interviews, and develop viable market pathways for their technologies. Researchers return to the lab with a framework for industry engagement to guide future research and inform a culture of market awareness within the labs. In this way, Energy I-Corps is ensuring our investment in the national labs is maintaining and strengthening U.S. competitiveness long-term.

More Information

Energy I-Corps, formerly known as Lab-Corps, is managed by DOE's National Renewable Energy Laboratory (NREL). NREL leads curriculum development and execution, recruits program instructors and industry mentors, and assembles teams from the 17 national labs. To date, teams have come from:

Argonne National Laboratory
Fermi National Accelerator Laboratory
Idaho National Laboratory
Lawrence Berkeley National Laboratory
Lawrence Livermore National Laboratory
Los Alamos National Laboratory
National Renewable Energy Laboratory
Oak Ridge National Laboratory
Pacific Northwest National Laboratory
Sandia National Laboratories
SLAC National Accelerator Laboratory



For each class of Energy I-Corps teams, national labs recruit researchers working on energy technologies that have shown potential for commercial application. Together, these researchers receive comprehensive training and conduct at least 75 customer discovery interviews with industry leaders over the course of the program. Once researchers complete the Energy I-Corps program, they have secured the necessary industry connections and insights to ready their energy technologies for the market, and gained an industry engagement framework to apply to future research and share with fellow researchers.

Curriculum

The Energy I-Corps curriculum was initially developed in 2015 in partnership with the National Science Foundation's (NSF's) Innovation Corps (I-Corps) program. With the support of the national labs and external industry advisors, NREL and DOE's Office of Technology Transitions (OTT) adapted NSF's nationally recognized I-Corps training.

Adjustments made to the I-Corps curriculum address the specific challenges scientists working within the national lab environment face when getting their innovations ready for market, such as navigating the complexities of bundling intellectual property. As more research teams complete the training, NREL and OTT continue to improve and enhance the Energy I-Corps curriculum to best meet participant and industry needs.



Energy I-Corps FAQs

What is Energy I-Corps?

Energy I-Corps is a two-month training where national lab researchers learn about industry needs and evaluate potential market applications for their technologies.

How many teams have gone through the program?

As of July 2019, 101 teams from 11 national labs have participated in Energy I-Corps over the course of nine training sessions.

What are the benefits?

Participants benefit from workshops taught by industry experts, as well as 75+ customer discovery interviews they conduct over the duration of the program. The training equips national lab researchers with tools to understand the real-world relevance of their technologies and viable pathways to market. These tools help inform future research at the national labs.

Who can participate?

DOE national lab researchers working on eligible technologies can apply. Areas of interest span the DOE investment portfolio including renewable energy, efficiency, advanced materials, nuclear energy, fossil energy, environmental management, national security, and others.

Energy I-Corps is also looking for program instructors and industry mentors.

Tech Office Support

Submitted applications are reviewed by relevant DOE program offices. The offices of Energy Efficiency and Renewable Energy, Fossil Energy, Nuclear Energy, Environmental Management, as well as the National Nuclear Security Administration, have supported teams.

How can I learn more?

Email energyicorps@nrel.gov to learn more about Energy I-Corps and how to get involved. If you are interested in becoming an instructor or mentor, contact Megan Gross at megan.gross@nrel.gov.

Energy I-Corps technologies have reached a point of commercial viability that has attracted more than \$30 million in follow-on funding.

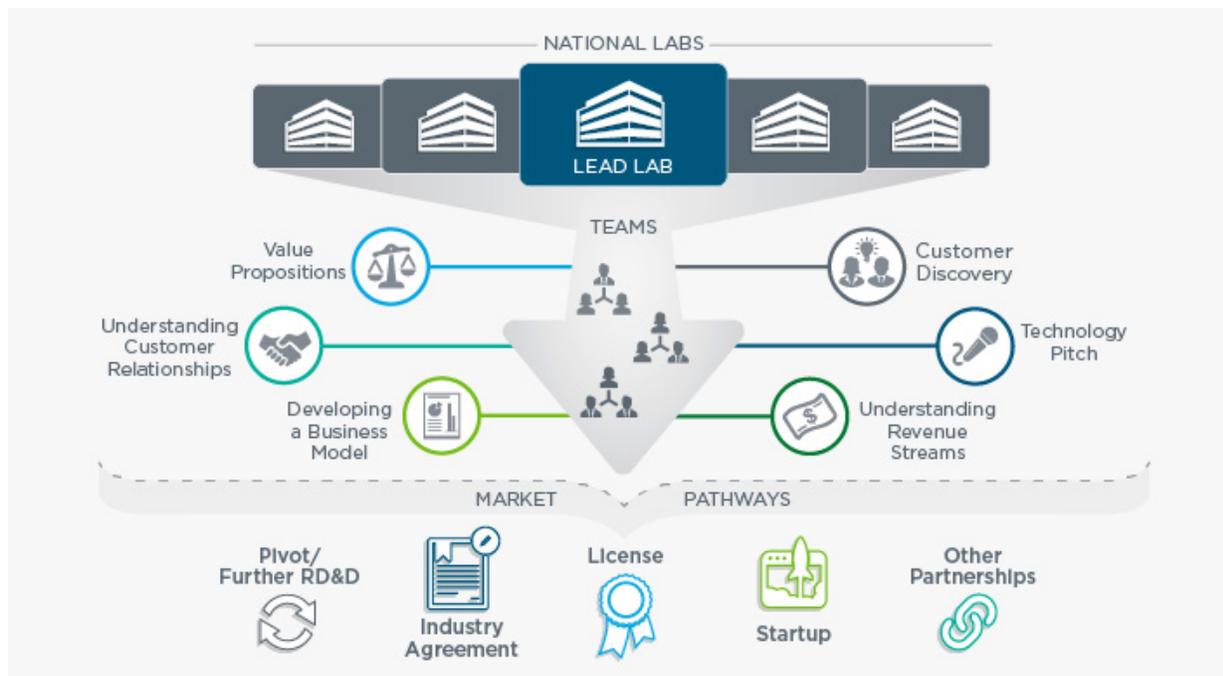


Teams from the fourth cohort analyze market pathways for their early-stage technologies. This is just one of many hands-on activities Energy I-Corps participants complete with support from industry mentors and instructors from the clean energy sector.

As of the end of the ninth training session in spring 2019, teams have collectively worked with more than 100 industry mentors to discover the commercial impact of their technologies and have conducted more than 7,000 customer discovery interviews with industry.



Program Structure



Energy I-Corps consists of four key elements:

Node: NREL serves as the node for this program. The node is responsible for developing and delivering the curriculum, as well as providing program guidance to participating labs. The node hosts both the opening and closing sessions, which involve in-person instruction and presentations.

Participating Labs (aka Sites): DOE's Energy I-Corps sites recruit, assemble, and send teams to the node for training, as well as support teams both during and after the program. Support might include assistance in identifying entrepreneurial leads and industry mentors, as well as technology transfer/technology deployment support for commercialization plans identified by the team during training. Each site collects metrics during and after their team(s) complete the program and distributes them quarterly to the node. These metrics are critical to assessing and improving the program.

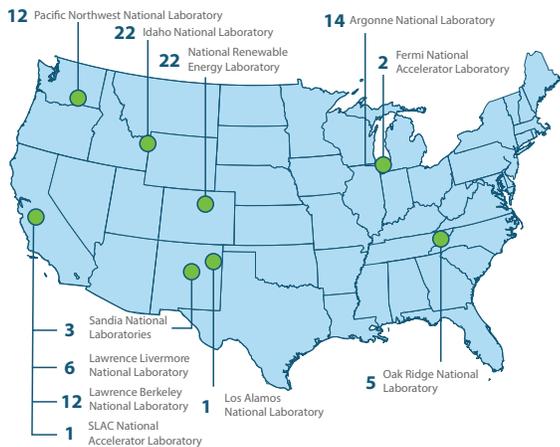
Teams: Applicants apply to DOE's Energy I-Corps as a team, composed of a principal investigator with a commercially relevant technology, an entrepreneurial lead, and an industry mentor. Over the course of the training, teams identify potential commercialization pathways for their selected technology, as well as identify opportunities where further development could lead to commercial value.

Training Program: The training program spans seven weeks utilizing a custom-designed curriculum built on the Lean LaunchPad methodology. During these seven weeks, teams attend in-person sessions, participate in weekly webinars, and learn from faculty how to systematically identify the most appropriate market applications and commercialization pathways for their technologies. Participation also requires a considerable amount of time spent outside of the classroom conducting customer discovery interviews.

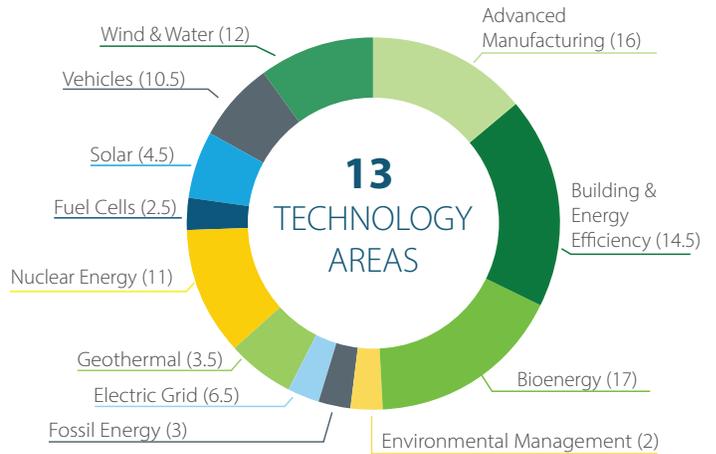


9 CLASSES of ENERGY I-CORPS

101 TEAMS | 11 NATIONAL LABORATORIES



BRINGING ENERGY INNOVATIONS TO



LEARNING FROM

100+ Industry Mentors



Hitachi, Lowes, Johns Manville, Lego, U.S. Army, Trane, Tesla, GM, Dow Chemical, Yingli, 3M, Whirlpool, GE, Home Depot, ReMax, Amazon



6 New Businesses

Six teams have launched new businesses based on their Energy I-Corps Technology



\$31M Follow-On Funding

Because of Energy I-Corps, technologies have reached a point of commercial viability that has attracted more than \$31M in follow-on funding



7,040 Customer Discovery Interviews



405 Applications Received



Our Team



Jennifer Ramsey
Acting Program Manager, NREL



Megan Gross
Program Coordinator and
Teaching Assistant, NREL



Shelly Curtiss
Director, Colorado Cleantech
Industries Association



Zack Baize
Energy I-Corps Program
Manager, Office of Technology
Transitions



Participation by Technology Program Offices

Energy I-Corps teams are funded by individual technology program offices. Labs also have the opportunity to fund teams or find industry partners to fund teams.

Advanced Manufacturing

Team	Lab	Cohort	Discovery Interviews
Micro Miners (.5)	LLNL	2	59
NanoHeatBlock	ANL	2	83
Saline Solutions	LLNL	2	50
Fermians	FNAL	3	48
E-RECOV	INL	4	57
BASIC	NREL	5	80
Electroplate	INL	5	56
Re-Light	INL	5	75
Comba	LBNL	7	79
FLO.materials	LBNL	7	78
Laser Sense	ANL	7	74
HyMag (\$37.5k)	ANL	8	107
CAN-Coatings	ANL	8	72
Shakti Power Systems	ANL	9	71

TOTAL TEAMS FUNDED
13

INVESTMENT TOTAL
\$975,000

FOLLOW-ON FUNDING
\$11,765,515

DISCOVERY INTERVIEWS
989

Bioenergy

Team	Lab	Cohort	Discovery Interviews
High-Moisture Pelletizing Process	INL	2	86
FiberSAS	ANL	3	76
WasteNot	ANL	3	70
FUSS: Fuels Synthesized from Sugars	LANL	4	71
Optiblend	INL	4	75
CuB Fuels	NREL	5	98
GLYCOPLASTICS	NREL	5	77
Nitrilica	NREL	5	77
Electro-Active (\$37.5k)	ORNL	7	80
Fermley	LBNL	8	81
Ecopod	LBNL	8	77
Embodied Carbon	NREL	9	78
Grab-X	ANL	9	83

TOTAL TEAMS FUNDED
12.5

INVESTMENT TOTAL
\$937,494

DISCOVERY INTERVIEWS
989

Buildings

Team	Lab	Cohort	Discovery Interviews
VOLTTRON	PNNL	2	5
MAIforBldgs	ORNL	3	74
SwitchGlaze (\$37.5k)	NREL	3	54
Thermoelectric Dryer	ORNL	4	45
BEYOND FAULT DETECTION	NREL	5	76
GreenBlox	NREL	6	74
Amber LEDs	NREL	9	77
ThermaStor	LBNL	9	78

TOTAL TEAMS FUNDED
7.5

INVESTMENT TOTAL
\$562,500

FOLLOW-ON FUNDING
\$1,875,000

DISCOVERY INTERVIEWS
484



Participation by Technology Program Offices

Environmental Management

Team	Lab	Cohort	Discovery Interviews
Gamma Rayality	LBNL	6	77
PureBeam	FNAL	7	78

TOTAL TEAMS FUNDED

2

INVESTMENT TOTAL

\$150,000

FOLLOW-ON FUNDING

\$1,150,000

DISCOVERY INTERVIEWS

155

Fuel Cells

Team	Lab	Cohort	Discovery Interviews
Polymer Membranes	SNL	2	41
CryoH2	LLNL	4	56
Electro-Active (\$37.5k)	ORNL	7	80

TOTAL TEAMS FUNDED

2.5

INVESTMENT TOTAL

\$187,500

FOLLOW-ON FUNDING

\$50,000

DISCOVERY INTERVIEWS

137

Fossil Energy

Team	Lab	Cohort	Discovery Interviews
MECS	LLNL	4	64
CO2BOL	PNNL	5	75

TOTAL TEAMS FUNDED

2

INVESTMENT TOTAL

\$150,000

FOLLOW-ON FUNDING

\$630,000

DISCOVERY INTERVIEWS

139

“As a former national lab scientist who launched a startup with my lab technology, I could have benefited so much from Energy I-Corps. The tools the program provides have such enormous practical application. Seeing that was one of the reasons I wanted to become an instructor and mentor to these scientists and engineers.”



Participation by Technology Program Offices

Geothermal

Team	Lab	Cohort	Discovery Interviews
TOUGH	LBNL	2	54
Micro Miners (.5)	LLNL	3	59
GeoCAES	NREL	4	51
Sandia Technology Systems	SNL	4	40

TOTAL TEAMS FUNDED
3.5

INVESTMENT TOTAL
\$262,500

FOLLOW-ON FUNDING
\$600,000

DISCOVERY INTERVIEWS
204

Nuclear

Team	Lab	Cohort	Discovery Interviews
Quake	INL	2	35
Monolith	SNL	3	37
Change Detection Systems	INL	4	71
Dry Cask Vital Signs	INL	4	51
AMAFT	INL	5	76
EMRLD	INL	5	76
4Cs	INL	6	38
ELINA	INL	6	102
AxiVis	INL	7	90
HOT	INL	7	75
M2LD - Mobile Modified Linear Delta	INL	8	116
Rotoro EH?	INL	9	77

TOTAL TEAMS FUNDED
12

INVESTMENT TOTAL
\$900,000

FOLLOW-ON FUNDING
\$3,646,000

DISCOVERY INTERVIEWS
844

Office of Electricity

Team	Lab	Cohort	Discovery Interviews
DCAT	PNNL	6	75
Glass Paper	INL	8	75
EnergyBlox	SLAC	8	27
EcoBlock	LBNL	9	75
DER-CAM	LBNL	9	78

TOTAL TEAMS FUNDED
5

INVESTMENT TOTAL
\$360,000

DISCOVERY INTERVIEWS
330

“It has been a great opportunity to learn how to talk to customers, so you can get an early read on what the market really wants for your product.”



Participation by Technology Program Offices

Solar

Team	Lab	Cohort	Discovery Interviews
Halo	NREL	6	83
Hydro Scanner	LLNL	8	44
SolGuard (\$30k)	NREL	8	51

TOTAL TEAMS FUNDED

2.5

INVESTMENT TOTAL

\$180,000

DISCOVERY INTERVIEWS

178

Vehicles

Team	Lab	Cohort	Discovery Interviews
Smart Charge Adapter	ANL	2	71
Cellsage	INL	4	44
Lubricant Engineers	PNNL	4	75
MICROWATTS	NREL	5	75
FAST	PNNL	6	91
Beyond Lithium Ion Batteries	ANL	7	82
routeE	NREL	8	80
BonD-Northwest: Bonding on Demand	PNNL	8	93
Resilicoat	ANL	9	82

TOTAL TEAMS FUNDED

9

INVESTMENT TOTAL

\$657,000

FOLLOW-ON FUNDING

\$665,349

DISCOVERY INTERVIEWS

693

Wind & Water

Team	Lab	Cohort	Discovery Interviews
DLR	INL	3	72
Autonomous Concrete Printing	NREL	4	79
RF Tag	PNNL	4	75
WindSOCK	NREL	5	75
HyMag (\$37k)	ANL	8	107
SpiderFloat	NREL	8	77
MADe3D	NREL	9	78
SAND	INL	9	77
ThermalTracker-3D	PNNL	9	56

TOTAL TEAMS FUNDED

8.5

INVESTMENT TOTAL

\$637,500

FOLLOW-ON FUNDING

\$600,000

DISCOVERY INTERVIEWS

696

“I’ve spent 29 years in the lab, and I thought I was close to industry. I learned more in the last eight weeks than in those 29 years.”



Participation by Technology Program Offices

Lab Funded

Team	Lab	Cohort	Discovery Interviews
CI-ReClad	ORNL	1	75
Dynamic Aperture	ANL	1	23
Eco-AC	NREL	1	45
HYDRA	PNNL	1	40
Sub Lambda	PNNL	1	13
Tunation	ORNL	1	86
WISDEM	NREL	1	80
BioAlchemy	LBNL	2	51
Biolyt Renewables	NREL	2	81
Evodia	LBNL	2	45
Resin Wafer Electrodeionization	ANL	2	75
SolGuard (\$45k)	NREL	2	51
SwitchGlaze (\$37.5k)	NREL	3	54
Oleo Sponge	ANL	6	62

TOTAL TEAMS FUNDED

13

INVESTMENT TOTAL

\$982,500

FOLLOW-ON FUNDING

\$4,802,500

DISCOVERY INTERVIEWS

781

Pilot

Team	Lab	Cohort	Discovery Interviews
Frequency Sensing Load Controller	ANL	0	75
My Green Car	LBNL	0	75
TwistAct	SNL	0	75
ARAI	INL	1	96
C-Best	LLNL	1	13
Co-Culture Green	PNNL	1	34
Ring Burner	LBNL	1	71
SonicLQ	ANL	1	11
STARS	PNNL	1	78
Switchable Polarity Solvents	INL	1	78

TOTAL TEAMS FUNDED

10

INVESTMENT TOTAL

\$750,000

FOLLOW-ON FUNDING

\$5,760,000

DISCOVERY INTERVIEWS

606

Privately Funded

Team	Lab	Cohort	Discovery Interviews
Opt-grid	NREL	6	87

TOTAL TEAMS FUNDED

1

INVESTMENT TOTAL

\$75,000

FOLLOW-ON FUNDING

\$246,861

DISCOVERY INTERVIEWS

87



Project Funding

Energy I-Corps teams are funded directly by a technology office, their laboratories, or privately funded by industry.

Technology Office Funding

Funding Technology Office	Investment	Follow-on Funding
AMO	\$975,000	\$11,765,515
BETO	\$937,494	-
BTO	\$562,500	\$1,500,000
EM	\$150,000	\$1,150,000
FCTO	\$187,500	\$50,000
FE	\$150,000	\$630,000
GTO	\$262,500	\$600,000
HTO	-	-
NE	\$900,000	\$3,646,000
OE	\$360,000	-
SETO	\$180,000	-
VTO	\$657,000	\$665,349
WWPTO	\$637,500	\$600,000
Total	\$5,959,494	\$20,606,864

**INVESTMENT
TOTAL**
\$7,766,994

**FOLLOW-ON
FUNDING**
\$31,790,725

	Investment	Follow-on Funding
Lab Funded	\$982,500	\$5,177,000
Pilot	\$750,000	\$5,760,000
Privately Funded	\$75,000	\$246,861
Total	\$1,807,500	\$11,183,861

Laboratory Statistics

Lab	Teams Funded	Investment by Tech Office	Post Program Funding Received	Customer Discovery Interviews
ANL	16	\$1,199,994	\$7,901,324	1117
FNAL	2	\$150,000	-	126
INL	22	\$1,650,000	\$6,376,000	1598
LANL	1	\$75,000	-	71
LBNL	13	\$960,000	\$7,500,000	919
LLNL	6	\$450,000	\$2,829,040	286
NREL	22	\$1,632,000	\$5,130,361	1633
ORNL	5	\$375,000	\$4,000	360
PNNL	12	\$900,000	\$2,000,000	710
SNL	4	\$300,000	\$50,000	193
SLAC	1	\$75,000	-	27
TOTAL	104	\$7,766,994	\$31,790,725	7040

Cohort Statistics

Cohort	Funding Received	Follow-on Funding	Customer Discovery Interviews
0	\$225,000	\$250,000	225
1	\$1,050,000	\$6,214,000	743
2	\$1,050,000	\$8,837,389	787
3	\$600,000	\$3,600,000	475
4	\$1,125,000	\$1,280,000	937
5	\$900,000	\$153,500	916
6	\$600,000	\$4,006,861	606
7	\$600,000	\$7,448,975	636
8	\$732,000	-	805
9	\$884,994	-	910
TOTAL	\$7,766,994	\$31,790,725	7040



Project Funding

Team Follow-on Funding

TEAM	Follow-on Funding Received	Funded Technology Office
4C's	\$760,000	NE
AMAFT	\$103,000	NE
ARIA	\$161,000	Pilot
BaSiC	\$17,500	AMO
Biolyst Renewables	\$1,166,000	Lab Funded
Change Detection Systems	\$650,000	NE
COMBA	\$3,600,000	AMO
DLR	\$600,000	WWPTO
Eco-AC	\$200,000	Lab Funded
ELINA	\$1,500,000	NE
EMRLD	\$33,000	NE
FLO.materials	\$2,500,000	AMO
Gamma Royalty	\$1,150,000	EM
HOT	\$600,000	NE
Laser Sense	\$748,975	AMO
MECS	\$630,000	FE
Micro Miners	\$1,200,000	AMO/GTO
My Green Car	\$250,000	Pilot
NanoHeatBlock	\$3,300,000	AMO
OLEO Sponge	\$350,000	Lab Funded
Opt-Grid	\$246,861	Private
Polymer Membranes	\$50,000	FCTO
RWEDI	\$1,457,000	Lab Funded
Saline Solutions	\$999,040	AMO
Smart Charge Adapter	\$665,349	VTO
Sonic LQ	\$1,380,000	Pilot
STARS	\$2,000,000	Pilot
SwitchGlaze	\$2,250,000	BTO/Lab Funded
Switchable Polarity Solvents	\$1,969,000	Pilot
Tunation	\$4,000	Lab Funded
WISDEM	\$500,000	Lab Funded
Total	\$31,790,725	

9 cohorts completed as of
Spring 2019

including
101 teams from **11** national labs

100+
industry mentors and
instructors involved

Innovations have spanned
13 DOE program areas

Teams have conducted more than
7,000
customer discovery interviews
with companies like:
**Hitachi, Lowes, Johns Manville, Lego,
U.S. Army, Trane, Tesla, GM, Dow Chemical,
Yingli, 3M, Whirlpool, GE, Home Depot,
ReMax, and Amazon**



Case Studies

Energy I-Corps aims to accelerate the deployment of energy technologies by granting U.S. DOE laboratory scientists and engineers access to direct market feedback on their technology offerings. Inspired by the National Science Foundation Innovation Corps (I-Corps) model, the two-month Energy I-Corps program empowers teams with the tools, resources, and relationships necessary to discover potential market pathways for their innovations. The following pages showcase the success of just a few of the teams that have participated in the Energy I-Corps program.



“This was a rich out-of-the-comfort-zone-type opportunity and it was worth the time investment for us. The instructors really put a lot into it so we knew that our energy and buy-in had to at least match theirs. It’s almost mind boggling how much more there potentially is to do as follow-up to this. I can’t recommend the experience enough, and I think that it pays for itself just from the eye-opening perspective for people who have never seen the business side of taking tech to market.”



MECS

Lawrence Livermore
National Laboratory

Cohort 4

Problem

Craft beer is a booming business in the United States. The number of craft breweries operating since 2009 has grown from nearly 1,600 to more than 5,200.

CO₂ is a critical element for craft breweries, needed for both carbonization of the beer and final packaging. It's also a byproduct of the fermentation process. Every brewery, no matter its size, produces three times as much CO₂ as is needed during the fermentation process. Companies with large operations often have CO₂ recovery systems, like those currently used at power plants. But many microbreweries don't have the ability to capture and recycle the gas back into their operations. Because of this, the CO₂ already produced is wasted, and small breweries must purchase additional CO₂ from local suppliers to meet their CO₂ needs.

If smaller breweries had a way to capture their own gas and recycle or sell it, they could save up to 75% of that expense, increasing efficiency, saving money, and ultimately making them more competitive.

Focus

MECS (micro-encapsulated CO₂ sorbents) is a group of researchers from Lawrence Livermore National Laboratory (LLNL) who had previously developed microcapsule technology to efficiently capture CO₂ from power plants. Now they are using their technology to help these craft breweries capture the savings from recovering and reusing CO₂.

Through exploration of new potential markets in the Energy I-Corps program, the LLNL MECS team identified significant potential for the microcapsule technology in the beer brewing industry.

To make the system feasible for microbreweries to implement, MECS envisions a tank-swap model. Tanks filled with millions of microcapsules collect carbon dioxide at the brewery and are then taken to a centralized facility to reclaim the absorbed carbon dioxide.

According to a U.S. Department of Energy article, "Low Carbon Capture Technology Keeps Beer Bubbling," (<https://energy.gov/eere/articles/lab-carbon-capture-technology-keeps-beer-bubbling>), if the technology is successful, the process could potentially save breweries



tens of thousands of dollars a year and prevent millions of pounds of CO₂ produced during fermentation from escaping into the atmosphere.

Solution

This national lab technology, initially designed to capture carbon from power plants, uses microcapsules made of gas-permeable polymer shells. Those shells contain the base ingredient (sodium carbonate) to better absorb and react with carbon dioxide. The microcapsules are then suspended on a mesh structure to allow CO₂ to move in and out of the shells—absorbing carbon dioxide about 10 times faster than encapsulated chemicals.

Where are they now? Post Program Advancements

Awarded the Innovation Development Fund (IDF) from LLNL-IPO to pursue some risk reduction for the beer application.

Won a technology commercialization fund (TCF) from DOE-FE to integrate MECS into a partner company's commercial product for performance enhancement.

Working with UC Davis Enology/Chemical Engineering and Trumer Pils Brewery for experimental validation of using MECS with fermentation gas.

Inventing and optimizing a new capsule mass production tool, called In-air Drop Encapsulation Apparatus (IDEA), which can be used to make MECS and other capsules/particles.



Twistact

Sandia National Laboratories

Pilot

Problem

As wind turbines are being scaled up in size to achieve better economies of scale, direct-drive wind turbine technology is being adopted by the wind industry to eliminate gearbox lifetime limitations. However, the rare-earth magnets used in these permanent-magnet rotor assemblies of direct-drive wind turbines present two challenges: high initial cost and the supply chain uncertainties of reliance on rare earth metals. Rare earth metals such as neodymium and dysprosium have always been in short supply, and competing applications like electric vehicles are increasing demand. The unpredictability of the future rare earth supply chain is a hindrance to large-scale proliferation of wind power because it increases risk to investor return on investment. Moreover, the mining of rare earth metals is notorious for its adverse environmental impact.

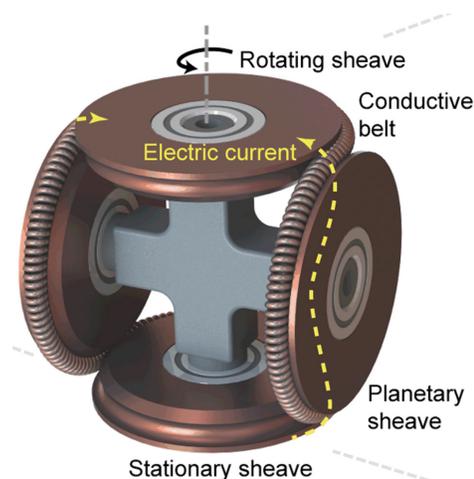
In addition, conventional brush/slip ring technology faces two limitations: (1) short operating lifetime due to sliding-contact wear, and (2) electrical arcing associated with contact bounce. Addressing these two issues, along with eliminating the need for rare earth metals, will allow wider adoption of renewable wind technology.

Solution

Sandia's Twistact technology provides a solution both to high-maintenance brush/slip ring assemblies and rare-earth-metal-dependent wind turbines. Twistact technology comprises a pure-rolling-contact device that transmits electrical current between a stationary and rotating frame (or two rotating assemblies having different speeds and/or direction of rotation) along an ultra-low resistance path (e.g., 1 milliohm). Twistact devices accomplish pure-rolling-contact galvanic connection using a flexible, electrically conductive belt and a matching set of epicyclic sheaves. Laboratory testing has proven that a single Twistact device will be capable of operating over the full 30-year service time of a multi-megawatt direct-drive wind turbine without maintenance or replacement.

Market Focus

- Wind turbines
- Synchronous motors and generators
- Doubly-fed induction generators



- Electrified railways
- Radar towers
- Grounding of rotating assemblies (e.g., lighting protection)
- Brush/slip ring replacement in existing applications

Having completed all of the milestones of its six-year R&D program on Twistact technology, Sandia is now ready to work with generator OEMs to assist with the transfer of Twistact technology into next-generation direct-drive wind turbines. Sandia is also open to partnering on the development of high-rpm Twistact technology for applications such as electric vehicles or doubly-fed induction generators.

Where are they now? Post Program Advancements

Patents and Licensing: US Pat. No.: 8,585,413

Industry Engagements, etc.:

- TechConnect World 2019, Boston, MA June 17-19, 2019
- ARPA-E Energy Innovation Summit; Denver, CO July 8-10, 2019
- 26th Rio Grande Symposium on Advanced Materials in Albuquerque, NM from Oct. 5-6, 2014

Twistact Technology: Enabling More Efficient Large-Scale Wind Turbines. Salzbrenner, Bradley; Argibay, Nicolas; Koplow, Jeffrey P.; Dugger, Michael Thomas; Boyce, Brad; Staats, Wayne Lawrence; Nation, Brendan Laverne; Babuska, Tomas Farley; Vanness, Justin William; Smith, Kent S.; & Matthew, Ned Daniel.

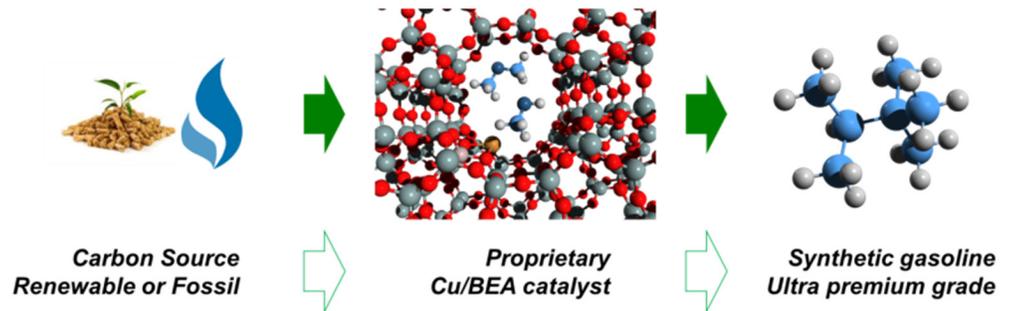
Articles: [Twistact IP Fact Sheet](#)

For more information or speaking engagements, contact Jeff Koplow, jkoplow@sandia.gov.



CuB Fuels

National Renewable Energy Laboratory
Cohort 5



Problem

Mid-sized automotive fuel refiners can have difficulty meeting regulatory mandates while making a profit. By using the high-octane CuB Fuels product, those refiners can increase net revenues by more than \$60 million/year. The CuB Fuels product allows refiners to:

- Produce more premium-grade fuel to address growing demand
- Blend-up lower grades to salable products
- Increase efficiency of reformer operation
- Reduce the volume of crude oil purchased.

All of this is possible while still meeting regulatory mandates (RFS, LCFS, CARB) with cellulosic biofuel RINs.

Focus

CuB Fuels is seeking strategic partnerships and co-operative R&D through:

- Methanol producers targeting the U.S. fuel market and looking to increase demand and value of their product
- Syngas producers targeting a high-value product from gas-to-liquids technology
- Renewable feedstock providers (bio-methanol, bio-syngas, bio-gas) looking to capitalize on RINs with a non-oxygenate product
- Refiners seeking a low- or no-capital source of high-value octane, and those looking to meet regulatory volume mandates
- Automotive OEMs looking to leverage high-octane gasoline to meet CAFÉ standards.

Solution

CuB Fuels enables automotive manufacturers and oil refineries to improve fuel economy and meet regulatory mandates while increasing their gross profits through a proprietary catalyst technology that produces a high-octane synthetic gasoline blendstock from domestic resources.

Where are they now? Post Program Advancements

The CuB Fuels team has continued to develop the commercialization plan around their high-octane gasoline blendstock by:

- Meeting with a natural gas company looking for a project in Canada and visits to major refiners and catalyst producers to discuss potential partnerships
- Performing a technology demonstration at the pilot scale with partner Enerkem
- Purifying high-octane gasoline samples and sending to a major auto manufacturer, an aviation gasoline producer, and an aviation gasoline blender for testing as high-performance race and aviation fuel
- Formalizing plans to partner with a multinational energy company to conduct a demonstration to produce 5000 gallons of high-octane gasoline.



EcoSnap

The first window AC without the window

National Renewable Energy Laboratory

Cohort 1

Problem

EcoSnap is an R&D 100 Award winning room cooling and heating solution that addresses the major drawbacks of room air conditioners and heat pumps. It uses proven technology in combination with novel engineering to provide convenient and local space conditioning in a low-cost, easy-to-install package. EcoSnap does this without requiring the use of windows, virtually eliminating interior noise, improving energy efficiency and home security while decreasing cooling and heating loads.

Focus



Minisplit heat pump with EcoSnap integrated joining system and EcoSnap integrated connection system.

Benefits over existing room AC products:

- Window views
- Higher efficiency
- Reduced noise
- More secure
- Install anywhere on exterior walls
- No need to remove seasonally
- DIY installation—saves time and money
- Fewer greenhouse gas emissions

Solution

The EcoSnap joining system reduces installation time from several hours for a minisplit heat pump system to several minutes for an EcoSnap system. EcoSnap's patent-pending design focuses on the tight integration of the indoor and outdoor sections allowing for a tool-less, weathertight, fast installation after a single hole is drilled in an exterior wall.



Where are they now? Post Program Advancements

Technical development

- Awarded Colorado Advanced Industries Grant for industrial design and product development
- Awarded project with major utility for performance characterization in their service territory.

Licensing

- Active discussions with multiple interested organizations
- In negotiations for full license for multinational commercialization
- Developing advanced prototypes for initial field trials
- In discussion with an energy efficiency agency about funding for a field demonstration.

Articles

- R&D 100 Award winner
<https://www.rd100conference.com/awards/winners-finalists/6131/ecosnap-ac-heat-pump-system/>
- U.S. Department of Energy Amped Up! Magazine
<https://energy.gov/eere/ampedup/articles/new-easy-install-air-conditioning-unit-frees-window-space-snap>
- National Lab Impact Summit
https://www.energy.gov/sites/prod/files/2016/05/f31/DOE_EERE_Lab%20Impact%20Summit_Packet_FINAL%20FOR%20PRINTING%204-27-16-wdoe-JF-web150.pdf

For more information or speaking engagements, contact co-inventors Chuck Booten (chuck.booten@nrel.gov) and Jon Winkler (jon.winkler@nrel.gov).



General Line Ampacity State Solver (GLASS)

Idaho National Laboratory

Cohort 3

Problem

The nation's electrical grid, which until recently was overbuilt and operated under relatively static principles for more than 100 years, is in the middle of a dramatic transformation. The biggest developments have been communication throughput and computing capacity and the integration of renewable energy resources and reduction in nuclear and coal generation. As utilities consider large investments in replacing aging infrastructure and incorporate renewables from remote locations, unlocking extra capacity within existing transmission lines is likely to offer huge advantages in immediate and cost-effective transformation that shore up grid efficiency and reliability.

Focus

Power transfer capacity is affected by three main elements: stability, voltage limits, and thermal ratings. All three are critical, but thermal ratings represent the greatest opportunity to quickly, reliably, and economically improve the grid's capacity.

Static Line Ratings (SLRs) are based on a fixed set of conservative environmental conditions to establish a limit on the amount of current that lines can safely carry without overheating. Dynamic Line Ratings (DLRs) inform system planners and grid operators of available transmission capacity beyond traditionally calculated SLRs.

Accurate and reliable real-time and forecast information about network-wide conductor temperature has been difficult to obtain. The dynamics in power lines make comprehensive predictive mathematical models nearly impossible. Conductor cooling varies with wind speed, direction, ambient air temperature, and solar radiation exposure. All of these must be factored in for operators to quickly and safely make decisions about limiting power flow to avoid inconveniencing customers and forgoing revenue.

Solution

INL's GLASS innovation offers the potential to safely provide more robust line ampacities by using real-time information rather than overly conservative SLRs. It uses commercially available weather monitors mounted on industry-informed brackets developed by INL, in combination with Computational Fluid Dynamics-enhanced weather analysis and DLR software.



Where are they now? Post Program Advancements

Through the customer discovery process and nearly 200 interviews throughout the industry, INL researchers have:

- Collaborated with Idaho Power Company to fully instrument two test beds with weather stations and line rating software.
- Executed one cooperative research and development agreement (CRADA) and initiated another with WindSim AS.
- Completed one CRADA with AltaLink LLC, Alberta, Canada's largest regulated electric transmission company, on a field study of four transmission line segments.
- GLASS was named a finalist for the 2017 R&D 100 Awards.
- INL was awarded a Technology Commercialization Fund award from the U.S. Department of Energy Office of Technology Transfer, and will be in collaboration with one industry partner for fiscal years 2018 and 2019.

Speaking Engagements: Presenters from INL have engaged in more than 25 speaking opportunities in more than 5 countries.

Licensing: INL has recently executed one license agreement with an industry partner for the use of GLASS.

Articles: "Transmission line ampacity improvements of AltaLink wind plant overhead tie-lines using weather-based dynamic line rating" by Bishnu P. Bhattarai, Jake P. Gentle, Porter Hill, Tim McJunkin, Kurt S. Myers, Alex Abboud, Rodger Renwick, and David Hengst presented at IEEE PES GM 2017.

Video: <https://youtu.be/X8laVYN6tUw>

For more information or speaking engagements, contact Jake Gentle at (208) 526-1753 or jake.gentle@inl.gov.



Nitrilica

Enabling automotive carbon fiber through cleaner, cost advantaged chemistry

National Renewable Energy Laboratory

Cohort 5

Problem

Replacing steel and aluminum components in automobiles with lightweight carbon fiber composites would have great benefits to society. For example, using existing engine technology, carbon fiber components would enable the average car to see a 20%–40% reduction in greenhouse gas emissions and fuel economy > 50 mpg, and for electric vehicles a range over 300 miles per charge becomes easily achievable. However, in order for lightweight carbon fiber composites to see widespread application in automobiles, the price of carbon fiber needs to be around \$4/lb. Today the price of carbon fiber is around \$6–\$8/lb with 51% of manufacturing cost dominated by the cost of the base chemical acrylonitrile (AN). Thus, in order to lower the price of carbon fiber, cost advantaged routes to acrylonitrile are key to achieving widespread use of carbon fiber composites.

Focus

The average carbon fiber manufacturer focus:

- Purchases ~50 ktons of AN per year totaling ~80 million USD per year.
- Requires 2 lbs of AN to produce 1 lb of carbon fiber making the manufacturer extraordinarily price sensitive to AN.
- AN accounts for 51% of the manufacturing cost of carbon fiber.
- AN prices < \$0.50/lb (today AN is ~\$0.70/lb) are needed to enable carbon fiber price points < \$5/lb.
- Would like to be vertically integrated owning acrylonitrile production capability.



Solution

The conventional petrochemical route produces acrylonitrile from two ingredients, propylene and ammonia. Propylene is a somewhat volatile and expensive chemical that is not helped by the shale gas boom. Thus, the price of acrylonitrile tracks the fluctuation in the price of propylene. Carbon fiber manufacturers need the price of AN to be lower <\$0.50/lb and less volatile to realize carbon fiber prices below \$5/lb.

Nitrilica, an NREL lab team patented chemistry, allows production of AN from renewable ethanol or petrochemically derived ethylene. Both of these chemicals are cost advantaged, abundant, and price stable compared to propylene. The result of this technology is a cost advantage of ~\$0.24/lb AN over the conventional AN. Purchasing AN from Nitrilica's technology over the conventional chemistry on the spot market would result in a saving of \$30–\$40 million USD per year for the average carbon fiber manufacturer and push carbon fiber prices < \$5/lb. Additionally, the compact skid based design of the chemical processing technology allows carbon fiber manufacturers to purchase their own AN manufacturing capability at the 50 kton/yr scale and the potential to become fully vertically integrated.

Where are they now? Post Program Advancements

Through the customer discovery process and 100 total interviews, Nitrilica:

- Won a 2018 R&D 100 award
- Is pursuing funding through the TCF program
- Is currently raising \$20–\$40k to build robust economic models
- Is partnering with MATRIC to derisk the technology further.



CO₂BOL-NG

Acid Gas Separation Technology

Pacific Northwest
National Laboratory

Cohort 5

Problem

Liquefied natural gas demand is ~400 million metric tonnes per annum (MTA), which is expected to increase to 500 MTA by year 2030. This industry is on the order of billions of dollars per year. Toxic acid gas impurities present in parts per million (ppm) levels cause pipeline corrosion and must be removed from gas streams. Large centralized refineries are used to remove these impurities, requiring millions of gallons of solvent per year and costly units of operation.

Researchers at PNNL have developed a reusable organic liquid that can pull harmful gases such as carbon dioxide or H₂S out of industrial processes, natural gas streams, and emissions from power plants. The process could directly replace current methods and capture double the amount of harmful gases in a way that uses no water, less energy, and saves money.

Focus

Gas producers, natural gas refineries, power plants:

- Costly, large centralized processing facilities
- Hundreds of millions of standard cubic feet a day of gas to treat
- Ppm-level impurities are costly to remove (CO₂, H₂S, COS, H₂O)
- Use millions of gallons of solvents annually to treat
- Acid gases and water-based solvents are highly corrosive.

Solution

Separations of ppm level impurities require strong chemical complexing agents, often liquids for their ease of use. These solvent-based processes often use organic bases dissolved in water, which introduces corrosion and the need for high temperatures to release the impurity to regenerate the solvent. PNNL has developed a technology platform known as carbon dioxide binding organic liquid (CO₂BOLs) that



uses solvents to absorb acid gas impurities such as CO₂ or H₂S for applications such as carbon capture, and acid gas “sweetening” to remove toxic H₂S. CO₂BOLs can capture twice as much gas as conventional solvents and is readily regenerated under mild conditions, requiring lower energy demands. The CO₂BOL platform can be applied to any acid gas, making it the “Swiss Army Knife” of chemical solvents because of the ability to tailor the specific chemistry to the specific gas separation application.

Where are they now? Post Program Advancements

Through the customer discover process and 77 total interviews, CO₂BOL-NG has:

- Licensed the CO₂ capture technology to an engineering firm.
- Received DOE seed money to further develop the solvent platform for purifying synthesis gas.
- Discussed potential follow-on continued R&D with IP-Group.
- Participated in Energy I-Corps Pitch competition in November 2017.

Speaking Engagements:

- Gordon Research Conference, CO₂ capture and conversion. Colby Sawyer College, NH, June 2017.
- Mission Innovation, Carbon Capture Innovation Challenge. Houston, TX, Sept 26–28, 2017.

For more information or speaking engagements, contact David Heldebrant (david.heldebrant@pnnl.gov) or Phillip Koech (phillip.koech@pnnl.gov) or visit www.pnnl.gov.



Quake (MASTODON) A Risk-Based Design Optimization Software for Critical Infrastructure

Idaho National Laboratory

Cohort 2

Problem

The United States infrastructure received a D+ rating in the American Society of Civil Engineers infrastructure report card of 2017. Much of the United States' new and existing critical infrastructure such as dams, levees, bridges, power plants, etc., are located in seismically active areas. They are designed for earthquakes using numerical tools, combined with consensus codes and standards that use experience-based empirical factors to account for uncertainties. There is a lack of rigor in accounting for this uncertainty, which leads to large design conservatisms and therefore inflated capital and maintenance costs, while not necessarily making the structures safer. Over the next 30 years the United States will replace its aging infrastructure. It is important that the most at-risk infrastructure be replaced first, and that the replacement designs be optimized.

Focus

Identify the infrastructure that is most vulnerable to earthquakes. Additionally, optimize new construction so that it is not excessively conservative and overly expensive. The current focus is on dams, nuclear facilities, and nuclear power plants. Seismic costs of new nuclear power plants can exceed 30% of the total overnight capital costs and existing structures can require millions of dollars in periodic maintenance. Capital costs and construction delays have virtually halted the nuclear industry and led to the bankruptcy of one of the largest companies.

Solution

The MASTODON technology is built on sophisticated physical models for soils and structures. It also automates and greatly simplifies risk calculations, and optimizes the design to reduce costs while maintaining required safety margins by keeping the seismic risk below the required threshold level. The risk-based design procedure identifies the most vulnerable parts of the infrastructure system and helps provide the most cost-effective retrofitting solutions like seismic isolation. This enables owners to make decisions on what should be replaced first and reduces overnight



MASTODON

capital costs as well as life-cycle costs by up to 30%. It will also allow owners to strategically use risk mitigation tools such as seismic isolation to further reduce capital and life-cycle costs.

Where are they now? Post Program Advancements

Through the customer discovery process, extended discussions, and research collaborations with owners of critical infrastructure, the QUAKE team has:

- Extended their technology from a risk assessment tool to a risk-based design optimization tool to more directly meet their value proposition: to reduce unnecessary costs while maintaining required safety.
- Filed for a patent on the key technology in the software.
- Been working on an MOU to apply MASTODON to seismic dam analysis and infrastructure decision making.
- Released an open source version of MASTODON.
- Reached out to commercial companies, universities, and international partners to be beta users of MASTODON and provide feedback to improve the code.
- Received \$1,420,000 of technology commercialization funds through a competitive proposal process to develop an analytical optimization process, in MASTODON, for advanced nuclear reactors. The partners are TerraPower, X-energy, and Southern Company.

For more information regarding MASTODON, contact Justin Coleman (justin.coleman@inl.gov) or Chandu Boliseti (chandrakanth.boliseti@inl.gov).



RE-Mag

Idaho National Laboratory

Cohort 5

Problem

The electrification of modern society has resulted in an 8% compound annual growth rate in the rare earth magnet market sector over the past decade, reaching a market value of around \$11 billion USD in 2016. Forces driving expansion of the magnet market include 40% growth rate in the U.S. electric vehicle market, which is approaching 10% of all vehicle sales in the United States, and hard drive magnets used for personal computers and cloud computing infrastructure (cloud data centers) which underpin a \$200 billion USD cloud computing market. Over the next decade it is projected that worldwide demand for rare earth metals used in magnets will exceed supplies; thus making magnet recycling a potentially attractive and lucrative business. With magnet scrap currently valued at \$1.54/Kg, recovery of rare earths from hard drive and electric motor magnets requires efficient and inexpensive recycling technology if the recycle business is to realize profit. Existing rare earth recovery technologies operate at -\$3/Kg - \$6/Kg or higher. Obviously, new and more cost-effective recovery technology is needed.

Focus

RE-Mag (previously known as RE-Light), a team from Idaho National Laboratory, has developed an advanced solvent extraction process that recovers high-value rare earth elements from computer hard drive and electric motor magnets for the following:

- Cloud computing data centers
- Computer hard drive manufacturers
- Electric vehicle motor manufacturers
- Scrap magnet recyclers.

Solution

The RE-Mag process recovers >95% of the rare earth value at a processing cost of less than \$3/Kg.



Where are they now? Post Program Advancements

Intellectual Property

- Non-disclosure agreements with six rare earth element recovery companies. Currently in discussion with industry to gain interest and cost share.
- IP is progressing
- Patent application is moving forward
- Developing new IP related to the metalization of rare earth elements
- Driving process costs even lower by developing a new, low-pressure application that reduces capital equipment expenses by 50%.

Speaking Engagements

- Invited to speak at the Argus Americas Rare Earths Summit
- 5th-International Nuclear Chemistry Congress
- International Chemical Congress of Pacific Basin Societies (Pacifichem)
- Northwest Regional Meeting

Publications

- Baek, D. L.; Fox, R. V.; Case, M. E.; Sinclair, L. K.; Schmidt, A. B.; McIlwain, P. R.; Mincher, B. J.; Wai, C. M., *Ind. Eng. Chem. Res.*, 2016, 55, 7154. DOI: 10.1021/acs.iecr.6b00554
- Sinclair, L.K.; Baek, D.L.; Thompson, J.; Tester, J.W.; Fox, R.V., *J. Supercrit. Fluids*, 2017, 124, 20. DOI:10.1016/j.supflu.2017.01.005
- Case, M. E.; Fox, R. V.; Baek, D. L.; Mincher, B. J.; Wai, C. M., *Solvent Extr. Ion Exc.*, 2017, DOI: 10.1080/07366299.2017.1373984



SonicLQ

The Sonic Leak Quantifier

Argonne National Laboratory

Cohort 1

Problem

Most commercial and residential buildings have air leaks that waste energy and cost owners as much as 30% too much on their utility bills. To solve this problem they hire air leak testers, but the technologies that testers use are currently limited.

Focus

SonicLQ uses sound waves to locate and size air leaks in building walls, doors, and windows.

1. A portable speaker inside the building sends sound waves through the exterior wall.
2. A digital microphone array outside the building listens to the sound coming through the solid wall.
3. The microphone array transmits sound data to a tablet with the SonicLQ app that analyzes the data, locates and sizes any cracks, and overlays them on a photo of the wall.

SonicLQ has several benefits over traditional blower doors and thermal cameras:

- SonicLQ can both locate and size specific leaks allowing testers to recommend prioritized sealing.
- SonicLQ can be used on both commercial and residential buildings of any size.
- SonicLQ can be used on buildings under construction or complete, even when occupied.
- SonicLQ can be used at any time of the year, even when inside and outside temps are similar.

These benefits give air leak testers more useful data and far more opportunities for testing, which allows them to sell more services and save more money for building owners.



Where are they now? Post Program Advancements

- William Shadid, I-Corps Industrial Mentor, has created SonicLQ LLC to commercialize the technology
- Received \$285,000 in follow-on funding from DOE Building Technologies Office for additional R&D and \$1,050,000 in follow-on funding from DoD ESTCP/SERDP program for demonstration and testing on DoD sites
- Chicago Innovation Mentors Program
- Invited to several pitch competitions including DOE Lab Accelerator (Sept. 2017); USG-Illinois Corporate Startup Challenge (Nov. 2016); and Clean Energy Trust (April 2016)
- Speaking Engagements: IP Group-Argonne Investment Meetings; Bosch-Argonne Technology Exchange Day; North American Insulation Manufacturer Association (NAIMA); follow-up speaking engagement at USG; pitch at DOE-NYSERDA Laboratory-Investor Knowledge Series; and invited to present at Chicago Innovation Mentors.
- Patents and Licensing: Patent Pending

Articles:

- <http://www.greenbuildingadvisor.com/blogs/dept/building-science/sonicq-reconnecting-acoustics-and-airtightness>
- <http://www.chicagotribune.com/bluesky/originals/ct-sonicq-financing-bsi-20160328-story.html>
- <http://www.constructrr.com/ep8/>
- <https://www.anl.gov/articles/shark-tank-argonne-scientists>

For more information or speaking engagements, contact Dr. Ralph T. Muehleisen (rmuehleisen@anl.gov).



SwitchGlaze

The window solar panel that responds to sunlight by dynamically switching color

National Renewable Energy Laboratory
Cohort 3



Problem

Buildings account for ~75% of electricity use in the United States. Current trends in commercial building design are toward all-glass facades, which place aesthetics and interaction with the external environment ahead of energy efficiency. Dynamic glass shows promise as an exciting solution to this issue by mitigating solar heat gain during times of high solar glare while allowing high visual clarity and light transmittance during other times. However, the return on investment for current dynamic glass technology is too high for widespread adoption.

Focus

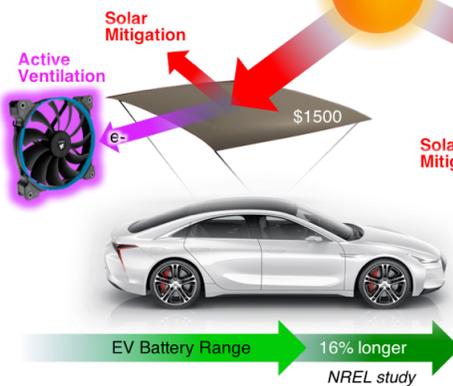
Residential Skylights

Retrofit without wiring
Power sensors/lighting



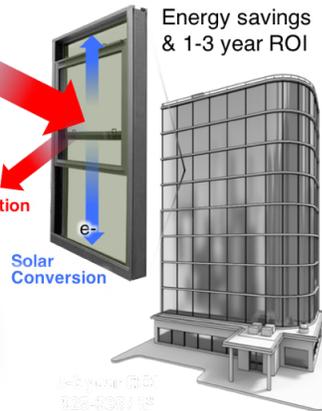
Automotive Roofs

Enhanced Range & comfort



Commercial buildings

Energy savings & 1-3 year ROI



Where are they now? Post Program Advancements

- Received \$2.25 million in funding from EERE Buildings Technologies Office in recent lab call FOA award.
- Received \$50,000 in strategic funding from the U.S. Department of Energy to address technological barriers identified during Energy I-Corps customer discovery process.
- Teamed up with commercial partners for fabrication and scale-up of prototype products.
- Proof-of-concept paper accepted for publication in high-impact scientific journal.
- To be featured in Annual issue of Innovative Energy Review Magazine.
- Invited to pitch at NREL's Innovations Showcase and at Pitch! Energy Competition.

Solution

SwitchGlaze couples the energy savings of dynamic glass with solar energy generation. The technology is poised for immediate impact in skylight retrofits by saving consumers the construction cost of tearing out walls for wiring and enabling integrated designs where SwitchGlaze powers a CPU that controls rain sensors, motors to open/close the window, and powers internal LED lighting. Low-cost production and energy generation in SwitchGlaze technology dramatically reduces the return on investment of dynamic glazing to 1 to 3 years, enabling practical deployment in commercial buildings and automotive industries.



AMAFT

Additive Manufacturing as an Alternative Fabrication Technique for Nuclear Fuel

Idaho National Laboratory

Cohort 5

Problem

As the nuclear industry strives to improve passive safety features of nuclear power plants, there is a growing interest in safer and improved-performance nuclear fuels.

Traditional fuel-manufacturing methods require several steps to convert raw uranium (U) ore into uranium hexafluoride (UF₆), and then into the UO₂ is used in light water reactors.

Focus

Both nuclear fuel fabricators (e.g., Westinghouse Engineering, Babcock and Wilcox Technologies) and end users (e.g., LWR commercial market, special fuel-production users) will benefit from additive manufacturing as an alternative fabrication technique (AMAFT) technology:

- Fuel fabricator: reduce cost of nuclear fuel for fabricators (Westinghouse) from \$50/kg U to \$40/kg U.
- End-user receives benefits from fuel efficiency, and reduced capital and operating costs.
- Cost structure: qualification costs, inspection tools, capital and operating costs, licensing, waste handling, and training.

Solution

AMAFT will decrease the number of fabrication steps and eliminate metallic U as a feedstock material. Fabrication yield will increase use of the direct AMAFT approach, also contributing to a more economical process. By the direct AMAFT synthesis of U₃Si₂ fuel pellets using other forms of U (e.g., UF₄, uranium tetrafluoride), it is envisaged that the use of U metal can be avoided and a commercially feasible fabrication process can be delivered.

In traditional manufacturing, changes to pellet design require new tooling and fabrication process parameters. Changes to design parameters for AMAFT pellets can be made quickly, allowing for rapid-prototyping and testing, enabling a shorter time-to-market. Additionally, the successful deployment of this technology will result in the significant use of other U waste products or interim U-based products, which will result in a beneficial environmental effect as well.



Where are they now? Post Program Advancements

Through the customer discovery process, AMAFT has:

- Continued work on technology maturity funded through a Topic 1 Technology Commercialization Fund (TCF) awarded 2016
- Completed 76 industry interviews
- Obtained additional funding from industry partner (Westinghouse) to continue with research (April to August 2019)
- Highlighted other products that are now being further explored.

Speaking Engagements:

- CAES Materials Initiative Working Meeting, 2017
- Advanced Manufacturing and Supply Chain Innovation Nuclear Energy Leadership Summit and Showcase, 2017
- Guest lecture to Ph.D. students at University of Idaho, 2017
- NRC Additive Manufacturing for Reactor Materials & Components, North Bethesda, MD, 2017
- Accelerated Certification of Additively Manufactured Materials, Lawrence Livermore National Laboratory, 2018
- Discussions on Collaboration Opportunities with LLNL & Idaho State University in 2019, and Ohio State University, 2019

Licensing/Patent:

- U.S. Patent App 15/908,505, filed on March 1, 2018; I.J. van Rooyen, C.J. Parga

Publications:

- INL's Nuclear Science and Technology communications, 2017, <https://www.inl.gov/article/industry-laboratory-team/>.
- J. Rosales, I. van Rooyen, and C. Parga, American Nuclear Society Winter Conference 2017
- J. Rosales, I. J van Rooyen, S. Meher, R. Hoggan, C. Parga, and J. Harp, Journal of Materials
- Ph.D. thesis, J. Rosales, Nuclear Engineering Sciences, University of Florida, April 2018
- Rosales, J., I. J van Rooyen, C. Parga, Journal of Nuclear Materials, 2019

For more information or speaking engagements, contact the Inventor and Principal Investigator, Isabella van Rooyen at Isabella.vanrooyen@inl.gov or Technology Manager, Art Baker at arthurbaker2@inl.gov.



STARS Technology Corporation (STC): A Pacific Northwest National Laboratory Spinout/Startup

Pacific Northwest National
Laboratory

Cohort 1

Problem

In recent years, California sought to reduce its statewide greenhouse gas emissions to 1990 values. This effort appears to be successful as California expects to reach this goal by 2020. However, California has recently imposed a more stringent goal: to achieve another 40% reduction in greenhouse gas emissions by 2030. This will require a much more aggressive approach, and major changes to capital infrastructure.

Focus

STC's opportunity is enhanced by the inclusion of Southern California Gas as a strategic partner and launch customer that plans to propose a major capital project demonstration of the Solar Thermochemical Advanced Reaction System (STARS) technology in their service territory.

The opportunity is defined by increasing demand for affordable, renewable fuels and chemicals; in particular, low-carbon hydrogen (H_2) and methanol (CH_3OH). STC's near-term business opportunity is to provide advanced thermochemical hardware—unavailable elsewhere—that produces hydrogen and/or methanol, at competitive costs but with much lower CO_2 emissions than traditional sources.

Solution

STC is an advanced chemical process technology company providing economical low-carbon fuel and chemical solutions. STC's launch product is low-cost, low-carbon hydrogen supplying a \$150 billion+ annual worldwide market.

STC has licensed STARS™ intellectual property from the U. S. Department of Energy and Battelle Memorial Institute, the operator of PNNL. STC will establish the value chain associated with the manufacturing of STARS components, assembly of STARS systems, and delivery and assembly of STARS hardware. STC will partner with manufacturing entities where appropriate, or alternately establish dedicated manufacturing facilities as needed.



Principal Investigator Bob Wegeng was an invited presenter at the NREL Industry Growth Forum in 2019.

The core product is the STARS™ system—a very efficient, micro- and meso-channel, process intensive thermochemical reactor module that readily enables renewable energy integration/augmentation to cost effectively produce low-carbon fuels and chemicals. Low-carbon hydrogen is the launch product to be closely followed by carbon-neutral hydrogen in combination with methanol, and ultimately by “fuel from thin air” by capturing and utilizing atmospheric CO_2 as a feedstock.

Where are they now? Post Program Advancements

- \$8 million+ from federal funding sources and strategic partners
- Demonstrated TRL 6 system in Southern California in collaboration with SoCalGas Company
- Received an R&D 100 Award (November 2014)
- Featured in March 2018 article in CEP Magazine (the American Institute of Chemical Engineers): “Realize the Potential of Process Intensification”
- Invited speaker at the 2019 NREL Industry Growth Forum•



Case Studies

Electro-Active Technologies

Oak Ridge National Laboratory
Cohort 7

Problem

Forty percent of food is wasted today, which is both a huge problem and a huge opportunity. Meanwhile, the high cost of hydrogen and lack of renewable sources is restricting growth of zero-emission fuel cells. Our system provides a solution to both of these issues, converting waste into affordable, renewable hydrogen. Our technology can reduce greenhouse gas (GHG) emissions by 66% compared to SMR, while achieving twice the electrical efficiency of water electrolysis. It is a pathway to the sustainable economy of the 21st century.

Focus

Enabling hydrogen-fueled:

- Forklifts
- Class 8 trucks
- Generators
- Personal vehicles
- City fleets
- Maritime applications

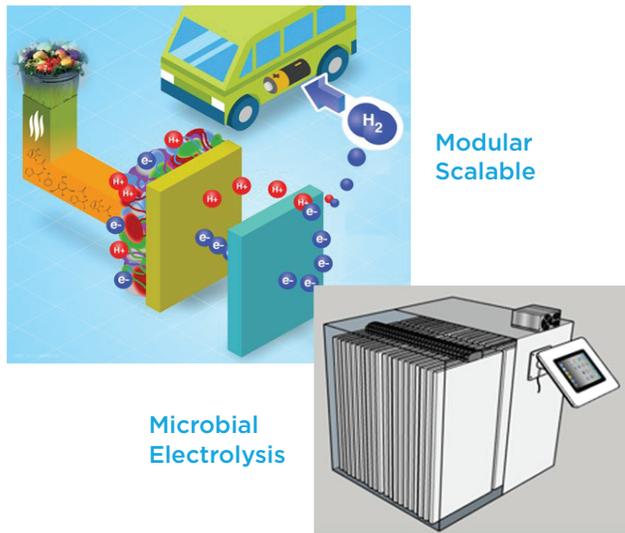
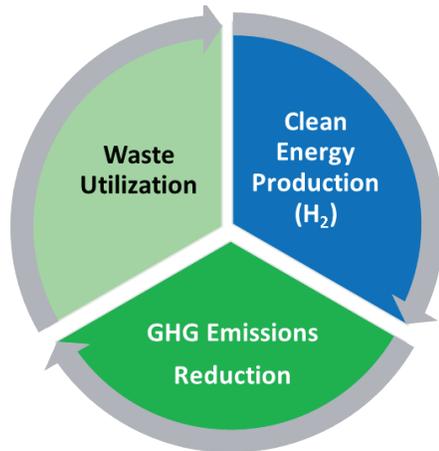
Solution

Key offerings:

e-H2Gen: Renewable hydrogen generation system using organic waste, adaptable to low- and high-volume customers.

e-active C: Soil co-products for sustainable agriculture and a circular food value chain.

Electro-Active integrates biology, electrochemistry, and engineering in these multidisciplinary applications. Through our expertise in these areas, while working with industry, we are bringing the next generation of clean energy and ag technologies to market.



“This technology can help bring together the different aspects of hydrogen creation and consumption across agriculture, waste management, transportation, renewables, microgrids, grid services, etc.”

-CAISO

Where are they now? Post Program Advancements

Accepted into the H2 Refuel Accelerator, a collaboration between the Urban Future Lab, Greentown Labs and the Fraunhofer TechBridge Program, sponsored by Shell, Toyota and NYSERDA.

For more information, contact Abhijeet P. Borole at aborole@electroactive.tech or alewis@electroactive.tech or visit www.electroactive.tech.



Gamma Rayality

Lawrence Berkeley
National Laboratory
Cohort 6

Problem

Specialized equipment is required to identify and locate radiological/nuclear material, and map contamination. Many available commercial systems are static, employ manual location-triangulation methods that are error prone, require a human to hold and operate the system, and lack contextual sensors (such as visual cameras or LiDAR) which provide environmental information about an area of interest. As a result, users of these systems typically need to take multiple measurements of an area for tens of minutes at a time and track the location of the system manually, risking longer exposure to radioactive material, and are limited to ground measurements.

Focus

This technology has applications in defense, nuclear power plant decontamination and decommissioning, emergency response and homeland security, and international nuclear safeguards.

Solution

The Localization and Mapping Platform (LAMP) is a lightweight, compact, contextual sensor package that integrates off-the-shelf components (e.g., visual camera, LiDAR, GPS, etc.) and Scene Data Fusion software to visualize radioactive and nuclear sources in 3D and in real-time. The Scene Data Fusion software on LAMP fuses radiation data with 3D models of an area to show the location of radiological/nuclear material and map radioactive contamination. Development of this technology is supported by the Defense Threat Reduction Agency.

LAMP is designed to be modular, allowing it to integrate seamlessly with a wide range of radiation detectors, including laboratory prototypes and commercial systems, and can also be deployed in a handheld configuration or on manned or unmanned ground and aerial vehicles. This enables the customer to tailor the LAMP system configuration to meet mission needs.

LAMP can significantly enhance traditional radiation detection systems by enabling:

- Faster and more efficient operations: LAMP enables free-moving source localization and mapping (meaning a person or robot can continuously move through the environment with it) and provides a real-time map of the area of interest.



- Improved situational awareness: LAMP enables visualization of radiological/nuclear material in 3D, which provides greater detail about the size, location, and other characteristics of a radioactive source.
- Configuration customization and safer operation: LAMP is both platform- and detector-adaptable, meaning it can be integrated with a wide range of radiation detectors (including laboratory prototype and commercial radiation detectors) and on various deployment platforms, including unmanned and manned ground or aerial platforms.

Several different configurations of LAMP, including versions integrated with commercial radiation detectors, have been successfully demonstrated in real-world environments, including in Fukushima Prefecture, Japan, and the Chernobyl Exclusion Zone, Ukraine, to map radioactive contamination.

Where are they now? Post Program Advancements

Additional funding/awards

- August 2018: Awarded \$2.6 million, two-year projects to LBNL research program by Defense Threat Reduction Agency (DTRA) to continue developing technology
- November 2017: Second Place, inaugural LBNL IPO Pitch Competition (\$2500 award for continued customer discovery)
- 8 speaking engagements
- 10 demonstrations to potential end users.

Publications:

- R. Pavlovsky, A. Haefner, T.H. Joshi, V. Negut, K. McManus, E. Suzuki, R. Barnowski, K. Vetter, "3D Radiation Mapping in Real-time with the Localization and Mapping Platform (LAMP) from Unmanned Aerial Systems and Man-Portable Configurations," arXiv: 1901.05038. (2018)
- A. Haefner, et. al., "3D Gamma-ray Mapping from Unmanned Aerial Systems for Nuclear Decommissioning," Proceedings of the 2018 Waste Management Symposium, March 18-27, 2018, Phoenix, Arizona.
- A. Haefner, et. al. "3D Mapping and Visualization of Radioactive Sources for Nuclear Safeguards Applications." Symposium on International Safeguards: Building Future Safeguards Capabilities, International Atomic Energy Agency. November 5-8, 2018.



High Temperature Irradiation Resistant Thermocouple (HTIR-TC)

Idaho National Laboratory

Cohort 7

Problem

Nuclear reactors designs are embracing new developments such as utilizing process heat for advanced manufacturing, hydrogen production and desalination—all while maintaining a low carbon footprint. The critical temperatures necessary to drive each of these concepts, such as those within the protective fuel cladding, need to be measured directly, accurately and reliably. However, to date, there is no direct method of sustainably measure the temperatures of nuclear fuel.

Between now and 2030, new reactors from at least three private companies are expected to come online, operating at lower pressures but much higher temperatures than those in traditional light and pressurized water reactors. These new reactor designs offer even safer and more economical power production, but will require new fuels, cladding, and structural materials.

Reactor engineers will need detailed data to characterize fuels and materials in extreme conditions, and the Nuclear Regulatory Commission (NRC) will require exact and exhaustive test data before certifying that they're safe to use. Also, once in operation, to maintain the safety and long-term reliability of these reactors, new temperature sensors and methods for in-situ measurements will be necessary.

Focus

With temperatures exceeding 1100°C while in the presence of neutrons bombarding materials to their absolute limit, radiation tolerant and/or hardened materials must be utilized to prevent the signal drift (or de-calibration) of instruments. Further, the constant shutdown and restarting of nuclear reactors for refueling or reactor tests puts sensors through large temperature transients leading to breakage of wires as repetitive thermal expansion can not keep up with the demand.

Solution

HTIR-TCs are sophisticated thermocouples developed at the Idaho National Laboratory's (INL) High Temperature Test Laboratory (HTTL) that measures temperature in the world's most drastic environments. The HTIR-TC has been experimentally proven to withstand temperatures up to 1510°C and neutron flux levels ten times (10X) that of a typical commercial pressurized water reactor. This experiment is still on-going at the time of this note, but over the past year the HTIR-TCs present have shown very little signal drift. Further, reactor shutdowns and restarts have put the HTIR-TCs through the most extreme temperature transients—to no avail, the HTIR-TCs keep reporting reliable and consistent temperatures.



Where are they now? Post Program Advancements

Through the customer discovery process, INL researchers have:

- Been awarded a Technology Commercialization Fund (TCF) with Idaho Laboratories Corporation (ILC) through the U.S. Department of Energy Office of Technology Transfer
- Been awarded an US-EURATOM International Nuclear Energy Research Initiative (I-NERI) to work internationally with University of Cambridge's Department of Materials Science and Metallurgy to discuss the direct application of HTIR-TCs on Gen IV reactor designs
- Collaborated with Boise State University's (BSU) Micron School of Materials Science and Engineering over the past two years to continually improve upon the HTIR-TCs past performance
- Licensed HTIR-TCs with an industry partner.

Video:

- <https://www.youtube.com/watch?v=L4gtwJsKkX4>

Article:

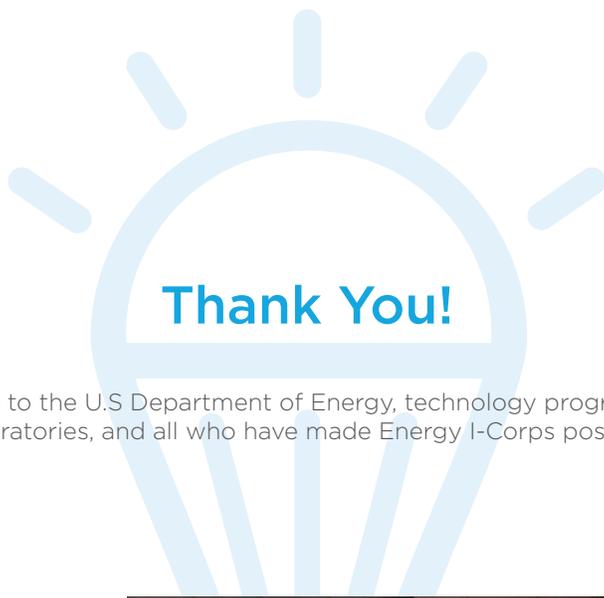
- New breakthroughs in high temperature measurement technology
- US Department of Energy Science News
- <https://www.eurekalert.org/features/doe/2019-04/dnl-nbi040819.php>

Speaking Engagements:

- Development and Testing of Thermocouples for the Advanced Gas Reactor Fuel Experiment AGR-5/6/7, A. J. Palmer, R. S. Skifton, D. C. Haggard, W. D. Swank (INL), M. Scervini (Univ of Cambridge)
- Summary of High Temperature Irradiation Resistant Thermocouple Standardization Tests, Richard S. Skifton, Joe Palmer, Kurt Davis, Patrick Calderoni (INL), Ember Sikorski (Boise State Univ), Doug Corbett (Idaho Laboratories Corp.)

For more information or speaking engagements, contact the Inventor and Principal Investigator, Richard Skifton at Richard.Skifton@inl.gov or 208.526.2696.





Thank You!

Thank you to the U.S Department of Energy, technology program offices, laboratories, and all who have made Energy I-Corps possible.

“Energy I-Corps helped me learn pretty quickly that people will talk to you if you just pick up the phone... you shouldn’t be afraid to ask questions, whether it be from lab techs or CEOs. Through these interviews, we gained three new collaborators, and the eye of a venture capitalist firm that may be interested in co-developing our technology.”

David Heldebrandt
Cohort 5, CO₂BOL-NG



“Energy I-Corps taught me to engage industry and understand their needs BEFORE starting research so everything is aligned with genuine demand.”

Phillip Koech
Cohort 5, CO₂BOL-NG





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