Annual Report | December 2020

ENERGY I-CORPS
U.S. Department Of Energy

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 the public benefit on this significant R&D investment.

This program, now in its sixth year, has engendered a new way of thinking about commercialization and the transition of emergent technologies toward the marketplace. Each year of Energy I-Corps has seen the birth of new companies, the signing of new licenses, and additional private investment in DOE-powered innovations.

Energy I-Corps has helped our National Lab community recognize and act on the potentially transformative consequences of their research—for the public good, our economic competitiveness, and our national security. It allows us to fulfill an essential part of the DOE mission, and helps secure our place at the fore of global technological leadership.

As we continually explore new ways to turn research into reality, we invite you to connect with us, discover new opportunities, and partner with this one-of-a-kind research enterprise for many more years to come.

Sincerely,

Conner Prochaska

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

Contents

"ELINA's participation helped us better frame and highlight the uniqueness and value of the technology. Our experience has resulted in three ongoing TCF Topic 2 efforts with three of the main vendors in this market, two patent applications, and one copyright, and participation in an incubator or accelerator program to expand into other markets. The technology developed in one of the TCF efforts will be deployed at one domestic and one international nuclear utility within the next year! We are collaborating with the largest vendor in our market to submit four TCF Topic 2 proposals."

Johanna Oxstrand
Team ELINA
Cohort 6
President of the Energy I-Corps Alumni Association

"Energy I-Corps was one of the best experiences of my life."

Aaron Ptak
Team HALO
Cohort 4

"Energy I-Corps challenged me to think about the problems facing users or stakeholders first, then design research efforts in response, rather than the inverse. This has been invaluable to my career in the National Labs and my effectiveness at identifying the highest priority problems to solve."

Jacob Holden
Team routeE
Cohort 8

"Energy I-Corps taught us how to legitimize our research to the business community, and it has led to fruitful partnerships and a trajectory toward commercialization that simply would not have happened if we had relied on a program office to fund it. In the current research environment, our invention would be dead by now – deemed "yesterday's news" to the science wonks looking for the next great *Science* paper – but thanks to I-Corps, CuB Fuels' technology is still on a path toward market impact."

Jesse Hensley
Team CuB Fuels
Cohort 5

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 (ANL)
Fermi National Accelerator Laboratory (FNAL)
Idaho National Laboratory (INL)
Lawrence Berkeley National Laboratory (LBNL)
Lawrence Livermore National Laboratory (LLNL)
Los Alamos National Laboratory (LANL)
National Renewable Energy Laboratory (NREL)
Oak Ridge National Laboratory (ORNL)
Pacific Northwest National Laboratory (PNNL)
Sandia National Laboratories (SNL)
SLAC National Accelerator Laboratory (SLAC)

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 will have developed important industry connections and insights to better prepare their energy technologies for market acceptance. In addition, they will have established an industry engagement framework applicable to future research.

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 preparing their innovations 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 program 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 September 2020, 111 teams from 11 National Labs have participated in Energy I-Corps over the course of ten 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 and potential partnerships 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.

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

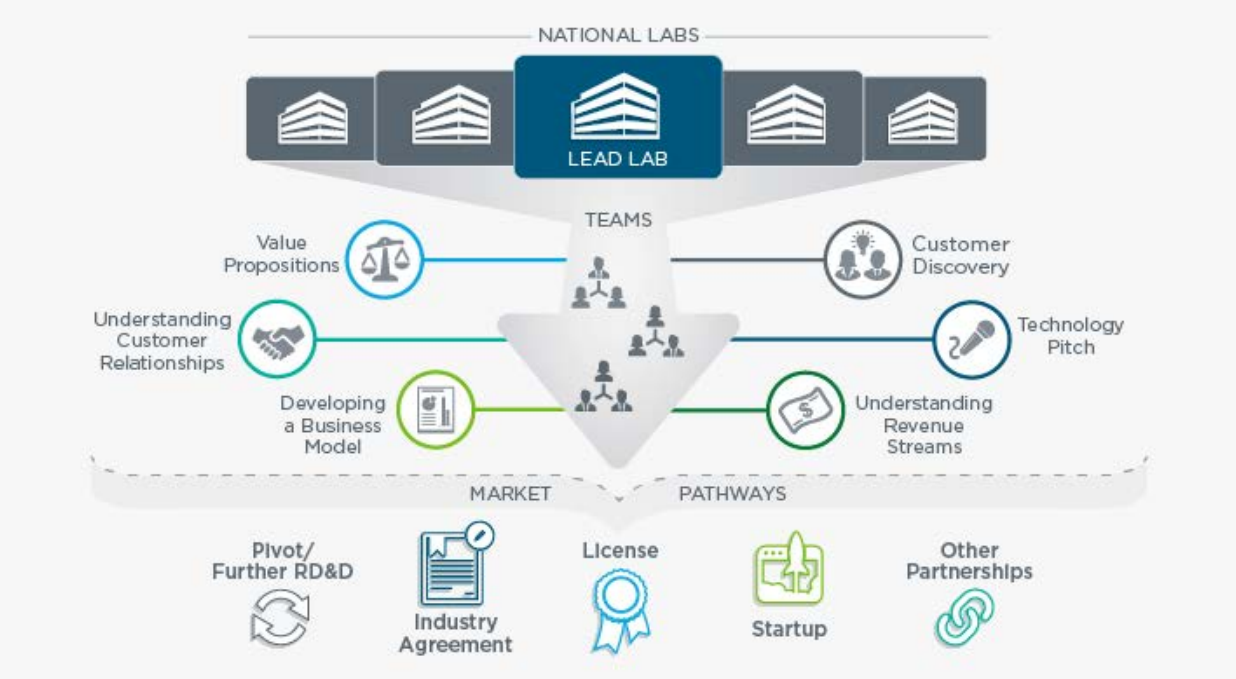
How can I learn more?
Email energyicorps@nrel.gov to learn more about Energy I-Corps and how to get involved.

Energy I-Corps technologies have collectively attracted more than $83 million in post-program funding.

Teams in the program 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.

As of the end of the tenth training session in the fall of 2019, teams have collectively worked with more than 110 industry mentors to discover the commercial impact of their technologies and have conducted more than 7,750 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 opportunities where further development could lead to commercial value.

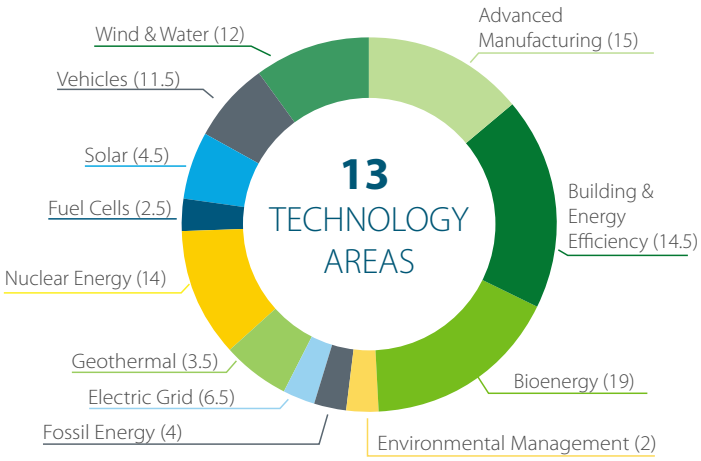
Training Program: The training program spans seven-to-ten weeks, utilizing a custom-designed curriculum built on the Lean LaunchPad methodology. During these seven weeks, teams attend in-person sessions, participate in weekly webinars, and learn from faculty how to systematically identify the most appropriate 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.

Quick Stats

10 COHORTS *of* ENERGY I-CORPS

111 TEAMS | **11** NATIONAL LABORATORIES

BRINGING **ENERGY INNOVATIONS** TO



LEARNING FROM

110+ Industry Mentors

including Hitachi, Lowes, Johns Manville, Lego, U.S. Army, Trane, Tesla, GM, Dow Chemical, Yingli, 3M, Whirlpool, GE, Home Depot, RE/MAX, Amazon, and Shell.

12 New Businesses

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

$83M Post-Program Funding

Because of Energy I-Corps, technologies have reached a point of commercial viability that has attracted more than **$83M in post-program funding**

7,750+ Customer Discovery Interviews

60+ Licenses Executed

Our Team

Shelly Curtiss
Energy I-Corps
Program Manager, NREL

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

Megan Gross
Energy I-Corps
Project Manager, NREL

Steve Christensen
Energy I-Corps
Project Support, NREL

Participation by Technology Program Offices

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

Teams are denoted as half-funded by a technology office, as indicated by (0.5).

Advanced Manufacturing Office (AMO)

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 (.5)	INL	5	56
Re-Light	INL	5	75
Comba	LBNL	7	79
FLO.materials	LBNL	7	78
Laser Sense	ANL	7	74
HyMag (.5)	ANL	8	107
CAN-Coatings	ANL	8	72
Shakti Power Systems	ANL	9	71
C-CHiRP	ANL	10	78
E-Ionsorb	LLNL	10	61

TOTAL TEAMS FUNDED
15

INVESTMENT TOTAL
$1,087,500

POST-PROGRAM FUNDING
$11,004,026

DISCOVERY INTERVIEWS
1,128

Bioenergy Technologies Office (BETO)

Team	Lab	Cohort	Discovery interviews
High-Moisture Pelleting 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 (.5)	ORNL	7	80
Fermley	LBNL	8	81
Ecopod	LBNL	8	77
Embodied Carbon	NREL	9	78
Grab-X	ANL	9	83
CYCLE	NREL	10	86
Scum Ranchers	SNL	10	78

TOTAL TEAMS FUNDED
14.5

INVESTMENT TOTAL
$1,087,494

POST-PROGRAM FUNDING
$2,462,500

DISCOVERY INTERVIEWS
1,153

Building Technologies Office (BTO)

Team	Lab	Cohort	Discovery interviews
VOLTTRON	PNNL	2	5
MAIforBldgs	ORNL	3	74
SwitchGlaze (.5)	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

POST-PROGRAM FUNDING
$3,300,000

DISCOVERY INTERVIEWS
484

Participation by Technology Program Offices

Office of Environmental Management (EM)

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

TOTAL TEAMS FUNDED
2

INVESTMENT TOTAL
$150,000

POST-PROGRAM FUNDING
$6,972,500

DISCOVERY INTERVIEWS
155

Hydrogen and Fuel Cell Technologies Office (HFTO) *Formerly known as Fuel Cells Technology Office (FCTO)*

Team	Lab	Cohort	Discovery Interviews
Polymer Membranes	SNL	2	41
CryoH2	LLNL	4	56
Electro-Active (.5)	ORNL	7	80

TOTAL TEAMS FUNDED
2.5

INVESTMENT TOTAL
$187,500

POST-PROGRAM FUNDING
$1,662,500

DISCOVERY INTERVIEWS
137

Office of Fossil Energy (FE)

Team	Lab	Cohort	Discovery Interviews
MECS	LLNL	4	64
CO2BOLONG	PNNL	5	75
Memzyme	SNL	5	81

TOTAL TEAMS FUNDED
3

INVESTMENT TOTAL
$225,000

POST-PROGRAM FUNDING
$1,780,000

DISCOVERY INTERVIEWS
220

Participation by Technology Program Offices

Geothermal Technologies Office (GTO)

Team	Lab	Cohort	Discovery Interviews
TOUGH	LBNL	2	54
Micro Miners (0.5)	LLNL	3	59
GeoCAES	NREL	4	51
Sandia Technology Systems	SNL	4	40

TOTAL TEAMS FUNDED
3.5

INVESTMENT TOTAL
$262,500

POST-PROGRAM FUNDING
$750,000

DISCOVERY INTERVIEWS
204

Office of Nuclear Energy (NE)

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
Electroplate (.5)	INL	5	56
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
Thermal Sound On	INL	10	73

TOTAL TEAMS FUNDED
13.5

INVESTMENT TOTAL
$1,012,500

POST-PROGRAM FUNDING
$6,673,000

DISCOVERY INTERVIEWS
973

Office of Electricity (OE)

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

POST-PROGRAM FUNDING
$1,645,000

DISCOVERY INTERVIEWS
330

Participation by Technology Program Offices

Solar Energy Technologies Office (SETO)

Team	Lab	Cohort	Discovery Interviews
SolGuard ($30k)	NREL	2	51
Hydro Scanner	LLNL	3	44
HALO	NREL	6	83

TOTAL TEAMS FUNDED
2.5

INVESTMENT TOTAL
$180,000

POST-PROGRAM FUNDING
$28,480,000

DISCOVERY INTERVIEWS
178

Vehicle Technologies Office (VTO)

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
HeadCount	NREL	10	74

TOTAL TEAMS FUNDED
10

INVESTMENT TOTAL
$732,000

POST-PROGRAM FUNDING
$1,978,198

DISCOVERY INTERVIEWS
767

Wind & Water Power Technologies Office (WWPTO)

Team	Lab	Cohort	Discovery Interviews
DLR	INL	3	72
Autonomous Concrete Printing	NREL	4	79
RF Tag	PNNL	4	75
WindSOCK	NREL	5	75

TOTAL TEAMS FUNDED
4

INVESTMENT TOTAL
$300,000

POST-PROGRAM FUNDING
$2,065,000

DISCOVERY INTERVIEWS
301

Participation by Technology Program Offices

Wind Energy Technologies Office (WETO)

Team	Lab	Cohort	Discovery Interviews
HyMag (0.5)	ANL	8	107
SpiderFloat	NREL	8	77
MADe3D	NREL	9	78
SAND	INL	9	77
ThermalTracker-3D	PNNL	9	56

TOTAL TEAMS FUNDED
4.5

INVESTMENT TOTAL
$337,500

POST-PROGRAM FUNDING
$3,620,000

DISCOVERY INTERVIEWS
395

National Nuclear Security Administration (NNSA)

Team	Lab	Cohort	Discovery Interviews
Enduring Advantage	SNL	10	75
UXI	SNL	10	81

TOTAL TEAMS FUNDED
2

INVESTMENT TOTAL
$150,000

POST-PROGRAM FUNDING
$2,280,000

DISCOVERY INTERVIEWS
156

Lab Funded Teams

Team	Lab	Cohort	Discovery Interviews
CI-ReClad	ORNL	1	75
Dynamic Aperture	ANL	1	23
Eco-Snap	NREL	1	45
HYDRA	PNNL	1	40
Sub Lambda	PNNL	1	13
Tunation	ORNL	1	86
WISDEM	NREL	1	80
BioAlchemy	LBNL	2	51
Biolyst Renewables	NREL	2	81
Evodia	LBNL	2	45
Resin Wafer Electrodeionization	ANL	2	75
SolGuard (0.5)	NREL	2	51
SwitchGlaze (0.5)	NREL	3	54
Oleo Sponge	ANL	6	62

TOTAL TEAMS FUNDED
13

INVESTMENT TOTAL
$982,500

POST-PROGRAM FUNDING
$5,525,000

DISCOVERY INTERVIEWS
781

Participation by Technology Program Offices

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

POST-PROGRAM FUNDING
$2,897,000

DISCOVERY INTERVIEWS
606

Privately Funded

Team	Lab	Cohort	Discovery Interviews
Opt-grid	NREL	6	87

TOTAL TEAMS FUNDED
1

INVESTMENT TOTAL
$75,000

POST-PROGRAM FUNDING
$246,861

DISCOVERY INTERVIEWS
87

Office of Technology Transitions

Team	Lab	Cohort	Discovery Interviews
UTS - Ultrasonic Technology Solutions	ORNL	10	76

TOTAL TEAMS FUNDED
1

INVESTMENT TOTAL
$75,000

POST-PROGRAM FUNDING
$1,290,000

DISCOVERY INTERVIEWS
76

Project Funding

Energy I-Corps teams have been funded by the pilot, individual National Laboratories, various DOE offices, and private entities. The data shown below highlight the initial investment from the funding entities to fund the teams to attend the Energy I-Corps program, and the post-program funding those teams have earned.

Technology Office Funding

DOE Funding Office	Investment	Post-Program Funding
AMO	$1,087,500	$11,004,026
BETO	$1,087,494	$2,462,500
BTO	$562,500	$2,150,000
EM	$150,000	$6,972,500
FCTO	$187,500	$1,662,500
FE	$225,000	$1,780,000
GTO	$262,500	$750,000
NNSA	$150,000	$2,280,000
NE	$1,012,500	$6,673,000
OE	$360,000	$1,645,000
SETO	$180,000	$28,480,000
VTO	$732,000	$1,978,198
WWPTO	$300,000	$2,065,000
WETO	$337,500	$3,620,000
OTT	$75,000	$1,290,000
Total	**$6,709,494**	**$74,812,724**

INVESTMENT TOTAL

$8,516,994

POST-PROGRAM FUNDING

$83,481,585

	Investment	Post-Program Funding
Lab Funded	$982,500	$5,525,000
Pilot	$750,000	$2,897,000
Privately Funded	$75,000	$246,861
Total	**$1,807,500**	**$8,668,861**

Laboratory Statistics

Lab	Teams Funded	Initial Investment	Post-Program Funding Received	Customer Discovery Interviews
ANL	17	$1,274,994	$6,403,224	1,195
FNAL	2	$150,000	$950,000	126
INL	23	$1,725,000	$11,589,000	1,671
LANL	1	$75,000	-	71
LBNL	13	$960,000	$12,197,500	919
LLNL	7	$525,000	$3,660,000	347
NREL	24	$1,782,000	$37,781,861	1,793
ORNL	6	$450,000	$3,569,000	436
PNNL	12	$900,000	$4,451,000	710
SNL	8	$600,000	$2,880,000	508
SLAC	1	$75,000	-	27
TOTAL	**111** (+3 pilot teams)	**$8,516,994**	**$83,481,585**	**7,803**

Cohort Statistics

Cohort	Initial Funding	Post-Program Funding	Customer Discovery Interviews
Pilot	$225,000	$250,000*	225
1	$1,050,000	$3,701,000	743
2	$1,050,000	$12,001,224	787
3	$600,000	$3,365,000	475
4	$1,125,000	$32,095,000	937
5	$900,000	$1,248,000	916
6	$600,000	$9,779,361	606
7	$600,000	$10,582,000	636
8	$732,000	$4,345,000	805
9	$884,994	$2,795,000	910
10	$750,000	$3,570,000	763
TOTAL	**$8,516,994**	**$83,481,585**	**7,803**

* Pilot Post-Program funding not included in Total Post-Program Funding.

Project Funding

Team Post-Program Funding

Team Name	Post-Program Funding Received	Funded through Energy I-Corps by:
ARAI	$161,000	Pilot
Eco-Snap	$200,000	NREL
SonicLQ	$285,000	Pilot
STARS	$2,001,000	Pilot
Switchable Polarity Solvents	$450,000	Pilot
Tunation	$154,000	Lab
WISDEM	$450,000	NREL
Biolyst Renewables	$1,520,000	NREL
High-Moisture Pelleting Process	$1,400,000	BETO
Micro Miners	$900,000	AMO/GTO
Resin Wafer Deionization	$1,701,000	ANL
NanoHeatBlock	$1,567,026	AMO
Polymer Membranes	$600,000	HFTO
QUAKE	$1,420,000	NE
Saline Solutions	$1,500,000	AMO
Smart Charge Adapter	$1,393,198	VTO
GLASS	$1,065,000	WWPTO (wind)
SwitchGlaze	$2,300,000	BTO/NREL
MECS	$1,260,000	FE
e-Recov	$280,000	AMO
GeoCAES	$300,000	GTO
Change Detection Systems	$775,000	NE
HALO	$28,480,000	SETO
RF Tag	$1,000,000	WWPTO (water)
EMRLD	$625,000	NE
AMAFT	$103,000	NE
CO2BOLONG	$520,000	FE
Gamma Rayality	$6,022,500	EM
Opt-grid	$246,861	IP Group (Private)
4Cs	$1,500,000	NE

Project Funding

Team Post-Program Funding *(continued)*

Team Name	Post-Program Funding Received	Funded through Energy I-Corps by:
ELINA	$1,650,000	NE
DCAT	$10,000	OE
Oleo Sponge	$350,000	ANL
PureBeam	$950,000	EM
HOT	$600,000	NE
Electro-Active	$2,125,000	HFTO/BETO
COMBA	$3,600,000	AMO
LaserSense	$807,000	AMO
FLO.materials	$2,500,000	AMO
CAN-Coatings	$300,000	AMO
Glass Paper	$1,560,000	OE
routeE	$585,000	VTO
SpiderFloat	$1,900,000	WETO
Amber LEDs	$1,000,000	BTO
EcoBlock	$75,000	OE
MADe3D	$800,000	WETO
ThermalTracker-3D	$920,000	WETO
UTS – Ultrasonic Technology Solutions	$1,290,000	OTT
Enduring Advantage	$380,000	NNSA
UXI	$1,900,000	NNSA
Total	**$83,481,585.00**	

10 cohorts completed as of Fall 2019

Innovations have spanned 13 DOE program areas

including 111 teams from 11 National Labs

Teams have conducted more than 7,750 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, RE/MAX, and Amazon

100+ industry mentors and instructors involved

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.

CO_2 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 CO_2 as is needed during the fermentation process. Companies with large operations often have CO_2 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 CO_2 already produced is wasted, and small breweries must purchase additional CO_2 from local suppliers to meet their CO_2 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 CO_2 sorbents) is a group of researchers from Lawrence Livermore National Laboratory (LLNL) who had previously developed microcapsule technology to efficiently capture CO_2 from power plants. Now they are using their technology to help these craft breweries capture the savings from recovering and reusing CO_2.

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, "Lab 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 CO_2 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 CO_2 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.

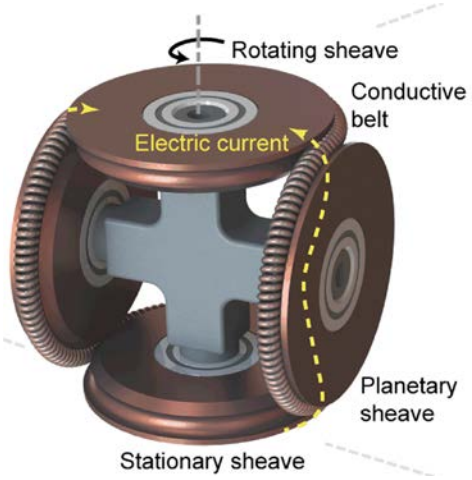
In addition, conventional brush/slip ring technology faces two limitations: (1) short operating lifetime due to sliding-contact wear and (2) electrical arcing associated with contact bounce. Addressing these two issues, along with eliminating the need for rare earth metals, will allow wider adoption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

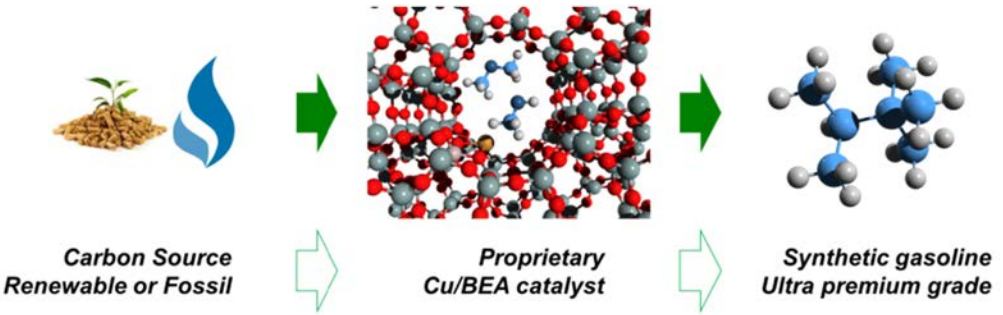
Articles: Twistact IP Fact Sheet

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 Renewable Identification Numbers (RINs).

Focus

CuB Fuels is seeking strategic partnerships and cooperative 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 original equipment manufacturers looking to leverage high-octane gasoline to meet Corporate Average Fuel Economy (CAFE) 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:

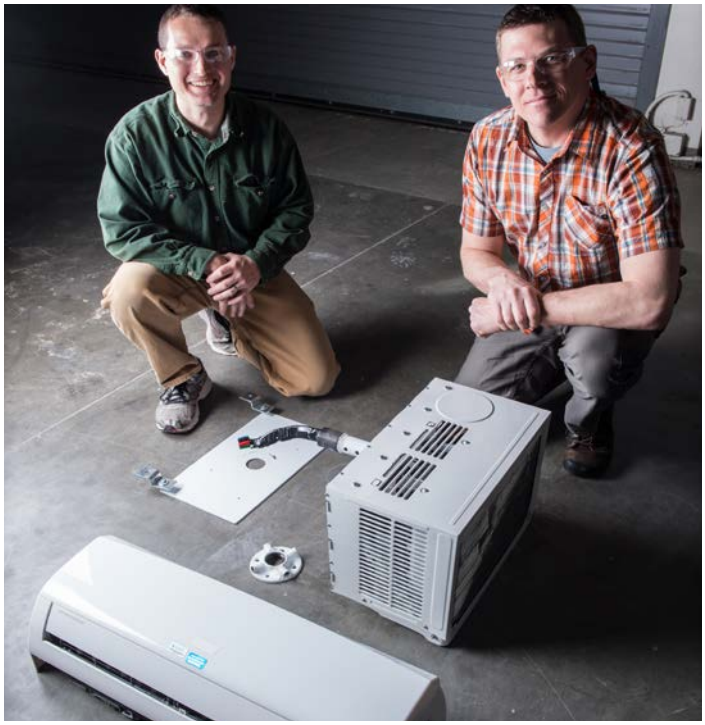
- Meeting with a natural gas company looking for a project in Canada and visiting major refiners and catalyst producers to discuss potential partnerships
- Performing a technology demonstration at the pilot scale with partner Enerkem
- Purifying high-octane gasoline samples and sending to a major auto 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 5,000 gallons of high-octane gasoline.

EcoSnap

The first window AC without the window

National Renewable Energy Laboratory

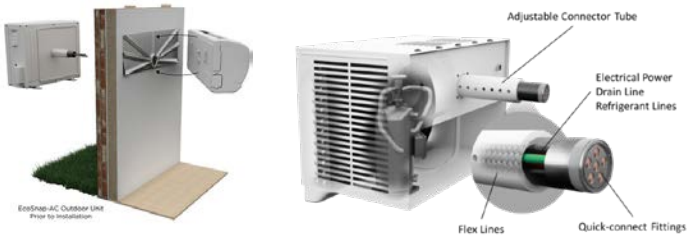
Cohort 1



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 toolless, 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
- Constructed a prototype based on professionally designed EcoSnap components added to a commercially available mini split heat pump
- Laboratory characterization demonstrated performance and energy efficiency equivalent to the commercially available pump
- Performed national-scale simulations to estimate energy savings potential of replacing window air conditioners.

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 replacing aging infrastructure and incorporating 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

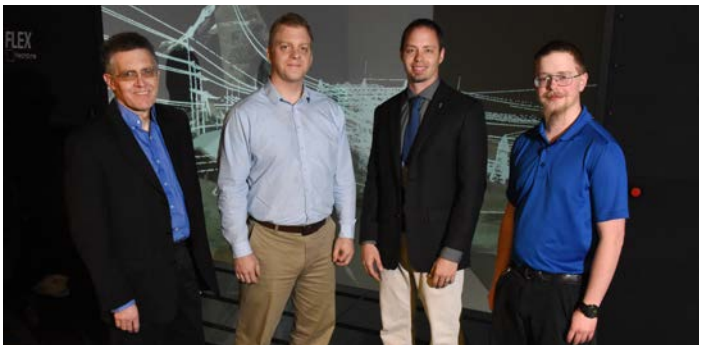
Power transfer capacity is affected by three main elements: stability, voltage limits, and thermal ratings. All three are critical, but thermal ratings represent the greatest opportunity to quickly, reliably, and economically improve the grid's capacity.

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 networkwide 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.

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

- 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 and 2018 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 collaborate with one industry partner for fiscal years 2018-2020.

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 WindSim Power 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.

Abboud, Alexander W., Jake P. Gentle, Timothy R. McJunkin, and Jacob P. Lehmer. "Using Computational Fluid Dynamics of Wind Simulations Coupled With Weather Data to Calculate Dynamic Line Ratings." IEEE Transactions on Power Delivery 35, no. 2 (2020): 745-753.

Abboud, J. Gentle, J. Coffey, K. Parikh, "Sensitivity Effects of High Temperature Overhead Conductors to Line Rating Variables," CIGRE Session 48, Paris, FR, 2020.

Video: https://youtu.be/X8IaVYN6tUw

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 <$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/year 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.

CO_2BOL-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 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 H_2S 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 (CO_2, H_2S, COS, H_2O)
- 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 (CO_2BOLs) that uses solvents to absorb acid gas impurities such as CO_2 or H_2S for applications such as carbon capture, and acid gas "sweetening" to remove toxic H_2S. CO_2BOLs can capture twice as much gas as conventional solvents and readily regenerated under mild conditions, requiring lower energy demands. The CO_2BOL 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, CO_2BOL-NG has:

- Licensed the CO_2 capture technology to an engineering firm
- Received DOE seed money to further develop the solvent platform for purifying synthesis gas
- Discussed potential post-program continued R&D with IP-Group
- Participated in Energy I-Corps Pitch competition in November 2017.

Speaking Engagements:

- Gordon Research Conference, CO_2 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.pnl.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, and power plants 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 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 a memorandum of understanding (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 Bolisetti (chandrakanth.bolisetti@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.
- Patent granted, Jan. 14, 2020: U.S. Patent 10,533,239: "Methods of Recovering Rare Earth Elements From a Material."
- 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

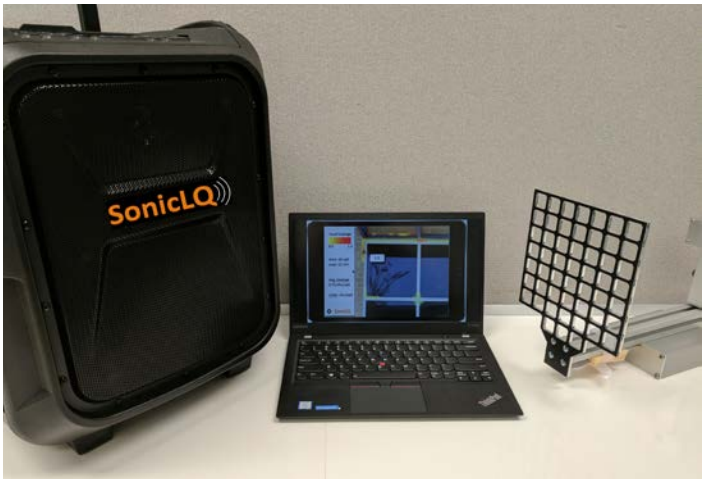
SonicLQ uses sound waves to locate and size air leaks in building walls, doors, and windows.

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 post-program funding from DOE Building Technologies Office for additional R&D and $1,050,000 in post-program 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/soniclq-reconnecting-acoustics-and-airtightness
- http://www.chicagotribune.com/bluesky/originals/ct-soniclq-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

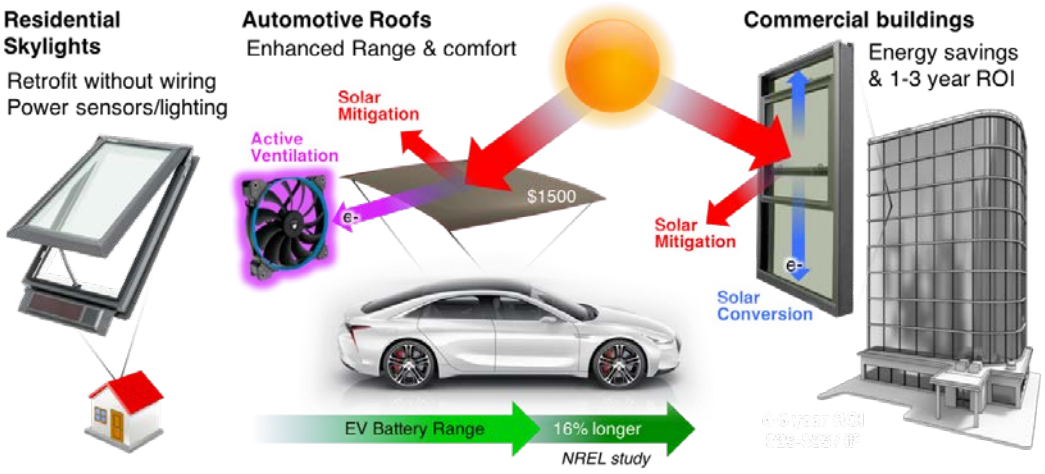
National Renewable Energy Laboratory

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



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.

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.

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 (UF_6), and then into the UO_2 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 U_3Si_2 fuel pellets using other forms of U (e.g., UF_4, 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 in 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, 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 arthur.baker2@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-plus 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.

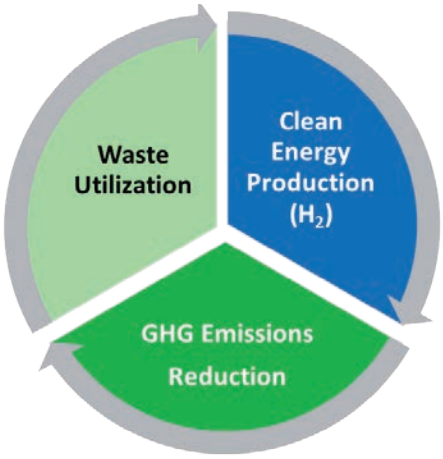
Where are they now? Post-Program Advancements

- $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.

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.

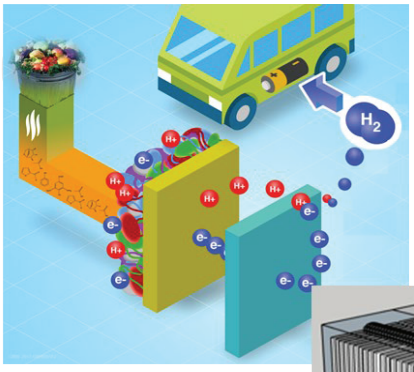
Solution

Key offerings:

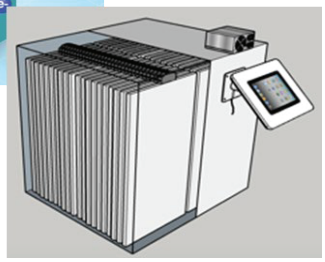
e-H2Gen: Renewable hydrogen generation system using organic waste, adaptable to low- and high-volume customers.

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.



Modular
Scalable



Microbial
Electrolysis

"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@electroavtive.tech or alewis@electroactive.tech or visit www.electroactive.tech.

Gamma Reality, Inc.

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) that 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) 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

Gamma Reality Inc. or GRI is now a company with five employees and several government-funded projects, including an Small Business Innovation Research grant:

- GRI is looking to expand into nuclear power as a commercial opportunity. The company has licensed the LAMP technology from LBNL and the research in this area continues there.

For more information, please visit:
www.gammareality.com

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 1,100°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 decalibration) 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 cannot keep up with the demand.

Solution

HTIR-TCs are sophisticated thermocouples developed at INL's High Temperature Test Laboratory (HTTL) that measure temperature in the world's most drastic environments. The HTIR-TC has been experimentally proven to withstand temperatures up to 1,510°C and neutron flux levels 10 times that of a typical commercial pressurized water reactor. This experiment is still ongoing 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

INL researchers have:

- Been awarded the prestigious "R&D 100" award for 2019. www.rdworldonline.com/2019-rd-100-award-winners-unveiled/
- Been awarded a Technology Commercialization Fund (TCF) with Idaho Laboratories Corporation (ILC) through the U.S. Department of Energy Office of Technology Transfer
- Completed a 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 Micron School of Materials Science and Engineering over the past two years to continually improve upon the HTIR-TC's past performance
- Licensed HTIR-TC to an industry partner as well as two post-program technologies.

Video:

- www.youtube.com/watch?v=L4gtwJsKKx4

Media:

- "New breakthroughs in high-temperature measurement technology," *U.S. DOE Science News* www.eurekalert.org/features/doe/2019-04/dnl-nbi040819.php

For more information or speaking engagements, contact the Inventor and Principal Investigator, Richard Skifton, at Richard.Skifton@inl.gov or (208) 526-2696.

Nomenclature

AMO	Advanced Manufacturing Office
ANL	Argonne National Laboratory
BETO	Bioenergy Technologies Office
BTO	Building Technologies Office
DOE	U.S. Department of Energy
EM	Office of Environmental Management
FE	Office of Fossil Energy
FNAL	Fermi National Accelerator Laboratory
GTO	Geothermal Technologies Office
HFTO	Hydrogen and Fuel Cell Technologies Office
INL	Idaho National Laboratory
LANL	Los Alamos National Laboratory
LBNL	Lawrence Berkeley National Laboratory
LLNL	Lawrence Livermore National Laboratory
NE	Office of Nuclear Energy
NNSA	National Nuclear Security Administration
NREL	National Renewable Energy Laboratory
NSF	National Science Foundation
OE	Office of Electricity
ORNL	Oak Ridge National Laboratory
OTT	Office of Technology Transitions
PNNL	Pacific Northwest National Laboratory
SETO	Solar Energy Technologies Office
SLAC	SLAC National Accelerator Laboratory
SNL	Sandia National Laboratories
VTO	Vehicle Technologies Office
WETO	Wind Energy Technologies Office
WWPTO	Wind & Water Power Technologies Office

"Energy I-Corps helped us understand the recycling industry as it is today in preparation for the kick-off of the BOTTLE consortium. It made us understand that for recyclers to adopt new technologies, the value propositions are going to have to focus on handling mixed or contaminated waste streams for recyclers to avoid disposal fees. Processes that can create more value (e.g., upcycling) will be easier to adopt. It also helped us identify that the complexity of the recycling technology will influence who the first adopters are."

Nicholas Rorrer
Team CYCle
Cohort 10

"We granted Lawrence Berkeley National Lab a government-use license, and it wouldn't have occurred without Energy I-Corps!"

Jacob Holden
Team routeE
Cohort 8

"Energy I-Corps taught me to distill my research, technology, or ideas into a message that connects to my target audience. By going through the program, I have learned to develop better technology, write more impactful papers, and win more funding awards."

Steven Christensen
Team Biolyst Renewables
Cohort 2

"There was a revelation speaking with each instructor!"

Spencer Dutton
Team Thermastor
Cohort 9

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
U.S. Department Of Energy

U.S. DEPARTMENT OF
ENERGY

Office of
TECHNOLOGY TRANSITIONS

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