Energy I-Corps
Annual Report
2022

Energy I-Corps 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

ENERGY I-CORPS

U.S. DEPARTMENT OF ENERGY | OFFICE OF Technology Transitions

Greetings,

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

Now in its eighth year, Energy I-Corps addresses critical gaps in workforce development for our National Lab researchers and enables the private sector uptake of clean energy technologies. It provides meaningful real-world opportunities for the application of commercialization and entrepreneurial skills to DOE technologies. This on-the-job training bridges the "valleys of death" often found along the research, design, demonstration, and deployment continuum and speeds the path to market for taxpayer-funded discoveries.

This has been a banner year for DOE with a trifecta of transformational pieces of legislation: the Bipartisan Infrastructure Law, the CHIPS and Science Act, and the Inflation Reduction Act. The overarching goal of these bills is to drive a new era of economic competitiveness in cutting-edge technology, and they do so through a collective $97 billion in strategic DOE investments to accelerate clean energy deployment in the private sector and innovation at our world-class National Laboratories. Energy I-Corps sits at the nexus of this strategy.

By supporting a clear path to commercialization for DOE-funded technologies, Energy I-Corps maximizes the public benefit not only of the entire National Laboratory complex, but for the department as a whole. We continue to deepen Energy I-Corps' impact by replicating its success through offshoots like the Energy I-Corps Satellite program and the Summer Entrepreneurship intern program. Through these efforts, we're opening doors of opportunity by investing in real-time, applicable training that will build a skilled, diverse workforce and spur green collar careers for years to come.

Public investments in research and innovation power the private engine of the American economy. With the activities of OTT's Energy I-Corps, the National Lab community has increased capacity to ensure that research can have impact on our innovators, in our economy, and ultimately, for the public good. These continued and renewed investments help amplify this program's success and shape breakneck innovation.

Dr. Vanessa Z. Chan
Chief Commercialization Officer, U.S. Department of Energy
Director, Office of Technology Transitions

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Researchers Avantika Singh and Nic Rorrer represent Team CYCLE during Cohort 10. *Photo by Werner Slocum, NREL.*

Members of Team RoutE collaborate on their Business Model Canvas during Cohort 8 opening session. *Photo by Amy Glickson, NREL.*

"Energy I-Corps challenged me to think about the problems facing end users 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."

– Dan Oryshchyn, NETL, Principal Investigator

"What Energy I-Corps did for us was to help us shape all our milestones for the projects. Otherwise, we could do a bunch of cool science, but if it didn't meet the goals we set in Energy I-Corps, the technology wasn't going to leave the lab."

– Christina Wildfire, NETL, Entrepreneurial Lead

"Energy I-Corps is a transformation in the way research scientists approach something. That transformation is still underway and probably will continue for the rest of my career."

– Jim Coons, LANL, Principal Investigator

"It was an amazing experience and what you think you know or feel about the program at the beginning is not how you feel about it at the end."

– Wendy Rue, SNL, Entrepreneurial Lead

Discovering Market Pathways for National Lab Research

About Energy I-Corps

The U.S. Department of Energy (DOE) invests billions of dollars every year into the National Lab complex. This investment allows the National Laboratories to tackle the critical scientific challenges of our time—from renewable energy to quantum computing to creating a more resilient energy grid. The discoveries and innovations being developed by the labs have an even greater impact when we invest in bringing these ideas to the market where they can benefit the nation and world.

To better arm researchers to collaborate with industry and turn research and development into demonstration and deployment, DOE employs Energy I-Corps to help researchers gain industry insight to guide innovation.

Energy I-Corps invites teams of researchers to participate in an intensive two-month training during which the researchers define technology value propositions, conduct stakeholder discovery interviews, and explore viable market pathways for their technologies. Researchers return to their labs with a framework for industry engagement to guide future research and inform a culture of market engagement within the lab environment. In this way, Energy I-Corps ensures our investment in the National Labs and maintains and strengthens long-term U.S. competitiveness.

Energy I-Corps became a part of the Office of Technology Transitions (OTT) portfolio in 2018. Established within DOE in 2015, OTT is committed to expanding the commercial impact of DOE's research, development, demonstration, and deployment portfolio to advance the economic, energy, and national security interests of the nation. Energy I-Corps is managed by DOE's National Renewable Energy Laboratory (NREL) in Golden, CO.

For each cohort of Energy I-Corps, National Labs recruit researchers working on energy technologies that show potential for commercial application. Researchers selected for the program receive comprehensive training and conduct at least 75 discovery interviews with industry stakeholders during 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 and deployment. In addition, they will have established an industry-engagement framework applicable to future research.

Energy I-Corps Instructors and NREL operations team gather in September for the first in-person meeting in three years. *Photo by Kira Vos, NREL.*

Curriculum

The Energy I-Corps curriculum was initially developed 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 OTT adapted NSF's nationally recognized I-Corps training to meet the needs of the lab participants.

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 intellectual property, licensing opportunities, and startup development pathways. As more teams complete the training, NREL and OTT continue to improve and enhance the Energy I-Corps curriculum to best meet participant and industry needs.

> "Within the first or second day, the team had already learned a new language."
>
> **– Mark Chavez, Mentor**

Energy I-Corps FAQs

What is Energy I-Corps?

Energy I-Corps is a two-month experiential training program where National Lab researchers learn about industry needs and evaluate potential market applications specific to their technologies.

How many teams have participated in the program?

As of November 2022, 191 teams from 12 National Labs have participated in Energy I-Corps over the course of 15 cohorts and the pilot.

What are the benefits?

Participants benefit from workshops taught by industry experts while gaining market insights gleaned from the more than 75 discovery interviews conducted during the duration of the program. The training equips National Lab researchers with tools to evaluate 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.

Program office support

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

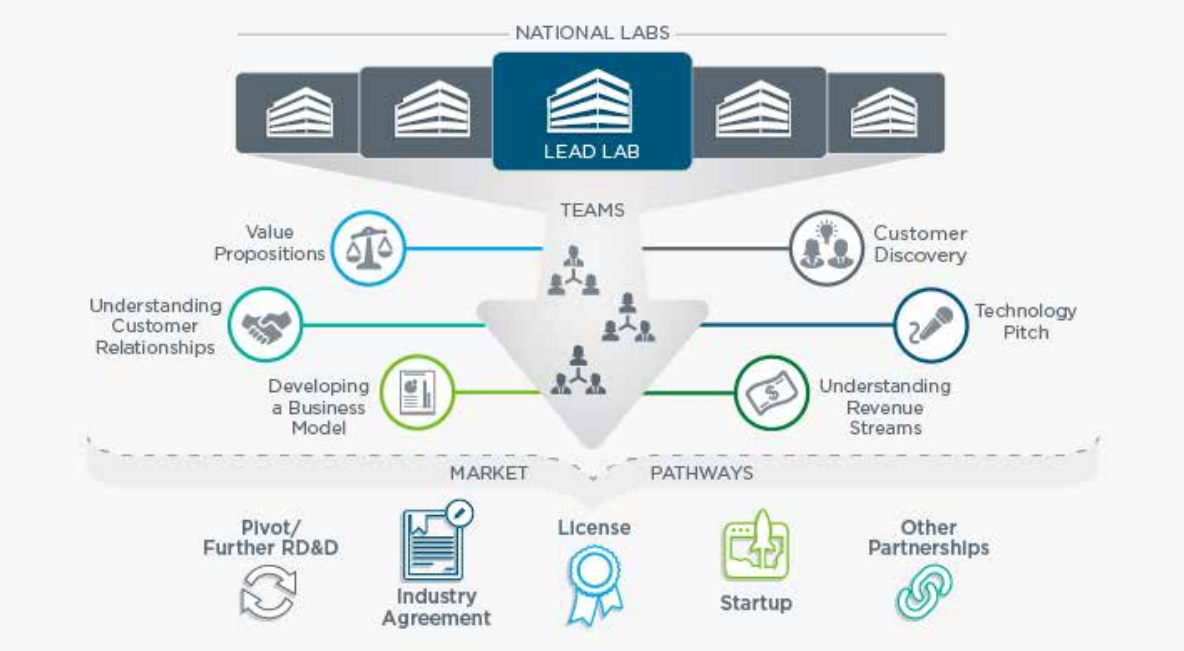
How can I learn more?

Email energyicorps@hq.doe.gov to learn more about Energy I-Corps and how to get involved.

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.

Energy I-Corps technologies have collectively attracted more than $150 million in post-program funding. As of the end of the 15th training session in the fall of 2022, teams have worked with more than 190 industry mentors and conducted more than 13,600 discovery interviews to determine the commercial impact of their technologies.

Program Structure



Energy I-Corps is comprised 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 and virtual instruction and presentations.

Participating Labs (aka Sites): Sites recruit, assemble, and send teams to the node for training. The sites play an integral role in supporting teams before, 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.

Teams: Applicants apply to Energy I-Corps as a team composed of a principal investigator with a commercially relevant technology, an entrepreneurial lead, and an industry mentor. The team works together to identify potential commercialization pathways for their selected technology, as well as opportunities where further development could lead to commercial value.

Training Program: Energy I-Corps spans seven-to-ten weeks, utilizing a custom-designed curriculum. During the program, teams attend in-person and/or virtual 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 requires a considerable amount of time spent outside of the classroom conducting stakeholder discovery interviews.

To date, teams have participated 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 Energy Technology Lab (NETL)
- National Renewable Energy Laboratory (NREL)
- Oak Ridge National Laboratory (ORNL)
- Pacific Northwest National Laboratory (PNNL)
- Sandia National Laboratories (SNL)
- SLAC National Accelerator Laboratory (SLAC).

Energy I-Corps Teaching Team

The Teaching Team brings the Energy I-Corps curriculum to life. Energy I-Corps instructors are truly the backbone of the program and provide the time, energy and intensity needed to successfully shepherd 12-18 teams through each cohort. Instructors bring critical industry expertise to the program and introduce the language of innovation and commercialization to the participating teams. By leveraging deep technical backgrounds and advanced business experience, instructors bring their industry knowledge to each session—sharing lessons learned while incorporating program elements, professional development and commercialization pathways. Instructors leverage their business and startup experience to the benefit of the Energy I-Corps teams through instruction, one-on-one advisory sessions, presentation coaching, stakeholder discovery review, team building and network expansion.

Alice Havill
Business Fellow,
Breakthrough Energy

Grant Warner
Director of Innovation,
College of Engineering &
Architecture, Howard University

Jean Redfield
CFO & Co-Founder,
Fordsell Machine Products

Latane Brackett
Principal Manager,
Innovation Programs, GEM i4

Max Green
Founder & Managing
Member, Ratio Flux

Nakia Melecio
Senior Research Faculty,
Senior Startup & Deep-Tech Catalyst,
Georgia Institute of Technology

Sally Hatcher
General Partner,
Buff Venture Fund

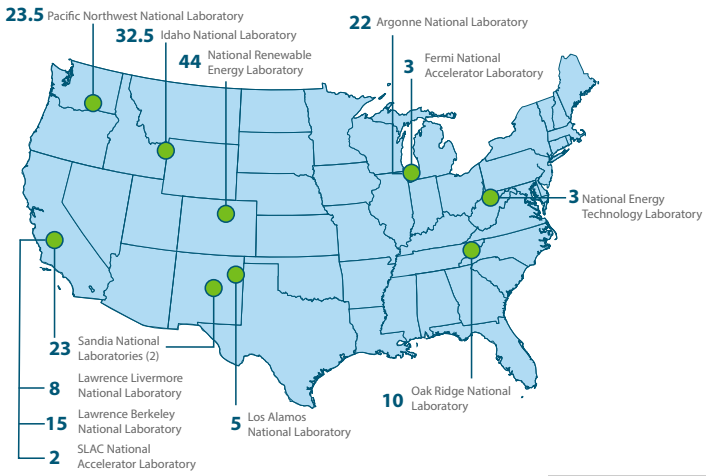
Rebecca Kauffman
Principal, Sun Raven

Tom Teynor
CEO, Bell Plumbing & Heating

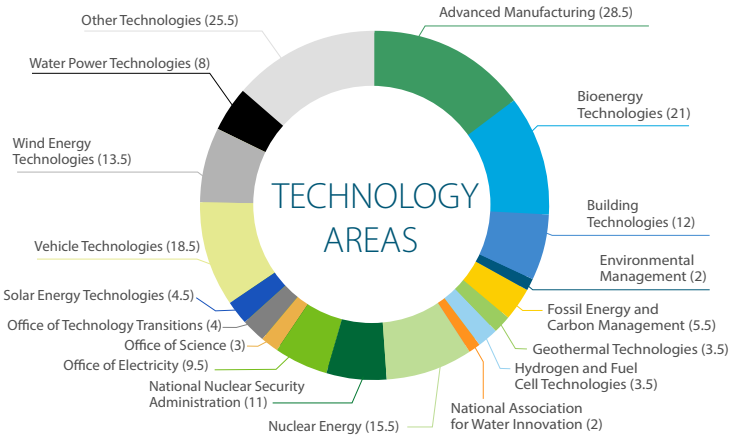
Quick Stats

15 COHORTS **of** ENERGY I-CORPS

191 TEAMS | **12** NATIONAL LABORATORIES



BRINGING **ENERGY INNOVATIONS** TO



LEARNING FROM

190+ Industry Mentors **and** 13,600+ Customer Discovery Interviews With Companies Like:

EPRI, Shell, Ford, World Bank, Breakthrough Energy, John Deere, Siemens Gamesa, Chevron, Eaton, Samsung, Lowes, Johns Manville, LEGO, U.S. Army, Trane, Tesla, GM, Dow Chemical, 3M, Whirlpool, GE, Home Depot, Amazon

20+ New Businesses

Over twenty teams launched new businesses based on their Energy I-Corps Technology

$150M+ Post Program Funding

Post Energy I-Corps, technologies have attracted **over $150M in post-program funding**

13,600+ Customer Discovery Interviews

75+ Licenses Executed

Our Team

Zack Baize
Energy I-Corps
Program Manager, OTT

Shelly Curtiss
Energy I-Corps
Program Manager, NREL

Lauren Magin
Energy I-Corps
Project Manager, NREL

Danielle France
Investor Network & Industry Growth
Forum Strategic Lead, NREL

Participation by Technology Program Offices

Energy I-Corps teams are funded by individual technology program offices within DOE. Labs also have the opportunity to fund teams or find industry partners to fund teams. Information provided on the following pages incorporates reporting from the first cohort pilot through Cohort 15, ending in November 2022.

Teams are denoted as half-funded by a technology office, 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
ARME	PNNL	11	77
Sustainability Integrators	INL	11	70
EMEE	INL	11	75
RE-Metal	INL	11	75
EC-Leach	INL	12	69
RECOVER (0.5)	PNNL	12	77
WESAP	PNNL	12	93
CO2 Converters (0.5)	ANL	12	75
Wolfram Plating	SNL	13	65
GALILEO	ANL	13	80
Phase Changers	NREL	14	78
FrozEn	PNNL	14	79
CAML	SNL	14	55
Regenerable Catalysts	SNL	15	65
Mixed Plastic Upcycling	ORNL	15	88

TOTAL TEAMS FUNDED
28.5

INVESTMENT TOTAL
$2,147,500

POST-PROGRAM FUNDING
$27,497,151

DISCOVERY INTERVIEWS
2,249

Participation by Technology Program Offices

Bioenergy Technologies Office (BETO)

Team	Lab	Cohort	Discovery Interviews
High-Moisture Pelleting Process	INL	2	86
WasteNot	ANL	3	70
FiberSAS	ANL	3	76
Bio-Blend aka OptiBlend	INL	4	75
FUSS	LANL	4	71
Nitrilica	NREL	5	77
Glycoplastics	NREL	5	77
CUB Fuels	NREL	5	98
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
Scrum Ranchers	SNL	10	78
BETTER	NREL	11	73
UltraSep	LANL	12	76
Bio-NIPU (.5)	NREL	12	78
BioPack-ML	LANL	12	76
REVAMP	NREL	13	81
Bioreactor	LLNL	14	60
O2SAF	PNNL	15	77

TOTAL TEAMS FUNDED
21

INVESTMENT TOTAL
$1,580,000

POST-PROGRAM FUNDING
$5,456,857

DISCOVERY INTERVIEWS
1,714

Building Technologies Office (BTO)

Team	Lab	Cohort	Discovery Interviews
VOLTTRON	PNNL	2	33
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
EB Treement	FNAL	11	56
Bio-NIPU (0.5)	NREL	12	78
FreeSpace Tank Team	NREL	12	77
UBEM	LBNL	12	77
EnStore for BTMS	NREL	13	88

TOTAL TEAMS FUNDED
12

INVESTMENT TOTAL
$900,000

POST-PROGRAM FUNDING
$2,750,000

DISCOVERY INTERVIEWS
887

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)

Team	Lab	Cohort	Discovery Interviews
Polymer Membranes	SNL	2	41
CryoH2	LLNL	4	56
Electro-Active (.5)	ORNL	7	80
High Flying Hydrides	NREL	13	75

TOTAL TEAMS FUNDED
3.5

INVESTMENT TOTAL
$262,000

POST-PROGRAM FUNDING
$1,786,857

DISCOVERY INTERVIEWS
252

Fossil Energy and Carbon Management (FECM)

Team	Lab	Cohort	Discovery Interviews
MECS	LLNL	4	64
CO2BOLONG	PNNL	5	75
Memzyme	SNL	5	81
CO2 Converters (0.5)	ANL	12	78
ALFa-LDS for Methane	LANL	15	72
Pipeline Sensors	NETL	15	78

TOTAL TEAMS FUNDED
5.5

INVESTMENT TOTAL
$422,500

POST-PROGRAM FUNDING
$2,225,000

DISCOVERY INTERVIEWS
448

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
$2,750,000

DISCOVERY INTERVIEWS
204

National Alliance for Water Innovation – LBNL (NAWI)

Team	Lab	Cohort	Discovery Interviews
Water-TAP3	NREL	11	72
WaterDAMS	NREL	11	82

TOTAL TEAMS FUNDED
2

INVESTMENT TOTAL
$150,000

POST-PROGRAM FUNDING
$4,000,000

DISCOVERY INTERVIEWS
154

Participation by Technology Program Offices

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	INL	9	77
Thermal Sound On	INL	10	73
Mesofluidics	PNNL	13	63
Feedforward K9	INL	14	60

TOTAL TEAMS FUNDED
15.5

INVESTMENT TOTAL
$1,162,500

POST-PROGRAM FUNDING
$8,818,000

DISCOVERY INTERVIEWS
1,096

National Nuclear Security Administration (NNSA)

Team	Lab	Cohort	Discovery Interviews
Enduring Advantage	SNL	10	75
UXI	SNL	10	81
HECATE	SNL	11	81
CAP Fastener	SNL	11	60
MAD3	SNL	12	74
EPDR	SNL	12	71
ThermaSET	SNL	13	102
Fractured	SNL	13	76
Disease Prerecognition	LANL	14	82
nDETECT	SNL	14	75
Tough Adhesive	ORNL	15	74

TOTAL TEAMS FUNDED
11

INVESTMENT TOTAL
$830,000

POST-PROGRAM FUNDING
$7,440,000

DISCOVERY INTERVIEWS
851

Office of Electricity (OE)

Team	Lab	Cohort	Discovery Interviews
DCAT	PNNL	6	75
Glass Paper	INL	8	75
EnergyBlox	SLAC	8	59
EcoBlock	LBNL	9	75
DER-CAM	LBNL	9	78
TRAST	PNNL	11	78
THERMS (.5)	SNL	12	68
C3D	INL	13	87
MASTERRI	INL	14	55
GRIP	SLAC	14	56

TOTAL TEAMS FUNDED
9.5

INVESTMENT TOTAL
$712,500

POST-PROGRAM FUNDING
$10,385,000

DISCOVERY INTERVIEWS
706

Participation by Technology Program Offices

Office of Science (OS)

Team	Lab	Cohort	Discovery Interviews
SuperChips	LBNL	11	72
INN-Design	NREL	12	69
RoboDT	ANL	14	76
Efficient Isotopes*	PNNL	15	76

**This research was supported by the DOE Isotope Program, managed by the Office of Isotope R&D and Production.*

TOTAL TEAMS FUNDED
4

INVESTMENT TOTAL
$305,000

POST-PROGRAM FUNDING
$600,000

DISCOVERY INTERVIEWS
293

Solar Energy Technologies Office (SETO)

Team	Lab	Cohort	Discovery Interviews
SolGuard	NREL	2	51
Hydro Scanner	LLNL	3	44
HALO	NREL	6	83
THERMS (.5)	SNL	12	68
AVIAN-SOLAR	ANL	15	123

TOTAL TEAMS FUNDED
4.5

INVESTMENT TOTAL
$305,000

POST-PROGRAM FUNDING
$33,155,000

DISCOVERY INTERVIEWS
369

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
SWaP Electronics	SNL	11	47
RECOVER (0.5)	PNNL	12	77
e-Mission	NREL	12	78
Athena	NREL	13	82
DFI	SNL	13	76
Lithium Battery	INL	13	75
Real-Twin	ORNL	14	78
ShAPE Recycling	PNNL	14	63
ZAV-SNL	SNL	14	48

TOTAL TEAMS FUNDED
18.5

INVESTMENT TOTAL
$1,387,500

POST-PROGRAM FUNDING
$7,035,323

DISCOVERY INTERVIEWS
1,391

Participation by Technology Program Offices

Wind and Water Power Technologies Office (WWPTO)

Team	Lab	Cohort	Discovery Interviews
DLR aka GLASS	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
$2,815,000

DISCOVERY INTERVIEWS
301

Water Power Technologies Office (WPTO)

Team	Lab	Cohort	Discovery Interviews
IHESS-2020	INL	11	72
SLIC	PNNL	11	61
IrrigationViz	PNNL+INL	12	96
GLIDES	ORNL	13	75
Lab-on-a-Fish	PNNL	13	52
μnder the C	NREL	14	71
Hydrogen Ships	SNL	14	40

TOTAL TEAMS FUNDED
7

INVESTMENT TOTAL
$525,000

POST-PROGRAM FUNDING
$6,746,000

DISCOVERY INTERVIEWS
467

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
HOPP	NREL	11	44
OpenOA	NREL	11	44
RBLO	NREL	12	57
TAP	NREL	12	76
WindEZ	NREL	14	76
HighWind	NREL	15	107

TOTAL TEAMS FUNDED
10.5

INVESTMENT TOTAL
$792,500

POST-PROGRAM FUNDING
$4,670,000

DISCOVERY INTERVIEWS
799

Participation by Technology Program Offices

Lab-Funded Teams

Team	Lab	Cohort	Discovery Interviews
Cl-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
SwitchGlaze (0.5)	NREL	3	54
Oleo Sponge	ANL	6	62
APeX Imaging	NREL	15	77

TOTAL TEAMS FUNDED
13.5

INVESTMENT TOTAL
$987,500

POST-PROGRAM FUNDING
$10,112,514

DISCOVERY INTERVIEWS
807

Office of Technology Transitions

Team	Lab	Cohort	Discovery Interviews
UTS - Ultrasonic Technology Solutions	ORNL	10	76
Microwave Assisted Catalysis (MAC)	NETL	12	69
memQ	ANL	13	87
Hyper Team	NETL	13	75

TOTAL TEAMS FUNDED
4

INVESTMENT TOTAL
$300,000

POST-PROGRAM FUNDING
$2,963,000

DISCOVERY INTERVIEWS
307

Participation by Technology Program Offices

Pilot Funded

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

By the Numbers

Energy I-Corps teams receive funding from DOE technology offices, their National Lab, or industry partners. After the program concludes, teams often seek additional funding for continued commercialization activities. Post-program funding may take many forms including grants, laboratory research funding, cooperative research awards, industry support, etc. The information shown below highlights the initial funding investments as well as the post-program funding teams have reported.

INVESTMENT TOTAL
$14,345,000

POST-PROGRAM FUNDING
$151,322,063

Funding Snapshot

	Teams Funded	Investment	Post-Program Funding
Technology Office Funded[+]	166.5	$12,532,500	$138,065,688
Lab Funded	13.5	$987,500	$10,112,514
Pilot	10	$750,000	$2,897,000
Privately Funded	1	$75,000	$246,861
Total	**191**	**$14,345,000**	**$151,322,063**

[+]Technology Office Funding Detailed Breakdown

DOE Funding Office	Teams Funded	Investment	Post-Program Funding
AMO	28.5	$2,147,500	$27,497,151
BETO	21	$1,580,000	$5,456,857
BTO	12	$900,000	$2,750,000
EM	2	$150,000	$6,972,500
FECM	5.5	$422,500	$2,225,000
GTO	3.5	$262,500	$2,750,000
HFTO	3.5	$262,500	$1,786,857
NAWI-LBNL	2	$150,000	$4,000,000
NE	15.5	$1,162,500	$8,818,000
NNSA	11	$830,000	$7,440,000
OE	9.5	$712,500	$10,385,000
OS	4	$305,000	$600,000
SETO	4.5	$342,500	$33,155,000
VTO	18.5	$1,387,500	$7,035,323
WWPTO	4	$300,000	$2,815,000
WPTO	7	$525,000	$6,746,000
WETO	10.5	$792,500	$4,670,000
OTT	4	$300,000	$2,963,000
Total	**166.5**	**$12,532,500**	**$138,065,688**

By the Numbers

TEAMS FUNDED
191

STAKEHOLDER DISCOVERY INTERVIEWS
13,611

By Laboratory

Lab	Teams Funded	Post-Program Funding Received	Discovery Interviews
ANL	22	$7,838,224	1,672
FNAL	3	$950,000	182
INL	32.5	$20,209,000	2,368
LANL	5	$1,410,000	377
LBNL	15	$23,522,500	1,092
LLNL	8	$14,730,000	456
NETL	3	$703,000	227
NREL	44	$53,294,375	3,281
ORNL	10	$6,617,714	751
PNNL	23.5	$11,940,250	1,605
SNL	23	$9,862,000	1,517
SLAC	2	$245,000	83
Total	**191**	**$151,322,063**	**13,611**

By Cohort

Lab	Teams Funded	Post-Program Funding Received	Discovery Interviews
0	3	NA	225
1	14	$3,851,000	876
2	14	$28,353,738	815
3	8	$3,615,000	475
4	15	$38,915,000	937
5	12	$1,608,000	916
6	8	$10,284,361	606
7	8	$14,570,714	665
8	10	$5,970,000	776
9	12	$9,720,000	910
10	10	$7,375,000	763
11	17	$13,549,000	1,148
12	18	$7,190,250	1,360
13	16	$5,750,000	1,250
14	16	$570,000	1,052
15	10	TBD	837
Total	**191**	**$151,322,063**	**13,611**

Post-Program Funding

Team Post-Program Funding Reported through September 2022

Team Name	Post-Program Funding Received	Funded through Energy I-Corps by:
ARAI	$161,000	Pilot
Eco-Snap	$350,000	NREL
SonicLQ	$285,000	Pilot
STARS	$2,001,000	Pilot
Switchable Polarity Solvents	$450,000	Pilot
Tunation	$154,000	ORNL
WISDEM	$450,000	NREL
Biolyst Renewables	$5,957,514	NREL
High-Moisture Pelleting Process	$1,400,000	BETO
Micro Miners	$4,900,000	AMO; GTO
Resin Wafer Deionization	$1,701,000	ANL
NanoHeatBlock	$1,782,026	AMO
QUAKE	$2,820,000	NE
Saline Solutions	$8,250,000	AMO
Smart Charge Adapter	$1,393,198	VTO
SolGuard	$150,000	SETO
GLASS aka DLR	$1,315,000	WWPTO (wind)
SwitchGlaze	$2,300,000	BTO, NREL
MECS	$1,580,000	FECM
e-Recov	$280,000	AMO
GeoCAES	$300,000	GTO
Change Detection Systems	$775,000	NE
HALO	$32,880,000	SETO
RF Tag	$1,500,000	WWPTO (water)
Thermoelectric Dryer	$1,600,000	BTO
EMRLD	$625,000	NE
AMAFT	$103,000	NE
CUB Fuels	$360,000	BETO
CO2BOLONG	$520,000	FECM
Gamma Rayality	$6,022,500	EM
Opt-grid	$246,861	IP Group (Private)
4Cs	$1,500,000	NE
ELINA	$2,155,000	NE
DCAT	$10,000	OE
Oleo Sponge	$350,000	ANL
PureBeam	$950,000	EM

Post-Program Funding

Team Post-Program Funding *(continued)*

HOT	$840,000	NE
Electro-Active	$3,573,714	FCTO + BETO
COMBA	$3,600,000	AMO
LaserSense	$807,000	AMO
FLO.materials	$4,800,000	AMO
CAN-Coatings	$300,000	AMO
Glass Paper	$1,560,000	OE
routeE	$1,670,000	VTO
Fermley	$500,000	BETO
BonD Northwest	$40,000	VTO
SpiderFloat	$1,900,000	WETO
EcoBlock	$8,000,000	OE
MADe3D	$800,000	WETO
ThermalTracker-3D	$920,000	WETO
UTS – Ultrasonic Technology Solutions	$1,290,000	OTT
Enduring Advantage	$385,000	NNSA
UXI	$5,700,000	NNSA
IHESS 2020	$4,000,000	WPTO
Water-TAP3	$4,000,000	NAWI-LBNL
OpenOA	$250,000	WETO
ARME	$173,000	AMO
SLIC	$2,746,000	WPTO
Sustainability Integrators	$550,000	AMO
RE-METAL	$1,230,000	AMO
Superchips	$600,000	OS
UltraSep	$1,410,000	BETO
RECOVER	$1,960,250	AMO + VTO
Water Energy Systems for Advanced Purification (WESAP)	$1,770,000	AMO
CO2 Converters	$250,000	AMO + FE
THERMS	$250,000	SETO + OE
EDPR	$50,000	NNSA

Post-Program Funding

Team Post-Program Funding *(continued)*

MAD3	$195,000	NNSA
e-Mission	$505,000	VTO
TAP	$800,000	WETO
Athena	$375,000	VTO
DFI	$2,072,000	VTO
Thermaset	$1,085,000	NNSA
Wolfram Plating	$100,000	AMO
MemQ	$970,000	OTT
Hyper Team	$703,000	OTT
C3D	$445,000	OE
FrozEn	$300,000	AMO
nDETECT	$25,000	NNSA
GRIP	$245,000	OE
Total	**$151,322,063**	

15 cohorts* completed as of Fall 2022

Innovations have spanned 18 DOE program areas

including 191 teams from 12 National Labs

Teams have conducted more than 13,600 stakeholder discovery interviews with companies like: EPRI, Shell, Ford, World Bank, Breakthrough Energy, John Deere, Siemens Gamesa, Chevron, Eaton, Samsung, Lowes, Johns Manville, LEGO, U.S. Army, Trane, Tesla, GM, Dow Chemical, 3M, Whirlpool, GE, Home Depot, and Amazon

190+ industry mentors and instructors involved

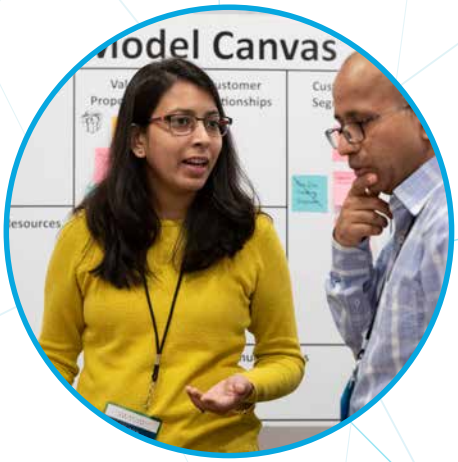
*Plus Pilot program cohort

Team Profiles

Energy I-Corps aims to accelerate the deployment of energy technologies by encouraging National Lab scientists and engineers access to direct market feedback for their technology offerings. 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.

"Biggest takeaways? Question your assumptions, validate your hypotheses."

– Caitlyn Clark, NREL, Entrepreneurial Lead



CO2BOL-NG Acid Gas Separation Technology

Pacific Northwest National Laboratory
Cohort 5

Problem

Global demand for liquefied natural gas is around 400 million metric tonnes per year and is expected to increase to 500 tonnes by 2030. The industry is valued in the billions of dollars per year and toxic acid gas impurities present at parts per million (ppm) levels can 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 to operate the costly facilities.

Researchers at PNNL have developed a reusable organic liquid that can pull harmful gases such as CO_2 or H_2S (hydrogen sulfide) out of industrial processes, natural gas streams, and emissions from power plants. The process could directly replace current methods and capture double the volume of harmful gases in a way that uses no water, consumes less energy, and saves money.

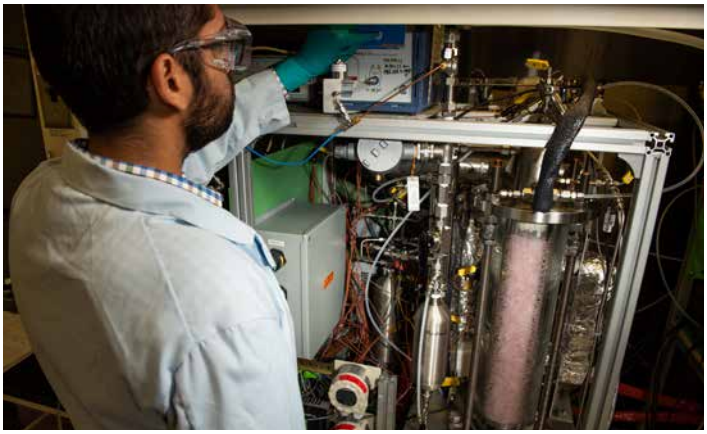
Industry Focus

Producers, natural gas refineries, power plants:

- Need costly, large, centralized processing facilities to remove impurities from gas streams
- Produce hundreds of millions of standard cubic feet a day of gas requiring treatment
- Use highly corrosive acid gases and water-based solvents
- Currently remove ppm-level impurities (CO_2, H_2S, COS [carbonyl sulfide], H_2O) with costly processes that use millions of gallons of solvents annually

Solution

Separating ppm-level impurities requires strong chemical complexing agents, often liquids for their ease of use. These solvent-based processes most commonly 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 regenerate under mild conditions, reducing energy demands. The CO_2BOL platform can be applied to any acid gas, making it the "Swiss Army knife" of chemical solvents because of its ability to tailor the specific chemistry to the specific gas separation application.



PNNL researcher Dushyant Barpaga operates the Laboratory Continuous Flow System, which can evaluate typical, analogous industrial absorption and stripping operations such as novel CO_2 capture solvents, packing materials, and a wide range of process conditions at a much smaller scale than previously possible. *Photo by Andrea Starr, PNNL.*

Where are they now? Post-Program Advancements

Through the stakeholder discovery process and a total of 77 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
- Participated in National Lab Pitch Competition at LLNL in November 2017.

For more information or to request speakers, contact David Heldebrant (david.heldebrant@pnnl.gov), Phillip Koech (phillip.koech@pnnl.gov), or visit www.pnl.gov.

Electro-Active Technologies

Oak Ridge National Laboratory
Cohort 7

Problem/Opportunity

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. The Electro-Active system provides a solution to both issues, converting waste into affordable, renewable hydrogen. This technology can reduce greenhouse gas emissions by 66% compared to steam methane reforming, and can provide a negative carbon pathway to hydrogen, with the potential to remove 82 tons of CO_2e per ton of hydrogen generated. Additionally, the system can achieve twice the electrical efficiency of water electrolysis. It is a pathway to the sustainable economy of the 21st century.

Industry Focus

This technology enables hydrogen-fueled equipment such as forklifts, class 8 trucks, generators, personal vehicles, city fleets, and maritime applications.

Solution

Key offerings:

e-H_2Gen: Modular renewable hydrogen generation system using organic waste, adaptable to low- and high-volume customers that can be deployed on-site with large waste generators, waste haulers, and municipalities. Additional coproducts include a residual solids stream for use in composting, animal feed, and regenerative agriculture, as well as a nutrient-rich liquid that can also be utilized in regenerative agriculture or for urban greenspaces.

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 agricultural technologies to market.

Alex Lewis and Abhijeet P. Borole (speaking), representing ORNL, present Electro-Active, a modular system that can be placed on-site to convert waste into renewable hydrogen.
Photo by Amy Glickson, NREL.

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

-Peter Klauer, CAISO

Where are they now? Post-Program Advancements

- Accepted into the Innovation Crossroads program at ORNL
- Raised $1.6 million in private capital and received a DOE grant to work with Southern Company on further scale-up and demonstration
- Participated in a number of accelerators, including IndieBio, H_2 Refuel, Plug and Play, Valley Ventures, Scale For ClimateTech, Smarty City X, and Startup Bootcamp.

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

Electronic Instructions for Nuclear Applications (ELINA)

Idaho National Laboratory

Cohort 6

Problem/Opportunity

Many nuclear power plants rely on inefficient and bulky paper copies of procedures and work instructions. Some have adopted electronic work packages—paper documents converted to PDFs or similar digital formats—in an attempt to streamline work processes, improve efficiency, and reduce costs. Unfortunately, the industry did not experience the anticipated human performance improvements of transitioning from paper to digital information.

Industry Focus

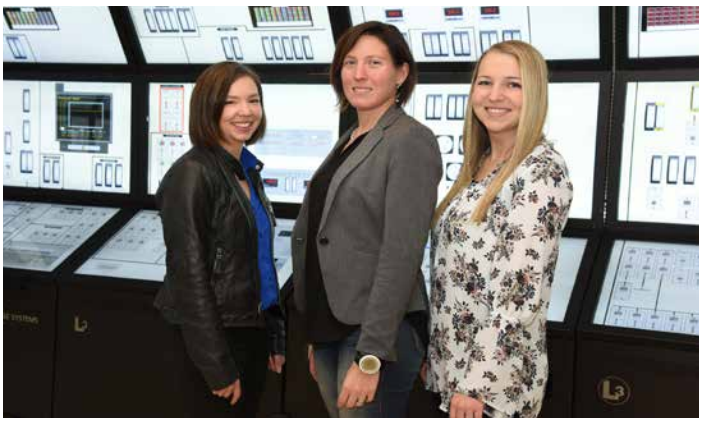
INL and NextAxiom Technology, Inc. formed a partnership in 2018 to develop a dynamic instructions solution that guides workers through correct task paths based on decisions and inputs recorded as the work proceeds.

Additional relevant information is available at the worker's fingertips whenever it is needed. This strategy increases the time employees devote to work and reduces waiting time and administrative burdens. A mature, commercially available dynamic instructions technology enables more effective and efficient completion of work in nuclear power plants, which reduces costs. This work was funded through the DOE OTT Technology Commercialization Fund.

Where are they now? Post-Program Advancements

Patents

- Method To Convert Written Instructions To Structured Data, And Related Computer Based Context Sensitive Procedures That Use The Same. U.S. Patent 11,126,789, issued September 21, 2021.



Team ELINA: Katya LeBlanc, Johanna Oxstrand and Rachael
Photo by Chris Morgan, INL.

Copyrights

- CW-17-09-SEIDR. Computer-Based Procedure Execution Software (SEIDR). Copyright asserted July 2017.
- CW-20-20-OPENS. Operating Procedure Extender for Novel Systems (OPENS). Copyright asserted February 2021.

Standards

- Oxstrand, J., and Hargett, D. (Eds.) 2017. PPA AP-907-005.001, Rev. 0. Functional Requirements For Advanced And Adaptive Smart Documents. Procedure Professionals Association.
- Hargett, D., and Oxstrand, J. (Eds.) (2020) PPA AP-907-005.002, Rev. 0. Dynamic Instruction Set Editor Functional Requirements and Implementation Considerations. Procedure Professionals Association.
- Hargett, D., and Oxstrand, J. (Eds.) (2020) PPA AP-907-005.003, Rev. 0. Common Dynamic Instruction Model (CDIM). Procedure Professionals Association.

Industry Initiatives

- INL initiated and led two large industry initiatives
  - Nuclear Electronic Work Packages-Enterprise Requirements (NEWPER)
  - Dynamic instructions editing tool requirements (DIRECTOR).
- Co-developed a solution with NextAxiom that was deployed at NextEra Energy and Ontario Power Generation
- INL team participated in Trailhead East, INL's incubator and follow-up opportunity to Energy I-Corps.

For more information or to request speakers, contact Johanna Oxstrand, johanna.oxstrand@inl.gov.

Gamma Reality Inc. (GRI)

Lawrence Berkeley National Laboratory
Cohort 6

Background

"Where can I get one?"

This is a question that the LBNL team developing 3D radiation mapping technologies heard repeatedly from potential end users at demonstrations and measurement campaigns all over the world. At the time, only a single research prototype existed, but the question stuck with team members as they conducted R&D and explored commercialization pathways.

In fall 2017, Team Gamma Rayality from Berkeley Lab participated in Cohort 6 of the Energy I-Corps program. The team was composed of Principal Investigator Dr. Andy Haefner and Entrepreneurial Lead Erika Suzuki. Both went on to co-found GRI, which launched in early 2020. Dr. Haefner developed the scene data fusion and 3D radiation mapping software as part of his Ph.D. research before growing it into a research portfolio at Berkeley Lab and leading development of the LAMP (Localization and Mapping Platform) system with a team of researchers, including co-founders, Dr. Ryan Pavlovsky and Dr. Kai Vetter.

Problem/Opportunity

Specialized equipment is required to identify and locate radiological/nuclear material and map contamination. Most available commercial systems require static measurements (you have to place the system in a single location and wait for it to collect data), 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 [light detection and ranging]) 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.

Erika Suzuki at a demonstration of the research prototype on an unmanned system. *Photo by Erika Suzuki.*

Industry Focus

This technology has application opportunities in defense, nuclear power plant operations, 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 [global positioning system]) 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 and automatically correlates radiation data with 3D models of an area in real time to show the location of radiological/nuclear material and map radioactive contamination. The intuitive 3D mapping shows features in the local environment, such as cars, buildings, people, and other objects in addition to highlighting the location of the radioactive source and doesn't require a scientist to interpret and communicate. Development of this technology is supported by the Defense Threat Reduction Agency and enables:

- **More efficient operations:** LAMP is fully mobile and provides actionable information in real time, enabling faster decision making
- **Safer operations:** LAMP can be remotely deployed on both ground robots and unmanned aerial systems, or drones, for example, to map radioactive hazards.
- **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

Gamma Reality Inc. (GRI)

(continued)

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.

Two versions of LAMP are currently commercially available for different applications. LAMP-Imager features higher resolution gamma-ray imaging and LAMP-Mapper provides nonimaging gamma-ray mapping as well as a dual gamma-ray and neutron mapping option.

Where are they now? Post-Program Advancements

Post-Program Advancements

GRI is now a company with 12 employees and the LAMP system is commercially available. GRI has several government-funded projects, including a Small Business Innovation Research grant, and is also pursuing commercial sales. GRI has licensed the LAMP technology from Berkeley Lab, where research in this area continues. GRI provides real-time, mobile, 3D radiation mapping capabilities deployable in handheld mode, on unmanned robotic platforms (unmanned aerial vehicles or unmanned ground vehicles), and on other vehicles to enable safer, more efficient, and more dynamic radiation detection missions.

The company's core capabilities include multi-sensor data fusion and data analysis, 3D radiation mapping with situational awareness sensors, and integration of multi-sensor 3D radiation mapping systems with robotic platforms. GRI provides gamma-ray imaging, non-imaging, and dual neutron and gamma-ray mapping capabilities based on user needs for applications including nuclear security, emergency response, safeguards, defense, decontamination, and more. The GRI team has more than a decade of experience developing and integrating hardware and software for multi-sensor systems, as well as designing and building custom radiation mapping systems.

For more information, visit www.gammareality.com.

Gamma Reality's LAMP-Imager. *Photo by Gamma Reality Inc.*

General Line Ampacity State Solver (GLASS)

Idaho National Laboratory
Cohort 3

Problem/Opportunity

The U.S. electrical grid is in the middle of a dramatic transformation. As utilities consider replacing aging infrastructure and incorporating renewables from remote locations, unlocking extra capacity within existing transmission lines can immediately and cost-effectively increase the capacity, efficiency, and reliability of existing power lines.

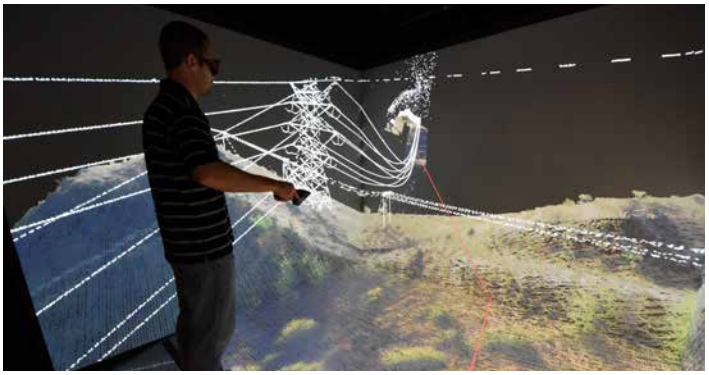
Industry Focus

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 improve grid capacity. Static line ratings use 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 inform system planners and grid operators about available transmission capacity beyond traditionally calculated static line ratings.

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.

Solution

INL's GLASS innovation offers the potential to safely provide more robust line ampacities by using real-time operating conditions and predicted weather information rather than overly conservative static line rating assumptions. It uses commercially available weather monitors mounted on industry-informed brackets developed at INL, in combination with computational fluid dynamics-enhanced weather analysis and dynamic line rating software.



INL researcher Jake Gentle conducts critical infrastructure analysis using INL's General Line Ampacity State Solver (GLASS) software. *Photo by Chris Morgan, INL.*

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, the largest regulated electric transmission company in Alberta, Canada, on a field study of four transmission line segments
- GLASS named a finalist for the 2017 and 2018 R&D 100 Awards
- INL awarded a TCF award from DOE's OTT, and collaborated with an industry partner during fiscal years 2018–2020
- GLASS awarded Idaho Innovation Award's "Early-Stage Innovation of the Year" for 2021.

Licensing:

GLASS has been exclusively licensed to WindSim Power. They recently launched their "WindSim Power Line" product, which is based on GLASS. More information can be found at https://windsim.com/power-line/windsim-power-line/.

Video:

https://youtu.be/X8laVYN6tUw

For more information or to request speakers, contact Jake Gentle at jake.gentle@inl.gov.

Iris Light Technologies, Inc. (formerly LaserSense)

Argonne National Laboratory

Cohort 7

Problem/Opportunity

Light chips are booming, but the lasers aren't cutting it.

Silicon photonics ("light chips") are an enabling technology platform powering applications in optical communications, autonomous vehicles, drone sensing, and the Internet of Things (IoT). The technology in these markets is evolving from large, expensive systems towards photonic integrated circuits (PICs), which contain full optical systems on thumbnail-size chips and cost a fraction of their bulky predecessors. PICs leverage the tremendous manufacturing infrastructure of semiconductor electronics to produce huge volumes compared to traditional optics manufacturing. These cost benefits have resulted in >45% year-on-year growth in the past decade.

However, the silicon photonics industry is held back by complicated manufacturing and a constrained supply chain. Today, chip-design companies are required to source silicon photonic chips from one foundry and separate laser chips from a second foundry due to lack of on-chip laser integration. There is no open-access foundry with on-chip lasers. Moreover, a single laser typically comprises at least 25% of the total module cost, limiting the number of lasers per chip, and therefore chip value, due to limited functionality. This bottleneck holds back broad adoption of light chips in high volume applications demanding lower price points.

"Unless this [laser] gap is resolved in the next 5-10 years, a showstopper will arise for major sectors of the silicon photonics markets." - **2020 IPSR Roadmap**

Industry Focus

Iris integrates lasers on-chip, with broad spectral coverage

Iris Light's mission is to accelerate broad adoption of light chips by lowering manufacturing barriers. Iris Light's "secret sauce" is an on-chip laser technology created from printed nanomaterial 'inks' enabling high-volume, wafer-scale production of photonic chips. In an industry where access to laser colors drives business opportunity and market segments, Iris Light hits the whole rainbow with color-tunable inks. With these two core differentiators of broad spectrum and on-chip laser production, Iris Light is the only company positioned to cover the growing needs of spectral coverage in silicon photonics.

Iris Light founder Chad Husko holding a 12-inch (300-mm) silicon wafer composed of hundreds of chips. Iris Light on-chip lasers are made by depositing proprietary photonic ink onto the surface of a pre-patterned wafer like the one shown here. *Photo by: Mary Reid Ervin.*

Iris solves the most critical unmet industry need and is positioned to capture a significant share of the current $4 billion/year market that is expected to exceed $18 billion by 2025.

Solution

Native silicon cannot emit light efficiently (efficiency is <0.0001%). Thus, a hybrid approach with a partner light-emitting material coupled to silicon is required to make lasers. The Iris Light approach consists of printing light-emitting nanomaterial inks on state-of-the-art 300-mm silicon substrates. The solution takes advantage of the separation of the nanomaterial synthesis and subsequent deposition, an advance representing a fundamental shift in silicon photonics manufacturing. Specifically, nanomaterial "inks" are produced off-site with different emission properties that are then delivered as different laser "colors" to the foundry. The impact of this streamlined manufacturing is light chips with increased functionality, and therefore value, all at the wafer-scale.

Where are they now? Post-Program Advancements

- Financing received: $1.7M –SBIR/STTR, Chain Reaction Innovations, angel funding, revenue, and non-dilutive (grant) opportunities
- Accepted into Cohort 2 Chain Reaction Innovations (ANL), a unique two-year fellowship for innovators focusing on clean energy and science technologies
- CRADA with the Air Force Research Lab following on from SBIR/STTR Phase 2 funding
- Licenses: Exclusive Option with ANL and Northwestern University
- One new patent filed.

Speaking engagements: Entrepreneur panel at Optica—Frontiers in Optics 2020 conference.

IrrigationViz

Pacific Northwest National Laboratory and Idaho National Laboratory

Cohort 12

Problem/Opportunity

Modernizing irrigation needs a helpful tool. Many irrigation systems in the United States were established in 1900 by the government and are aging out quite quickly. This means a good portion of American farmlands and agriculture are watered inefficiently.

With water scarcity a growing problem, especially in western states, there needs to be improvement in many irrigation districts to prevent seepage. Some irrigation districts have seepage rates of 60% to 80%. The best way to tackle this problem is to modernize the facilities, but many districts simply don't know where to start.

Industry Focus

One of the few multi-lab teams to participate in Energy I-Corps, IrrigationViz originated in PNNL and INL as part of Cohort 12. The multi-lab team formed virtually and participated in a virtual cohort due to the pandemic, making collaboration easier in many respects.

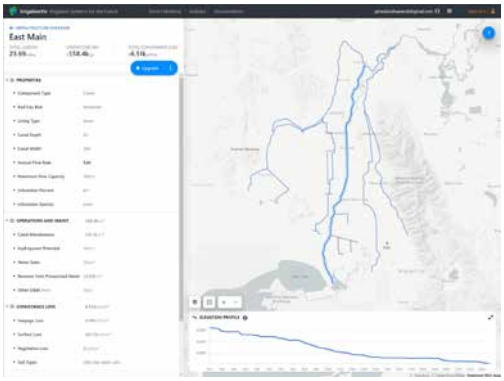
Funded by the Water Power Technologies Office, team members, INL Data Scientist Shiloh Elliott and PNNL Software Engineer James Kershaw, specifically targeted the gap in communicating the benefits of irrigation modernization to the districts. These organizations often don't know what they need to do to improve existing systems, and they may lack the knowledge of potential funding sources and the engineering staff to make it happen.

Solution

The IrrigationViz team created a software system that serves as an irrigation modernization master-planning tool. The software models high-level costs and plans for a project.

"They are not engineering designs, but we're using data modeling and algorithms to produce estimates in a generic way in order to give districts a high-level understanding before they hire an engineer to map this out," Kershaw said.

The tool gives cost estimates of using concrete or pipelines to modernize, as well as the benefits of either option. Pipelines tend to be more expensive, but also more efficient.



To bring the irrigation industry into the modern century, the IrrigationViz team created a software system that serves as a master-planning tool modeling high-level costs and plans for a project. *Photo from IrrigationViz..*

"Most irrigation systems don't have a modernization plan, so IrrigationViz can fill that gap, creating a to-do list and prioritization," Elliott said. Additionally, the tool will provide irrigators with options for grants and other sources of funding to help pay for the modernization process.

Where are they now? Post-Program Advancements

The Energy I-Corps program informed the IrrigationViz team that few end users would pay for the software, so they decided to make it completely free. The team continues to spread the word about their tool, urging users to take advantage of it.

"We've partnered with a number of other irrigation districts and we're trying to develop capabilities specific to each district's questions. The tool is not in the wild yet. We're continuing to see input and seek validation, but we think we're on the right path, and time will tell on that," Kershaw said.

- Completed two case studies
- Plan to release public version 1 in the next 12 to 18 months
- Upcoming interview to be published in Irrigation Leader Magazine
- Upcoming presentation at the 2022 Washington State Water Resources Association
- Presented at the 2022 Clean Currents conference.

For more information, contact Congwang Ye at ye4@llnl.gov.

Microwave Assisted Catalysis (MAC)

National Energy Technology Laboratory

Cohort 12

Problem/Opportunity

The production of oil in the United States primarily occurs in remote areas of Texas, North Dakota, and Colorado. While oil is the desired product, the drilling is also accompanied by an associated natural gas by-product that often emerges intermittently during the process. In these regions, the natural gas is considered "stranded" due to the lack of infrastructure to transport it from the drilling location. As such, the cheapest and most viable solution to deal with these resources is for oil producers to use a technique called flaring, which combusts the natural gas on site.

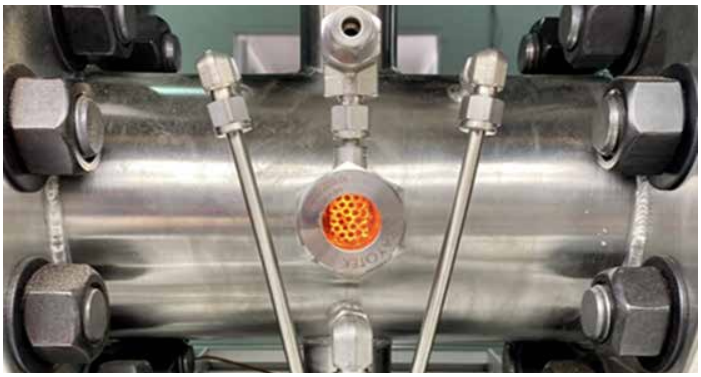
Flaring is a source of significant greenhouse gas (GHG) emissions as well as a waste of domestic resources. However, building a natural gas pipeline system is time consuming and expensive, and oil drillers are not likely to change their process unless it's mandated by federal or state policy to either stop flaring or takeaway capacity must be in place for before drilling new wells. For many of the larger oil and gas corporations, the flaring problem doesn't represent enough GHG emissions to make it a higher priority that needs to be addressed.

"Natural gas is a valuable resource and is not something that should be burned and wasted. Oil companies are trying to get to the oil, and the natural gas is not a priority for them," NETL research engineer Christina Wildfire said. "But it's terrible for the environment, so we need solutions that can actually capture this resource to utilize it in a more effective manner instead of burning."

Industry Focus

The flare process is popular because it's easy to do, so the industry won't change practices unless the replacement is just as simple. The best organizations to target with an alternate option are smaller oil drillers. They are looking for a complete solution that captures the gas, removes it from the site, and redistributes it to others who can use it.

This natural gas could become a source of supplemental income for these drillers or could offset larger CO_2 emissions that are on the record against their company.



To capture the natural gas instead of burning it, the Catalysis/MAC team uses a microwave reactor, which is an electric-based process to convert the methane into a higher-value chemical, called BTX, commonly used in plastics manufacturing and to create other chemicals. *Photo from Catalysis/MAC*

Solution

To capture the natural gas instead of burning it, the Catalysis/MAC team uses a microwave reactor, which is an electric-based process to convert the methane into a higher-value chemical, called BTX, commonly used in plastics manufacturing and to create other chemicals. When the gas is upgraded to BTX, it's easier to store and transport. The solution is autonomous and all-inclusive.

"They are already diverting the gas to the flare, so we would just connect the reactor system there instead," Wildfire said. "It's a mobile chemical plant, a reactor that changes the gas into the chemical."

Where are they now? Post-Program Advancements

The team continues to make the catalyst material needed for the mini reactor while trying to make it a more durable process. The team is also looking for industry partners for a pilot program and to help them scale up their reactors.

Additionally, other industries, such as chemical producers, are interested in the process of directly converting methane into BTX, outside of flaring.

"We're just trying to get the technology proven enough to where industry is interested in taking it," Wildfire said.

MECS

Lawrence Livermore National Laboratory

Cohort 4

Problem/Opportunity

Craft beer is a booming business in the United States. Since 2009, the number of craft breweries 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 during the fermentation process as it needs. Companies with large operations often have CO_2 recovery systems, like those currently used at power plants. Many microbreweries, however, don't have the ability to capture and recycle CO_2 back into their operations. Because of this, the CO_2 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.

Industry Focus

MECS (micro-encapsulated CO_2 sorbents), is the work of a group of researchers from LLNL who 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 CO_2.

Through exploration of new potential markets in the Energy I-Corps program, the 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 CO_2 at the brewery and are then taken to a centralized facility to reclaim the absorbed CO_2.

According to a DOE article, "Lab Carbon Capture Technology Keeps Beer Bubbling," if the technology is successful, the process could save breweries tens of thousands of dollars a year and prevent millions of pounds of CO_2 produced during fermentation escaping into the atmosphere.

LLNL Researcher Congwang Ye (right) visits with professors at UC Davis to see their pilot-scale winery and brewery and learn about fermentation tank operations. *Photo by LLNL.*

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 CO_2. The microcapsules are then suspended on a mesh structure to allow CO_2 to move in and out of the shells—absorbing CO_2 approximately ten times faster than encapsulated chemicals. Once the capsules are saturated, the trapped CO_2 is recovered and the capsules can be reused.

Where are they now? Post-Program Advancements

- Awarded the Innovation Development Fund from LLNL-IPO to pursue risk reduction for the beer application
- Won a TCF from OTT to integrate MECS into a start-up company's commercial product for indoor CO_2 removal, conversion, and air purification
- Working with the University of California, Davis Enology/Chemical Engineering and Trumer Pils Brewery for experimental validation of using MECS with fermentation gas
- Inventing and optimizing LLNL's patented capsule mass-production tool, called In-air Drop Encapsulation Apparatus, which can be used to make MECS and other capsules/particles.

For more information, contact Congwang Ye at ye4@llnl.gov.

RECOVER

Pacific Northwest National Laboratory

Cohort 12

Problem/Opportunity

Efforts to address climate change can focus on clean energy sources, energy efficiency, and/or waste reduction and recycling. Lightweight polymer materials that are highly recyclable will be increasingly critical for many applications. For example, in the transportation sector, polymer composites are increasingly replacing higher-weight metals while offering satisfactory performance. The major barriers for such lightweight polymers include the cost of both manufacturing and recycling, the hazardous chemicals associated with traditional polymermaterials, and inadequate material properties for structural applications.

Industry Focus

The RECOVER team's technology is a process for producing high performance, reformable polymers, called vitrimers, particularly from carbon dioxide, which is a common waste gas. The process enables a green pathway to form the chemical building blocks for the vitrimer material. Thanks to the unique chemistry, the CO_2-derived vitrimer can achieve excellent reprocessability and reformability, improving manufacturing rate, reducing manufacturing cost, all while valorizing an abundant greenhouse gas.

Solution

While this technology has many potential applications, RECOVER's focus during Energy I-Corps was on a likely early adopter of the CO2-derived, non-petroleum based vitrimer. The team explored addressing needs and demands of high-performing athletes looking for lightweight, environmentally friendly sports equipment. For example, the CO2-derived vitrimers can replace petroleum-based, non-recyclable thermosets in high-end bicycles to provide impact resistance at a low-carbon footprint while being able to be easily recycled at the end of the product's life—making it possible to retrieve and reuse the higher-value carbon fibers impregnated within the polymer.

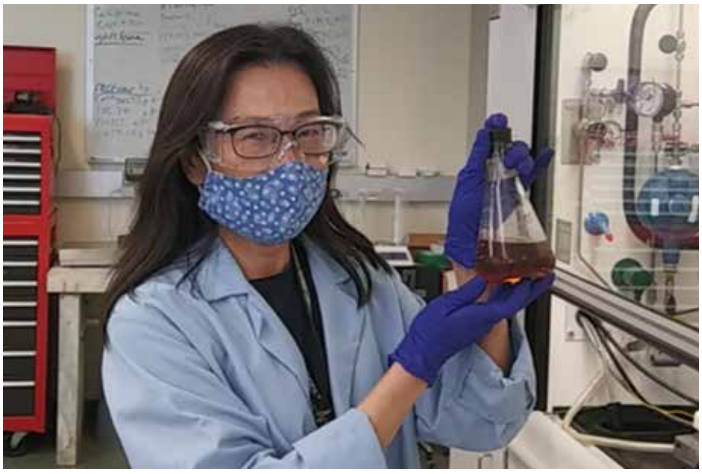


Photo by Senthil Subramaniam, PNNL.

The current carbon fiber bike market is a $2.6 billion addressable market. RECOVER's target would be small to medium-sized custom bicycle manufacturers, representing an approximately $260 million market.

Where are they now? Post-Program Advancements

In parallel to the Energy I-Corps market exploration, PNNL, the University of Akron, and Raytheon Technologies Research Center were awarded a $1.9 M grant by the DOE's Advanced Manufacturing Office and BioEnergy Technology Office through the Bio-Optimized Technologies to keep Thermoplastics out of Landfills and the Environment (BOTTLE™) program. The overall goal of the team's BOTTLE™ project is to create recyclable carbon fiber composites using vitrimer resins that are more energy efficient to produce and have improved properties over baseline technology. This project shares common ground with the CO2-derived vitrimer technology described above. The targeted composites will retain their tensile strength after multiple recycling and reprocessing steps. In addition, monomer will be recoverable through depolymerization and re-usable carbon fibers will be retrieved.

For more information contact Suh-Jane Lee, Suh-Jane.Lee@pnnl.gov.

RouteE

National Renewable Energy Laboratory

Cohort 8

Background

The RouteE project grew out of a program funded by ARPA-E (Advanced Research Projects Agency-Energy) called TRANSNET (Traveler Response Architecture using Novel Signaling for Network Efficiency in Transportation). NREL researchers developed a successful TRANSNET proposal in partnership with Metropia Inc., a transportation technology solutions and consulting firm, and performed the work with support from the University of Kansas and the University of Washington.

Problem/Opportunity

Working with Metropia, the team developed RouteE, an energy-informed trip planner, to incentivize or disincentivize changing departure times, taking alternative routes, or choosing different modes of transportation to avoid traffic congestion. Exiting the TRANSNET program and leading into Energy I-Corps, the team recognized broader transportation energy savings potential for RouteE but struggled with:

- How to scale for larger energy impacts
- Prioritizing expansion of RouteE core functionality.

Industry Focus

Energy I-Corps participants commit to a discovery process during which they determine the needs and pain points of stakeholders in a particular ecosystem and use the information to guide research. In the case of RouteE, after talking to some 100 industry stakeholders, team members familiar with the vehicle routing and navigation space used that knowledge to chart a path forward for RouteE.

Initially, the team was attracted to potential opportunities to integrate RouteE into platforms like Google Maps and Apple Maps. However, when they investigated financial incentives, they determined RouteE made more sense for fuel-intensive medium- and heavy-duty vehicles like UPS and FedEx vans or Walmart semis.

RouteE can help drivers avoid bumper-to-bumper traffic jams like this backup on I-25 in Denver, Colorado. *Photo by Dennis Schroeder, NREL.*

Solution

Energy I-Corps greatly impacted how the RouteE team approached future proposal development and influenced their published research to highlight how their work addresses industry and consumer challenges. Fast forward to 2020—Google makes sweeping sustainability commitments and tasked a team with adding sustainability features to their mapping platform. After learning about NREL's mobility research and transportation analysis capability, Google approached the RouteE team. Launched in 2021 on Android and iOS devices, Google Maps uses RouteE to default to the route with the lowest carbon footprint when the arrival time is roughly the same as the fastest route. If the more eco-friendly route increases travel time, Google Maps displays the relative CO_2 impact between the routes, allowing users to make informed choices about which to take.

Where are they now? Post-Program Advancements

NREL continues to collaborate with Google as the company grows and develops the eco-friendly routing feature. Researchers are also involved in using RouteE in other industry partnerships as well as with several DOE projects, including the SMART Mobility program, Big Data Solutions for Mobility, and Regional Mobility.

For more information or to request speakers, contact Jacob Holden, Jacob.Holden@nrel.gov.

SuperChips

Lawrence Berkeley National Laboratory

Cohort 11

Problem/Opportunity

As the world continues to modernize, computing power struggles to outpace the needs put upon the systems. With more sophisticated programs, it requires faster machines that can run complex programs at the speed users expect.

Quantum computing harnesses the phenomena of quantum mechanics, which can run much faster than classical computers. However, current quantum computers are too small to outperform existing machines. Much of this is because a quantum system needs a huge amount of wiring that makes it untenable for most users, while making it difficult to scale up the use of quantum computers.

Industry Focus

Dilip Vasudevan and the SuperChips team came to Energy I-Corps in October 2020 having already secured patents around developing chip designs for high-performance computing architecture using superconducting devices ("A Computational Temporal Logic for Superconducting Accelerators" and "TLNoC: A Statically-Scheduled Circuit-Switched Superconducting Race Logic NoC") but they sought direction of what to do with them.

Solution

SuperChips reduces the number of wires needed through a custom microchip design that controls the system in a better way using superconducting devices. SuperChips builds the virtual blueprint of the designs and then sends them to partners who manufacture them. These designs are based on reconfigurable computing architectures, which are more tuned toward the type of applications that are expected to run using quantum systems. Applications like machine learning, digital signal processing, financial algorithms, and scientific simulations can be run at a very high speed compared to current transistor-based electronic chips.

Many companies want to start selling quantum computers in 2026, and to reach that goal, Vasudevan says they need his market solution. "They need someone to help them build these efficient control chips. Without this missing piece of the puzzle, it cannot sell," he said. "We reduce the system control complexities so the user can easily interact with that quantum system."

SuperChips team member Dilip Vasudevan is improving quantum computing by reducing the number of wires needed with their custom microchip design. *Photo from SuperChips.*

Where are they now? Post-Program Advancements

During the program, SuperChips connected with two specific quantum system customers interested in their product. Those interviews led to Vasudevan incorporating the business (www.superchips-ml.com) and prototyping their chips. They have now tested five chips in progression.

Vasudevan says the company is now looking at other acceleration programs for funding to move forward

- Partnerships with two members of the quantum system community: Strangeworks and Super.tech
- R&D 100 awards, 2022 finalist
- Received a commitment for funding if they can raise to a certain goal
- Selected for the DOE Emerging Tech Studio powered by FedTech
- SuperChips was part of the top 10% of the 15,000 applications for Y Combinator
- Applying for two DARPA grants and planning for SBIR

Patents

- A Computational Temporal Logic for Superconducting Accelerators. U.S. Patent Application. 17/909,932, filed Sep. 7, 2022. Patent Pending.
- TLNoC: A Statically-Scheduled Circuit-Switched Superconducting Race Logic NoC. International Patent Application. PCT/US2022/028538, filed May 10, 2022. Patent Pending.

SwitchGlaze

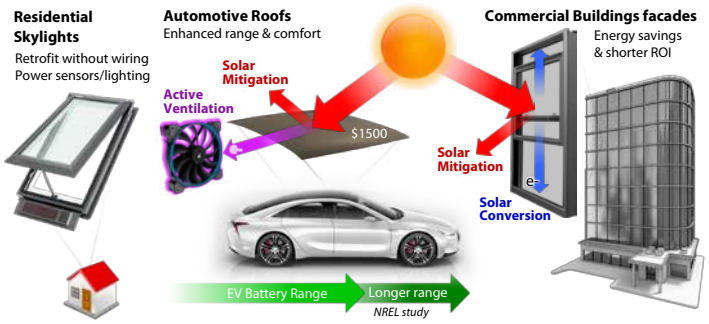
National Renewable Energy Laboratory

Cohort 3

Problem/Opportunity

Buildings account for approximately 75% of electricity use in the United States. Current trends in commercial building design are toward all-glass facades, which prioritize aesthetics and interaction with the external environment over 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 not attractive enough to support widespread adoption.

Industry Focus



Solution

SwitchGlaze couples the energy savings of dynamic glass with solar energy generation, dramatically improving the return on investment of dynamic glazing. The technology is poised for immediate impact in skylight retrofits; it will save consumers the cost and disruption of tearing out walls for wiring and enable integrated designs in which SwitchGlaze powers internal LED lighting as well as a CPU that controls rain sensors and motors to open and close the window. SwitchGlaze technology's low production costs, energy generation benefits, and attractive return on investment enable practical deployment in commercial buildings and automotive industries.

Researchers Rob Tenent, left, and Lance Wheeler make up the SwitchGlaze team, which created a product that turns glass into photovoltaic panels.
Photo by Werner Slocum, NREL.

Where are they now? Post-Program Advancements

- Received $2.25 million in funding from EERE Buildings Technologies Office in a lab-call funding opportunity announcement award
- Received $50,000 in strategic funding from DOE to address technological barriers identified during Energy I-Corps discovery process
- Teamed with commercial partners for fabrication and scale-up of prototype products
- Performed ongoing research that resulted in multiple high-impact publications, including two articles in Nature Communications
- Featured in annual issue of Innovative Energy Review magazine
- Invited to pitch at NREL's Innovations Showcase and at Pitch! Energy Competition
- Successfully negotiated with 2qV Technology Company to license and commercialize the technology.

UltraSep

Los Alamos National Laboratory

Cohort 12

Problem/Opportunity

Separating particles from liquids is an issue that affects industries ranging from food and beverages to toxic chemicals. Current processes often involve centrifuges, which are expensive and take a great deal of energy and for beverages, may remove more than desired from the liquid.

One example of this is beer. When brewers use a centrifuge to remove yeast from their beer, they end up removing other particles that add to the taste and quality of the beverage. Conversely, when yeast strike the solid surface at a high velocity, they break and release enzymes into the liquid, which can impact flavor and foaming properties. Regardless of the application, centrifuges require regularly scheduled maintenance and servicing that adds to their operating costs.

Another example is plutonium. Currently, those who work with plutonium must lift a 5-gallon container inside a box and pour it through a filter. That filtering process can then take weeks. The physical process is strenuous, and it exposes workers to radiation.

Focus

Finding better ways to separate solids from liquids could revolutionize many processes, especially if it is possible to use less energy to perform the task. Additionally, it is crucial to have the ability to gain more control of the process and be able to finesse it for targeted separation.

Solution

While no single technology will do everything, ultrasonic filtration or separation (UltraSep) is a membrane-free technology that removes particles from liquids. While the particles must be large enough, in both size and density, to significantly contrast from the liquid, an ultrasonic field, called a standing wave, causes the separation. The wave is held inside a device while the liquid flows through it.

The field causes the particles in the liquid to stop moving even as the liquid continues to move through. The trapped particles quickly clump together in regularly spaced positions called nodes. The forces continue to push the particles together at these nodes and gravity wins out over time, meaning the clumps settle to the bottom, capturable in a more concentrated state.

Ultrasonic filtration or separation (UltraSep) is a membrane-free technology that removes particles from a range of liquids, including beer and plutonium. *Photo from UltraSep.*

"We have a technology that is relatively poorly known. People aren't familiar with it," said Technical Project Manager Jim Coons. "It's a real change of paradigm and I think that if people see the technology works, then they will realize the potential advantages for a wide number of industries that suffer a great deal in terms of costs of maintaining hard surfaces, such as a centrifuge."

The UltraSep team received funding to create a prototype for plutonium filtration, which could see a major shift in the paradigm of handling highly radioactive materials.

Where are they now? Post-Program Advancements

During Energy I-Corps, the UltraSep team began discussions with brewers after determining that yeast was a large enough particle to become trapped in the standing wave. The UltraSep process may help brewers produce a full bodied product that can be packaged with a consistent taste and long shelf life.

"In the future, this technology can be used for any kind of chemical process where you're producing low to medium concentrations of solid materials in a liquid, it can be used for beer, it can be used for food applications, or it can be used for plutonium," Coons said.

Patents

- Acoustic Manipulation of Fluids Based on Eigenfrequency. U.S. Patent. 10,428,324 B1, Oct. 2019.
- Ultra Low Power Acoustic Separation, Ultra Low Power Acoustic Separation. U.S. Patent. 11,395,982, July 2022.

Ultra-Fast X-Ray Imager (UXI)

Sandia National Laboratories

Cohort 10

Problem/Opportunity

High-speed cameras are powerful tools for visualizing fleeting events in the natural world. Digital high-speed camera technology has made it commonplace to record images down to the microsecond timescale with exquisite spatial detail. This has enabled photos and video sequences of fast-moving objects, from speeding bullets to a hummingbird's wing. To capture events at faster timescales, options are limited. Complex transient phenomena happening at the nanoseconds timescale have been recorded, but the imaging systems used to capture these events utilize high-voltage electron-tube-based instruments that are bulky (benchtop scale or larger), expensive, and complex (requiring frequent calibration of multiple instruments). This leaves the visualization of many events in science and nature—from chemical reactions in cells to visible phenomena occurring near the speed of light—beyond the reach of all but large, well-funded research centers.

Industry Focus

- High energy density physics research
- Inertial confinement fusion research
- Laser diagnostics
- High-speed explosives imaging.

Solution

The UXI Focal Plane Arrays (FPAs) have the potential to provide an affordable, high performance, solid state imaging solution in a single sensor that is affordable to universities, physics laboratories, free electron laser facilities, commercial companies, and other research centers. The FPAs are currently fabricated in a government-owned, strategically radiation-hardened technology, which limits the use of the sensors due to U.S. export laws. Commercialization of the FPAs (porting the design to a commercial fabrication process) is needed to satisfy the increasing demand to provide these sensors to nongovernment facilities.

A UXI SNL Z-Machine camera system. *Photo by the UXI program, SNL.*

Where are they now? Post-Program Advancements

- Additional $2.4M in funding over fiscal years 2020 and 2022
- Deployment of Gen-IV sensor to LLNL National Ignition Facility and SNL Z-Machine
- Development of Gen-V sensor fabricated in Tower Jazz 130nm commercial process
- Invited panel member at National Lab Entrepreneurship Academy
- Issued Patent No. 10,547,805
- UXI team members leveraged Sandia's Entrepreneurial Separation for Technology Transfer program to found Advanced hCMOS Systems LLC, a start-up to commercialize the technology.

For more information or to request speakers, contact Marcos Sanchez (marcos@hcmos.com) or Liam Claus (liam@hcmos.com).

Water Energy Systems for Advanced Purification (WESAP)

Pacific Northwest National Laboratory

Cohort 12

Problem/Opportunity

Wastewater management is an expensive and unsustainable problem due to the cost associated with its handling, energy intensity, and water scarcity. Traditional wastewater treatment technologies such as anaerobic digestion do not remove diluted recalcitrant organic contaminants from wastewater, resulting in their discharge into the environment. Aeration ponds and lagoons are used to treat wastewater but have large area requirements, are energy inefficient, and do not completely remove the organic contaminants. If wastewater producers such as food processing and agricultural industries had a way to clean their own wastewater, they would be able to decrease costs associated with disposal, as well as lower their freshwater consumption, ultimately making them more sustainable.

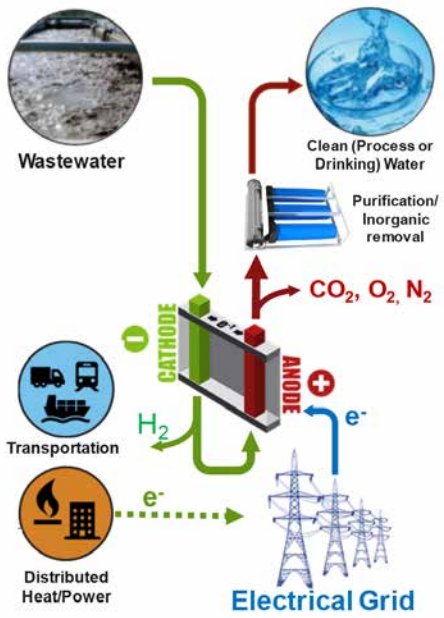
Industry Focus

A team of researchers from PNNL have developed electrochemical systems that convert organic compounds present in diluted aqueous systems while simultaneously generating hydrogen (H_2) as a side product using electricity as the only driving force.

In the Energy I-Corps program, the WESAP team identified potential markets and applications for this electrochemical technology such as cleaning wastewater generated in the wine and dairy industries to recover clean water for irrigation and cleaning purposes while in-situ generating electricity from the H_2 co-product. If successful, the process could save wineries and dairy farms tens of thousands of dollars in wastewater disposal costs, decrease their consumption of freshwater for cleaning and irrigation, and improve the sustainability of their process.

Solution

The PNNL technology uses solid electrodes to oxidize organic pollutants present in the wastewater into CO_2 while generating H_2 as a side product. The H_2 can be utilized onsite to power H_2 vehicles or converted into electricity (using fuel cells) that can be fed into the electrical grid. The electricity generated can be used to power the electrochemical wastewater treatment and improve the energy efficiency of the process. The technology is modular, operates at room temperature and atmospheric pressure, so it can be easily scaled and co-located with the wastewater management system at the generation point.



Process diagram for the on-site generation of clean water, hydrogen, and electricity via the electrochemical oxidation of wastewater. *Graphics by Juan A. Lopez-Ruiz, Ph.D., PNNL.*

Where are they now? Post-Program Advancements

- The WESAP team currently has a BETO project with Princeton University and University of Illinois Urbana-Champaign in which they are integrating the technology with biomass-liquefaction processes (for biofuel production) to simultaneously clean wastewater and generate H_2 at community scale (5 dry ton/day)
- Patents have been submitted for the technology, and it has been licensed to a company that will process biomass-derived organic and aqueous streams
- In discussion with multiple industrial partners for development of the technology in other applications
- This technology was recently discussed at the Electrochemical Society (ECS) 240th meeting and it will be further discussed at the TCBiomass 2022 conference.

Contact Juan A. Lopez-Ruiz for more information, juan.lopezruiz@pnnl.gov.

Award Winners: nDETECT

Cohort 14 Team Awarded First Ever Commercialization Award

As graduation for Cohort 14 drew closer, Wendy Rue and Mara Schindelholz from Sandia National Laboratories focused on the experience; they never expected the program instructors to award them a special prize.

"It was an amazing experience and what you think you know or feel about the program at the beginning is not how you feel about it at the end," Rue, Sandia administrative staff associate and entrepreneurial lead for the Energy I-Corps team, said. "At the start, you're intimidated by the amount of work, but by the end you just want it to continue."

That was before they learned the instructors, who voted each week during the three-month program, chose to award nDETECT a $25,000 prize. Funded by OTT, the Energy I-Corps Commercialization Award was the first-time instructors had the opportunity to award a prize during any of the cohorts. The money will help the team's commercialization journey.

"We were so excited. We put in a great deal of work and were honored to be recognized. We were a woman-led team, and proud of that as well," Schindelholz, principal member of technical staff at Sandia and the principal investigator for the team, said.

Cohort 14, which went from March to May 2022, enjoyed the participation of the most teams with women in leadership positions since the program began.

Rue and Schindelholz's team, nDETECT, created a nitrogen oxides sensor technology for real-time monitoring of pollutant gases. The sensors can tune to selectively absorb gases of interest through judicious material selection, and the electrical response directly correlated to gas concentration.

Before entering the program, the nDETECT team had only considered DOE and Department of Defense (DOD) applications for their technology, but participation in the Energy I-Corps program made them consider additional applications and markets in the future.

"Although we focused on going down a military application path, we were exposed to other ideas for scaling up the technology for other use cases," Rue said. "We have a better idea of these opportunities now, including the diesel engine market and air quality or environmental monitoring."

The nDETECT team created a nitrogen oxides sensor technology for real-time monitoring of pollutant gases. *Photo by Craig Fritz, SNL.*

With the bonus prize, the team plans to work toward building a prototype sensor over the next several months.

"I would love to have something by the end of the year that we can start showing off to potential customers," Schindelholz said.

A short time after graduation, Schindelholz participated in a roundtable discussion with U.S. Secretary of Energy Jennifer Granholm to discuss the future of local innovation and technology commercialization through DOE in New Mexico. Schindelholz discussed the Energy I-Corps program and what a valuable experience it was for her.

"I would encourage other National Laboratory staff to participate in the program if they are interested in a future pathway of commercialization and product transition for their technology. Even if we decided not to pursue commercialization more broadly, it was invaluable for better understanding the problem space with our current customer," Schindelholz said. "I also felt it was valuable personally and has helped me to continue to grow professionally in an area I am very passionate about."

Rue agrees, pointing out that Energy I-Corps participants can be in any stage of technology in terms of readiness, and it teaches important skills to individuals who may not otherwise get the opportunity to learn.

"Many inventors are working away in the labs and if they have the desire to get their technology out there for the public good, they need to learn to be a salesperson and other professional skills that they don't have in the laboratory," she said. "If anyone has an inkling of getting their technology out into the market, they should participate in Energy I-Corps. They teach you everything from A to Z."

Expanding Partnerships and Reaching New Audiences

Energy I-Corps Satellite Program

OTT launched the Energy I-Corps Satellite program in 2016 in response to the popularity of the traditional Energy I-Corps program but recognizing the time commitment may be too much for some researchers. Through the Satellite Program, each lab is supported to create a "mini" Energy I-Corps program that introduces scientists to the concepts on a much less intensive timeline. Today, every National Lab offers a custom Satellite program at their lab, providing elements such as:

- Training sessions open to researchers in conjunction with a local or national academic institution or accelerator
- Weekly lunchtime or after-hour sessions facilitated by Energy I-Corps alumni and/or qualified laboratory staff
- Coordination with other National Labs to create and deploy online or digital content aimed at all lab researchers
- Professional development sessions for all National Lab researchers through a lab's workforce training processes.

By taking core elements of the Energy I-Corps curriculum and making them accessible to a broader set of researchers, OTT encourages a more comprehensive approach to promoting and enabling commercialization and entrepreneurship within the National Lab system.

"We asked, 'Are there ways we could break pieces of the training out and offer a variety of different ways people can engage with this work?'" said Jean Redfield, Energy I-Corps instructor and coach. "Folks get better in thinking ahead on the next steps for their research agenda by understanding how their technology can orient to specific programs," Jean said. "We help these scientists move from the theoretical to the practical issues people currently wrestle with in the world that their science may help address. Energy I-Corps' focus is on how do we support a research community that is more engaged with real-world and industry problems?"

The Satellite program in no way competes with the traditional program, instead, it provides a launch point for labs to introduce concepts which allows scientists to sample the curriculum and program administrators to gauge interest. Ultimately, the Satellite program encourages application to the full program should the individual show an interest. A few researchers have chosen to do this, but Jean said the point is not about continuing participation, but the lessons they learn in any length of program.

The Satellite program increases the impact and reach of Energy I-Corps and subsequently builds more robust Energy I-Corps programming activities. This provides more Lab staff with the tools to amplify technology impact and improve effective communication, while increasing breakneck innovation and effective industry engagement.

> "It's more about culture change and skill-building around the importance of industry-informed research," Jean said. "We want them to use stakeholder discovery to do a better job as scientists. This helps them focus research, develop partnership strategies, think about the customer and how they define the problem and why that is the most important approach."

Energy I-Corps for Small Business Innovative Research (SBIR)/Small Business Technology Transfer (STTR)

Through a competitive awards-based program, SBIR and STTR enable small businesses to explore their technological potential and provide the incentive to profit from its commercialization. By including qualified small businesses in the nation's R&D arena, high-tech innovation is stimulated, and the United States gains entrepreneurial spirit as it meets its specific research and development needs. In 2020, the Office of SBIR/STTR Programs worked with OTT to develop a version of Energy I-Corps training aimed specifically at DOE SBIR/STTR Phase I awardees.

Overview

Energy I-Corps for SBIR is designed as an I-Corps "Short Course" intended to provide hands-on experience in customer development and business model generation for DOE SBIR Phase I awardees. An optional program, Energy I-Corps for SBIR allows participants to gain a practical understanding of fundamental principles and processes that support the successful management and discovery of innovations across the technology lifecycle. This includes an introduction to key elements of entrepreneurship designed to help craft a viable business model, illuminate opportunities and risks, and design a strong go-to-market strategy. Phase I awardees that participate in the program are able to develop a more refined and strategic commercialization strategy within their SBIR Phase II applications and thus, increase the overall impact of the SBIR program within DOE. As of year-end 2022, 194 companies have been trained across five cohorts.

SBIR·STTR
America's Seed Fund

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Program Design

The program includes distinct lessons to help support a structured understanding of innovation management, and the steps necessary to translate a technical idea into a commercial product. Participant companies are expected to conduct (target: 30) interviews across a broad spectrum of ecosystem stakeholders, and to participate in a series of virtual workshops spanning six weeks. Since the Fall 2021 program, the training has expanded to include integration with the SBIR's TABA (Technical and Business Assistance) Program to offer more direct support to develop a strong commercialization plan and create leverage between both programs in support of participant companies.

For more information, visit: energyicorps.energy.gov

OTT Summer Entrepreneurship Program

The summer of 2022 welcomed the second iteration of OTT's Summer Entrepreneurship Program. This exciting paid internship offers undergraduate students the opportunity to gain experience with the world-class National Laboratory complex, boost entrepreneurial thinking, and explore market opportunities for innovative energy technologies. The 11-week program paired students with technologies and mentors from a National Lab to develop commercialization strategies for moving taxpayer-funded discoveries from the lab to the market.

Parallel to working with the National Labs, students also participated in intensive commercialization training through an asynchronous Energy I-Corps curriculum. Interns were provided with lectures and resources while instructors offered online workshops to tie their lab work to the broader I-Corps framework. By providing interns with access to the best-in-class Energy I-Corps program, they enhanced their education and training in entrepreneurship and energy technology-related fields while increasing future marketability in these disciplines.

The 2022 program welcomed 19 students from various backgrounds, universities, geographical locations, and majors across the United States. More than 60% of the interns represented disadvantaged communities. Accepted interns were paired with mentors and projects from nine DOE National Laboratories.

OTT Entrepreneurship Program

Argonne NATIONAL LABORATORY	• Analysis of Commercial Opportunities for Intellectual Property
Brookhaven National Laboratory	• Semiconductor-Based Radiation Detector Systems • Transgenic Plant Factories for Production of Biofuels and Industrially Relevant Chemicals
INL Idaho National Laboratory	• Cyber Security Technology Commercialization Opportunity
Jefferson Lab	• Develop an Opportunity Landscape for Wastewater Treatment and Environmental Remediation Applications of Accelerator Technologies
KANSAS CITY NSC National Security Campus	• Market and Partner Analysis for National Security Technologies
BERKELEY LAB	• Promoting and Marketing Solderless Interconnects for Narrow Cascaded Printed Circuit Boards • Market Intelligence Analysis for Advanced High Throughput Device for Arsenic Removal from Drinking Water at Low Cost • Market Intelligence Analysis for A Universal Method to Integrate and Express Pathways in Broad Range of Bacteria
NETL NATIONAL ENERGY TECHNOLOGY LABORATORY	• Subsurface Optical Sensing for CO2 and/or Wastewater Injection Leakage Early Warning Measurements
OAK RIDGE National Laboratory	• High Strength Lignin-acrylonitrile Polymer Blend Materials
Sandia National Laboratories	• Finding Life After LDRD (or When the R&D Dollars Run Out) • Partner Validation and Verification • Science and Technology Advancing Resilience for Contested Space Multi-Use Commercialization Identification • Security System of the Future Technology Environmental Scan.

OTT Entrepreneurship Program

The Summer Entrepreneurship Program concluded with an in-person graduation event held at LBNL. The end-of-summer event showcased the interns' projects on market opportunities for National Laboratory technologies. Interns were also able to tour the facilities at Berkeley Lab and hear from experts including Betony Jones, the new director for the Office of Energy Jobs.

At the graduation event, interns' presentations were judged by commercialization experts. The top three presentations were:

- Carlie Sylvan (Sandia National Laboratories): "Rare Earth Extraction from Coal Ash"
- Troy Brennan (Jefferson Lab): "The Future of Clean Water"
- Danielle Ferreira (Brookhaven National Laboratory): "Brookhaven National Laboratory's Radiation Detectors"

Highlights

- One intern's work led to the formation of a joint venture out of SNL.
- Within a month of program completion, nearly 20% of the interns received internship extensions or offers, and another 15% of interns are in process of receiving offers from Labs.
- Six of the interns expect to participate in the 2023 EnergyTech University Prize to continue their energy entrepreneurship journey.

"I learned a great deal about the necessity that a product or service meet a real and established need in order to create a viable business, and I learned a great deal about performing market research, networking, and developing the interpersonal skills and relationships necessary to help a budding business find success."

"My favorite parts of this internship were the Energy I-Corps sessions, the weekly professional development and networking sessions, and the creative license we were given in regard to the direction of our projects."

– Brett Reamon

"I learned so much about entrepreneurship via the Energy I-Corps curriculum as well as the fireside chats. I think the main takeaway that I got was that to understand your market, you really need to go out and see what problems potential customers are having. That is the only way to know for sure if your product really is going to be desirable and useful."

– William Rong

"Energy I-Corps taught me some important things to consider when thinking about commercializing a product and the detailed ways to build an efficient business ecosystem. With this course, I was able to apply it to the multiple projects I worked on allowing me to become more comfortable and familiar with the process."

– Kadijat Alakiu

Acronyms

AMO	Advanced Manufacturing Office
ANL	Argonne National Laboratory
BETO	Bioenergy Technologies Office
BTO	Building Technologies Office
CRADA	Cooperative Research & Development Agreement
DOE	U.S. Department of Energy
EM	Office of Environmental Management
FECM	Fossil Energy and Carbon Management
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
OEM	Original Equipment Manufacturer
OS	Office of Science
OTT	Office of Technology Transitions
PNNL	Pacific Northwest National Laboratory
R&D	Research and Development
SETO	Solar Energy Technologies Office
SLAC	SLAC National Accelerator Laboratory
SNL	Sandia National Laboratories
TCF	Technology Commercialization Fund
VTO	Vehicle Technologies Office
WETO	Wind Energy Technologies Office
WWPTO	Wind & Water Power Technologies Office

Publications

Energy I-Corps teams have authored or been featured in several publications related to their work. Sample materials are provided below.

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Energy I-Corps Cohort 9 participants listen to the presentations on the final day of their workshop at the Buffalo Rose in Golden, Colorado. *Photo by Werner Slocum, NREL.*

"It was invaluable for better understanding the problem space with our current customer. I also felt it was valuable personally and has helped me to continue to grow professionally in an area I am very passionate about."

– Mara Schindelholz, SNL, Principal Investigator

"People want a solution, not a technology. People are more gracious and willing to provide info than we thought."

– Sam Bayham, NETL, Entrepreneurial Lead

"Energy I-Corps really helped us with a mindset of how to talk to end users. We've continued to reach out to stakeholders and because we learned how to do that, and do it well, that skill continues to serve us."

– James Kershaw, PNNL, Principal Investigator

Researcher Kristin Alberi presents during graduation of Cohort 9. *Photo by Werner Slocum, NREL.*

Thank You!

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ENERGY I-CORPS

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