Institute for a Secure & Sustainable Environment

2020-2021 Annual Report to THEC

ISSE Mission Statement

The University of Tennessee's Institute for a Secure and Sustainable Environment (ISSE) seeks to promote the development of policies, technologies, and educational programs that cut across multiple disciplines, engage the university's research faculty and staff, and grow in response to pressing environmental and security issues facing the state, the nation, and the globe.

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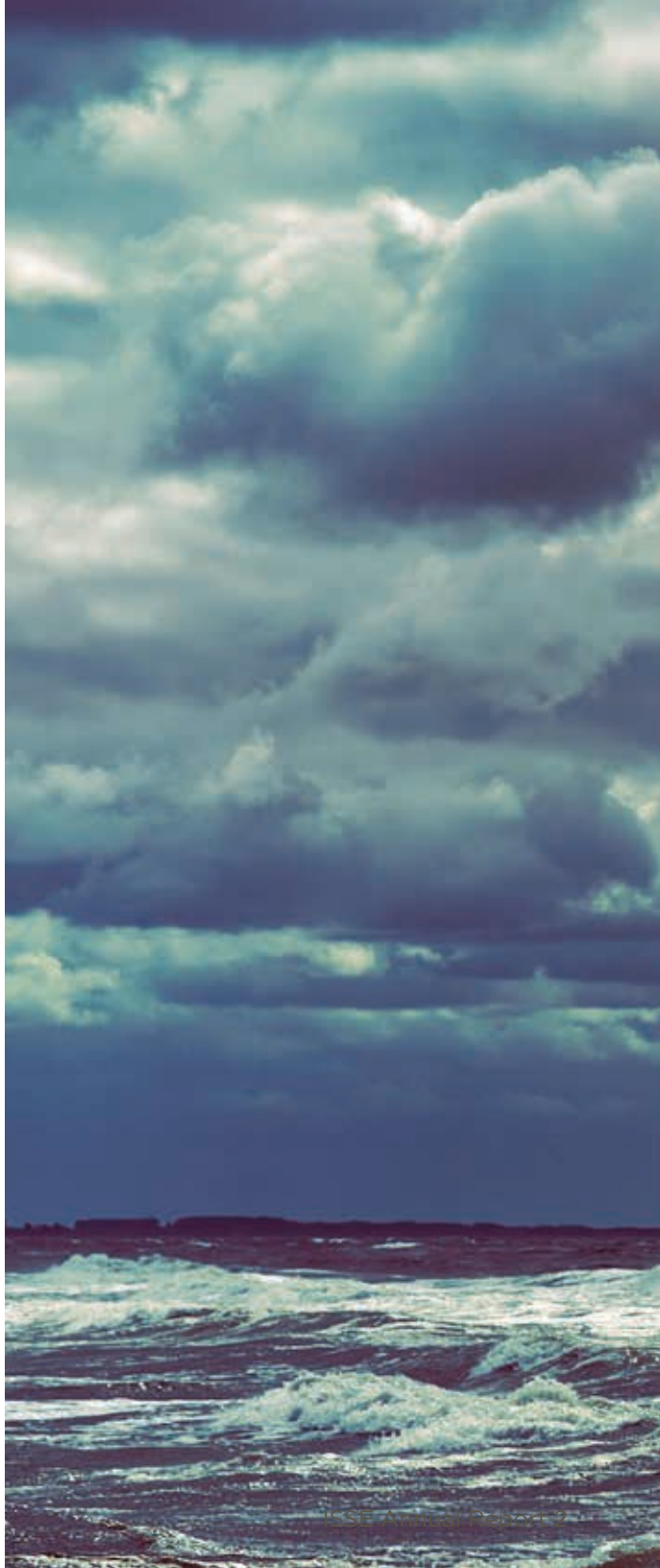


Message from the Director

I am pleased to highlight several of ISSE's current research projects in this annual report. To summarize ISSE's state of research, ISSE principal investigators are currently leading 27 active, sponsored projects for ISSE, and there are 16 individual agencies funding these projects. ISSE also has 10 funded seed grant projects in progress.

ISSE has five areas of research: clean energy and energy efficiency, climate change, regional sustainability, water research, and sustainable food systems. Each ISSE program has conducted significant research: water resources through four US Geological Survey projects; methane hydrates and global soil moisture datasets; ways to establish a US-China transdisciplinary research coordination network for identifying grand challenges at the nexus of food-energy-water systems (FEWS); and trends in Appalachian tourism and diversity. ISSE research projects have engaged more than 50 UT faculty members, one post-doctoral student, and many graduate and undergraduate students.

ISSE provides an important platform for interdisciplinary research to promote environmental sustainability. The Health Environment team led by Dr. Qiang He won the 2021 UTK Success in Multidisciplinary Research award. The team integrates expertise in environmental engineering, health, infrastructure, human factors, automation, systems engineering, and data science to attack complex health problems in a systematic way. Besides Dr. He, the team includes Shuai Li and Mingzhou Jin, who are affiliated with ISSE, and five other researchers from the Tickle College of Engineering, College of Arts & Sciences, College of Nursing, and the UT Institute of Agriculture.

Notably, Drs. Jon Hathaway and Kristen Wyckoff have obtained NSF funding for The Green Infrastructure for Sustainable Urban Environments Research Experience for Undergraduates (REU). This is a 10-week summer program designed to expose and immerse 10 undergraduate students per year to unique Green Infrastructure research. Green Infrastructure is a way to build better infrastructure, as a part of the National Academy of Engineering's Grand Challenge, to restore and improve urban infrastructure. This will begin in Spring 2022

As always, ISSE is indebted to the support given by the Tickle College of Engineering. It is the key to our continuing success.

Dr. Mingzhou Jin, ISSE Director

Executive Summary

During 2020-21, ISSE continued to expand its research, training, and outreach, and this report describes the activities carried out by ISSE staff, students, and ISSE-affiliated faculty.

ISSE has a robust internal operation with 15 research staff and 10 support staff along with several visiting scholars. Our 17 affiliated faculty members represent the departments of Ecology & Evolutionary Biology, Biosystems Engineering & Soil Science, Sociology, Economics, Supply Chain Management, the Baker Center for Public Policy, Civil & Environmental Engineering, and Industrial & Systems Engineering.

ISSE's external funding sponsors include US Geological Survey, US Department of Energy, US Environmental Protection Agency, UT-Battelle & Oak Ridge National Laboratory, National Park Service, East Tennessee State University, University of West Virginia, Metro Government Nashville, National Institute of Health, National Partnership for Environmental Technology Education, National Science Foundation, OnTrackNorthAmerica, Tennessee Department of Environment and Conservation, Tennessee Department of Transportation, Tennessee Valley Authority, and the Appalachian Regional Commission.

ISSE continued its seed project program to stimulate interdisciplinary research and awarded six projects during FY2021 to study geochemical interaction between CO2 and Caprock for safe Carbon Sequestration, precision environmental health risk management, bioengineering of the duckweed plastid genome, adaptive capacity of vulnerable populations to urban heat microbial transformation and degradation of sulfonated per- and polyfluoroalkyl substances, and novel field deployable biosensors to assessing arsenic concentrations in community water systems. The research teams represent a cross-section of UT's disciplines and academic departments – Biochemistry & Cellular and Molecular Biology, Earth and Planetary Science, Food Science, Geography, Social Work, Public Health, Microbiology, Chemistry, Electrical Engineering & Computer Science, and Civil & Environmental Engineering.

In its training programs, ISSE provided innovative educational and environmental projects that employ the latest technologies to resolve problems and explore complex issues. Most projects combine the resources of private and governmental sectors with the expertise of university staff, faculty, and students through team agreements.

This year, ISSE outreach promoted sustainability through clean, alternative fuels and electric vehicles, developing community leadership in the Appalachian region, and transferring technological knowledge through the Tennessee Water Resources Research Center. These initiatives have reached Tennessee's driving population, rural areas, and professionals working in technical research under the Water Resources Research Institute Program.

We are proud to play a part in the experiences of students who work with ISSE researchers. This year, ISSE supported 18 student, both graduate and undergraduate, in projects ranging from public policy to wetlands restoration.

ISSE faculty, students, and staff amassed a long list of conference presentations and publications this year, most in peer-reviewed journals and conference proceedings. ISSE has communicated knowledge and information through a variety of programs and activities, created and shared large datasets, and fostered international exchanges. Many ISSE faculty have been recognized by their peers with honors and awards.

ISSE Centers & Programs

Centers

FEWSUS International Research Coordination Network

FEWSUS stands for International Research Coordination Network to Create Transdisciplinary Nodes of Food-Energy-Water to Support Sustainable Urban Systems. FEWSUS is funded by the US National Science Foundation. The grant, awarded to faculty and scientists at the University of Tennessee and Oak Ridge National Laboratory, supports the development of an International Research Coordination Network, designed to facilitate transdisciplinary, multinational communications and accelerate the development and transfer of multisectoral data, standards, analysis tools, new technologies, and a trained workforce among differently urbanized countries.

Tennessee Water Resources Research Center (TNWRRC)

TNWRRC is a federally designated state research institute supported in part by the US Geological Survey. The center was established following enactment of the Water Resources Research Act of 1964. TNWRRC partners with the state of Tennessee as a primary resource to develop and implement programs that can achieve sustainable quantities of quality water in Tennessee and the nation. Dr. John S. Schwartz directs TNWRRC and is a professor in Civil & Environmental Engineering.

East Tennessee Clean Fuels (ETCF)

ETCF works to increase the use of cleaner American fuels and vehicles and energy saving transportation technologies to improve air quality and health, curb dependence on imported petroleum, and support Tennessee's economy. Its mission is to implement alternative fuel projects in East Tennessee and to make ETCF a sustainable coalition of involved participants from across East Tennessee. ETCF is a 501(c)3 under the umbrella of Transportation Energy Partners. Mr. Jonathan Overly is the Executive Director and Coordinator.

Drive ElectricTN

DET promotes the adoption of electric vehicles for fleets and individuals across Tennessee with a goal of getting 200,000 EVs on TN's roads by 2028. An autonomous program of TNCleanFuels, DriveElectricTN is supported by 60+ stakeholders from across Tennessee and the United States, with focus areas such as EV Awareness, EV Policies & Program, and EV Infrastructure intended to achieve precise, targeted development goals for electric vehicles in our state.

Methane Center

The Methane Center integrates science, engineering, and business models to create a broad conceptual understanding of CH4 (methane) as a driver of ecosystem processes and services. Center researchers use this understanding to create a lifecycle assessment framework for environmentally sustainable generation, management, and utilization of CH4. The center's mission is to produce young engineers and scientists who are dedicated to effective communication of scientific findings to inform and stimulate the public and provide structured rationale for economic and environmental policy decisions and regulations. Dr. Terry Hazen directs the Methane Center.

Programs & Initiatives

Appalachian Leadership Institute (ALI)

ISSE partnered with ARC to launch this program focused on the unique challenges and solutions around Appalachia's economic development. ALI trains community leaders who live and work in the region through skill-building seminars, best-practice reviews, and field visits across the 13 states that make up the Appalachian region. The goal is to create leaders who can help the region adapt to these changes and use opportunities to create thriving, equitable, and sustainable communities. Dr. Timothy Ezzell is the PI for this program and a Research Professor in Political Science.

Climate Change Initiative

Climate change is one of the most critical challenges faced by humans and our planet. Researchers at ISSE, working closely with the Climate Change Science Institute at Oak Ridge National Lab, are advancing our understanding of climate change and its impacts on human and natural systems. We use Earth system modeling, integrated ground and remote sensing observations, and advanced data analytical tools to study climate change and its effects on water availability, soil moisture, wildfires, and vegetation. Team members are Drs. Yaoping Yao, Yulong Zhang, Jiafu Mao, Joshua Fu, Mingzhou Jin.

Worker Health and Safety Training at Department of Energy Facilities

DOE Worker Training was developed to protect and inform DOE communities and their workers by delivering quality and flexible safety and health training to target populations of hazardous waste workers and emergency responders. Its mission is to prevent work-related harm by training workers to protect themselves and their communities from exposure during hazardous waste operations and transportation, environmental restoration at nuclear weapons facilities, or chemical emergency responses. Dr. Sheila Webster (retired) is the principal investigator.

Sponsored Research

PI	Project Title	Sponsor	Co-PI	Duration
Khalid Alshibli	3D dynamic evolution of pore water-air interaction within saturated sheared sand	NSF		7/15/2020 - 6/30/2023
Timothy Ezzell	Increasing Economic and Entrepreneurial Opportunities by Promoting Outdoor Recreation Among Underrepresented Visitor Groups	East Tennessee State University (ETSU)		08/15/2019 - 06/30/2021
Timothy Ezzell	Trends and Strategies for Tourism in Appalachia	US - ARC - Appalachian Regional Commission	Jui-Chi Chen, Catherine Wilt	10/1/2017 - 8/31/2020
Timothy Ezzell	PIPES: Possibilities in Postsecondary Education and Science among Rural Appalachian Youth	National Institute of Health		5/13/2015 - 8/4/2020
Timothy Ezzell	ASPIRE: Appalachian Students Promoting the Integration of Research in Education	National Science Foundation		9/5/2016 - 8/31/2021
Timothy Ezzell	Appalachian Leadership Institute	US - ARC - Appalachian Regional Commission	Katie Cahill, Catherine Wilt	2/6/2019 - 7/31/2022
Jon Hathaway	Wetland Restoration with RSC's	US-EPA-US Environmental Protection Agency	John Schwartz	10/1/19 - 9/30/2022
Mingzhou Jin	Industrial Landfill Waste Management (Reduce, Recycle, and Reuse) Technology Assessment	DOE - ORNL - UT-Battelle - Oak Ridge National Laboratory		08/01/2019 - 07/31/2021
Mingzhou Jin	Policy Study on the Adoption of Alternative Fuel Vehicles	DOE - ORNL - UT-Battelle - Oak Ridge National Laboratory		09/01/2019 - 02/28/2022
Mingzhou Jin	Anyalysis for Regional and Global Land Ecosystem Modeling	DOE - ORNL - UT-Battelle - Oak Ridge National Laboratory		8/1/2020 - 7/31/2021
Mingzhou Jin	Smart Manufacturing	DOE - ORNL - UT-Battelle - Oak Ridge National Laboratory		11/10/2020 - 11/9/2021
Mingzhou Jin	East Tennessee Clean Fuels Initiative	East Tennessee Clean Fuels Coalition		7/1/2011 - 6/30/2021
Mingzhou Jin	INFEWS: U.S.-China: Coupled FEWS Modeling for Sustainability of the Global Crop Supply Chain with a Focus on China - US Interactions	US - NSF - National Science Foundation		7/1/2019 - 6/30/2023
Mingzhou Jin	Supporting the Land Freight Lifecycle	OnTrackNorthAmerica	David Clarke	7/15/2021 - 4/15/2022
Mingzhou Jin	EV Requirement Analysis	TVA through Curent	Yulong Zhang, Nawei Liu	2/1/2021 - 9/30/2021
Jonathan Overly	TDOT I-40 Alternative Fuels Continuation	TDOT through CTR	Yulong Zhang	7/1/2021 - 9/30/2022
John Schwartz	Improving the GRSMs understanding of its natural resources and processes and thereby enhancing protection of the Park's resources	DOI - NPS - National Park Service - Great Smoky Mountains National Park		6/18/2014 - 6/29/2022
John Schwartz	FY2019 Water Resources Program Year 4	DOI - USGS - US Geological Survey	Timothy Gangaware	6/18/2019 - 12/31/2020
John Schwartz	FY2020 & FY2021 Water Resources Program Year 5	DOI - USGS - US Geological Survey	Timothy Gangaware	3/1/2020 - 12/31/2021
John Schwartz	FY2020 & FY2021 Water Resources Program Year 6	DOI - USGS - US Geological Survey	Jon Hathaway	3/1/2020 - 12/31/2021
John Schwartz	FY2020 & FY2021 Water Resources Program Year 7	DOI - USGS - US Geological Survey	Qiang He	3/1/2020 - 12/31/2021
John Schwartz	TN Stream Quantification Tool Training	Tennessee Department of Environment and Conservation		5/1/2020 - 4/30/2022

PI	Project Title	Sponsor	Co-PI	Duration
John Schwartz	Urban Waters Report Card	Metro Gov Nashville	Timothy Gangaware	3/1/2021 - 12/31/2023
Yaoping Wang	Data Analytics Support for Integrated Earth Model	DOE - ORNL - UT-Battelle - Oak Ridge National Laboratory	Mingzhou Jin	3/6/2019 - 3/1/2022
Sheila Webster	Worker Training at DOE facilities	National Partnership for Environmental Technology Education		9/1/2020 - 7/31/2021
Kristen Wyckoff	Appalachian Community Technical Assistance and Training (ACTAT) Program	West Virginia University		10/1/2018 - 9/30/2021
Hongyu, Zhou	Utilizing coal-derived solid carbon materials towards next-generation smart and multifunction pavements	DOE - National Energy Technology Lab	Boashan Huang, Wei Hu	1/5/2021 - 9/30/2022

Seed Grants

PI	Project Title	Co-PI	Duration
Khalid Alshibli	Gas Driven Fracture During Gas Production using 3D Synchrotron Computed Tomography (SMT)	Claudia Rawn	7/1/2018 - 12/31/2020
Chris Clark	Analyzing Strategies for Diverting and Managing Organic Waste Streams in Tennessee		7/1/2019 - 12/31/2020
Anahita Khojandi	Multi-Sensor Data-Driven Inspection/Maintenance of Green Infrastructure	Jon Hathaway	7/1/2019 - 6/30/2021
Steven Ripp	Emerging synthetic biology for plant phytosensing and agricultural sustainability	Tingting Xu, Sarah Werner, Scott Lenaghan	7/1/2019 - 12/31/2020
Khalid Alshibli	Geochemical Interaction between CO2 and Caprock for Safe Carbon Sequestration	Nicholas Dygert	1/1/2021-12/31/2021
Qiang He	Toward Precision Environmental Health Risk Management	Courtney Cronley, Shuai Li	1/1/2021-12/31/2021
Scott Lenaghan	Bioengineering of the Duckweed Plastid Genome	Barry Bruce	1/1/2021 - 6/30/2022
Kelsey Ellis	Beat the Heat: Builiding adaptive capacity of vulverable populations in Knox County to combined stressors from climate change and urban heat.	First & Kintziger	7/1/2021 - 6/30/2022
Frank Loeffler	Microbial transformation and degradation of sulfonated per- and polyfluoroalkyl substances.	Shawn Campagna	7/1/2021 - 6/30/2022
Jie Wu	Socioeconomic inequalities and drinking water quality: assessin arsenic concentrations in community water systems by novel field deployable biosensors.	Courtney Cronley, Qiang He	7/1/2021 - 6/30/2022

ISSE Advisory Board, Faculty & Staff

ISSE Research Staff	
Mingzhou Jin	ISSE Director, Professor of Industrial & Systems Engineering and Civil & Environmental Engineering
Bing Cao	Research Associate
Tim Ezzell	Director, Appalachian Leadership Institute, Assistant Research Professor
Tim Gangaware	Research Director, Tennessee Water Resources Research Center
Terry Hazen	Director, Methane Center, Governor's Chair, Professor of Civil & Environmental Engineering
Nawei Liu	Research Associate
Jonathan Overly	Director, East Tennessee Clean Fuels
John Schwartz	Director, Tennessee Water Resources Research Center; Professor, Civil & Environmental Engineering
Daniel Siksay	Chief of Staff, East Tennessee Clean Fuels
Yaoping Wang	Assistant Research Professor
Sheila Webster	Director, Technology Research and Development Program
Catherine Wilt	Research Associate
Yulong Zhang	Assistant Research Professor
Xu Zheng	Post-doctoral Research Associate

ISSE Support Staff	
Kellie Caughorn	Senior Administrative Services Assistant, Tennessee Water Resources Research Center
Madelyn Collins	Communications Consultant, East TN Clean Fuels
Lissa Gay	ISSE Communications Director
Susan Fusaro	Fiscal & Memberships Coordinator, East TN Clean Fuels
Ainsley Kelso	Communications Coordinator, East TN Clean Fuels
Bonnie Morris	Tennessee Water Resources Research Center
Dylida Ries	ISSE Accounting Specialist
Savannah Robertson	DriveElectricTN Coordinator, East TN Clean Fuels
Sherry Russell	ISSE Business Manager

ISSE Affiliated Faculty	
Paul Armsworth	Ecology & Evolutionary Biology
Walker Forbes	Biosystems Engr & Soil Science
Joshua Fu	Civil & Environmental Engr
Michael Galbreth	Haslam College of Business
Jon Hathaway	Civil & Environmental Engr
Qiang He	Civil & Environmental Engr
Robert Jones	Sociology
Anahita Khojandi	Industrial & Systems Engr
Jiafu Mao	Industrial & Systems Engr
Sean Schaeffer	Biosystems Engr & Soil Science
Charles Sims	Baker Center for Public Policy, Department of Economics
Wendy Tate	Haslam College of Business
Jie Zhuang	Biosystems Engr & Soil Science

ISSE Advisory Board			
Stan D. Wullschleger	Interim Assoc. Lab Director, Energy & Environmental Sciences; Director, ORNL Environmental Sciences	Kendra Abkowitz Brooks	TDEC Assistant Commissioner, Office of Policy and Sustainable Practices
James Parks	Section Head, Energy Efficient Manufacturing Sciences ORNL	Chris Cox	Professor and Dept Head, Civil & Environmental Engineering, Tickle College of Engineering
Monte Lee Matthews	TVA Senior Manager, Sustainability & Climate	David White	Associate Dean for Research, UT Institute of Agriculture
Bill Dunne (as observer)	Assoc. Dean for Research & Facilities, Tickle College of Engineering		

ISSE Welcomes New Staff

Madelyn Collins
ETCF Communications Consultant

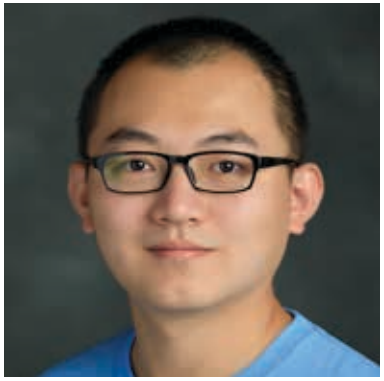
Madelyn joined ETCleanFuels 2019 as the Digital Media Coordinator through UT's Federal Work-Study program and continued her position through the Clean Cities University Workplace Development Program. After spending time away to focus on community organizing, she rejoined ETCleanFuels as a consultant to help make her home a greener and cleaner place, especially for the most vulnerable populations of Tennessee.

Ainsley Kelso
ETCF Communications Coordinator

Ainsley joined the ETCleanFuels team as part of the Clean Cities University Workplace Development Program in June 2020. She is now a full-time employee, putting her research, writing, and media management skills to good use promoting cleaner transportation. Ainsley is an avid concert goer, lover of dogs, and is passionate about advocating for others and helping the world around her.

Susan Fusaro
ETCF Fiscal & Memberships Coordinator

Susan, a Long Island transplant, has spent the past ten years in energy management, working to track and reduce energy consumption; saving money, avoiding costs, and helping the environment along the way. Susan is an experienced coordinator who has a knack for wearing any and all hats needed in the office.



Xu (Scott) Zheng
Post-doctoral Research Associate

Xu (Scott), Zheng is a research associate in ISSE, where he began as a visiting scholar in 2019. He received his Ph.D. from the University of Science and Technology of China in 2021. His research lies in the areas of modeling, optimization, scheduling, and the industrial application of machine learning to create a sustainable, energy-saving industry and environment.

Savannah Robertson
Drive Electric TN Coordinator

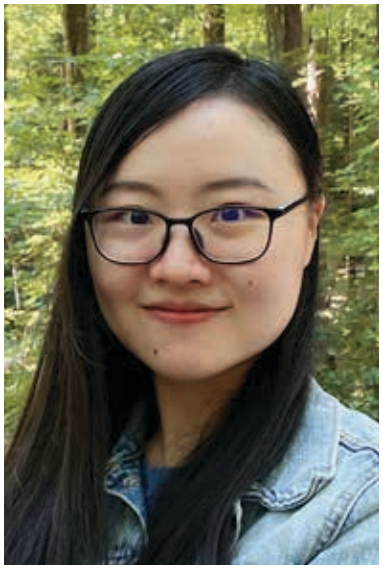
Savannah handles DET's working groups and planning events. She is a cat mom, runner, wannabe beekeeper, lover of the environment, and an East Tennessee native. She is most passionate about supporting people to thrive in our ever-changing world. Before joining ETCleanFuels, she managed Smart Trips, a federally funded program that encourages sustainable transportation.

ISSE Student Highlights

John Beatty is a third-year Ph.D. student in Biochemistry, Cellular, and Molecular Biology. He received his BS in Biology from the School of Science and Technology at Georgia Gwinnett College in 2012. His current research focuses on plastid transformations of the Lemnaceae family, commonly known as duckweed. With this technology, he can modify plants for improved photosynthesis, carbon fixation, bioremediation, and renewable energy potential. In addition to this project, John is investigating the structure of photosynthetic complexes by using a new protein isolation method using an industrial copolymer composed of Styrene and Maleic Acid groups, avoiding the use of harsh detergents that often denature membrane proteins. Mr. Beatty's research interests include photosynthetic supramolecular complexes, nanoscale imaging of isolated subunits, and ultrastructure and organizational effects in transformed tissues.

Blayne Wesley Chance is in his senior year at UTK's School of Arts & Sciences. Blayne will graduate this December with BA in Economics and Political Science and a concentration in law and the court system. He has assisted with the administration of online courses as well as data collection, inspection, and analysis. With ambitions to attend law school, Blayne aims to obtain his J.D. to pursue a practice in compliance law. Blayne has a high interest in public finance, regulation, and microeconomics. This is Blayne's third year working for ISSE and under Research Scientist Dr. Sheila Webster.

Griffin Bedell is a third-year undergraduate student in UTK's Department of Civil Engineering. Griffin is pursuing his Bachelor of Science in Structural Engineering and Construction Management, expecting to graduate in May 2023. He plans to pursue a Master's Degree in Energy Efficient and Sustainable Building Design after receiving his undergraduate degree. His current research focuses on developing and writing a cost-benefit analysis for coal-coke based electroconductive asphalt. His other research interests include sustainability, sustainable building design, recycled material, renewable technology, and energy-efficient building design.



Zhibo Cheng is a third-year Ph.D. student in the Department of Biosystems Engineering and Soil Science. Zhibo received her Master of Science in the Institute of Applied Ecology, Chinese Academy of Sciences, Shenyang, China, in 2019. Her current research focuses on the impact of metal and environmental conditions on soil viral dynamics. Her experimental research involves virus and bacteria counting, nucleic acid extraction, and 16S sequencing. Zhibo employs multiple novel techniques to explore the abundance and diversity of soil virus, including epifluorescence microscopy, real-time quantitative PCR. As co-author, Zhibo has published two research articles on plant mismatch repair genes under environmental stress conditions.

Ghada Diab is a second-year Ph.D. student in UTK's Department of Civil and Environmental Engineering. Ghada received her Master of Science in Civil Engineering from the German University in Cairo, New Cairo, Egypt, in 2019. Her current research focuses on improving modeling of bioretention cells for stormwater management to mitigate the hydrologic and water quality effects of urbanization. Ms. Diab is testing a site-scale drainage model to simulate bioretention cells with different site conditions at a fine temporal scale. She aims to advance the model's applicability by integrating it with a watershed-scale model to understand how multiple green infrastructures installations interact at watershed-scale. Ms. Diab's research interests include urban hydrology, stormwater mitigation, water quality modeling, computational fluid dynamics, renewable energy, and climate change.

McKenna Hoag is a fourth-year Undergraduate student in UTK's Department of Civil and Environmental Engineering studying Water Resource Engineering in order to study water quality management. Her current undergraduate research focuses on water quality in the Great Smoky Mountains and the effects of past acid pollutant discharge on natural streams. She works with Jason Brown, a first year doctoral student, to compile an understanding of the biogeochemical process in forested watersheds affected by acid pollutant deposition.

Zabrenna Griffiths is a fourth year Ph.D. student in Genome Science & Technology. She received her Bachelor of Science from the School of the Environment at Florida A&M University in 2014. Her current work builds upon previous studies conducted by Dr. Hazen and members of his lab. Zabrenna is conducting a multi-omics experiment to observe the microbial community response in aerobic and anaerobic conditions after the addition of crude oil in seawater collected from different depths in the Caspian Sea. Her current research focuses on analyzing changes in the microbial community of surface and deep water microbes to identify hydrocarbon degrading microbes and their potential role in crude oil biodegradation. She also plans to observe the changes in expression of oil-degrading genes. She is also interested in science policy and scientific communication , motivated by environmental challenges in her native Jamaica.

Zaher Jarrar graduated with his PhD in December 2020. He remained at the Department of Civil and Environmental Engineering as a research associate until May 2021. During that time, he worked on characterization of CO2-caprock geochemical interaction at micro- and nano-scale. Dr. Jarrar is currently an assistant project manager with GZA GeoEnvironmental in Boston. His research has focused on understanding underlying physical processes of the emergent phenomena during gas production from hydrate-bearing sediments. Such phenomena include fines migration, fines clogging, over-pressurization, and gas-driven fractures. Dr. Jarrar has papers published in *Soil Science Society of America Journal, Journal of Applied Crystallography, Journal of Engineering Mechanics, Journal of Geotechnical and Geoenvironmental Engineering,* among others.

Samantha Jurek is a fourth-year undergraduate student in the UTK's Department of Civil & Environmental Engineering. She will receive her Bachelor of Science in Civil & Environmental Engineering and her Bachelor of Science in Ecology & Evolutionary Biology in 2023. Samantha is an undergraduate researcher for Dr. John Schwartz and does water quality testing for the Great Smokey Mountains to track and understand the fluctuations in key substances in natural waterways. In her future career, Samantha hopes to use both her degrees to focus on environmental conservation or sustainable infrastructure.

Grace Long is a Master's student in the Department of Civil and Environmental Engineering at the University of Tennessee. She graduated from the University of Virginia in 2016, earning her Bachelor of Science in civil engineering. She then worked for three years in the Washington DC area for Dewberry in the Site/Civil department as an Engineer-In-Training. In 2019 she moved back to her hometown of Knoxville to attend UT and continue her education. Grace is interested in both sustainable stormwater management and stream restoration. She most enjoys field work assessing stream quality and inspecting stormwater management elements. She is currently assisting Dr. Schwartz on the Beaver Creek Stream Restoration Project and assessing and suggesting modifications to the Tennessee Stream Quantification Tool.

Cheng-Pin Ku is a fourth-year Ph.D. student in the Department of Civil and Environmental Engineering at the University of Tennessee, Knoxville. Cheng-pin received his Bachelor of Science and Master of Science in the College of Public Health from National Taiwan University, Taiwan, in 2011 and 2013 respectively. The focus of Kuo's research includes air quality modeling, machine learning, and exposure assessment. He also developed a hybrid framework with multiple machine learning techniques to build a model for planning better lockdowns during the COVID-19 pandemic. His publications have been presented in several international conferences including AGU, A&WMA, and CMAS, and six articles have been accepted to publish in SCI journals since 2018. His doctoral research will focus on the fusion of machine learning techniques and air quality models, and their application on the burden of the diseases estimations and public health policies.

Hope Newberry is a first year Ph.D. student at The University of Tennessee, Knoxville in the Department of Civil and Environmental Engineering. Newberry received her Bachelor of Science from The University of Tennessee in Chemical Engineering in 2016. Prior to attending graduate school, Newberry worked in the manufacturing industry as a technical and senior process engineer. Her current research is focused on anaerobic digestion. She plans to study the effects process conditions such as temperatures, substrate composition, and feeding cycles have on the microbial communities in anaerobic digestion, specifically methanogens and their methane production.

Gillian Palino is a second-year civil and environmental engineering PhD graduate student at the University of Tennessee, Knoxville under the guidance of Dr. Jon Hathaway. She received her undergraduate degree at the University of Florida in Environmental Engineering with a minor in Soil and Water Science. In 2018 she co-wrote an extension publication describing the basics of using Quantum Geographic Information System (QGIS) to create maps and analyze data. Her thesis project focuses on the application of regenerative stormwater conveyances as a method of improving hydrologic performance and subsequent water quality of urban stormwater. Her interests include GIS and modeling techniques to better understand surface water hydrology.

Emily Stanton is a senior undergraduate student in UTK's Department of Civil and Environmental Engineering. Emily works as an Undergraduate Research Assistant focusing on analyzing and characterizing physical, mechanical, and chemical properties for construction materials. Her interest straddles material science and transportation infrastructures. Further research and educational goals include sustainable engineering materials and construction practices.

Jenifer Rodriguez is in her senior year of her undergraduate degree at the University of Tennessee, Knoxville's Tickle College of Engineering. She will graduate in December 2022 with a Bachelor's in Industrial and Systems Engineering and double minors in Engineering Entrepreneurship and Reliability and Maintainability. Jenifer plans to pursue a Master's Degree in Industrial and Systems Engineering as well as an MBA in Supply Chain. She has assisted with the administration of online courses as well as data collection, inspection, and analysis. This is Jenifer's third year working for ISSE under Research Scientist Dr. Sheila Webster.

Rongyun Tang is a fourth-year Ph.D. student in the Department of Industrial & System Engineering at the University of Tennessee, Knoxville. Rongyun received her bachelor's degree at Capital Normal University in 2015 and master's degree at Beijing Normal University in 2018. Rongyun, under the supervision of Drs. Jiafu Mao and Mingzhou Jin, is working on the responses and feedback of wildfire to environmental changes. Her major interests include modeling wildfire in the Earth System Model, exploring climate driving mechanism of wildfire by statistical analysis and machine learning methods, and assessing wildfire impact on the natural environment and society. Her recent work, exploring global wildfire interannual variability and climate sensitivities based on satellite data and the DOE's Energy Exascale Earth System Model (E3SM) modeling results, has been published in the Advances in Climate Change Research.

David Vance is a third-year Ph.D. student in UTK's Bredesen Center Energy Science and Engineering Program. David received his Bachelor of Science in Energy Engineering in 2016 and Master of Science in Mechanical Engineering in 2018, both from Indiana University Purdue University at Indianapolis. His research there focused on simulating renewable energy and energy storage for off-grid applications. He was also part of a student-lead Industrial Assessment Center (IAC) where he accomplished 12 Level I-II energy audits, including 2 as lead engineer. His next work as an intern for Oak Ridge National Laboratory, working on development of MEASUR software for industrial energy simulation and researching the potential for waste heat recovery in the US, first brought him to Knoxville. David's current research focuses on assessing smart manufacturing maturity, developing smart manufacturing strategy, and quantifying the costs and energy saving potential of smart manufacturing applications.

Lexi Webster is a second-year graduate student in UTK's Department of Public Policy & Administration. Lexi received her Bachelor of Arts in Politics & International Affairs from Wake Forest University in 2020. Her current research focuses on Appalachian communities, capacity building, and electric vehicles. Lexi's research interests include rural/urban differences, Appalachian resiliency, immigration policies, and voting trends in elections. She would like to pursue a career in policy consulting and/or public affairs. Lexi's pending publication as a co-author is on *Sports Elites, Counter-stereotypical Statements, and Immigration Attitudes* that will be published in the **Social Science Quarterly** within the next few months.

List of Advisors & Students

Khalid Alshibli
- Sheetal Gujarati, CEE
- Zaher Asem Jarrar, CEE

Barry Bruce
- Abigail Wells, BCMB

Tim Ezzell
- Alexis Webster, ISSE

Joshua Fu
- Cheng-Pin Kuo, CEE

Jon Hathaway
- Gillian Palino, CEE
- Ghada Diab, CEE
- Padmini Persaud, CEE
- Devina Langarica, CEE
- Claudia Bible, CEE

Terry Hazen
- Zabrenna Griffiths, GST

Qiang He
- Clifford Swanson, CEE
- Hope Newberry, CEE
- Charles Cianciolo, CEE
- Songyi Liu, CEE
- Yifang Xu, CEE
- Kailong Ye, CEE
- Nicholas Weiner, CEE
- Jeffery Emmett Jr, CEE

Mingzhou Jin
- Rongyun Tang, ISE
- Wenquan Dong, ISSE
- Rui Zhou, ISE
- David Vance, Bredesen Center

Anahita Khojandi
- Rachel Wood, ISE
- Kalina Scarbrough, CEE

John Schwartz
- Jason Brown, CEE
- Grace Long, CEE
- Samantha Jurek, CEE
- Kelly Leffler, CEE
- McKenna Hoag, CEE

Sheila Webster
- Blayne Chance, PoliSci

Kristin Wyckoff
- Andrew Tsay, CEE
- Ginsberg, Madeline, CEE

Nick Zhou
- Adam Brooks, CEE
- Emily Stanton, CEE
- Griffin Bedell, CEE

Joe Zhuang
- Zhibo Cheng, BCMB

Sponsored Research

Since the last reporting period, each ISSE program has conducted significant research: water resources through four US Geological Survey projects; methane hydrates and global soil moisture datasets; ways to establish a US-China transdisciplinary research coordination network for identifying grand challenges at the nexus of food-energy-water systems (FEWS); and trends in Appalachian tourism and diversity. ISSE research projects have engaged more than 50 UT faculty members, one post-doc, and many graduate and undergraduate students.

ISSE's five main areas of research are

- Clean Energy & Energy Efficiency
- Climate Change
- Regional Sustainability
- Water Research
- Sustainable Food Systems

Clean Energy & Energy Efficiency

Methane Center. Terry Hazen, PI

The recycling and reuse of wastewater has been a significant issue in the fracking industry recently. This wastewater, flowback water, is loaded with salts, organics, and dissolved solids: the economical removal of which is much easier said than done. Over the past year, the Methane Center has focused on collecting and analyzing preliminary data to assess the usability of methane hydrates to desalinate and reuse flowback water efficiently. The Methane Center is currently collecting preliminary data to assess if methane hydrates can be used to desalinate and reuse this water efficiently. Methane hydrates consist of natural gas trapped on a frozen water matrix (bubble) and naturally occur on the seafloor. Dividing the approach into different phases, the Methane Center will use lab studies starting with synthetic produced water. Once the proof of concept is achieved (Phase 1), we will transition into Phase 2, using oil and gas produced water, called flowback and produced water (FPW), samples which are more complex and tend to have a wide range of organic and inorganic compounds that may affect nucleation efficiency. The resulting desalination parameters can then be coupled with remediation technologies. Phase 3 will involve scaling up, and for example, the FPW can be placed in a reactor with favorable kinetic conditions to promote homogenous hydrate nucleation using CH4 as a gas "guest."

As part of Phase 1, The Methane Center successfully synthesized methane hydrates using a saline solution at the Joint Institute of Advanced Materials at The University of Tennessee. Cold stage X-Ray Diffraction equipment was through the Center for Nanophase Materials Sciences (CNMS) at ORNL to compare the diffraction patterns of hydrates synthesized under different physical conditions and levels of salt. The synthesis experiments involved testing if other hydrate formation parameters affect hydrate kinetics and determining if the salt is excluded or introduced as impurities in the hydrate cage. Sa'ad Abd Ar Rafie, a graduate student at the Department of Civil and Environmental Engineering, analyzed the x-ray diffraction patterns to show the presence of the methane hydrate crystalline structure, which offers a proof of concept for the formation of gas hydrates from salty solutions. Sa'ad is currently further refining (Rietveld Refining) and fitting the XRD data to determine the amount of hydrate vs. ice in the samples for understanding and improving the kinetics of hydrate formation for determining the optimal conditions to promote homogeneous nucleation in our system and eventually help us better engineer a system for wastewater desalination.

These promising results bode well for the Methane Center's multiphase plan after the recent acquisition of the Seafloor Process Simulator (SPS) from ORNL, a 70-liter pressure vessel with an operating range of -2 to 10°C and 0.1 to 20 MPa of pressure. The SPS, along with much smaller pressure vessels, will help us to scale up our experiments to characterize the thermodynamics and kinetics of natural gas hydrate formation and, in addition, to characterize methane hydrates biochemically.

TDOT I-40 Alternative Fuels Corridor Continuation Project, Jonathan Overly, Yulong Zhang, Nawei Liu, PIs

Thanks to a federal grant, in 2019 TDOT received funding to build a partnership across Arkansas, Tennessee and North Carolina towards planning to fill the gaps in compressed natural gas (CNG) and electric vehicle direct current fast charging (DCFC) refueling infrastructure along I-40. The project was completed in 2020, but TDOT was not finished. At that time, discussions began about furthering the work done in Tennessee to develop more robust specifics on the process to actually fill the gaps through industry, fleet, and other partnerships for both fuels by way of a "How To" guide. This discussion led to a TDOT-UTK contract involving ETCF and ISSE researchers who will develop that guide including prioritization criteria, a site selection formula, and sustainable funding strategies. Work will conclude in fall 2022.

Mapping and Requirement Analysis for EV Workplace Charging in Metropolitan Areas
Mingzhou Jin, Yulong Zhang, Nawei Liu, PIs

Funded by Tennessee Valley Authority (TVA), this study provides an integrated modeling framework and a quantitative analysis on workplace charging requirement for two major metropolitan areas within the TVA service area (i.e., Nashville and Knoxville) under three charger levels, Level 1 (1.8 KW), Level 2 (7.2 KW) and Direct-Current Fast Charging (DCFC, 50 KW). Each target metropolitan area is decomposed into census tracts. By leveraging existing commuting trips related public data, such as the U.S. Census's Longitudinal Employer-Household Dynamics data and American Community Survey data, this study investigates the total daily charging demand (kWh) and temporally distributed power (kW) across all census tracts. This study also provides analysis on the required charging power level based on the considered charging scenarios (i.e., charger levels). The created interactive web maps dynamically show where and when workplace charging demands are located based on charger levels under the assumption of 100% penetration rate and 100% of commuting EVs being charged at workplaces. Users can interact with web maps to check the detailed information on each tract and adjust time intervals. The study further predicts the workplace charging demands in these two regions through 2040 based on projected EV penetration rates and under various workplace charging coverage levels for commuting EVs.

left: Nashville Peak Power Required (KW) By Level 1 Chargers

DRIVE Electric USA DOE Project
Jonathan Overly, PI

East Tennessee Clean Fuels is the project lead on this 2020 DOE-funded project that includes 14 mostly "flyover" states that are building statewide 'Drive Electric' programs.

The project includes work on these priority areas:

- Developing those branded statewide efforts, websites, and outreach and social media campaigns,
- Consumer education, including developing state chapters,
- Utility and regulator engagement,
- EV charging infrastructure planning,
- Local and state government official education,
- Dealer engagement, and
- Fleet partnerships and EV adoption.

In year one, efforts began on all priority areas and coalitions started assembling their branded programs. This included partnership building and logo development as statewide plan development is a top priority. Chapter development, building utility relationships, and dealer and fleet planning are other significant tasks underway in year one.

Before project completion, it is important that we develop long-term funding approaches and expand the program to include additional states beyond the original 14 (as that was included in project activities). During summer 2021, the project added four states (Indiana, Kentucky, Connecticut, and New York) and discussions are underway with another dozen Clean Cities Coalitions and states to bring them into the fold. Additional states will be able to utilize any materials developed from the project to help develop their initiatives.

Climate Change

The Climate Change team includes Yaoping Wang, Yulong Zhang, Jiafu Mao, Joshua Fu, and Mingzhou Jin.

Climate change is one of the most critical challenges faced by human being and our planet. Researchers at ISSE, closely working with the Climate Change Science Institute at Oak Ridge National Lab (ORNL), is advancing our understanding of climate change and its impacts on human and natural systems. We use Earth system modeling, integrated ground and remote sensing observations, and advanced data analytical tools to study climate change and its impacts on water availability, soil moisture, wildfires, and vegetation.

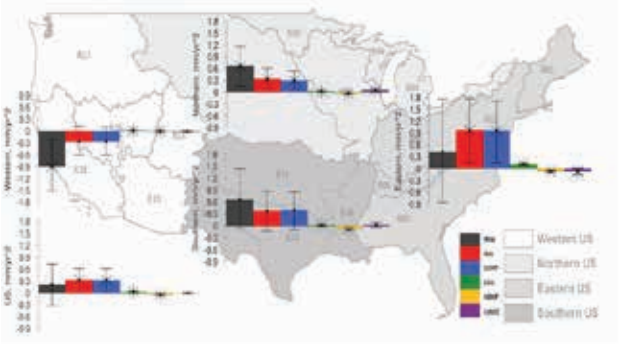
Water Availability

Water (or runoff) is an essential resource for the terrestrial biosphere as well as for human society; thus, it is important to detect and understand the potential drivers of changes in the hydrological cycle. Here We studied annual and seasonal runoff in the contiguous United States and streamflow in the Columbia River Basin for the period 1950 – 2010 and 1950 – 2008, respectively. For forcings, the effects of climate change and variability, CO2 concentration, nitrogen deposition, and land use and land cover change are used in both studies. Monthly observations of runoff from WaterWatch of the United States Geological

Survey, and an ensemble of semi-factorial land surface model simulations were used to quantify the effects due to external forcings. United States runoff had significant and insignificant increases in the east, north, and south, and a strong significant decrease in the west.

These changes were detected in the effects of climate change and variability, but could not be attributed due to the dry bias in the precipitation driver leading to underestimation in the model simulations. However, for the Columbia River Basin, the changes in annual total, center of timing of, and summer mean streamflow were attributed to climate change and variability. The most significant changes were the declines in the June – October months. On average, these months account for approximately 49% of the annual total flow. More specifically, the greatest decline was 28% for June which comprised approximately 22% of the total annual flow.

Regional Trends for US Annual Total Runoff (Forbes et al., 2018)

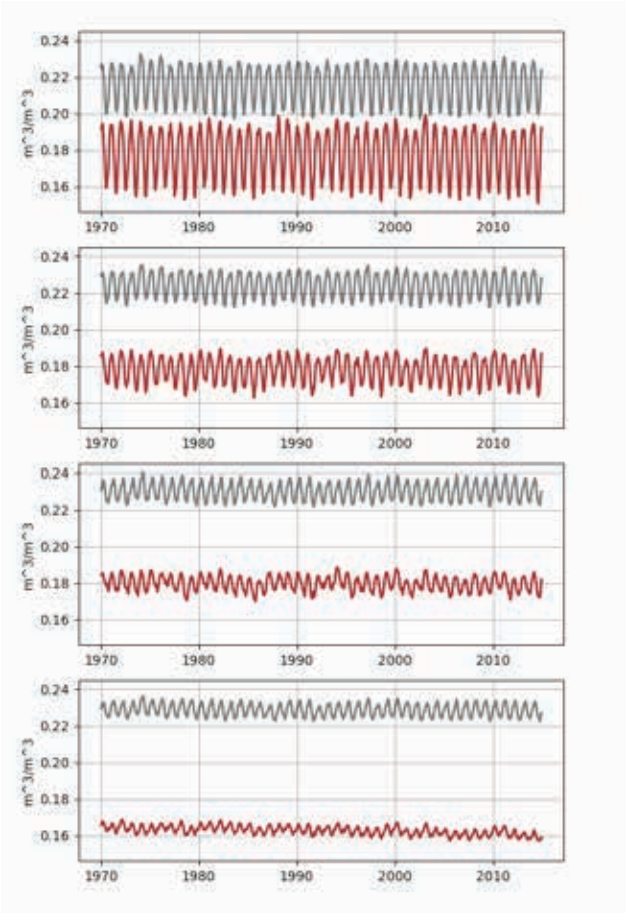


Soil Moisture: Data Analytics Support for Integrated Earth Model

Soil moisture is an important variable for understanding the terrestrial ecosystems and land-atmosphere interactions. Climate change induces changes in soil moisture by increasing atmospheric demand for evapotranspiration and changing the global precipitation, vegetation cover and behavior, and snow cover. Accurate quantification of soil moisture changes using statistical and modeling approaches require high-quality historical data sets and comprehensive benchmarking of model performance. However, current availability and accuracy of long-term, gap-free soil moisture data sets are limited. This limitation translates to high uncertainty in current understanding of the impacts of human forcings (e.g., emissions of greenhouse gases and aerosols) on soil moisture, and the lack of modeling benchmarking on soil moisture.

The project aims to (1) develop global, gap-free, long-term, multi-layer soil moisture data sets with improved accuracy over existing data sets, (2) use the developed data sets to conduct formal detection and attribution analysis to understand the impacts of human forcings on soil moisture, (3) add the developed data sets to the International Land Model Benchmarking Project (ILAMB) package.

Progress to Date: The team has developed the desired soil moisture data sets (1970–2016, monthly, 0.5, 0–10 cm, 10–30 cm, 30–50 cm, 50–100 cm) and published the results in an open-access journal (Wang et al., 2021). Using the developed data sets, detection and attribution analysis was conducted on zonally averaged global Standardized Soil Moisture Index, and the results were written up in a submitted manuscript. The results showed that human forcings, mainly greenhouse gas emissions, had significant impacts on historical changes in soil moisture. The impacts featured drying in the northern mid-latitudes and the southern hemisphere, and wetting in the northern high-latitudes in spring and in the northern subtropics, and were projected to continue in the 21st century. The surface



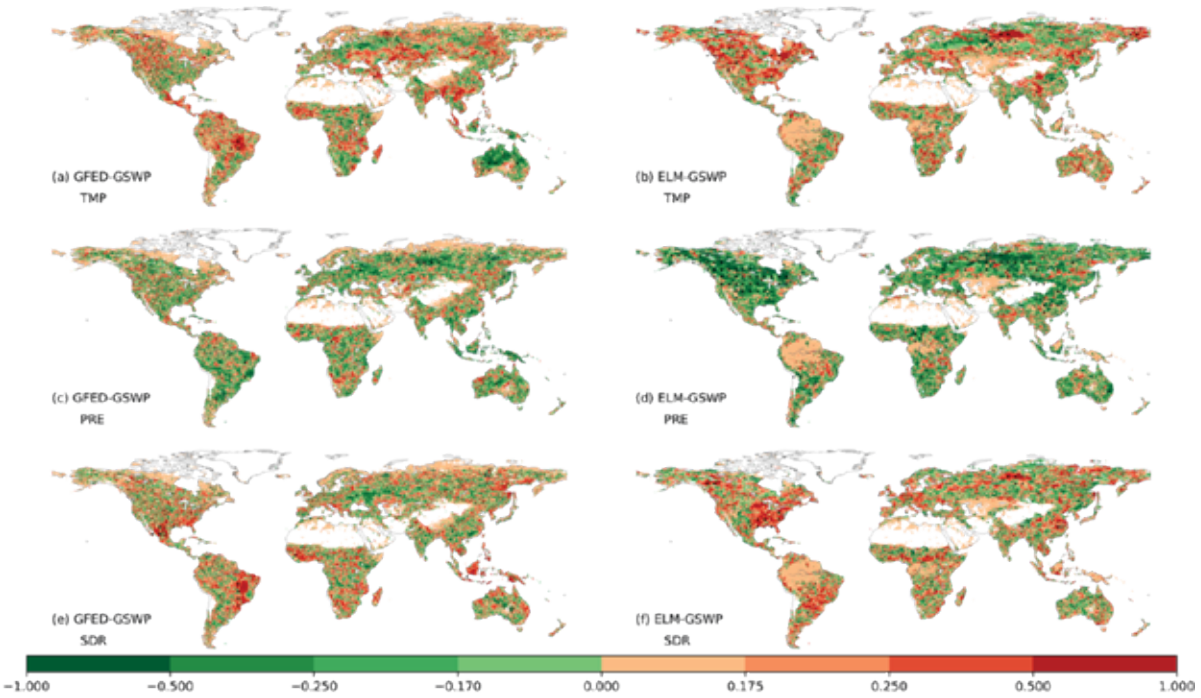
Example benchmarking graph using one of the developed soil moisture data sets showing global mean monthly soil moisture time series over the four soil layers.
Gray – benchmarking data set.
Red – the BCC-CSM2-MR historical simulation.
Top to bottom: 0–10 cm, 10–30 cm, 30–50 cm, 50–100 cm.

soil layer dried more rapidly than the root-zone (0–100 cm) layer. The contributions of temperature, precipitation, vegetation, and snow cover changes to these changes in soil moisture were quantified. The developed soil moisture data sets were added into the ILAMB package, enabling rapid benchmarking of soil moisture simulations by Earth

system models using standard metrics (e.g., bias, root mean squared error).

Wildfires

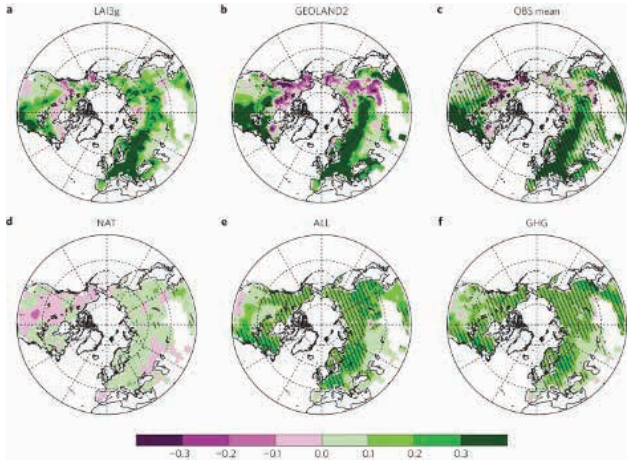
Understanding historical wildfire variations and their environmental driving mechanisms is key to predicting and mitigating wildfires. Using recent satellite-derived wildfire products and simulations from version v1.0 of the land component of the US Department of Energy's Energy Exascale Earth System Model (E3SM land model [ELM] v1) driven by three different climate forcings, we investigated the interannual variability (IAV) and its climatic sensitivity of the burned area globally and across nine biomes from 1997 to 2018. We found that (1) the ELM simulations generally agreed with the satellite observations in terms of IAV magnitudes, regional contributions, and covariations with climate factors of the burned area, confirming the robustness of the ELM to the usage of different climate forcing sources; (2) tropical savannas, tropical forests, and semi-arid grasslands were primary contributors to the global burned area IAV, collectively accounting for 71.7%–99.7% of the global wildfire IAV estimated by both the satellite observations and ELM simulations; (3) precipitation was a major fire suppressing factor and dominated the IAVs of global and regional burned area, and temperature and shortwave solar radiation were mostly positively related with burned area IAVs; and (4) noticeable local discrepancies between the ELM and remote-sensing results occurred in semi-arid grasslands, croplands, boreal forests, and wetlands, likely caused by uncertainties in the current ELM fire scheme and the imperfectly derived satellite observations. Our findings reveal the spatiotemporal diversity of wildfire variations, regional contributions, and climatic responses, and can provide new insights for wildfire modeling, prediction, and management.



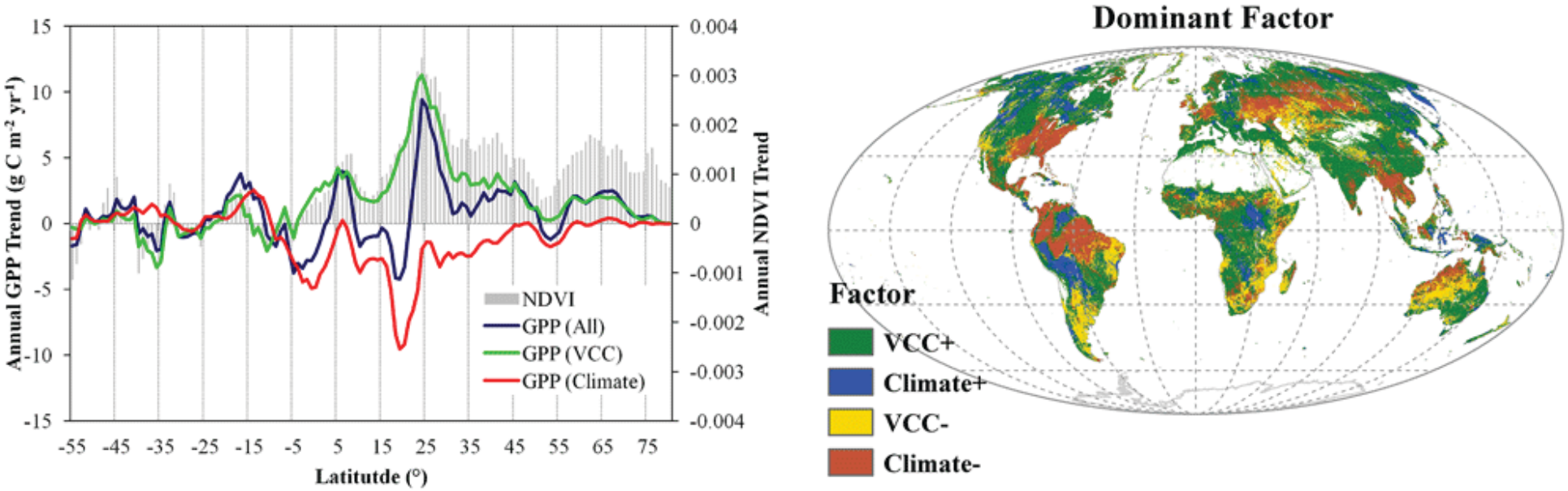
Spatial distributions of partial correlation coefficients between burned area IAVs and different climate factors from 1997 to 2012 (Tang et al., 2021)

Vegetation

The terrestrial biosphere on Earth is breathing continuously by inhaling carbon dioxide from the atmosphere (a process known as "photosynthesis") and exhaling water vapor into the atmosphere (a process known as "evapotranspiration"). These 'invisible' gas exchanges are key drivers of global carbon and water cycles, serving important roles in regulating climate system. We have worked on modeling and understanding these dynamic processes at the global scale based on remote sensing, ecological modeling, and ground observations. Specific research are related to eco-hydrological model development, Earth's greening, El Niño-Southern Oscillation, and climate drying and land use/cover change.



Spatial distribution of the linear trends in the growing season (April–October) LAI (m2 m−2 per 30 yr) (Mao et al., 2016)



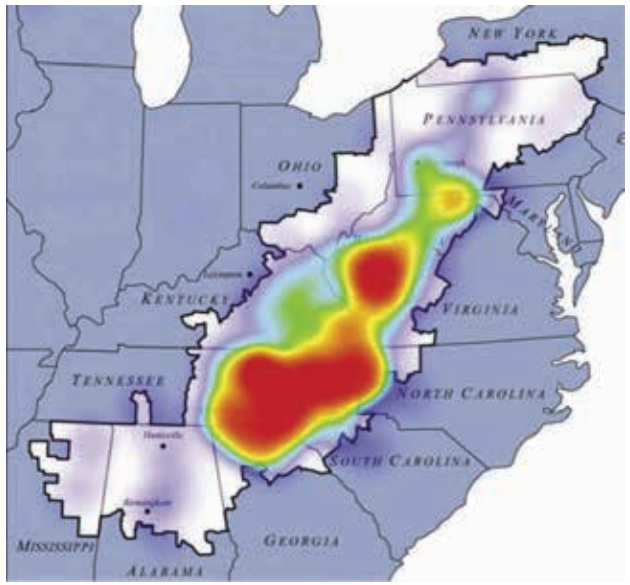
Spatial pattern of global GPP trend and its dominant factors from 2000 to 2015 (Zhang et al., 2019)

Regional Sustainability

Sustainable regional systems are connected urban and rural systems that work together for equitably advancing the well-being of people and the planet in a sustainable way. As a THEC center, ISSE is committed to the sustainable development of the State of Tennessee and surrounding areas with its research, education and outreach.

Increasing Economic and Entrepreneurial Opportunities by Promoting Outdoor Recreation Among Underrepresented Visitor Groups. Tim Ezzell, PI

From 2017-2020 researchers from ISSE led the largest and most comprehensive study of Appalachian tourism, a $60 billion industry. They were joined by Dr. Stefanie Benjamin from UT's Retail, Hospitality, and Tourism Management program and Bruce Decker, president and founder of Collective Impact, LLC, a consulting firm located in Huntington, WV. Their research, which covered all aspects of this rapidly changing industry, included detailed site visits to a dozen established and nascent communities across the thirteen-state region, The work resulted in significant findings and recommendations, which are detailed in the final report, Extending Our Welcome, Trends and Strategies for Tourism in Appalachia, which was released in February 2021. The report can be downloaded at https://www.arc.gov/report/extending-our-welcome-trends-and-strategies-for-tourism-in-appalachia/



Heat map of visitor destinations in Appalachia

Sustainability of Urban Water.
John Schwartz, PI

Urban water demand is expected to increase significantly in the next several decades and as these demands increase conflicts over use of this most vital human resource will surge without adequate integrated planning. Conflicts will cross jurisdictional boundaries and into the rural communities where watersheds largely provide the higher-quality resource supply. Resolving conflicts and achieving resource sustainability through integrated planning are constrained by many regulations and governed by multiple agencies. Regulations may have different directive or overlaying directives among agencies, and multiple levels of governance. Dr. John Schwartz and his team are developing a new framework for integrated water resource planning to achieve sustainably recognizing all system needs and socioeconomic interdependencies among the urban and rural communities, suggesting policy for more effective governance, and formulate the technologies to advance current water management planning procedures. To fully stress test regions and their water needs and infrastructure, advanced technology in terms of database management and watershed modeling will be required. Population growth is inferred as one stressor with increased future demands in urban centers, though incorporating the impacts from climate change on the regional hydrologic processes are equally important to expose system vulnerabilities and supply risks.

Water Research

The Tennessee Water Resources Research Center (TNWRRC) is a federally designated state research institute supported in part by the U.S. Geological Survey and the Environmental Agency. It serves as a primary link among water-resource experts in academia, government, and the private sector, and the diversity of its staff in terms of background and expertise enhances flexibility and positions the Center to establish productive partnerships.

TDEC: TN Stream Quantification Tool Training. John Schwartz, PI

The goal of this project is to strengthen the stream compensatory mitigation regulatory program by refining and validating success criteria the TN Stream Quantification Tool (TN SQT) version 1, and provide statewide stakeholder education and outreach on the use and implementation of the TN SQT to review functional loss and lift of §401 Water Quality Permits and compensatory mitigation projects. In August 2020, a working group was formed to review the existing TN SQT, meeting monthly. The working group consisted on seven consulting firms, a mitigation in-lieu fee program, TDEC staff, and US Army Corps of Engineers staff in Nashville and Memphis. With the aid from the Water Center, TDEC will work with the state's Interagency Review Team, consultants, and stakeholders to develop and provide statewide education for practitioners and regulators on how to use the TN SQT to increase the success of compensatory mitigation projects and prevent functional loss from 401 Water Quality permits. In April 2021, a final review by the working group was completed, and now graduate student Grace Long is working through the proposed revision of the metrics to assess how they influence the SQT condition scores. It is a work-in-progress, with the final aim to develop a training course for the practitioners estimating loss on functional condition from some near stream activity and preparing requests for mitigation credits through stream restoration projects.

Developing an Urban Waters Report Card. Jon Hathaway, PI

Development of the Urban Waters Report Card (UWRC) is sponsored by several municipal stormwater programs in the state of Tennessee, including Nashville Metro, City of Memphis, City of Chattanooga, and Shelby, Hamilton, and Knox counties. The UWRC will provide for tracking of improvements for streams that failed to meet their designated uses and are on the list of impaired waters. The UWRC grade scale spans from A to F, a structure that is simple and intuitive for the public to understand. Members from this state-wide working group have been meeting since 2020, and this year the working group has made progress identifying metrics that will be assessed for the final version of the UWRC. Metrics have been selected from four categories, which are: water quality, watershed hydrology (connectivity), stream corridor, and community value. A presentation on the UWRC development was given October 2020 at the annual conference of the Tennessee Stormwater Association by John Schwartz and Karina Bynum. They will again present at the annual conference in October 2021. A beta version of the UWRC will be finalized early next year and beta tested spring 2022. A web site for the UWRC have been created at http://tnurbanwaters, and is a work-in-progress.

USGS Water Resources Program 104b Funds FY2021. John Schwartz, PI

The Tennessee Water Resources Research Center (TNWRRC) is the state representation to the National Institute of Water Resources (NIWR), associated with Section 104 of the Water Resources Act with annual funding from the US Geological Survey (USGS). The TNWRRC serves as a primary link among water resource experts in academia, government, and the private sector across the state of Tennessee. Though 104b Program funds from the USGS, the TNWRRC supports competitive grants awarded annually to university researchers state-wide. For this year's round of call for proposals we asked for organization/agency to provide us their water resources research priorities. We obtained priorities from the Tennessee Department of Environment and Conservation, Tennessee Department of Agriculture, Tennessee Department of Transportation Environmental Division, Tennessee Valley Authority, The Nature Conservancy, and the USGS Nashville Science Center. We received nine proposals and funded four, in which funds were awarded in September 2021. Research topics included: validation of the Tennessee nitrogen budget model for secondary-treated reclaimed water, improved remoted sensing imaginary techniques to identify riparian corridor characteristics in headwaters, auto-depuration due to stream bar hyporheic exchange, and identifying patterns of water scarcity for Tennessee under climate change and urban growth. The institutions funded were UT Institute of Agriculture, University of Memphis, and University of Tennessee Knoxville.

NPS Project: Impacts of Acid Deposition on Water Quality and Aquatic Biota. John Schwartz, PI

(a Cooperative Agreement between National Park Service and UT)

Project Description—For decades, acidic air pollutants from regional and local sources have been transported by prevailing wind currents and deposited onto high-elevation watersheds in the Great Smoky Mountains National Park (GRSM), on the Tennessee/North Carolina border. In order to investigate the potential effects of acid deposition

right: The Urban Water Cycle, image coutesty NSF
Credit: Nicolle R. Fuller, Sayo-Art LLC

on stream water quality, the GRSM began a Water Quality Monitoring Program in 1991 consisting of: 1) detailed hydrologic and biogeochemical monitoring at Noland Divide Watershed, a high-elevation forested site, and 2) Park-wide stream survey monitoring for spatial mapping and temporal trend analysis of stream acidification. In addition to the routine monitoring, special studies are conducted to investigate questions that remain on the fate, biogeochemical transformation, and transport of acid/base ions and dissolved metals. This past year two special studies are on-going; they are: 1) a sulfate isotope analysis to quantify the mass flux of sulfate generated from the high-elevation Anakeesta pyritic shale formation in comparison to acid deposition inputs; and 2) a throughfall chemistry mapping, which has been over 15 years since the last GRSM effort by Dr. Kathleen Weathers at Cornell University. We work with Dr. Charles Driscoll at Syracuse University, whose research team developed and uses the BGC-PnET model for estimating critical loads in the GRSM.

One of the most interesting investigations is the observed responses in deposition and stream chemistry due to emission reductions from local and regional coal-fired power plants. Many geochemistry parameters of wet/dry deposition at the monitoring site show strong and direct responses to emissions reductions: measured deposition amounts decreased, precipitation pH and ANC increased, and nitrogen speciation in precipitation samples shifted; all within the same 2008-2009 time frame. Through fall sulfate deposition has declined from above 1,500 eq/ha/yr before 2007 to approximately 500 eq/ha/yr after which. However, the changes in deposition have not yet translated to significant changes in stream sulfate concentrations or annual mass exports. It appears the lack of response in stream sulfate is influenced by the biogeochemistry in associated with the nitrogen cycle dynamics, base cation availability, and carbon-sulfate dynamics.

Hydrologic Connectivity Using Regenerative Stormwater Conveyance.
Jon Hathaway, PI

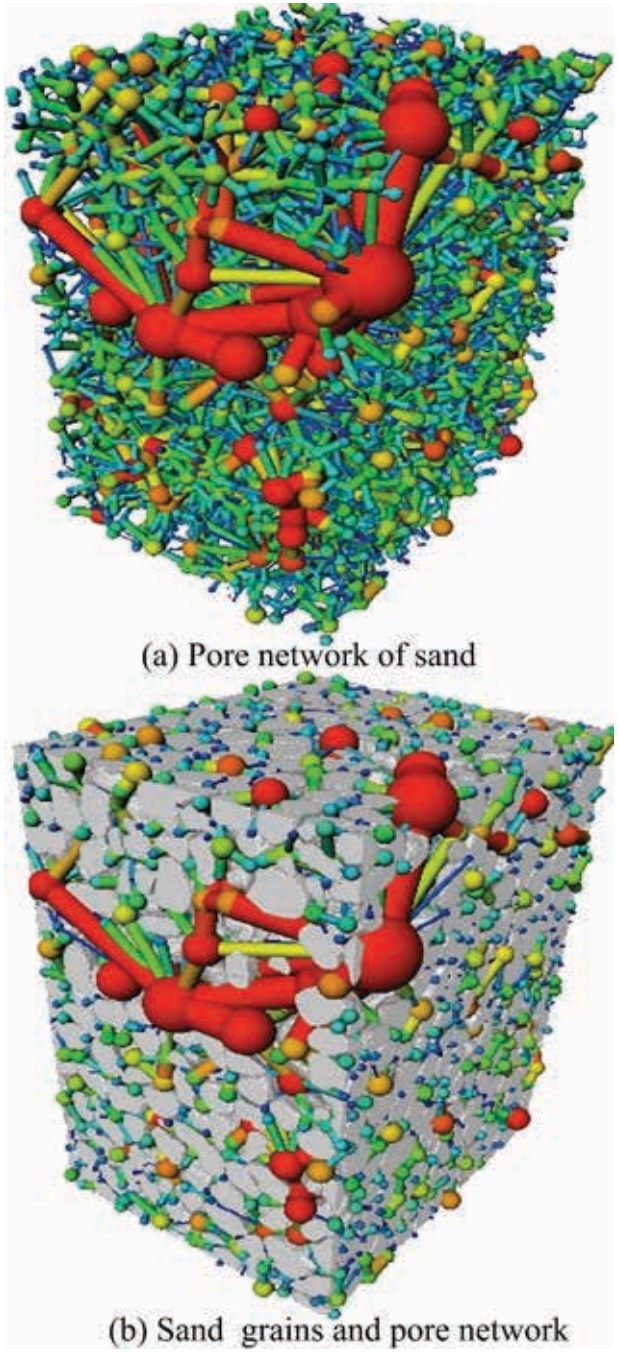
In Powell, Tennessee at Collier Preserve, a public park needs a remediation method for the erosive flows produced at a stormwater outfall bringing offsite drainage through the property. Implementing an RSC in this area will protect the park's trails, increase water quality of the receiving waters, and serve as a public attraction. The watershed routing to the site is 5.06 ha of predominantly field and forested land. The site itself consists of two 1.07 m diameter pipes that spill onto 61 m of previously unmanaged forest until discharging into a swale connected to Beaver Creek.

Earlier this year, Dr. John Schwartz, director of the Tennessee Water Resources Research Center, and Dr. Jon Hathaway received a grant from the Environmental Protection Agency to study the loss of headwater wetlands that have resulted from the Southeast region's rapid and explosive urbanization. Efficient drainage systems route water quickly to local streams, bypassing floodplains and drying once vibrant wetlands. New techniques studied by the University of Tennessee show promise in restoring hydrologic connections allowing wetlands to be reestablished in these environments. The goals of this project are 1) to demonstrate the possibilities that Regenerative Stormwater Conveyances offer for recreating wetlands in urban environments and 2) to identify and document best practices for design of these systems.

Grad student Gillian Palino working in an urban culvert for the Regenerative Stormwater Conveyance project.

3D Dynamic Evolution of Pore Water-Air Interaction within Saturated Sheared Sand. Khalid Alshibli, PI

Many foundation systems are supported by water-saturated sand deposits. At the micro-scale, the voids between sand grains (pore space) are filled with water. The sand resists applied foundation loads through friction and interlocking between particles, which is known as the shear strength of sand. The presence of air within the pore space in addition to water introduces new forces and fundamentally changes the shear strength of sand. Alshibli's preliminary experiments show that standard procedures to saturate laboratory sand specimens may suffer from a major shortcoming despite decades of use and wide acceptance by the geotechnical community. The goal of this research is to monitor the evolution of sand-water-air interaction using fast dynamic synchrotron microcomputed tomography imaging at 6-micron resolution under shear loading conditions. This research will (i) investigate the influence of particle morphology and gradation on the degree of saturation of sheared sand; (ii) monitor local water- air interaction within pore space of sheared sand under drained condition; and (iii) evaluate the effects of specimen density on the change of degree of saturation of sheared sand. The following fundamental questions will be answered: (1) what is the minimum value of pore water pressure to maintain the same degree of saturation in sheared sand; (2) does the sand specimen remain 100 percent saturated when it is sheared; (3) if air bubbles develop; how they will evolve and what are the factors that affect their onset and growth. 3D probing of dynamic particle-water-air interaction is expected to offer unique measurements to support the development of a new particle-scale theory that better describes the behavior of saturated sheared granular materials.



Sand pore network

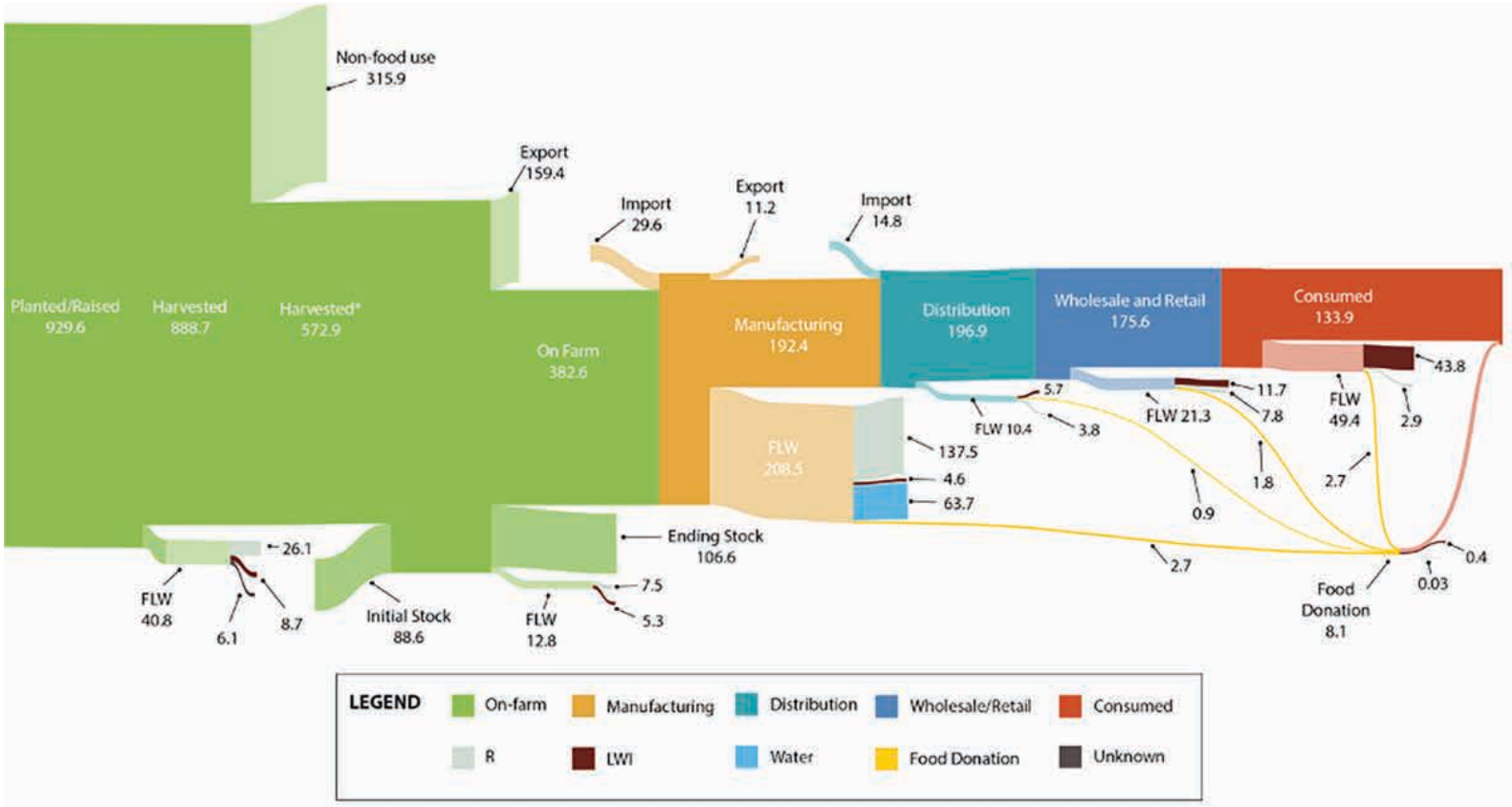
Sustainable Food Systems

The Sustainable Food team includes Yaoping Wang, Joe Zhuang, Scott Zheng, Andrew Muhammad, and Mingzhou Jin.

Responding to the second UN Sustainable Development goal of ending hungers and achieving food security, ISSE studies food sustainability in the United States and world, using analytic models and pursuing systematic solutions. We assess the sustainability and resiliency of the global food systems by carefully considering socioeconomic, policy, and climate scenarios.

Food Loss & Waste

Quantification of food loss and waste (FLW) generation is a vital step to FLW reduction, recycling, and recovery. Working with Oak Ridge National Lab, we estimate the mass flow and FLW according to the real weight of commodities at each stage of the Food Supply Chain (FSC) and evaluate the management of U.S. FLW through nine management pathways. In 2016, 572.9 MMT of food materials were harvested for human food consumption, while 40.8 MMT of food materials were planted/raised but unharvested (i.e., failed to enter U.S. FSC), pulsing 302.8 MMT (52.8% of the food materials entered FSC; including water evaporated during food manufacturing) entered but left the FCS ended as recovered/recycled products or disposed of via landfilling, incineration, and wastewater treatment. Among the total of 343.6 MMT of FLW, 63.7 MMT (18.5%) is the weight reduction due to water evaporation during the manufacturing process of some food commodities (e.g., sugar), 193.7 MMT (56.4%) is recycled or recovered, and 77 MMT (22.4%) is disposed of via landfill, incineration or wastewater treatment (LWI). In addition, the management of on-farm animal-related FLW (8.8 MMT; 2.6%) is left as unknown due to the data limitations. The Consumption



Sankey diagram of the 2016 U.S. Food Supply Chain (in MMT)

stage is the worst contributor to FLW disposed via LWI (51%). Conversely, even though U.S. food manufacturing contributes the most FLW (i.e., 208.5 MMT; 60.7% of total FLW), this stage demonstrates a high level of circular economy: only 4.6 MMT, 2.2%, of manufacturing FLW was landfilled or incinerated, 63.7 MMT (30.4%) is the weight reduction due to water evaporation which cannot be considered as waste, and the remaining was recycled or recovered (i.e., 140.2 MMT, 67.4%). However, U.S. food manufactures can contribute to a sustainable FSC by influencing the downstream stages, since the products with high demand and perishability contribute the most FLW and manufactures can contribute to FKW reduction by extending products' shelf-life. along the U.S. FSC.

Sustainability of Global Crop Supply Chain

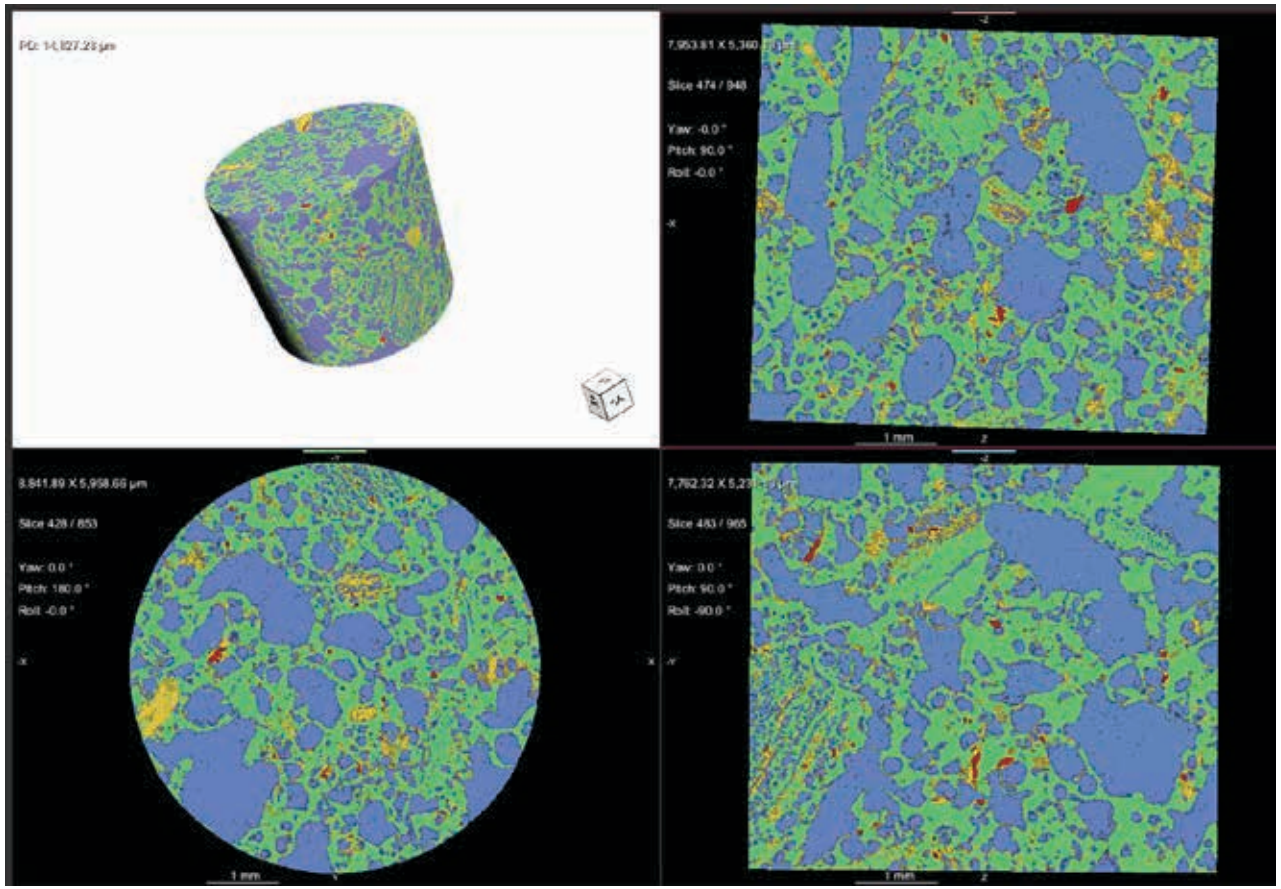
The largest challenges for global food systems are the spatial and temporal mismatches of their supply and demand. The crop supply chain (SC) helps to relieve the two mismatches through transportation, trade, and storage. However, long-distance shipment consumes a large amount of energy. Water, as a critical resource for crop production, is unevenly distributed all over regions and around seasons. The interaction as a Food, Energy, and Water System (FEWS) and spatial and temporal heterogeneity require a systematic and coupled method to study the global crop SC, which includes production, storage, transportation, distribution, and consumption. Funded by the National Science Foundation, we are developing a scalable framework that models decision-making in the global crop SC as embedded in the water resources and energy, socioeconomic, and policy environments and as affected by prices and climate factors. The framework will be applied to assess the sustainability and resiliency of the global crop SC as a FEWS under carefully designed socioeconomic, policy, and climate scenarios using the global soybean and wheat SCs as a case. Key performance indicators will be developed to measure individual and corporates utility, societal welfare, and environmental sustainability and identify technical, societal and policy solutions.

Utilizing coal-derived solid carbon materials towards next-generation smart and multifunction pavements. Zhou Hongyu, PI; Boashan Huang, Wei Hu, co-PIs

The objective of this project is to develop and demonstrate a novel multifunctional smart pavement system that incorporates coal-derived solid carbon to enable integrated de-icing, self-sensing, and microwave/induction/Ohmic-heating induced healing, with a goal to provide a cost-effective, resource-efficient and reliable solution to address safety, mobility, and resilience challenges on bridges and roadways enduring snowy winter weather.

Specifically, Phase I research will focus on assessment and demonstration of the technical and economic feasibility of the proposed system.

The objectives set forth above will be accomplished through five interrelated research tasks: Tasks 1 & 2 will focus the economic analysis including market need; Task 3 aims to establish the processing-structure-property relationships for coal-derived carbon to identify coal-char suitable for pavement construction; Task 4 designs, characterizes, and demonstrates the coal-char enabled functional pavement material, as well as develops a physics-based model to enable the design and optimization of the pavement layer layup; lastly, Task 5 addresses issues pertaining to the scale-up constructability by system-level prototyping and validation using an accelerated pavement tester.

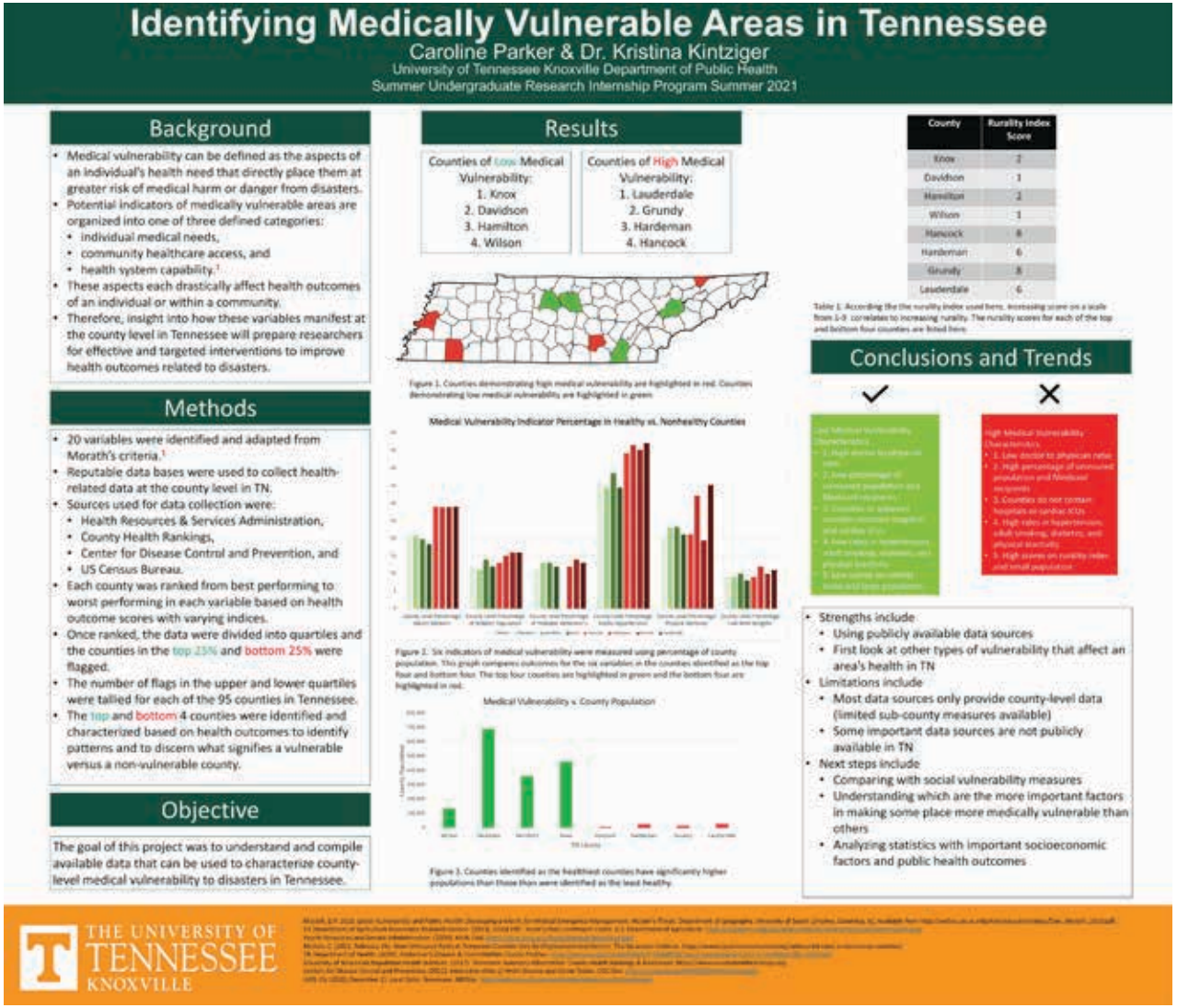


During this quarter we continued our market and economic analysis - preliminary life cycle cost analysis (LCCA) was conducted for the proposed technology in comparison with tradition deicing using deicing salt and chemicals. Literature study was continued to gather data needed for the LCCA and to understand the performance demand (both heating and mechanical) for the proposed Coal-Derived Carbon Enabled Smart Pavement (CDC-SP). Multiscale characterization of coke was carried out including several microscopy characterization techniques (i.e., optical microscopy, scanning electron microscopy, and X-ray microtopography), aiming to understand the microstructural features of coal-derived coke (both metallurgical coke, or 'Met coke', and Pitch coke) for their potential use in smart pavement.

ISSE-Funded Research

Seed Grant Awards for 2022

Beat the Heat: Building adaptive capacity of vulnerable populations in Knox County to combined stressors from climate change and urban heat. Kelsey Ellis, PI; Jennifer First & Kristina Kintziger, co-PIs



Climate change and urbanization threaten the well-being of human-environment systems. Urbanization influences humidity, precipitation, and air temperature; and is associated with negative impacts on human health, including chronic diseases and overall mortality. Climate change exacerbates the impacts of urbanization on these systems by increasing the frequency and intensity of extreme temperatures and other weather impacts (USGCRP 2018). While all people in the US are vulnerable to these threats, some populations are particularly at risk for heat-related illness and injury for various reasons (i.e., lack of access to housing, air-conditioning, or transportation to cooling centers; living in the hottest regions of cities; Li et al. 2015). The negative impacts of climate change combined with urbanization are exemplified through the urban heat island (UHI), which occurs when urban areas are warmer than surrounding areas due to heat-absorbing surfaces and limited green spaces (Oke 1982). A previous ISSE project (PIs: Ellis, Hathaway, and Mason) installed weather stations to demonstrate the existence of a Knoxville UHI (Ellis et al. 2017), but exposure to extreme heat and its effects on vulnerable populations (i.e., children, elderly adults, persons with underlying health conditions, and persons experiencing unstable housing or housing insecurity) in this metropolitan area are unknown. Recent research (for example, Davis et al. 2020) has suggested that heat health effects are not simply a direct result of daytime high temperatures, but are also related to the overnight low temperature (Tmin) and the diurnal temperature range (DTR), both of which are altered by the UHI and climate change (Portmann et al. 2009), though little is known about how DTR and Tmin are experienced by people. The overarching goals of this proposal are to a.) apply a systematic approach to characterize the impact of diurnal rhythms of heat on the human-environment systems in Knox County, Tennessee, with a particular focus on identifying high-risk populations such as elderly adults, low-income people, and those experiencing homelessness, and b.) develop a Heat Task Force of Knox County stakeholders to identify community-based adaptation strategies to improve outcomes for these vulnerable populations. This work supports the ISSE FY22 goal of modeling resilience under climate change and other social or environmental stressors; and by assessing mitigation strategies. Using a scientific framework developed by the Centers for Disease Control and Prevention (CDC),

entitled Building Resilience Against Climate Effects (BRACE; Marinucci et al. 2014), we will address the following specific research objectives and questions.

Objective 1: To identify the scope of UHI effects on human-environment systems in Knox County, with a focus on modeling the DTR and experienced temperatures of vulnerable populations. This connects to the BRACE framework by anticipating climate impacts.

Objective 2: To assess social and medical vulnerabilities to the impacts of climate change and urbanization, with a specific focus on the impacts of the UHI, in Knox County. This connects to the BRACE framework by assessing vulnerabilities to climate change.

Objective 3: To develop a Heat Task Force of local stakeholders to identify community-based strategies to address heat exposure and impacts on vulnerable populations in Knox County. This connects to the BRACE framework of prioritizing climate-sensitive health outcomes and developing adaptation plans in consultation with community stakeholders such as local public health agencies, community members, local government, academics, and social service organizations.

Microbial transformation and degradation of sulfonated per- and polyfluoroalkyl substances. Frank Loeffler, PI; Shawn Campagna, co-PI

This project's overarching objective is to challenge the paradigm of "forever chemicals" and demonstrate that sulfonated PFAS are susceptible for biotransformation by specialized bacteria.

Project Summary. Per- and polyfluoroalkyl substances (PFAS) are global contaminants linked to a variety of humans diseases. The proposed research will use the soil isolate Pseudomonas sp. strain 273, which harbors an unusually high number of 22 alkanesulfonate monooxygenase (ssuD) genes, to demonstrate that naturally occurring bacteria can transform and defluorinate perfluorosulfonic acids, including perfluorooctanesulfonic acid (PFOS). The research will generate evidence for the existence of a natural attenuation process for a major class of PFAS, which would have far-reaching implications for fate and transport modelling, sensible regulatory frameworks, and possibly enhanced remedies.

PFAS comprise thousands of synthetic chemicals produced since the 1950s for use in various industrial applications, diverse consumer products, and as components of aqueous film forming foam (AFFF) formulations for fire suppression. PFAS have emerged as global contaminants that can be detected in every person on the planet Earth and are linked to metabolic disruption, obesity, diabetes, immune suppression, and cancer in humans. Deemed "forever chemicals", some evidence is now emerging suggesting that naturally occurring microbes can transform PFAS 7. A major group of PFAS in AFFF are perfluorosulfonic acids with the general structure CnF2n+1-SO3H and various precursors with the general structure CnF2n+1-SO2R. Sulfonated PFAS and its precursors are pervasive groundwater contaminants originating from AFFF applications, landfill leachate, and wastewater treatment plants 10, but also from nonpoint sources, predominantly urban stormwater runoff.

Socioeconomic inequalities and drinking water quality: assessin arsenic concentrations in community water systems by novel field deployable biosensors. Jie Wu, PI; Courtney Cronley & Qiang He-PIs

Objectives and rationale: Arsenic (As) contamination in water poses a severe threat to a broad spectrum of living organisms. It is a carcinogen, highly toxic, and widely present in many aquifers around the world. It is estimated that about 150 million people around the globe are at risk because of arsenic contamination. The most common As exposure pathway is consumption of groundwater containing arsenic. Particularly in certain agricultural communities, irrigation and drainage would enhance arsenic releases from geogenic sources with high evapotranspiration rates further concentrating arsenic in surface water and shallow groundwater to elevated levels. This dire situation is expected to be exacerbated by climate change in these vulnerable communities. Inorganic arsenic in the form of arsenic cations (Asn+), i.e. As(III) & As(V), has long been an Environmental Protection Agency (EPA) priority pollutant, setting its maximum contaminant level (MCL) for public water supplies at 10 parts per million (ppb), or 10 µg/L. The EPA limits are set for the aggregate of As(III) and As(V). As(III) is 60 times more toxic than As(V). Therefore, it is critical to distinguish these two forms of toxic forms of As, which, however, is limited by long turnover time and high costs with currently available techniques. Therefore, there is a great need to develop rapid and affordable As sensing techniques for the monitoring of As in

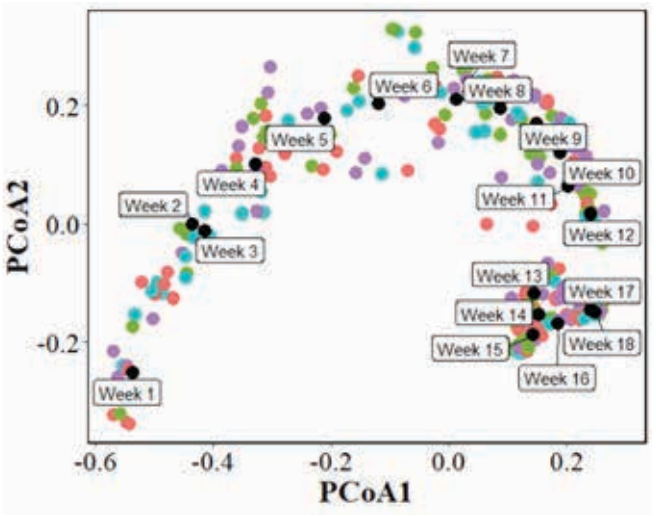


Figure: Temporal dynamics of exposure to indoor microbiome

disadvantaged communities where inadequate water quality monitoring and treatment have persisted.

Timely detection of traces of active arsenic (As3+) is imperative to addressing the presence of arsenic in water, and a simple and low-cost arsenic sensor is urgently needed to protect the community health. From a broader perspective, there is evidence suggesting that arsenic exposure is not uniform across all communities, and low-income and minority communities could face disproportionately high pollutant exposures, due to the structural inequality ingrained in land-use patterns, facility siting, and local regulatory policies. So far, nationwide assessments of arsenic exposure or other contaminants in community water systems and possible correlation with socioeconomic disparities are yet to be available. Our objectives are 1) to develop a simple, low cost and sensitive biosensor for the detection of arsenic in community water systems; 2) to obtain preliminary data on arsenic levels from selected communities with diverse racial/ethnic or socioeconomic backgrounds; and 3) to identify possible correlations between the arsenic levels and socioeconomic status. The outcome of this project will eventually yield an arsenic detection device readily available to all walks of life, the identification of the U.S. population subgroups disproportionately exposed to elevated water contaminants, which in turn will lead to informed decisions on public health interventions and regulatory action needed to eliminate exposure inequalities.

Ongoing Seed Grant Projects

Toward Precision Environmental Health Risk Management: Feasibility of Personalized Exposome Monitoring. Qiang He, PI; Courtney Cronley & Shuai Li, co-PIs

Humans are exposed to numerous chemical, physical, and biological factors, such as microorganisms and particulates, in the environments, collectively defined as the human exposome. The exposome plays important roles in human health, particularly in the development and progression of diseases such as cancer, infectious diseases, and chronic inflammatory diseases. The ongoing COVID-19 pandemic has exposed disparities in environmental exposure as individual transmission risks have been shown to correlate with one's socio-economic determinants. Thus, monitoring and understanding the exposome is particularly valuable to develop strategies to reduce environmental inequity and manage health risks. However, precision management of environmental health risks requires personalized monitoring of the exposome, which until now is conducted exclusively at the population level. Therefore, it is of great importance to develop methodologies feasible for personalized exposome monitoring to reduce exposure risks and mitigate environmental inequity.

During the first half of the project period, the project team has developed a sampling device for personalized exposome monitoring and sampling. The sampling device can be operated with an autonomous mode, enabling deployment even under COVID-19 restrictions. As a proof-of-concept, the sampling device has been used for the monitoring of exposure to indoor microbiomes. The airborne microbiome is sampled with the device by actively capturing airborne particulates on a 25-mm sterile filter (0.22-μm pore size) followed by determination of the quantity and composition of the airborne microbiome according to protocols established in the PI's laboratory, including DNA extraction, high-throughput sequencing, and bioinformatics analysis. Preliminary results indicate that human exposure to indoor microbiome exhibited significant temporal changes during a four-month period. Indoor microbial exposure experienced rapid changes during the first 6 weeks but stabilized during the last 6 weeks, coincided with the changes in cleaning and disinfection practices during the monitoring period. These results demonstrated the utility of the personalized exposome sampling device developed during this project.

The project team will continue with efforts to 1) publish results from this seed project to strengthen the track record in the research area of environmental exposomes, which is essential for developing competitive research proposals; and 2) expand the research scope to other health outcomes associated with environmental exposure, including asthma, allergy, and infectious diseases, particularly those associated with airborne transmission. Preliminary results from this seed project can be readily leveraged to support proposals in these extended research topic areas.

Bioengineering of the Duckweed Plastid Genome. Scott Lenaghan, PI; Barry Bruce, co-PI

The complete chloroplast genome for Lemna minor L. has been sequenced, along with comparative genomics of other duckweed species. Recently, PI Lenaghan published a modular cloning plastid engineering (MoChlo) kit for assembly of plastid transformation vectors. Using this kit and the available plastomic information, the team will synthesize homology arms for four insertion sites for homologous recombination in the native plastome of duckweed. The MoChlo kit contains 95 plastid regulatory sequences that can be used to control expression of transgenes in duckweed, as most plastid regulatory sequences are highly conserved and function in a variety of species. Thus, the kit's available resources provide a facile entry point for developing methods for plastid engineering in duckweed using existing resources with minimal gene synthesis. At the same time, the team will develop a method for automated duckweed tissue culture and chlorophyll analysis, using the robotic platform in PI Lenaghan's lab.

Previously, researchers at CASB have automated high-throughput protoplast isolation, transformation, and screening in switchgrass, corn, rice, tobacco, and soybean. We will use this expertise to develop an automated protocol for vegetative propagation of duckweed, which will enable more rapid screening of compounds to select for transplastomic duckweed. Since plastid engineering requires biolistics to physically insert gold-DNA nanocomplexes, it is not anticipated that adapting biolistics to duckweed will represent a significant challenge. Further, genetic similarities between the plastid genome of Lemna minor and species used in development of MoChlo suggest high vector compatibility. It will also be possible to apply constructs and selection strategies that are currently being tested in an existing DARPA-funded project to plastid engineering in duckweed. These strategies include toxin/antitoxin systems, positive selection for photoautotrophic growth, novel antibiotics that affect prokaryotic polymerases, pathways for essential amino acid synthesis, and the control spectinomycin selection. Quantum Yield (QY) is a relationship of the variable fluorescence (Fv) to the maximum fluorescence (Fm). QY reflects the efficiency of PS II and can be related to overall plant health. Aminoglycosides such as spectinomycin and kanamycin inhibit protein synthesis by binding at the ribosome, interfering with translation. Photosystems are large protein complexes, requiring 20 plus subunits. Inhibiting protein synthesis leads to diminished complex turnover thus a breakdown of photosynthesis.

Pulse Amplitude Modulated (PAM) fluorescence measurements allow for relatively non-intrusive, in-vivo monitoring of plant health as related through photo-efficiency. Preliminary work has already been conducted to determine several selection agent parameters, kanamycin and spectinomycin in Lemna minor and Spirodela. In addition to the strategies themselves, the regulatory elements driving expression of the genes play a significant role in success or failure of a selection strategy. In this way, this seedling project represents an ideal platform to demonstrate the high throughput potential of duckweed, while also demonstrating for the first time, stable monocot transplastomics. This research will open the door for a variety of applications targeting molecular farming, protein production, and phytoremediation. Specifically, following establishment of a homoplastomic transformation protocol, altered oxalate synthesis (improve human consumption), and Cs accumulation will be investigated.

above: close-up of Lemnoideae, commonly known as duckweed

Completed Seed Grant Projects

Analyzing Strategies for Diverting and Managing Organic Waste Streams in Tennessee. Chris Clark, PI

The work done in this successful seed grant has led to a funded project, *Battlefield Farm Community Compost*, through the **Tennessee Department of Environment and Conservation.** Another project is in Review, "Start Smart: Developing a Whole-Systems Geographic Decision Support Model for Food Waste Nutrient Capture and Cycling," through the Foundation for Food and Agricultural Research (FFAR). "Neighborhood Attitudes Toward Community Composting: Case of Knoxville, Tennessee," has been published online for EconPapers and is available at https://econpapers.repec.org/paper/agsutaerr/310493.htm.

Multi-Sensor Data-Driven Inspection/ Maintenance of Green Infrastructure. Anahita Khojandi, PI; Jon Hathaway, co-PI

This project has benefitted an undergraduate student in Industrial & Systems Engineering, Kalina Scarbrough. Ms. Scarbrough's extension to her original study, developing machine learning models to analyze sensor data, won first place at the Institute of Industrial and Systems Engineer's Mid-Atlantic Technical Regional Competition. The paper discusses her research with Dr. Anahita Khojandi (ISE). The project, which started two years ago, is about how to efficiently monitor green infrastructures, specifically bioretentions, and predict their future state. She presented this work at the IISE Annual Conference in May 2021. Building on her winning paper, Ms. Scarbrough is first author on an academic journal article, Real-Time Sensor-Based Prediction of Soil Moisture in Green Infrastructure: Case Study, that was published in Proceedings of the 2020 Industrial and Systems Engineering Conference. Kalina is a senior in the Institute of Industrial and Systems Engineers with a minor in reliability and maintainability. She expects to graduate in May 2022.

Geochemical Interaction between CO2 and Caprock for Safe Carbon Sequestration. Khalid Alshibli, PI; Nicholas Dygert, co-PI

This project was developed to understand the chemical reaction between Carbon dioxide (CO2) and rocks when it is stored deep into the ground for safe storage (sequestration) of CO2. CO2 emission into the atmosphere from human and industrial processes continues to pose a major environmental and health threat to public health worldwide, and many governments have launched initiatives to reduce the impact of CO2 emission. According to a report by the Intergovernmental Panel on Climate Change (IPCC), United Nations (2005), about 13,466 MT/ year of CO2 is emitted from fossil fuels and biomass where power plants and cement production are the top sources for CO2 emission. Some technologies can capture 85%-95% of CO2 processed in a capture plan (IPCC 2005). Carbon dioxide capture and storage (CCS) is a process of separating CO2 from industrial facilities and other point sources and injecting it in deep geological formation for long-term storage. Deep saline aquifers, depleted gas and oil fields, and coal mines are good potential places to store CO2.

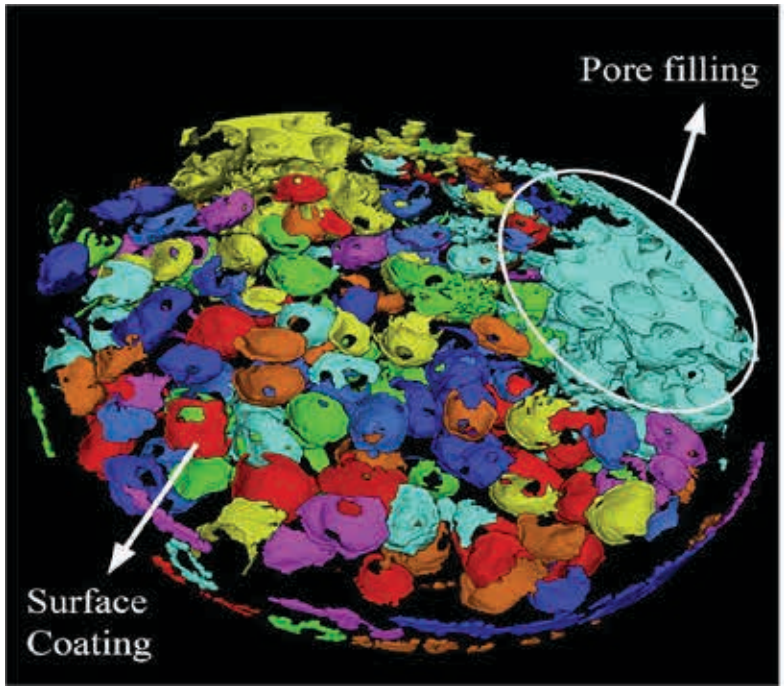
CO2 needs to be injected deep into porous rocks, deeper than 3000 feet, at a pressure higher than 3000 psi. To prevent the upward flow of CO2, which is caused by its low density, it must be trapped below a thick, low permeability rock such as limestone, shale, or salt rock (caprock). There are many challenges associated with CCS that include potential leaks of CO2 into the atmosphere and groundwater through natural/reactivated faults or man-made operations (e.g., abandoned oil wells). CO2 pressure can be a source for seismic damage and fracture of the caprock. A

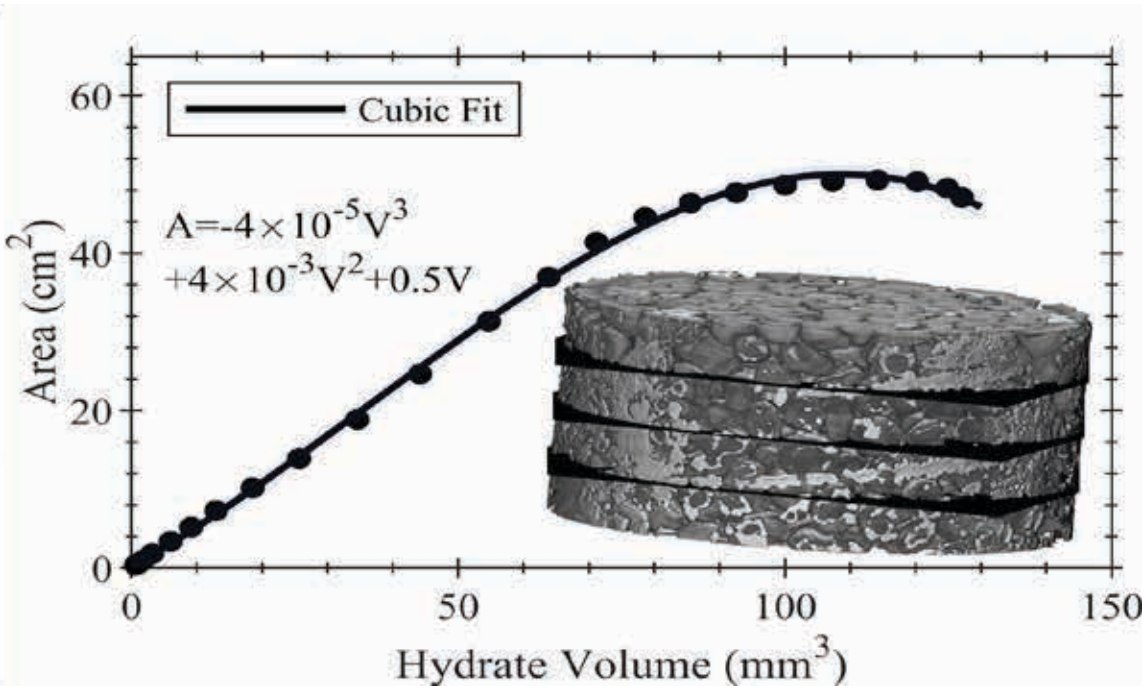
chemical reaction could occur between CO2 and the caprock, which may compromise the integrity of the caprock and result in the leak of CO2 back into the atmosphere. The overall aim of the project is to characterize CO2-caprock geochemical interaction at micro and nano-scales. The research team will use world-class analysis tools at the Advanced Photon Source (APS), IL to image specimens of limestone samples collected from a depth of 800 ft from East Tennessee before and after exposing them to CO2 at 3000 psi pressure at a temperature similar to field temperature for a long duration. Nanoscale changes of the pores within the limestone may occur and can potentially cause a clogging (desirable) or dissolution of the rock. The dissolution of the rock will open channels for CO2 to flow upward back to the earth's surface.

Gas Driven Fracture During Gas Production using 3D Synchrotron Computed Tomography. Khalid Alshibli, PI; Claudia Rawn, co-PI

A better understanding of the kinetics of hydrate dissociation is essential to reliably predict gas production potential from natural hydrate reservoirs. Most hydrate dissociation models assume hydrates to be a constant number of equal-sized spheres dissociating at a constant rate. This project uses dynamic 3D synchrotron micro-computed tomography (SMT) imaging to study hydrate surface area evolution during Xenon hydrate dissociation. Hydrates are formed inside a high-pressure low-temperature cell filled with partially saturated ASTM 20-30 Ottawa sand.

Hydrate dissociation is initiated through depressurization in the first experiment and through thermal stimulation in the second experiment. During dissociation, continuous full 3D SMT images were acquired where each scan took 45 s to complete. A combination of cementing, pore-filling, and surface coating pore habits were observed for the depressurization experiment and pore-filling for the thermal stimulation experiment. Surface coating hydrates dissociate faster than hydrates with pore-filling pore habit due to the higher specific area which allows for more surface for hydrates to dissociate it. Direct measurements of hydrate volume and hydrate surface area suggest that even with a combination of hydrate pore habits formed within the 3D porous media, estimation of hydrate surface area as a linear relation with (hydrate volume)2/3 is best for hydrate saturation less than a threshold value depending on the dissociation method and driving force. (hydrate volume)2 and (hydrate volume)3 were found to better estimate hydrate interfacial area in comparison to (hydrate volume)2/3 for the depressurization experiment and thermal stimulation experiment, respectively.





Training & Education

ISSE focuses on innovative educational and environmental projects that employ the latest technologies (or explore the use of such technologies) to resolve problems and explore complex issues. Most projects combine the resources of private and governmental sectors with the expertise of University staff, faculty, and students through team agreements.

Worker Health and Safety Training at Department of Energy (DOE) Facilities, Sheila Webster

The training is funded by a grant from the National Institute of Environmental Health and Sciences (NIEHS) and administered by the Partnership for Environmental Technology Education (PETE). The use of HAZWHOPER ONLINE (developed by AWARDEES CCCHST and PETE) started transitioning to Roane State Community College (RSCC) in September 2020. Vol State incorporated HAZWOPER ONLINE with numerous OSHA and related Safety and Health courses that are offered on a regular basis.

ISSE's primary role was to obtain feedback and determine workplace impact of HAZWOPER ONLINE training. ISSE analyzed data for surveys for end of course and workplace follow up provided by Roane State Community College. ISSE also conducted follow up interviews to determine how training is applied in the workplace and how it is benefits the employee and the employer. ISSE observed classroom training and continues to with RSCC as they maintain the online training. Staff continued to attend virtual meetings including, training sessions offered by NIEHS, quarterly meetings hosted by PETE and the annual PETE Advisory Committee meeting.

Worker Safety students dress out for a field experience.

STEMM Programs in Appalachia, National Institute of Health & National Science Foundation, Tim Ezzell

Dr. Ezzell assists with two established STEMM programs at UT - *PIPES: Possibilities in Postsecondary Education and Science among Rural Appalachian Youth* and *ASPIRE: Appalachian Students Promoting the Integration of Research in Education.*

PIPES, funded by the National Institute of Health, provides opportunities for tenth- and eleventh-grade students in two Appalachian counties, Monroe and Campbell, to explore STEMM careers (science, technology, engineering, math, and medical science) and to promote college awareness. ASPIRE is funded by the National Science Foundation and builds on PIPES success by providing scholarships to academically talented Appalachian high school seniors majoring in STEM and STEMM fields. ASPIRE also creates a learning community for participating students and assists Appalachian students, and their families, in making the transition to college life.

Tennessee Water Resources Research Center Training, Tim Gangaware

Since October 1, 2020, TNWRRC has offered seven different courses:

- Levels 1 and 2 of Tennessee Erosion Prevention and Sediment Control (TNEPSC) Training Program for Construction Sites plus a TNEPSC Recertification courses;
- Levels 1 and 2 of Tennessee Hydrologic Determination Training and its corresponding Recertification course; and the Storm Water Control Measure Inspection and Maintenance Workshop.

TNWRRC has offered a total of 30 course sessions and trained 2,000 professionals in these workshops. The courses were a combination of virtual, online, and in person training.

TNEPSC offers three training workshops for developers, contractors, engineers, and other professionals, inspection personnel, and enforcement officials responsible for all aspects of preparation and implementation of Storm Water Pollution Prevention Plans for preventing erosion and controlling sediment at construction sites one acre or more in size.

Tennessee Hydrologic Determination Training is a course for conducting hydrologic determinations. Successful completion of the training course is one of the requirements for certification as a Qualified Hydrologic Professional.

Storm Water Control Measure Inspection and Maintenance Workshops are available to design engineers and architects as well as plan reviewers and other local municipal program personnel. They provide insights on avoidance and minimization approaches to site layout, design guidance on specific permanent stormwater control measures, and experience using tools developed to assist designers and plan reviewers with implementation of runoff reduction and pollutant removal requirements.

right: Knoxvillians get acquainted with Electric Vehicles during a Ride & Drive Event at Ijams Nature Center

Outreach & Collaboration

Drive Electric TN/East TN Clean Fuels, Daniel Siksay, Jonathan Overly

East Tennessee Clean Fuels is the project lead on this 2020 DOE-funded project that includes 14 states that are building statewide 'Drive Electric' programs. The project's includes priority areas include developing branded websites, outreach events, and social media campaigns; educating consumers and developing state chapters; planning EV charging infrastructure; reaching local and state government officials; engaging car dealers; and creating fleet partnerships for EV adoption. In year one, efforts began on all priority areas and coalitions started assembling their branded programs. Chapter development, building utility relationships, and dealer and fleet planning are other significant tasks underway in year one.

Before project completion, DET will develop long-term funding approaches and expand the program to include additional states beyond the original 14. During summer 2021, the project added four states (Indiana, Kentucky, Connecticut, and New York) and discussions are underway with another dozen Clean Cities Coalitions and states. States will be able to use all materials developed from the project to help establish their initiatives.

A cooperative partnership with Tennessee Tech expanded to include a second, multi-state project that will bring a medium-duty electric truck ("eTruck") to fleets across Tennessee, which fleet managers will be able to borrow for up to two months to vet its use in fleet operations. Data from fleet use will both help the fleets understand their potential applicability to electric truck use and feed an information system to better understand fleets needs and desires with EVs.

Drive Electric TN (DET) worked on chapter development and holding more Ride & Drive events across Tennessee. In April 2021, the first ever Ride & Drive was held in Bristol, Tennessee that brought together about 25 local EV owners and nearly 100 citizens during the day with information about how EVs work and where you charge them. Attendees were able to drive EVs like the Mustang Mach-E, the Tesla Model 3, and the Nissan Leaf.

Tennessee Water Resources Research Center Information Transfer Program, Tim Gangaware

The major emphasis of the information transfer program during the FY 2020 period focused on technical publication support, conference planning and development, and improvement in the information transfer network. The primary purpose of the program was to support the objectives of the technical research performed under the FY 2020 Water Resources Research Institute Program.

During the FY 2020 grant period, a major focus of the information transfer activities was on the participation of the Center staff in the planning and implementation of several statewide conferences and training workshops.

As an on-going sponsor, the TNWRRC was involved in the planning and implementation of the 29th Tennessee Water Resources Symposium. Due to COVID19 restriction the 2020 Symposium was held virtually on April 22-24, 2020. The goals of the symposium are: (1) to provide a forum for practitioners, regulators, educators and researchers in water resources to exchange ideas and provide technology transfer activities, and (2) to encourage cooperation among the diverse range of water professionals in the state. As with previous symposia, the 29th Symposium was very successful with 59 professional presentations and 32 student posters being presented on-line over the two-day period.

TNWRRC was a co-sponsor of the 2020 Tennessee Stormwater Association Annual Conference, held virtually on October 21-22, 2020. Over 150 attended on-line and hear 43 professional presentations that covered a variety of topics including Green Infrastructure, FEMA Permitting and Grant Funding., Urban Waters Report Card, TN GIS Data Resources and How to ACE your MS4 Audit.

Appalachian Leadership Institute, Tim Ezzell, Katie Cahill, Catherine Wilt

The Appalachian Leadership Institute, a program of the Appalachian Regional Commission, conducted a graduation ceremony for its second class of fellows in Washington in July. The UT ALI team, and its partners, are getting ready to welcome the new class of 40 fellows in October. As always, this class will be learning from experts and peers about several topics, include economic opportunities, natural and cultural resources, and critical infrastructure. We will also soon be launching a new leadership alumni program, which will create new networking and learning opportunities for our growing cohort of ALI graduates.

above: The 2021 ALI class members get silly at their graduation in Washington, D.C.
right: UTK's ALI Team, Tim Ezzell, Cat Wilt, Lexi Webster, Katie Cahill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Publications, Presentations, Recognition & Awards

Publications

Alshibli, K. A. and Jarrar, Z. (2021) "Four-Dimensional Dynamic Synchrotron Micro Computed Tomography Imaging of Gas-Water Interface at High Pressure and Low Temperature", ASTM Geotechnical Testing Journal, Vol. 44, No. 4, pp. 1000-1014, https://doi.org/10.1520/GTJ20190332

Alhajar, R. K., R. B. Ghannam, J. R. Chen See, M. F. Campa, O. G. Wright, T. C. Hazen, R. Lamendella, and S. M. Techtmann. 2021. Comparative study of the effects of biocides and metal oxide nanoparticles on microbial community structure in a stream impacted by hydraulic fracturing. Chemosphere 284:131255 https://doi.org/10.1016/j.chemosphere.2021.131255.

Alshibli, K. A. and Jarrar, Z. (2020) "4D Dynamic Synchrotron Micro Computed Tomography Imaging of Gas-Water Interface at High Pressure and Low Temperature", ASTM Geotechnical Testing Journal, in press

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Campa, M. F., J. C. See, L. Unverdorben, O. Wright, K. A. Roth, J. M. Niles, D. Ressler, E. Macatugal, A. Putt, S. M. Techtmann, T. C. Hazen, and R. Lamendella. Contributed. Geochemistry, land coverage, and multiomics data differentiate streams in Pennsylvania based on unconventional oil and gas activity. World Microbe Forum, Online, June 20-24, 2021. American Society for Microbiology and Federation of European Microbiological Societies. World Microbe Forum <meetingsmarketing@asmusa.org>.

Chakraborty, R., X. Wu, D. C. Joyner, T. C. Hazen, R. G. Malana, A. P. Arkin and P. D. Adams. Invited. Applying Stable Isotopes for Source Fingerprinting of Dissolved Organic Nitrogen in Groundwater. February 23-26, 2020. Washington, DC. 2020 Genomic Sciences Program (GSP) Annual Principal Investigator (PI) Meeting. ORAU www.orau.gov › gsp2020.

D. M. Vance, C. Price, S. Nimbalkar, T. Wenning and M. Jin, Selecting a Smart Manufacturing Maturity Model, IISE Annual Conference, May 2021.

Dixon, E. R., K. F. Walker, D. Williams, and T. C. Hazen. Contributed. Modeling Dynamic Geochemical Processes: How Diurnal and Seasonal Water Table Fluctuations Influence Contaminated Groundwater Geochemistry. December 10, 2019, San Francisco, CA. AGU Fall Meeting.

Ellis, K. N. Variability in Knoxville's urban heat and residential exposure. Social Inequality in Energy, Environment, and Technology Workshop. University of Tennessee. 13 August 2021.

Fukai, I., and T. C. Hazen. 2021. Germ Anti-Warfare: Evaluating Microbial Biosensors for Nuclear Arms Nonproliferation. 9th Annual Oak Ridge Postdoctoral Association (ORPA) Research Symposium, Oak Ridge, TN, July 28–29, 2021.

Fukai, I., and T. C. Hazen. Contributed. Evaluation of Microbial Biosensors with Applications In Nuclear Arms Nonproliferation. World Microbe Forum, Online, June 20-24, 2021. American Society for Microbiology and Federation of European Microbiological Societies. World Microbe Forum

Fukai, I., and T. C. Hazen. Contributed. Evaluation of Microbial Biosensors With Applications In Nuclear Arms Nonproliferation. World Microbe Forum, Online, June 20-24, 2021. American Society for Microbiology and Federation of European Microbiological Societies. World Microbe Forum <meetingsmarketing@asmusa.org>.

Fuqai, Isis and T. C. Hazen. 2020. Biosensors for Detecting Nuclear Production Activity in the Environment. March 12, 2020. Ann Arbor, MI. MTV, University of Michigan.

Griffiths, Z., A. Putt, M. Campa, D. Joyner, J. Miller, O. Pelz, N. GaraJayeva, P. Gardinali, and T. C. Hazen. Contributed. Observing the Indigenous Microbial Community Response to Crude Oil Amendment in Aerobic and Anerobic Conditions. World Microbe Forum, Online, June 20-24, 2021. American Society for Microbiology and Federation of European Microbiological Societies. World Microbe Forum

Griffths, Z., A. Putt, M. Campa, D. Joyner, J. Miller, O. Pelz, N. GaraJayeva, P. Gardinali, and T. C. Hazen. Contributed. Observing the Indigenous Microbial Community Response to Crude Oil Amendment in Aerobic and Anerobic Conditions. World Microbe Forum, Online, June 20-24, 2021. American Society for Microbiology and Federation of European Microbiological Societies. World Microbe Forum <meetingsmarketing@asmusa.org>.

Gushgari-Dolye, S., A. P. Arkin, L. M. Lui, R. Chakraborty, T. C. Hazen and X. Wu. Contributed. Functional Diversity of Arthrobacter Strains Across the Dynamic Capillary Fringe and Adjacent Sediment Zones. December 16, 2020, San Francisco, CA. AGU Fall Meeting.

Gushgari-Doyle, S., M. O. Yee, J. V. Kuehl, H. J. Smith, M. P. Thorgersen, X. Ge, A. E. Otwell, T. L. Lie, K. A. Hunt, M. W. W. Adams, E. J. Alm, N. S. Baliga, J.-M. Chandonia, A. M. Deutschbauer, D. A. Elias, M. W. Fields, T. C. Hazen, T. R. Northen, A. Mukhopadhyay, G. E. Siuzdak, D. A. Stahl, P. J. Walian, J. Zhou, R. Chakraborty, A. P. Arkin, P. D. Adams. Invited. Targeted Isolation Using Field-Informed Approaches. February 22-24, 2021. Washington, DC. 2021 Genomic Sciences Program (GSP) Annual Principal Investigator (PI) Meeting. ORAU www.orau.gov › gsp2021.

H. Kose and M. Jin, Planning and Scheduling for a Single Additive Manufacturing Machine Using Multi-material Types, May 2021.

H. Sun, Y. Sun, R. E. Wagner, M. Jin, W. Tate, and J. Zhuang, Food losses and waste challenges for the food-water-energy nexus in the United States, AGU Annual Conference, December 2020

Harik, A.-M., T. C. Hazen, D. C. Joyner, and S. Rafie. Contributed. Imaging and Analysis of Methanotroph Induced Bioaggregation in Sand. World Microbe Forum, Online, June 20-24, 2021. American Society for Microbiology and Federation of European Microbiological Societies. World Microbe Forum

Harik, A.-M., T. C. Hazen, D. C. Joyner, and S. Rafie. Contributed. Imaging and Analysis of Methanotroph Induced Bioaggregation in Sand. World Microbe Forum, Online, June 20-24, 2021. American Society for Microbiology and Federation of European Microbiological Societies. World Microbe Forum <meetingsmarketing@asmusa.org>.

Hazen, T. C. Invited. After Chat June 21 3:45-4:30PM. “Environmental Systems Biology: The Whole is Greater than the Sum of its Parts – Team Science” ASM Environmental Microbiology Award. World Microbe Forum, Online, June 20-24, 2021. American Society for Microbiology and Federation of European Microbiological Societies. World Microbe Forum

Hazen, T. C. Invited. Biosensors for Detecting Nuclear Production Activity in the Environment (Consortium for Monitoring, Technology, and Verification (MTV)). September 8-10, 2021. Office of Defense Nuclear Nonproliferation Research and Development, University Program Review (UPR) 2021 Meeting.

Hazen, T. C. Invited. Careers in National Labs. U Mass Amherst online, 5/16/21.

Hazen, T. C. Invited. Environmental Systems Biology: The Whole is Greater than the Sum of it’s Parts – Team Science. Online, August 6, 2021. Louisiana Tech Environmental Class.

Hazen, T. C. Invited. Environmental Systems Biology: The Whole is Greater than the Sum of it’s Parts – Team Science. World Microbe Forum, Online, June 20-24, 2021. American Society for Microbiology and Federation of European Microbiological Societies. World Microbe Forum

Hazen, T. C. Invited. Environmental Systems Biology: The Whole is Greater than the Sum of it’s Parts – Team Science. World Microbe Forum, Online, June 20-24, 2021. American Society for Microbiology and Federation of European Microbiological Societies. World Microbe Forum <meetingsmarketing@asmusa.org>.

Hazen, T. C. Invited. Environmental Systems Biology: The Whole is Greater than the Sum of its Parts – Team Science. World Microbe Forum, Online, June 20-24, 2021. American Society for Microbiology and Federation of European Microbiological Societies. World Microbe Forum

Hazen, T. C., E. R. Kelly*, A. Putt, K. Walker, D. C. Joyner, I. Fukai, K. Lowe, M. Rodriguez Jr, M. W. Fields, R. Chakraborty, X. Wu, D. Stahl, T. Lie, M. W. W. Adams, F. Poole, P. J. Walian, J. Zhou, J. V. Nostrand, T. R. Northen, J.-M. Chandonia, A. P. Arkin, and P. D. Adams. Invited. Cone Penetrometer 3-D Characterization of Y-12 Site to Determine the Hydrological, Geological and Biogeochemistry Best Sites for ENIGMA Subsurface Observatories. February 22-24, 2021. Washington, DC. 2021 Genomic Sciences Program (GSP) Annual Principal Investigator (PI) Meeting. ORAU www.orau.gov › gsp2021.

Hazen, T. C., I. Fukai, A. P. Arkin, E. Alm, and H. Dulai. Invited. Environmental Surveillance for Biological Traces of Radionuclide Sources. MTV Monthly Seminar, online, 15 May 2021. University of Michigan.

Hazen, T. C., I. Fukai, A. P. Arkin, E. Alm, and H. Dulai. Invited. Environmental Surveillance for Biological Traces of Radionuclide Sources. MTV Monthly Seminar, online, 15 May 2021. University of Michigan.

Hunt, K. A., A. E. Otwell, S. Bowman, S. D. Wankel, K. F. Walker, E. R. Dixon, M. Rodriguez, K. A. Lowe, D. C. Joyner, A. Carr, L. Lui, T. Nielsen, N. S. Baliga, T. C. Hazen, D. A. Stahl, A. P. Arkin, P. D. Adams. Invited. Resolving Biotic and Abiotic Controls of Nitrous Oxide Flux in a Subsurface Site Contaminated with High Nitrate Concentrations. February 22-24, 2021. Washington, DC. 2021 Genomic Sciences Program (GSP) Annual Principal Investigator (PI) Meeting. ORAU www.orau.gov › gsp2021.

Hunt, K. A., A. V. Carr, K. F. Walker, E. R. Dixon, M. R. Jr, K. A. Lowe, D. C. Joyner, A. E. Otwell, S. D. Wankel, N. S. Baliga, T. C. Hazen, D. A. Stahl, A. P. Arkin and P. D. Adams. Invited. High nitrous oxide emissions from a nitrate contaminated subsurface indicate significant metabolic activity. February 23-26, 2020. Washington, DC. 2020 Genomic Sciences Program (GSP) Annual Principal Investigator (PI) Meeting. ORAU www.orau.gov › gsp 2020

J. Hale and M. Jin, Monitoring Additive Manufacturing Machine Health Using Partially Observed Markov Decision Process and a Witness Parts Framework, IISE Annual Conference, May 2021.

J. Overly, "ETCleanFuels – Actions & partnerships for Success", ISSE Advisory Board Meeting, December 2020, Knoxville, TN.

J. Overly, "Innovative, Diverse EV Applications for Your Fleet", Presented virtually in partnership with the Quebec Government Office in Atlanta, April 2021.

J. Overly, "Renewable Energy in Transportation – Actors & Opportunities for Fleets in Tennessee", Tennessee City Management Association Spring 2021 Conference, April 2021, Murfreesboro, TN.

J. Overly, "Statewide Action & Rural Alt Fuels Leadership – Examples of Success in Tennessee", TDOT RPO Virtual Conference, October 2020.

J. Wu, Socioeconomic inequalities and drinking water quality: Assessing arsenic concentrations in community water systems by novel field deployable biosensors, Social Inequality of Energy, Environment and Technology Workshop, University of Tennessee, August 6

Jarrar, Z. A., Al-Raoush, R. I., Alshibli, K. A., and Jung, J-W (2020). "Dynamic 3D Imaging of Gas Hydrate Kinetics using Synchrotron Computed Tomography", 2nd International Conference on Energy Geotechnics (ICEGT-2020), Published online 18 November 2020, E3S Web of Conferences 205, 11004, https://doi.org/10.1051/e3sconf/202020511004

Jarrar, Z. A., Al-Raoush, R. I., Alshibli, K. A., and Jung, J-W (2020). "Dynamic Imaging of Hydrate Specific Area Evolution during Xenon Hydrate Formation", International Conference on Civil Infrastructure and Construction (CIC2020), Feb. 2-5, 2020, Doha, Qatar, http://dx.doi.org/10.29117/cic.2020.0081

Jarrar, Z. A., Al-Raoush, R. I., Alshibli, K. A., Hannun, J. A., and Jung, J-W (2019). "Hydrate Surface Area Measurements During Dissociation using Dynamic 3D Synchrotron Computed Tomography". The 3rd European Association of Geoscientists and Engineers (EAGE) WIPIC workshop: Reservoir Management in Carbonates, 18-20 November 2019, Doha, Qatar.

Joyner, D. C., and T. C. Hazen. Contributed. Managing Your Graduate Career: Guidelines for Success. World Microbe Forum, Online, June 20-24, 2021. American Society for Microbiology and Federation of European Microbiological Societies. World Microbe Forum <meetingsmarketing@asmusa.org>.

Joyner, D. C., and T. C. Hazen. Contributed. Managing Your Graduate Career: Guidelines for Success. World Microbe Forum, Online, June 20-24, 2021. American Society for Microbiology and Federation of European Microbiological Societies. World Microbe Forum.

Kalina Scarbrough Real-Time Sensor-Based Prediction of Soil Moisture in Green Infrastructure: Case Study, Maintenance of Stormwater Control Measures, March 2022 (under review)

Kalina Scarbrough, Identifying a Minimal Set of Real-Time Sensors to Predict Soil Moisture in Green Infrastructure, 1794 Scholars Showcase, University of Tennessee, Spring 2020

Kalina Scarbrough, Identifying a Minimal Set of Real-Time Sensors to Predict Soil Moisture in Green Infrastructure, 2020 IISE Annual Conference, Virtual, May 30-June 2, 2020

Kalina Scarbrough, Identifying a Minimal Set of Real-Time Sensors to Predict Soil Moisture in Green Infrastructure, Poster presentation, EUReCA, University of Tennessee, Spring 2020

Kalina Scarbrough, Real-Time Sensor-Based Prediction of Soil Moisture in Green Infrastructure: Case Study, 2021 IISE Annual Conference, Virtual, May 22-25, 2021

Kalina Scarbrough, Real-Time Sensor-Based Prediction of Soil Moisture in Green Infrastructure: Case Study, 2021 IISE U.S. Mid-Atlantic Region Conference, Virtual, March 27, 2021

Larsen, D., and Waldron, B., 2020, Low-level soluble chloride extraction in soil: MethodsX, v. 7, 100967, https://doi.org/10.1016/j.mex.2020.100967

Larsen, D., Bursi, J., Waldron, B., Schoefernacker, S., and Eason, J., 2020, Recharge pathways and rates for a sand aquifer beneath a loess-mantled landscape in a humid region: Journal of Hydrology, Regional Studies, v. 28, 100667, https://doi.org/10.1016/j.ejrh.2020.100667

Li, Y., K. Ash, D. C. Joyner, D. E. Williams, C. Iler, I. Alamilla, P. McKay, B. Green, F. Kara-Murdoch, C. Swift, F. Löffler, and T. C. Hazen. Contributed. Decay of SARS-CoV-2 and Pepper Mild Mottle Virus (PMMoV) RNA in raw wastewater to inform application in wastewater-based epidemiology of the University of Tennessee student residential buildings. World Microbe Forum, Online, June 20-24, 2021. American Society for Microbiology and Federation of European Microbiological Societies. World Microbe Forum

Li, Y., K. Ash, D. C. Joyner, D. E. Williams, C. Iler, I. Alamilla, P. McKay, B. Green, F. Kara-Murdoch, C. Swift, F. Löffler, and T. C. Hazen. Contributed. Decay of SARS-CoV-2 and Pepper Mild Mottle Virus (PMMoV) RNA in raw wastewater to inform application in wastewater-based epidemiology of the University of Tennessee student residential buildings. World Microbe Forum, Online, June 20-24, 2021. American Society for Microbiology and Federation of European Microbiological Societies. World Microbe Forum <meetingsmarketing@asmusa.org>.

Lui, L. M., H. J. Smith, F. V. Netzer, K. B. D. León, E. L.-W. Majumder, J. V. Kuehl, F. Song, A. Sczesnak, T. Nielsen, M. P. Thorgesen, X. Ge, F. L. Poole, B. P. Bowen, S. M. Kosina, C. J. Paradis, K. F. Walker, K. A. Lowe, D. C. Joyner, J. M. Rodriquez, B. A. Adams, D. Williams, J.-W. Moon, J. D. V. Nostrand, D. Ning, Y. Fu, W. Shi, Y. Li, D. J. Curtis, Y. Fan, L. Wu, R. Tian, G. M. Zane, A. B. Aaring, X. Wu, A. E. Kazakov, J.-M. Chandonia, P. S. Novichkov, P. J. Walian, R. Chakraborty, M. W. W. Adams, J. Zhou, T. R. Northen, J. D. Wall, D. A. Stahl, D. A. Elias, T. C. Hazen, M. W. Fields, A. P. Arkin and P. D. Adams. Invited. Core Values: Spatial Variation in Microbial Function, Activity, and Community Assembly in Groundwater and Sediment from a Contaminated Subsurface Aquifer. February 23-26, 2020. Washington, DC. 2020 Genomic Sciences Program (GSP) Annual Principal Investigator (PI) Meeting. ORAU www.orau.gov › gsp2020.

Lui, L. M., T. Nielsen, H. J. Smith, F. V. Netzer, E. L.-W. Majumder, J. V. Kuehl, F. Song, A. Sczesnak, M. P. Thorgesen, X. Ge, F. L. Poole, C. J. Paradis, K. F. Walker, K. A. Lowe, D. C. Joyner, D. Ning, J. M. Rodriquez, A. B. Aaring, B. A. Adams, D. Williams, J. D. V. Nostrand, G. M. Zane, M. W. W. Adams, J. Zhou, R. Chakraborty, J. D. Wall, D. A. Stahl, T. C. Hazen, M. W. Fields, A. Arkin and P. Adams. Invited. A Method for Circularizing Microbial Genomes from Metagenomics Data. February 23-26, 2020. Washington, DC. 2020 Genomic Sciences Program (GSP) Annual Principal Investigator (PI) Meeting. ORAU www.orau.gov › gsp2020.

Lui*, L. M., E. L.-W. Majumder*, H. J. Smith*, H. K. Carlson, F. V. Netzer, N. Nielsen, M. Peng, X. Tao, A. Zhou, M. Price, J. V. Kuehl, A. J. Hendrickson, V. Trotter, S. Gushgari-Doyle, J. Valenzuela, A. Otwell, K. Hunt, A. Carr, K. Walker, E. Dixon, F. Poole, M. Thorgersen, X. Ge, M. W. W. Adams, E. J. Alm, N. S. Baliga, J.-M. Chandonia, A. M. Deutschbauer, D. A. Elias, M. W. Fields, T. C. Hazen, T. R. Northen, A. Mukhopadhyay, G. E. Siuzdak, D. A. Stahl, P. J. Walian, J. Zhou, R. Chakraborty, A. P. Arkin, and P. D. Adams. Invited. Mechanism across scales: integrating laboratory and field studies for microbial ecology as illustrated by the ENIGMA SF. February 22-24, 2021. Washington, DC. 2021 Genomic Sciences Program (GSP) Annual Principal Investigator (PI) Meeting. ORAU www.orau.gov › gsp2021.

M. Galbreth, and M. Jin, Should OEMs Authorize Third-Party Remanufacturers? INFORMS Annual Conference, November, 2020.

M. Jin, Remanufacturing and Supply Chain Managements: Dynamics between Dynamics between Original Equipment Manufacturers and Third Part Remanufacturers, PRES'20, August, 2020.

Miller, J. I., S. M. Techtmann, J. Fortney, N. Mahmoudi, D. C. Joyner, J. Liu, S. Olesen, E. Alm, A, Fernandez, P. Gardinali, N. GaraJayeva, F. S. Askerov and T. C. Hazen. Contributed. Potential for rapid microbial biodegradation of petroleum hydrocarbons in hypoxic marine environments. San Antonio, TX. October 7-9, 2019. International Petroleum Environmental Conference Annual Meeting.

Miller, J. I., Z. Griffiths, S. Techtmann, J. Fortney, N. Mahmoudi, D. Joyner, J. Liu, S. Olesen, E. Alm, A. Fernandez, P. Gardinali, N. GaraJayeva, F. S. Askerov, O. G. Brakstad, O. Pelz, M. Kuijper and T. C. Hazen. Contributed. Microbial Community Structure and Oil Biodegradation in a Hypoxic Marine Environment. May 6, 2020. Dublin, Ireland (online). SETAC SciCon SETAC Europe 30th Annual Meeting.

Needham, D. M., A. Zhang, J.-M. Chandonia, D. Chivian, L. M. Lui, W. Zheng, S. Zhao, Y. Yin, D. A. Weitz, T. C. Hazen, P. S. Novichkov, J. Zhou, E. J. Alm, A. P. Arkin and P. D. Adams. Invited. Integrating data and algorithms from the ENIGMA project into KBase. February 23-26, 2020. Washington, DC. 2020 Genomic Sciences Program (GSP) Annual Principal Investigator (PI) Meeting. ORAU www.orau.gov › gsp2020.

Ning, D., Y. F., L. M. Lui, J. P. Michael, Y. Fu, J. D. Van Nostrand, R. Tian, Y. Wang, K. F. Walker, E. R. Dixon, A. D. Putt, D. E. Williams, D. C. Joyner, K. A. Lowe, F. L. Poole, X. Ge, M. P. Thorgersen, M. W. W. Adams, R. Chakraborty, X. Wu, D. A. Elias R. L. Wilpiszeski, J. Zhou, M. W. Fields, T. C. Hazen, A. P. Arkin, and P. D. Adams. Invited. Physical size matters in groundwater bacterial community assembly. February 22-24, 2021. Washington, DC. 2021 Genomic Sciences Program (GSP) Annual Principal Investigator (PI) Meeting. ORAU www.orau.gov › gsp2021.

Palino GM, Thompson J, Schwartz J, Hathaway J. 2021. Urban floodplain reconnection through regenerative stormwater conveyances. Tennessee Water Resources Symposium. Web. April 15.

Parker, C. and Kintziger, K. Identifying medically vulnerable areas in Tennessee. Summer Undergraduate Research Internship Program, Discovery Day. University of Tennessee. 31 August 2021.

Pineda, P., I. Alamilla, A. Salim, A. Putt, and T. C. Hazen. Contributed. Comparison of Bacterial DNA Extraction from Stream Water. World Microbe Forum, Online, June 20-24, 2021. American Society for Microbiology and Federation of European Microbiological Societies. World Microbe Forum

Pineda, P., I. Alamilla, A. Salim, A. Putt, and T. C. Hazen. Contributed. Comparison of Bacterial DNA Extraction from Stream Water. World Microbe Forum, Online, June 20-24, 2021. American Society for Microbiology and Federation of European Microbiological Societies. World Microbe Forum <meetingsmarketing@asmusa.org>.

Putt, A., P. Pineda, I. Alamilla, A. Salim, A. P. Arkin, P. D. Adams, and T. C. Hazen. Contributed. Response of Filterable Microbes to a Beta-Cyclodextrin Injection. World Microbe Forum, Online, June 20-24, 2021. American Society for Microbiology and Federation of European Microbiological Societies. World Microbe Forum

Putt, A., P. Pineda, I. Alamilla, A. Salim, A. P. Arkin, P. D. Adams, and T. C. Hazen. Contributed. Response of Filterable Microbes to a Beta-Cyclodextrin Injection. World Microbe Forum, Online, June 20-24, 2021. American Society for Microbiology and Federation of European Microbiological Societies. World Microbe Forum <meetingsmarketing@asmusa.org>.

R. Li and M. Jin, Defect Detection on Additive Manufacturing Parts with Machine Learning Informed by Discrete Mean Curvature Measures, IISE Annual Conference, May 2021.

R. Zhou, Z. Li, and M. Jin, Techno-economic Analysis of CO2 Conversion to Jet via Ethanol, IISE Annual Conference, May 2021.

Rafie, S. A. A., K. P. Hoyt, M. R. Schubert, M. T. Kerr, L. R. Blentlinger, A. M. Faiia, A. Szynkiewicz, J. F. Franklin, S. P. Horn, and T. C. Hazen. Contributed. Soil bacterial response to prescribed fires in a southern Appalachian clear cut with fuel manipulation. World Microbe Forum, Online, June 20-24, 2021. American Society for Microbiology and Federation of European Microbiological Societies. World Microbe Forum

Rafie, S. A. A., K. P. Hoyt, M. R. Schubert, M. T. Kerr, L. R. Blentlinger, A. M. Faiia, A. Szynkiewicz, J. F. Franklin, S. P. Horn, and T. C. Hazen. Contributed. Soil bacterial response to prescribed fires in a southern Appalachian clear cut with fuel manipulation. World Microbe Forum, Online, June 20-24, 2021. American Society for Microbiology and Federation of European Microbiological Societies. World Microbe Forum <meetingsmarketing@asmusa.org>.

Salehi, M., Aghilinasrollahabadi, K., Salehi Esfandarani, M. (2020). An Investigation of Stormwater Quality Variation within an Industry Sector Using the Self-Reported Data Collected under Stormwater Monitoring Program. Water, 12(11), 3185

Salehi, M., Salehi Esfandarani, M. Evaluate the Industrial Facilities Stormwater Pollution Prevention Plan Using the Self-Reported Stormwater Quality Data, A Case Study in West Tennessee, USA. In Preparation Manuscript

Salim, A. A., A. Putt, and T. C. Hazen. Invited. Learning and growing as a Scholar : My Experience as an Undergraduate Researcher. April 14, 2020. Knoxville, TN. 1794 UTK Annual Scholars Showcase one of 20 finalists.

Salim, A. A., P. Pineda, I. Alamilla, A. Putt, and T. C. Hazen. Invited. A Novel approach for Characterizing the Ultra-Micro Size-Fraction Community. April 13, 2020. Knoxville, TN. EURēCA Undergraduate UTK Annual Research Meeting.

Serrano Matos, Y., A. Gonzalez, A. Rivera, D. Williams, T. C. Hazen, and G. A. Toranzos. Contributed. Prophage and CRISPR Sequences Detected in Enterococci Isolates From Soils and Waters with Low Anthropogenic Disturbances. November 20-24, 2019, Anaheim, CA. Annual Biomedical Research Conference for Minority Students (ABRCMS) 2019.

T. Cokyasar, W. Dong, M. Jin and O. Webas, Optimization Methods for Innovative UAV Applications, INFORMS Annual Conference, November, 2020.

W. Dong and M. Jin, Travel Time Models for Tier-to-tier SBS/RS with Different Storage Assignment Policies and Shuttle Dispatching Rules, IISE Annual Conference, May 2021.

Walker, K. F., E. R. Dixon, D. C. Joyner, K. A. Lowe, F. L. Poole, X. Ge, M. P. Thorgersen, D. Ning, Y. Fan, J. P. Michael, Y. Fu, R. Tian, Y. Wang, J. D. V. Nostrand, L. M. Lui, X. Wu, K. J. Davis, M. W. W. Adams, R. Chakraborty, D. A. Elias, R. L. Wilpiszeski, J. Zhou, M. W. Fields, T. C. Hazen, A. P. Arkin and P. D. Adams. Invited. Spatiotemporal Dynamics of Groundwater and Sediment: Geochemistry, Microbial Communities and Activities in a Contaminated Aquifer. February 23-26, 2020. Washington, DC. 2020 Genomic Sciences Program (GSP) Annual Principal Investigator (PI) Meeting. ORAU www.orau.gov › gsp2020.

Walker, K. F., E. R. Dixon, D. C. Joyner, K. A. Lowe, F. L. Poole, X. Ge, M. P. Thorgersen, D. Ning, Y. Fan, J. P. Michael, Y. Fu, R. Tian, Y. Wang, J. D. V. Nostrand, L. M. Lui, X. Wu, M. W. W. Adams, R. Chakraborty, D. A. Elias, R. L. Wilpiszeski, J. Zhou, M. W. Fields, A. P. Arkin, P. D. Adams, and T. C. Hazen. Contributed. Diurnal and Seasonal Fluctuations with the Subsurface: A 17-Week Survey of Groundwater and Sediment in 27 Contaminated Wells. World Microbe Forum, Online, June 20-24, 2021. American Society for Microbiology and Federation of European Microbiological Societies. World Microbe Forum

Walker, K. F., E. R. Dixon, D. C. Joyner, K. A. Lowe, F. L. Poole, X. Ge, M. P. Thorgersen, D. Ning, Y. Fan, J. P. Michael, Y. Fu, R. Tian, Y. Wang, J. D. V. Nostrand, L. M. Lui, X. Wu, M. W. W. Adams, R. Chakraborty, D. A. Elias, R. L. Wilpiszeski, J. Zhou, M. W. Fields, A. P. Arkin, P. D. Adams, and T. C. Hazen. Contributed. Diurnal and Seasonal Fluctuations with the Subsurface: A 17-Week Survey of Groundwater and Sediment in 27 Contaminated Wells. World Microbe Forum, Online, June 20-24, 2021. American Society for Microbiology and Federation

of European Microbiological Societies. World Microbe Forum <meetingsmarketing@asmusa.org>.

Wang, Y. (Presenter), J. Mao, M. Jin, F. Hoffman. 2020. Developing a Gridded Upscaled Soil Moisture Dataset Using Sparse in situ Observations. AGU Fall Meeting. Online virtual meeting, United States.

Wu, X., D. C. Joyner, T. C Hazen, R. G. Malana, and R. Chakraborty. Invited. Applying Stable Isotopes for Source Fingerprinting of Dissolved Organic Nitrogen in Groundwater. Goldschmidt2020.

Wu, X., L. Lui, Y. Liu, N. Justice, T. Simmons, T. Nielsen, S. Jagadamma, N. J. Hess, T. C. Hazen, A. P. Arkin, and R. Chakraborty. Contributed. Insights into the Depth-resolved Geochemical Constraints on Microbial Community Structure and Metabolic Potential for Carbon Cycling in Shallow Subsurface Sediment. December 10, 2019, San Francisco, CA. AGU Fall Meeting.

Zhang, A., D. M. Needham, A. E. Kazakov, W. Zheng, S. Zhao, Y. Yin, D. A. Weitz, T. C. Hazen, E. J. Alm, N. S. Baliga, A. M. Deutschbauer, J.-M. Chandonia, M. W. Fields, T. R. Northen, J. D. Wall, M. W. W. Adams, M. Auer, K. Bender, G. Butland, R. Chakraborty, D. A. Elias, P. S. Novichkov, A. Mukhopadhyay, G. E. Siuzdak, D. A. Stahl, P. J. Walian, J. Zhou, A. P. Arkin, and P. D. Adams. Invited. Strain dynamics and functional diversity of 22 high-quality single cell genomes from ENIGMA ground water. February 22-24, 2021. Washington, DC. 2021 Genomic Sciences Program (GSP) Annual Principal Investigator (PI) Meeting. ORAU www.orau.gov › gsp2021.

2021 Chancellor's Award—Success in Multidisciplinary Research: Healthy Environment Team

This award is given to a team of faculty members in more than one academic college who have succeeded in gaining major external resources and recognition for multidisciplinary research. The members of this multiciliary team share common interest and have a strong passion to achieve a healthy environment. Their convergent research integrates expertise in environmental engineering, health, infrastructure, human factors, automation, systems engineering, and data science to systematically attack complex health problems. Team members are Team Leader Qiang He (CEE); Shuai Li (CEE); Mingzhou Jin (ISE); Xueping Li (ISE); Jindong Tan (MABE); Nina Fefferman (Ecology & Evolutionary Biology); Tami Wyatt (College of Nursing); and Jun Lin (Department of Animal Sciences).

Special Service Award—Terry Hazen, Governor's Chair for Environmental Biotechnology

Many of the college's remarkable leaders took on extra responsibilities beyond their full-time positions this past year for the good of the university and the state. TCE Interim Dean Matthew Mench recognized Terry Hazen for his work chairing a committee on COVID testing for Fall 2020 semester and then establishing weekly wastewater testing for all student residences on campus on from early September to the present. Dr. Hazen was also lauded for his high number of citations in academic scholarly papers worldwide.

Terry Hazen also received the American Society for Microbiology Environmental Microbiology Award for 2021

Research Achievement Award Winner—Joshua Fu, John D. Tickle Professor

This award recognizes faculty members who have been tenure-line for more than 10 years and have received national or international recognition in their field. Dr. Fu's work in the areas of air quality modeling and climate change is nearly encyclopedic in scope. His work includes studies both at the global and regional scales. His work also comprises the full spectrum of atmospheric pollutants, including particulate matter, ozone, dust, nitrogen deposition, carbon black, aerosols, acid deposition, and greenhouse gases, emanating from diverse sources such as industrial emissions, electrical power generation, transportation, forest fires and erosion.

He, Li, Tan Awarded Best Paper

Prof. Qiang He, Ass't Prof. Shuai Li (CEE), and Prof. Jindong Tan (MABE) recently won the Best Paper Award from Building and Environment for their paper, Segmenting areas of potential contamination for adaptive robotic disinfection in built environments. The research integrates robotic decontamination and infrastructure design, which could help mitigate the threat of pathogens like COVID-19 in buildings of mass gatherings, such as airports, offices, and restaurants.

Other Recognition

- ISSE Director Mingzhou Jin was named a *John D. Tickle Professor* in the Tickle College of Engineering.
- Dr. Tim Ezzell was named a *Leadership and Governance Fellow* at the Howard H. Baker Center for Public Policy.

Student Competition

Kalina Scarbrough, Civil & Environmental Engineering

- Third place, Global Undergraduate Student Technical Paper Competition, IISE, 2021
- First place, Mid-Atlantic Region, Regional Undergraduate Student Technical Paper Competition, IISE, 2021
- Third place, Operations Research Division Undergraduate Student Research Dissemination Award, IISE, 2020
- Second place, 1794 Scholars Showcase for Academic Engagement, University of Tennessee, Spring 2020

Media Coverage

Qiang He, WBIR 10NEWS 9/23/2021. *UT professor: Mind how you cook and clean because poor air quality in your home can hurt your health.*

Director's Goals for 2020-21

As part of our mandate, ISSE continues to implement its five-year strategic plan to increase its research, educational, and outreach activities at the University of Tennessee. ISSE will promote the development of policies, technologies, and educational programs that will address and help remedy critical environmental issues around the world.

This past year, ISSE reclassified its research initiatives into five categories:

- Clean Energy & Energy Efficiency
- Climate Change
- Regional Sustainability
- Water Research
- Sustainable Food Systems

Building on this new approach, ISSE will seek new partnerships across the university as well as the state and region. We will promote opportunities for faculty and students as well as partners in local government agencies, business, manufacturing, industry, non-governmental organizations, and others involved in environmental sustainability. We intend to grow regional sustainability research in Appalachia and Tennessee with support from the National Science Foundation (NSF). Multiple research teams at ISSE are developing proposals for additional funding from the National Oceanic and Atmospheric Administration and NSF.

This coming year, ISSE will start a new research initiative for *building environments*, which is critical to human health and energy efficiency. We are in the process of receiving sensors and monitoring systems donated by a major corporation and working with researchers at national labs. In addition, ISSE will expand its interdisciplinary research related to climate change, water resources, and electric vehicles through our collaborations with the US Geological Survey, Tennessee Department of Transportation, Tennessee Valley Authority, and Oak Ridge National Lab. ISSE will also keep working with the UT Institute of Agriculture on sustainable agriculture systems and food supply chains.

To recruit and retain quality PhD students for conducting sustainability research at UT, ISSE will offer new and ongoing fellowship and internship opportunities. ISSE will award an add-on fellowship for new students who will pursue a PhD in environment and sustainability at UTK. Also, ISSE will continue to offer various internship opportunities on an ongoing basis.

For undergraduate opportunities that will begin in Spring 2022, Drs. Jon Hathaway and Kristen Wyckoff in CEE have obtained NSF funding for the *Green Infrastructure for Sustainable Urban Environments Research Experience for Undergraduates (REU)*. This is a 10-week summer program designed to expose 10 undergraduate students per year to unique Green Infrastructure research. Green Infrastructure is a way to build better infrastructure, as a part of the National Academy of Engineering's Grand Challenge, to restore and improve urban infrastructure. This program will allow students to perform field, laboratory, or modeling studies to explore how green infrastructure can mitigate the effects of urban runoff on surface water quality and hydrology. This research will impact not only eastern Tennessee but any area that deals with urban stormwater runoff. Students will also be immersed into a professional and social atmosphere to develop their fundamental research methodologies and critical thinking skills.

In summary, ISSE will continue building its research strength through its own inhouse capabilites and interdisciplinary collaborations with other academic and research units on campus, thus growing sustainability research at UTK to serve our nation and our state.

Individual programs have also set goals for the coming year:

Tennessee Water Resources Research Center: Background data collection is ongoing to characterize the site's hydrology pre-implementation of the regenerative stormwater conveyance (RSC). Over this project year, we intend to construct the RSC and begin to monitor the site post-construction. This pre – post experimental design is intended to identify changes in hydrology due to the RSC installation.

East Tennessee Clean Fuels/Drive Electric TN: Partner relationship growth abounds with school district and local power company (LPC) discussions and meetings taking place much more frequently. This includes reaching smaller rural school districts and LPCs that stretch from counties along the Mississippi River to the Cumberland Gap to Erwin, Tennessee. For ETCF, 2022 needs to include continuing that growth because new and healthy partnerships are what drive ETCF's success.

Geochemical Interaction between CO2 and Caprock for Safe Carbon Sequestration: The research team is planning to visit the Advanced Photon Source (APS) to acquire x-ray diffraction measurements and will work with metarock company to test a core of limestone under high confining pressure, pore pressure and flooding the sample with CO2. Once metarock finishes the test, the core will be analyzed to evaluate the possible reaction between CO2 and minerals within the core.

Multi-Sensor Data-Driven Inspection/Maintenance of Green Infrastructure: Goals to accomplish in the upcoming year: We have collected additional data that we hope to analyze over the coming year. Our goal is to extend the proposal that was previously submitted to other funding agencies using the new preliminary results and submit it to NSF CIS in the coming year.

Neighborhood Attitudes Toward Community Composting: Case of Knoxville, Tennessee: If the FFAR grant is funded, then we will perform the research described in that proposal. If the FFAR grant is not funded, we will continue to seek funding to advance this work. In addition, we have recently connected with a large private firm in the waste-to-energy business, and we are working with them on possible collaborations.

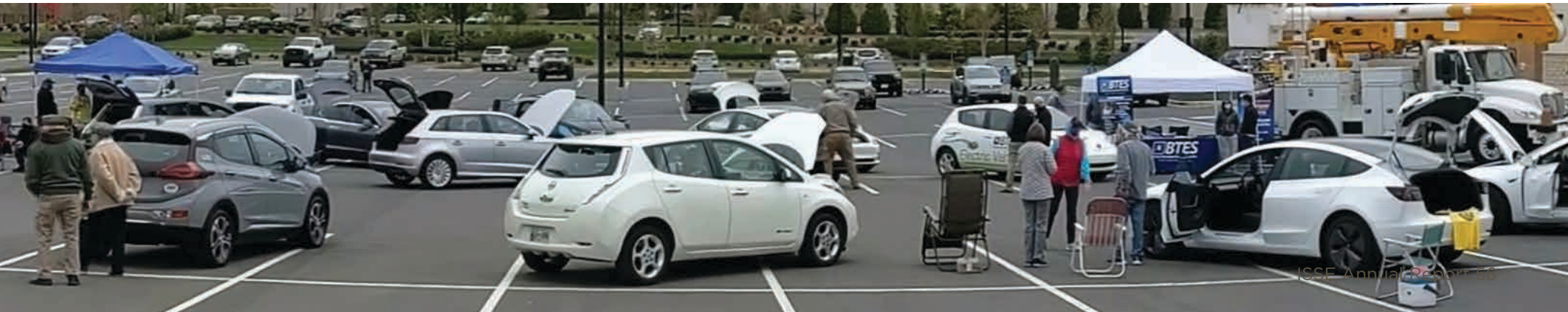
Microbial transformation and degradation of sulfonated per- and polyfluoroalkyl substances: The overarching goal is to demonstrate that naturally occurring bacteria can transform PFAS. We focus on a unique Pseudomonas sp. isolate whose genome harbors an unusually high number of alkanesulfonate monooxygenase genes. Work by doctoral students: Diana Ramirez is exploring if this bacterium can utilize sulfonate-sulfur from per- and polyfluorinated sulfonates. Alexander Walls has established specific analytical techniques to monitor defluorination reactions. Given the progress we have made to date, we anticipate reporting significant results in the near term.

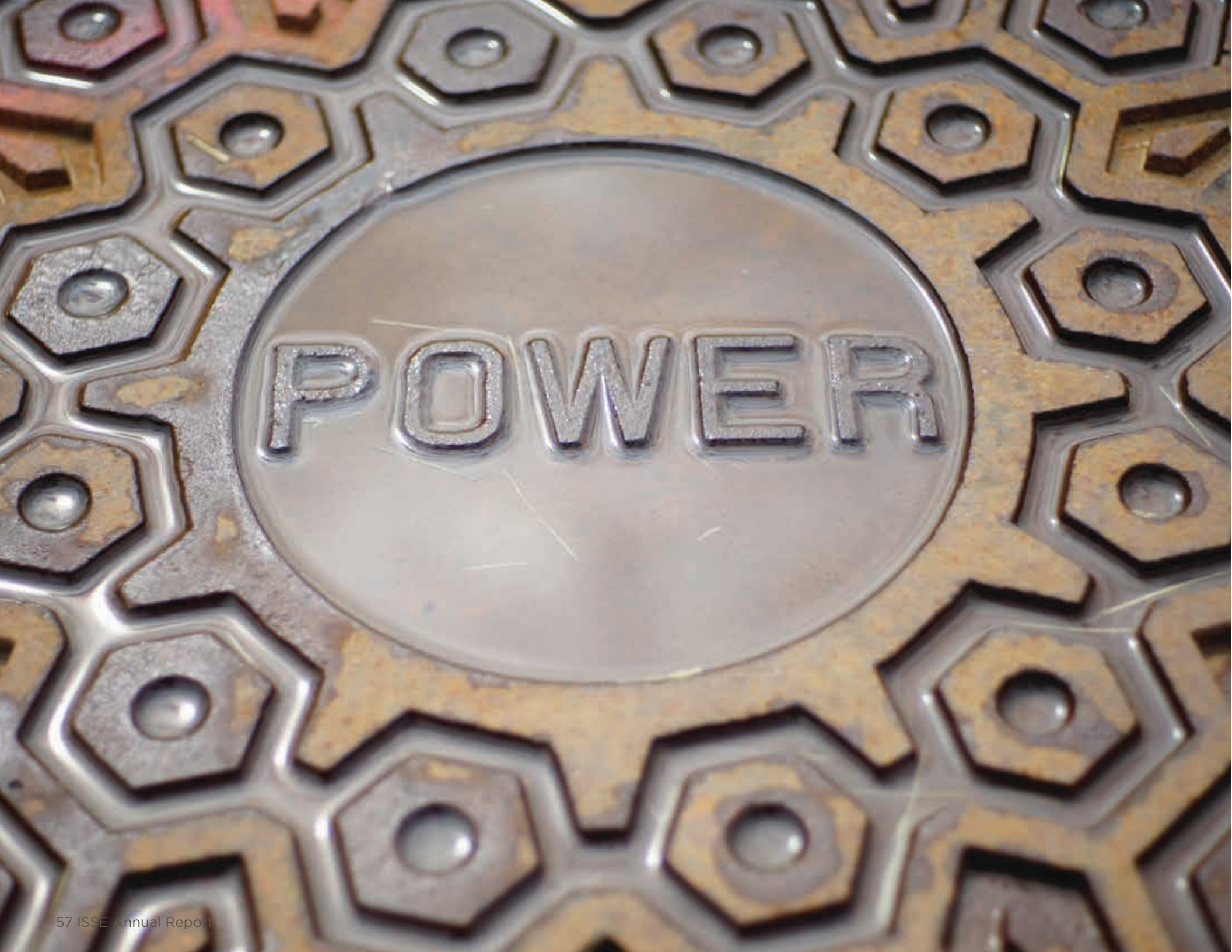
Socioeconomic inequalities and drinking water quality: assessing arsenic concentrations in community water systems by novel field deployable biosensors: The tasks of this project are two pronged. On one front, we are developing a portable sensing system to monitor the quality of community water. Specifically, a new low-cost biosensor along with a readout system will be developed to detect arsenic in drinking water at home. For the other front, we will obtain preliminary data on arsenic levels from selected communities with diverse socioeconomic backgrounds. The objective is to identify possible correlations between arsenic levels and socioeconomic status, in order to be able to remediate the societal disparity. The team has filed for an IRB application to recruit community participants. Once we have preliminary results from both tasks, we expect to submit external grant proposals.

Beat the heat: Building adaptive capacity of vulnerable populations in Knox County to combined stressors from climate change and urban heat: We aim to complete data collection and analysis this semester so that they can inform planning in the Spring 2022. This includes the analysis of overnight temperatures both climatologically and as experienced in Knoxville in August, as well as the vulnerability assessment. During the spring we will also write a manuscript and begin to develop a proposal, which we aim to submit in the summer or fall depending on funding opportunities.

3D dynamic evolution of pore water-air interaction within saturated sheared sand: The research relies heavily on using Beamline 13D at the Advanced Photon Source (APS). Due to COVID19, APS limited researchers access to the beamline since March 2021. APS granted us access to Beamline 13D in November 2021 and we plan to visit and acquire dynamic 3D Synchrotron computed tomography (SMT) scans of triaxial sand specimens. Also, the research team will apply for more beam times in the Spring and summer of 2022. The visits to APS are expected to achieve major research milestones and will generate critical measurements to achieve the objectives of the research.

Toward Precision Environmental Health Risk Management: Feasibility of Personalized Exposome Monitoring: The project team will continue with efforts to 1) publish results from this seed project to strengthen the track record in the research area of environmental exposomes, which is essential for developing competitive research proposals; and 2) expand the research scope to other health outcomes associated with environmental exposure, including asthma, allergy, and infectious diseases, particularly those associated with airborne transmission. Preliminary results from this seed project can be readily leveraged to support proposals in these extended research topic areas.




POWER

Insert Schedule 7 here.

TICKLE COLLEGE OF ENGINEERING

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