Enterprise + Infrastructure Resilience Workshop

September 30 – October 1, 2020
Houston, TX

Organized by the Institute for Sustainability

TABLE OF CONTENTS

TIPS FOR A SUCCESSFUL MEETING

Say **hello** to everyone.
You might make someone's day.

Introduce yourself to people you don't know.
They may be your next good friends.

Stop and **smile**.
You will brighten the room considerably.

Be **understanding**.
Everybody makes mistakes.

Help those with less experience.
We were all novices at some point.

Respect others.
We all have something valuable to contribute.

Value staff and volunteers.
They are here for you.

Be **kind**.
You will never like everybody, but you can be cordial to all.

Enjoy the meeting!
You can have fun while sharing,learning and networking.

Abstracts appear as submitted by their authors. Neither the American Institute of Chemical Engineers (AIChE) and its entities, nor the employers affiliated with the authors or presenting speakers, are responsible for the content of the abstracts.

WELCOME ADDRESS

Greetings!

We want to welcome you to virtually for the 2020 Enterprise and Infrastructure Resilience Workshop brought to you by the Institute for Sustainability (IfS), an AIChE Technological Community.

The Resilience Workshop explores multifaceted resilience strategies for the modern enterprise that address dependence on external systems, such as the environment, stakeholders, shareholders, and society. This year's conference highlights the emerging topics like Defining, Quantifying, and Engineering Resilience, Resilience in Complicated and/or Complex Systems, Sustainability and Circularity in Resilience, Safety in Resilience.

This great conference is headlined by our plenary featured speaker lectures which will be delivered by influential members working in the sector along with other top researchers and leaders in the Environmental Resiliency field.

This conference will also feature a poster session featuring the new age of undergrad and post-doctoral students.

Much work has gone into making this conference a success. If it were not for the contributions of our Organizing Committee, who was instrumental in selecting our speakers and shaping the program, as well as the invaluable assistance from our corporate sponsors, academic supporters, and media partners, this conference could not have happened. Moreover, the tremendous support of the IfS and AIChE staff has played an invaluable role.

Finally, we would like to thank you for attending the conference. We hope these next two days will be pleasant, educational and inspiring.

Sincerely,

Selen Cremaschi, Auburn University; Conference Chair

Bhavik Bakshi, Ohio State University; Conference Chair

CONFERENCE ORGANIZERS

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TECHNICAL PROGRAM

September 30th, 2020			
11:00 AM	11:10 AM	Introduction to Day 1	Selen Cremanchi
11:10 AM	12:30 PM	**Defining, Quantifying, and Engineering Resilience**	
Resilient Systems Show a Trade-Off between Efficiency and Redundancy			Brian Fath
Resilience Analytics in Supply Chain Modeling: Quantification in the Context of the COVID-19 Pandemic			Igor Linkov
Disaster Resilience - Defining, Quantifying and Engineering for Intervention Approaches			Debalina Sengupta
Why Resilience Must Be Assessed, Not Measured			Tom Seager
Resilient Infrastructure and Environmental Systems: An NSF Research Traineeship Program			Christopher L. Kitchens
12:45 PM	1:15 PM	**A Discussion with the Speakers: Defining, Quantifying, and Engineering Resilience**	
1:15 PM	*1:25 PM*	*Break*	
1:25 PM	2:00 PM	Meet and Greet	
2:00 PM	3:00 PM	**Sustainability and Circularity in Resilience Featured Talks**	
Infrastructure and the Anthropocene			Mikhail V. Chester
Can Circularity Increase the Resilience of Chemical Manufacturing Systems? Case Study of Polymer Manufacturing			David Allen
Synergies Among Resilience, Sustainability, and Circularity			Joseph Fiksel
Expanding Broadband Access in SC			Amy Burton
Multimodal Network Modeling of US Coal Transportation for Resilient Infrastructure			Jacob M. Arnold
Adaptation of Manufacturing Systems to Climate Change			Kyuha Lee
3:45 PM	4:15 PM	**A Discussion with the Speakers: Sustainability and Circularity in Resilience**	
4:15 PM	4:25 PM	**End of Day 1 Discussion**	
October 1st, 2020			
11:00 AM	11:10 AM	Introduction to Day 2	Bhavik Bakshi
11:10 AM	12:30 PM	Resilience in Complicated and/or Complex Systems	
Optimal Design of Supply Chains with Facility Disruptions			John Wassick & Ignacio Grossmann
Design and Planning of Resilient Supply Chain			Ana Póvoa
An Optimization Approach for Green Resilient Supply Chain			João Pires Ribeiro
Resilience of Interconnected Networks in a Water-Energy Nexus			Spyridon D. Tsolas
From Newton to Shannon and Back Again: Information Mechanical Thermodynamics Characterization of Resilience at the Cold Food Storage Node of the US Food Supply Chain			Richard Donovan
12:30 PM	1:00 PM	Discussion and Breakout: Resilience in Complicated and/or Complex Systems	
1:00 PM	*1:10 PM*	*Break*	
1:10 PM	2:10 PM	Safety in Resilience	
Engineering for Resilience			Ali Mosleh
Optimizing Efficiency-Robustness Trade-Offs in Complex Systems for Safety and Sustainability			Venkat Venkatasubramanian
Resilience is a Verb: How adaptive capacity is built, sustained, degraded, & lost in complex systems			David Woods
Survivability-Aware Resilient Supply Chains			M. M. Faruque Hasan
2:10 PM	2:40 PM	Discussion and Breakout: Safety in Resilience	
2:40 PM	*2:45 PM*	*Break*	
2:45 PM	3:05 PM	Transformation towards Resilience- Emerging Trends	
Effective Energy Efficiency Solutions for a Sustainable Future			Johan Ulloa
Outperforming Organizations Are Resilient and Agile			Nicholas Bahr
3:05 PM	3:35 PM	A Discussion about the Transformations towards Resilience	
3:35 PM	3:45 PM	End of Day 2 Discussion	

Featured Speaker Biographies

Brian Fath

Towson University

Brian D. Fath is Professor in the Department of Biological Sciences at Towson University (Maryland, USA) and Senior Research Scholar at the International Institute for Applied Systems Analysis (Laxenburg, Austria). He has published over 180 research papers, reports, and book chapters on environmental systems modeling, specifically in the areas of network analysis, urban metabolism, and sustainability. He co-authored the books A New Ecology: Systems Perspective (2020), Foundations for Sustainability: A Coherent Framework of Life–Environment Relations (2019), and Flourishing Within Limits to Growth: Following Nature's Way (2015). He is also Editor-in-Chief for the journal Ecological Modelling and Co-Editor-in-Chief for Current Research in Environmental Sustainability. He was the 2016 recipient of the Prigogine Medal for outstanding work in systems ecology and twice a Fulbright Distinguished Chair (Parthenope University, Naples, Italy, in 2012 and Masaryk University, Czech Republic, in 2019). In addition, he has served as Secretary General of the International Society for Ecological Modelling, Co-Chair of the Ecosystem Dynamics Focus Research Group in the Community Surface Modeling Dynamics System, and member and past Chair of Baltimore County Commission on Environmental Quality.

Igor Linkov

US Army Engineer Research and Development

Dr. Igor Linkov is the Risk and Decision Science Focus Area Lead with the US Army Engineer Research and Development Center, and Adjunct Professor with Carnegie Mellon University. Dr. Linkov has managed multiple risks and resilience assessments and management projects in many application domains, including critical infrastructure, food security, and safety, cybersecurity, transportation, supply chain, homeland security, and defense. He was part of several Interagency Committees, and Working Groups tasked with developing resilience metrics and resilience management approaches, including the US Army Corps of Engineers Resilience Roadmap and OECD Resilience Initiative. He has published widely on environmental policy, environmental modeling, and risk analysis, including twenty books and over 350 peer-reviewed papers and book chapters in top journals, like Nature, Nature Nanotechnology, Nature Climate Change, among others. Dr. Linkov is Society for Risk Analysis Fellow and recipient of 2005 Chauncey Starr Award for exceptional contribution to Risk Analysis as well as the 2014 Outstanding Practitioner Award. He is Elected Fellow with the American Association for the Advancement of Science (AAAS). Dr. Linkov has a B.S. and M.Sc. in Physics and Mathematics (Polytechnic Institute) and a Ph.D. in Environmental, Occupational and Radiation Health (University of Pittsburgh). He completed his postdoctoral training in Risk Assessment at Harvard University.

Debalina Sengupta

Texas A&M Energy Institute

Dr. Sengupta's research focuses on sustainability in the context of process systems engineering. She has worked on process design, integration, intensification, optimization, life cycle assessment and other related concepts for Sustainable Supply Chain Design of Biofuels, Natural Gas, and Consumer Products, and decision-making in Sustainability using metrics and indicators. She has also been actively involved in the development of educational modules for sustainable manufacturing. Dr. Sengupta is currently appointed as the Associate Director of the TEES Gas and Fuels Research Center, Water, Energy and Food Nexus Coordinator at Texas A&M Energy Institute, and Lecturer at Texas A&M University, Artie McFerrin Department of Chemical Engineering.

Dr. Sengupta serves as co-PI or senior personnel on several multi-million-dollar Department of Energy (DOE) research projects from the RAPID Manufacturing USA Institute (Process Intensification) and the CESMII Manufacturing USA Institute (Smart Manufacturing). She was also integral to the successful National Science Foundation planning grant, "Engineering Research Center for Resiliency Enhancement and Disaster-Impact Interception (READII) in the Manufacturing Sector." Following up from that work, her current research interests are related to resilience in the process industrial sector under disaster conditions. She has organized five workshops funded by the National Science Foundation in the area of disaster resilience and is also working on several publications that capture the impact of disasters in the manufacturing sector.

Tom Seager

Arizona State University

Thomas P Seager is an associate professor in the School of Sustainable Engineering & the Built Environment at Arizona State University in Tempe AZ. Seager leads research teams working at the boundaries of engineering and social science to understand innovation for resilient infrastructure systems, including the life-cycle environmental consequences of emerging energy technologies, novel approaches to teamwork and communication in socio-technical integrative settings, and engineering ethics education. Current research sponsors include the National Science Foundation, the US Army Corp of Engineers, the Environmental Protection Agency, and several industry partners. Seager is the Faculty Director of the Resource Innovation Solutions Network (RISN), a partnership of between ASU, City of Phoenix and other local municipalities for fostering circular, closed-loop economies. Additionally, he serves as Chairman and Chief Executive Officer of two startup companies. The first is eXperiential Sustainability Ethics Training (XSETGames, LLC) creates digital simulations for examining economic and ethical dimensions of wicked problems including pharmaceutical pricing, intergenerational equity, and the Tragedy of the Commons. These simulations have been used by corporations, government agencies, and higher education clients, including dozens of Universities on three different continents. The second is Building Integrated Solar Thermal Electricity Generation (BISTEG-USA, LLC), which is developing full-scale working sculptures that create electricity from sunlight without using photovoltaics. BISTEG is currently working with the City of Adelaide, Australia to create a technology demonstration wall that will help realize their vision of becoming the first carbon neutral city in the world. Lastly, Seager founded the non-profit Sustainability Conoscente Network as a mechanism for sharing knowledge related to systems approaches to sustainable technologies.

Mikhail V. Chester

Affiliation

Dr. Chester is the Director of the Metis Center for Infrastructure and Sustainable Engineering at Arizona State University where he maintains a research program focused on preparing infrastructure and their institutions for the challenges of the coming century. His work spans climate adaptation, disruptive technologies, innovative financing, transitions to agility and flexibility, and modernization of infrastructure management. He is broadly interested in how we need to change infrastructure governance, design, and education for the Anthropocene, an era marked by acceleration and uncertainty. He is co-lead of the Urban Resilience to Extremes research network composed of 19institutionsand 250 researchers across the Americas, focused on developing innovative infrastructure solutions for extreme events. He was awarded the American Society of Civil Engineer's early career researcher Huber price in 2017.

David Allen

University of Texas

Dr. David Allen is the author of seven books and over 250 papers, primarily in the areas of urban air quality, the engineering of sustainable systems, and the development of materials for environmental and engineering education. Dr. Allen has been a lead investigator for multiple air quality measurement studies, which have had a substantial impact on the direction of air quality policies. He directs the Air Quality Research Program for the State of Texas, and he is the founding Editor-in-Chief of the American Chemical Society's journal ACS Sustainable Chemistry & Engineering. He has developed environmental educational materials for engineering curricula and for the University's core curriculum, as well as engineering education materials for high school students. He led the development of a year-long high school engineering course, Engineer Your World, which is used in hundreds of high schools nationwide.

Joseph Fiksel

Ohio State University

Joseph Fiksel is an author, consultant, researcher, and educator who retired from The Ohio State University in 2018. His publications and real-world projects have advanced the science and practice of sustainability and resilience, earning him an international reputation as an expert in environmental risk analysis, design for sustainability, supply chain resilience, circular economy, and complex systems modeling. Joseph has served on numerous advisory and editorial boards, including the U.S. Technical Advisory Group for ISO 14000. He was an officer and founding member of the Society for Risk Analysis, and has testified on cancer risk attribution to Congress and the White House. He has published over 100 articles and 5 books, and has been a frequent invited speaker at professional conferences throughout the world. In 2009 McGraw-Hill published the second edition of his landmark textbook, Design for Environment: A Guide to Sustainable Product Development. His most recent book, Resilient by Design: Creating Businesses That Adapt and Flourish in a Changing World, was published by Island Press in 2015.

Joseph holds a B.Sc. degree from M.I.T., a Ph.D. in Operations Research from Stanford University, and an applied mathematics degree from La Sorbonne, University of Paris. He and his wife, Diane now reside in Washington, DC, and they continue to devote time to projects in both the U.S. and India. In 2019, Joseph was appointed a Visiting Scholar at George Washington University's Environmental and Energy Management Institute.

Fengqi You

Cornell University

Fengqi You is the Roxanne E. and Michael J. Zak Professor at Cornell University, and is affiliated with the Graduate Fields of Chemical Engineering, Electrical and Computer Engineering, Operations Research and Information Engineering, Systems Engineering, Mechanical Engineering, Civil and Environmental Engineering, and Applied Mathematics. Prof. You also serves as Chair of PhD Studies for Cornell Systems Engineering and Associate Director of Cornell Energy Systems Institute. His research focuses on novel computational models, optimization algorithms, statistical machine learning methods, and multi-scale systems analytics tools for energy systems, and sustainability. He has published more than 150 peer-reviewed journal articles, and has an h-index of 58. Some of his recent awards include National Science Foundation CAREER Award (2016), AIChE Sustainable Engineering Research Excellence Award (2017), Computing and Systems Technology (CAST) Outstanding Young Researcher Award from AIChE (2018), Cornell Engineering Research Excellence Award (2018), ACS Sustainable Chemistry & Engineering Lectureship Award (2018), AIChE Excellence in Process Development Research Award (2019), Curtis W. McGraw Research Award from ASEE (2020), and American Automatic Control Council (AACC) O. Hugo Schuck Award (2020).

John Wassick

DOW

John M. Wassick is the supply chain technology leader at Dow, Inc. He is also the 2019 Lawrence B. Evans Award in Chemical Engineerign Practice winner.

Ignacio Grossmann

Carnegie Mellon University

Professor Ignacio E. Grossmann is the R. R. Dean University Professor of Chemical Engineering at Carnegie Mellon University. He obtained his B.S. degree at the Universidad Iberoamericana, Mexico City, in 1974, and his M.S. and Ph.D. at Imperial College in 1975 and 1977, respectively. He is currently director of the 'Center for Advanced Process Decision-making,' an industrial consortium that involves 20 petroleum, chemical, engineering and software companies. He is a member of the National Academy of Engineering and his major awards include the 1994 Computing in Chemical Engineering Award of AIChE, the 1997 William H. Walker Award of AIChE, 2009 Warren Lewis Award of AIChE, and 2011 Research Excellence in Sustainable Engineering Award. He was also named "One of the Hundred Chemical Engineers of the Modern Era" by AIChE in 2008.

His research interests lie in the application of mathematical programming to the design and operation of chemical plants and process supply chains. Within these areas he has worked on a number of problems that are related to the optimal design of sustainable chemical processes and supply chains. He has authored more than 300 papers, several monographs on design cases studies, and the textbook 'Systematic Methods of Chemical Process Design.'

Ana Barbosa-Póvoa

University of Lisbon

Ana Barbosa-Póvoa is a Full Professor in Operations and Logistics, at the Engineering and Management Department of Instituto Superior Técnico (IST), University of Lisbon. She holds a PhD from the Imperial College of Science Technology and Medicine and her research focus is on developing a comprehensive understanding of complex problems in supply chains and operations management, supported by novel and sound engineering systems models and techniques. Sustainability, resilience, uncertainty and risk in the design and planning of supply chains are among the main research addressed domains. Ana has created and coordinates the research group in Operations Management and Logistics (OpLog) at the Centre for Management Studies of IST. Her research has led to several national and international awards having received recently the honour of being considered the best researcher in Industrial Management at the University of Lisbon. She is a member of the Computer Aided Process Engineering Working Party of the European Federation of Chemical Engineers and a founder member of the Euro Working Group in Sustainable Supply Chains of the European Association of Operational Research – where she is currently part of the coordination team. She is an editor of the Computers and Chemical Engineering Journal and a member of the editorial boards of the European Journal of Operational Research and International Journal of Production Economics.

Ali Mosleh

University of California-Los Angelos

Ali Mosleh is a Distinguished University Professor and holder of the Evelyn Knight Chair in Engineering. He is also the Director of UCLA's B. John Garrick Institute for the Risk Sciences. Previously he was the Nicole J. Kim Eminent Professor of Engineering and Director of the Center for Risk and Reliability at the University of Maryland. He was elected to the National Academy of Engineering in 2010 and is a Fellow of the Society for Risk Analysis, and the American Nuclear Society, recipient of several scientific achievement awards, including the American Nuclear Society Tommy Thompson Award. He has been technical advisor to numerous national and international organizations, including appointment by Presidents Bush and Obama to the U.S. Nuclear Waste Technical Review Board. He conducts research on methods for probabilistic risk analysis and reliability of complex systems, holds several patents, and has authored or co-authored over 500 publications including books, guidebooks, and technical papers.

Venkat Venkatasubramanian

Columbia University

Professor Venkat Venkatasubramanian is Samuel Ruben-Peter G. Viele Professor of Engineering in the Department of Chemical Engineering, Professor of Computer Science (Affiliate), and Professor of Industrial Engineering and Operations Research (Affiliate) at Columbia University in the City of New York. He earned his Ph. D. in Chemical Engineering at Cornell, M.S. in Physics at Vanderbilt, and B. Tech. in Chemical Engineering at the University of Madras, India. Venkat worked as a Research Associate in Artificial Intelligence in the School of Computer Science at Carnegie-Mellon University. He taught at Purdue University for many years, before returning to Columbia in 2011. At Columbia, Venkat directs the research efforts in the Complex Resilient Intelligent Systems Laboratory. He is also the founding Co-Director of the Center for the Management of Systemic Risk, a transdisciplinary center focused on understanding how complex systems fail in order to prevent or mitigate such failures in the future, with faculty from a number of departments at Columbia University.

Prof. Venkatasubramanian received the Norris Shreve Award for Outstanding Teaching in Chemical Engineering three times at Purdue University. He won the Computing in Chemical Engineering Award from AIChE and is a Fellow of AIChE. In 2011, the College of Engineering at Purdue University recognized his contributions with the Research Excellence Award. He is a past-President of the Computer Aids for Chemical Engineering (CACHE) Corporation. He currently serves as an Editor for Computers and Chemical Engineering. His new book, How Much Inequality is Fair? Mathematical Principles of a Moral, Optimal, and Stable Capitalist Society, was published in 2017. Venkat's other interests include comparative theology, classical music, and cricket.

David Woods

Ohio State University

David Woods, Professor in Department of Integrated Systems Engineering at the Ohio State University (PhD, Purdue University) has worked to improve systems safety in high risk settings for almost 40 years. These include studies of human coordination with automated and intelligent systems and accident investigations in aviation, nuclear power, critical care medicine, crisis response, military operations, and space operations.

He is Past-President of the Human Factors an Ergonomics Society and Past-President of the Resilience Engineering Association. He has received many awards including the Laurels Award from Aviation Week and Space Technology (1995), IBM Faculty Award, Google Faculty Award, Ely Best Paper Award and Kraft Innovator Award from the Human Factors and Ergonomic Society, the Jimmy Doolittle Fellow Award from the Air Force Association (2012).

Johan Ulloa

Constellation

Dynamic and accomplished business leader with 18 years of experience managing large projects, teams, and initiatives in finance and energy markets. Robust sales, financial and strategic background with a proven track record of executing successful commercial transactions, partnerships, business plans, new product development, and leading finance organizations.

Nicholas Bahr

DuPont Sustainable Solutions

Nicholas Bahr helps clients identify, prioritize and reduce risk along their complete value chain and throughout their portfolio of operations. He has over 35 years' experience and is an internationally recognized thought leader and expert in operational and enterprise risk management, business continuity, process safety, resiliency, system safety and security. He works globally with clients in the manufacturing, chemical, oil and gas, power and water, aerospace, and transport industries to improve their safety, security and continuity of operations. Mr. Bahr is the author of the book System Safety Engineering and Risk Assessment used by various universities around the world and the US Federal Aviation Administration as their aviation system safety model. He is a founding member of the International Association for the Advancement of Space Safety and has led U.S. delegations on various standards writing bodies.

CODE OF CONDUCT

AIChE's volunteers are the core of the Institute and make all of its programs, conferences and educational efforts possible. These offerings provide excellent opportunities for AIChE members and meeting attendees to gain greater technical expertise, grow their networks, and enhance their careers. AIChE events provide engineers, scientists, and students a platform to present, discuss, publish and exhibit their discoveries and technical advances.

At all times, volunteers and meeting attendees should act in accordance with AIChE's Code of Ethics, upholding and advancing the integrity, honor and dignity of the chemical engineering profession. AIChE's Board of Directors has developed these guidelines to foster a positive environment of trust, respect, open communications, and ethical behavior. These guidelines apply to meetings, conferences, workshops, courses and other events organized by AIChE or any of its entities and also to volunteers who conduct other business and affairs on behalf of AIChE.

SPECIFICALLY:

1. Volunteers and meeting attendees should understand and support AIChE's Code of Ethics.
2. Volunteers and meeting attendees should contribute to a collegial, inclusive, positive and respectful environment for fellow volunteers and attendees, and other stakeholders, including AIChE staff.
3. Volunteers and meeting attendees should avoid making inappropriate statements or taking inappropriate action based on race, gender, age, religion, ethnicity, nationality, sexual orientation, gender expression, gender identity, marital status, political affiliation, presence of disabilities, or educational background. We should show consistent respect for colleagues, regardless of discipline, employment status, and organizations for which they work, whether industry, academia, or government.
4. Disruptive, harassing or other inappropriate statements or behavior toward other volunteers, members, and other stakeholders, including AIChE staff, is unacceptable.
5. Volunteers and meeting attendees should obey all applicable laws and regulations of the relevant governmental authorities while volunteering or attending meetings. Volunteers and meeting attendees taking part in any AIChE event, including the Chem-E-Car Competition®, should also comply with all applicable safety guidelines.

Any violations of the foregoing should be reported to the President or the Executive Director of the Institute.

DEFINING, QUANTIFYING, AND ENGINEERING RESILIENCE

Resilient Systems Show a Trade-Off between Efficiency and Redundancy.

Brian D. Fath
Biological Sciences, Towson University, Towson, MD

The study of ecological resiliency has led to interesting insights about the structure and function of systems. Ecological resilience (defined by Holling) refers to a systems ability to respond and recover following a perturbation. This definition has been expanded by Fath et al. 2015 to include the entire life cycle of system's dynamics including growth, conservation, collapse, and reorganization. Network methods, particularly those derived using information-theory based approaches, can assess the system organization and quantify the embedded network efficiency and redundancy. These methods were developed with ecological systems in mind and have recently been applied to socio-economic systems such as trade networks, economies, and urban metabolism. A main conclusion of this work is that ecological systems are observed to evolve toward an optimum balance of these two key resilience factors. This presentation will overview the network methodologies and give examples in the above mentioned domains.

Resilience Analytics in Supply Chain Modeling: Quantification in the Context of the COVID-19 Pandemic.

Igor Linkov
US Army Corps of Engineers, Concord, MA

The increasingly global context in which businesses operate supports innovation, but also increases uncertainty around supply chain disruptions. The COVID-19 pandemic clearly shows the lack of resilience in supply chains and the impact that disruptions may have on a global network scale as individual supply chain connections and nodes fail. This cascading failure underscores the need for the network analysis and advanced resilience analytics we find lacking in the existing supply chain literature. This presentation reviews supply chain resilience literature and discuss gaps and limitations. The common goal of supply chain modeling has been to optimize efficiency and reduce costs, but tradeoffs of efficiency and leanness with flexibility and resilience may not be fully addressed. I will provide a comprehensive approach to network resilience quantification encompassing the supply chain in the context of other social and physical networks. The connection to systemic threats, such as disease pandemics, will be specifically discussed.

Disaster Resilience - Defining, Quantifying and Engineering for Intervention Approaches.

Debalina Sengupta
Gas and Fuels Research Center, Texas A&M Engineering Experiment Station, College Station, TX

The intensity of natural disasters has been increasing over the past two decades, and the damages caused by them have been impacting the lives of millions. Hurricanes and flooding events have increasingly influenced coastal communities, and given rise to terms as climate refugees. Disaster management has primarily been a top down approach from governance perspectives. The Post-Katrina Emergency Management Reform Act of 2006 saw a comprehensive push towards disaster management strategies, and the need for emergency planning and implementation.

As we start to understand the impacts from natural disasters and their long term effects, we realize that it may not be just a governance or management issue. There is a stronger component of engineering required that will intercept the disaster management cycle. A convergent, interdisciplinary research approach is required to address the four stages of disaster management: Response, Recovery, Mitigation and Preparedness.

From analyzing vulnerabilities and risks, to identifying root causes and critical elements in the full cycle of disaster management, interventions can be designed for timely recovery and minimizing loss of life. Deriving from concepts of sustainable development, this talk will aim to define and quantify disaster resilience, provide a framework for resilience studies focused on basic human needs, and seek to develop futuristic engineered solutions.

Why Resilience Must Be Assessed, Not Measured.

Tom Seager,
School of Sustainable Engineering & the Built Envrionment, Arizona State University, Tempe AZ

While the scientific revolution that has driven technological progress since the time of Galileo insists upon quantification and measurement, the complexity of post-Industrial surprises now challenge the supposition that only what gets measured will be managed. Resilience is at the leading edge of an emerging, post-Industrial revolution is science that reveals the limitations of our current, risk-based paradigm. This presentation reveals the necessity of thinking about resilience as a set of ongoing processes, rather than a property of state. As research advances a new theory of resilience, it is becoming increasing clear that these processes are: sensing, anticipating, adapting, and learning. That is, resilience is not found in what systems have, but only in what they do. Thus, quantification of resilience is problematic, in the sense that these processes are not "countable." An introduction to alternative assessment of each essential process is presented, and some difficulties inherent in bureaucratic approaches to management of resilience are described.

Resilient Infrastructure and Environmental Systems: An NSF Research Traineeship Program.

Christopher L. Kitchens
Department of Chemical and Biomolecular Engineering, Clemson University, Clemson, SC

The vision the Resilient Infrastructure and Environmental Systems (RIES) NRT program at Clemson University is to build a sustainable interdisciplinary community of student and faculty researchers from across multiple disciplines who are dedicated to identifying and mitigating the vulnerabilities of complex, critical, and interdependent infrastructure systems. Guided by this vision, our focus is to train graduate students to conceptualize complex systems where physical, cyber, and human infrastructure elements converge, and transform this conceptual understanding into reliable computational models that are validated by data. Just as importantly, our graduates will be equipped with skills to effectively communicate with their peers in other disciplines and with decision makers to ensure cohesion between science and policy. In this presentation, we will present our program structure, highlight the research efforts, and describe our vision to transform the function of Clemson as a land grant institution.

SUSTAINABILITY AND CIRCULARITY IN RESILIENCE

Infrastructure and the Anthropocene.

Chester Mikhail
Arizona State University, Tempe, AZ

At the dawn of the twenty-first century, there are signs that several critical social, technological, and environmental variables are changing in ways that will have major effects on how we design and manage infrastructure. These variables include climate non-stationarity, uncertainty in financing, increasing ideological polarization in politics, and acceleration of technologies, as well as their interactions. These variables are positioned to increase the uncertainty and complexity of the systems that infrastructure must operate in and support, and are likely to require new competencies of engineers and infrastructure managers. In this talk I will attempt to characterize the emerging uncertainty and complexity that is becoming the new normal for infrastructure. In doing so I will describe the changing relationship between infrastructure and the environment, how infrastructure implementation and operation have become wicked and complex problems, and how the accelerating integration of cyber technologies is likely to fundamentally shift the capabilities and vulnerabilities of infrastructure. I will then discuss how our approaches to infrastructure need to shift from a focus on the complicated problems that we tackled in the past century, to a paradigm that acknowledges the growing complexity in the Anthropocene and our inability to manage it. I will argue that agility and flexibility will need to be core design principles (instead of rigidity) and education will need to be transitioned towards training infrastructure managers for goals of guiding complex systems.

Can Circularity Increase the Resilience of Chemical Manufacturing Systems? Case Study of Polymer Manufacturing.

David Allen
McKetta Department of Chemical Engineering, The University of Texas at Austin, Austin, TX

Chemical manufacturing systems are complex networks of interconnected processes. To assess the resilience of these systems, a network model of the industry has been developed. Models of chemical manufacturing networks originated with Stadtherr and Rudd (1976, 1978) and many iterations of the original industry model have been constructed. Recently, the model framework and material flows have been updated by DeRosa and Allen (2015, 2016). The spatial location of manufacturing operations have been included in additional updates, enabling the simulation of localized disruptions, such as Hurricane Harvey (DeRosa, et al., 2019), on the infrastructure. The impact of Hurricane Harvey as a disruption will be described, and then the opportunity for circular chemical manufacturing to improve resilience will be described.

Synergies Among Resilience, Sustainability, and Circularity.

Joseph Fiksel
Integrated Systems Engineering, The Ohio State University, Columbus, OH

In a hyper-connected and turbulent world, **resilience** has become an essential core competency. Resilience may be defined as the capacity for complex systems to survive, adapt, and grow in the face of turbulent change, including gradual stresses and sudden shocks. Natural and biological systems have evolved a variety of resilience mechanisms. Likewise, resilience strategies can help both enterprises and communities to embrace change rather than clinging to historical practices. Building resilience is a valuable complement to conventional risk management in situations where risks are interdependent, systemic, and difficult to quantify. Consequently, resilient organizations are better prepared for disruptions—whether from human or natural causes—and are able to adapt more effectively to unforeseen challenges.

The resilience of a business or an urban community will depend upon its linkages with complex systems, including environmental, social, and infrastructure systems. Thus, improving short-term resilience may influence long-term sustainability, and planners should take a **systems approach** to understand the potential synergies and trade-offs. For example, the use of just-in-time practices to reduce inventory will benefit supply chain sustainability, but may jeopardize resilience if there are significant fluctuations in supply or demand. The speaker will describe innovative assessment tools and and simulation methods that can enhance supply chain resilience, including an in-depth application by a global chemical manufacturing enterprise. Case studies have demonstrated that the co-benefits of resilience strategies may include improvements in both sustainability and shareholder value.

In particular, the concept of **circular economy** as a strategy for waste elimination has been broadly adopted in the business world. Companies have sought to achieve “zero waste” by finding uses for discarded materials and closing the loop in their supply network. Circularity not only offers economic benefits and reduces a company’s ecological footprint, but also increases both business and community resilience by reducing dependence upon scarce resources and long-distance supply chains. A successful example is the Ohio Byproduct Synergy Network, launched over a decade ago, in which companies collaborate to convert industrial wastes into feedstocks for other processes, effectively turning waste into profit while creating local jobs.

Expanding Broadband Access in SC.

Amy Burton[1], *Jacob M. Arnold*[2], *Cora Bisbee*[3], *Pamela Bretscher*[3], *Daniel Greene*[3], *Victoriana Malvoso*[3], *Zachariah Pittman*[3], *and David Vaughn*[3]
(1)School of Mathematical and Statistical Sciences, Clemson University, Clemson, SC, (2)Environmental Engineering, Clemson University, Clemson, SC, (3)Clemson University, Clemson, SC

Access to high speed internet should be considered a utility, as it is necessary to achieve equal opportunity and complete everyday tasks. However, 24.7% of South Carolina residents still lack broadband internet access. The COVID-19 pandemic has only magnified the effects of poor broadband coverage and highlighted areas with the most urgent needs. With physical contact discouraged, many patient-provider interactions now rely on telecommunications due to safety concerns. Many students in South Carolina are unable to effectively participate in virtual and hybrid learning due to lack of broadband and/or access to a device. Working remotely is also not an option without reliable broadband, forcing many residents to go without income. Inadequate broadband access can stem from a lack of infrastructure, overestimated coverage statistics, unaffordability, non-adoption, lack of digital literacy skills, and legislative obstacles. Clemson's NRT REIS program, in cooperation with the university's Practical Community Resilience program, is making the case for treatment of broadband as a utility. We have gathered and studied educational, demographic, economic, and health related data from all counties in South Carolina to make this argument and are in the process of statistical analysis on such points. With the help of researchers at Emory University we are able to perform hypothesis testing, specifically on the relationship between broadband access and health outcomes.

Multimodal Network Modeling of US Coal Transportation for Resilient Infrastructure.

Jacob M. Arnold[1], *Michael Carbajales-Dale*[2], *and John Sherwood*[3]
(1)Environmental Engineering, Clemson University, Clemson, SC, (2)Environmental Engineering, Clemson University, (3)Clemson University

In order to keep up with the increasing reliance on infrastructure with exponentially growing populations and worsening effects of climate change, sustainability must be attained through resilience. Resilient infrastructure is defined as any societal system that both resists disaster, natural or artificial, as well as returns to full capacity as soon as possible afterwards. Modern infrastructure is also highly interconnected, with many systems mutually relying on each other, so multiple systems and their interconnectivity must be analyzed to properly assess any portion of infrastructure. This project focuses on the energy sector of infrastructure, particularly that of the common yet inefficient fossil fuel of coal. Despite the presence of cleaner sources of energy, coal-burning power plants still provide about 30% of the US electricity production capacity. Efforts have been made to reduce coal-firing emissions in the plants themselves, such as using cleaner coal and recapturing CO_2. However, the extensive distances between many coal mines and power plants in the US cause the coal transportation itself to contribute upwards of 35% of the total CO_2 emissions attributed to coal.

This project evaluates coal transportation emissions through railroads, highways, and waterways. With transition terminals available between modes, a multimodal model has been developed to more holistically evaluate coal transportation emissions. Coal transactions from 2008 to 2018 serve as the basis for a GIS routing analysis to empirically model how coal was transported in the US for the last decade. As each transportation mode has its own vehicle emissions rate, the model predicts how much of each of the three available modes a particular route uses, allowing the total emissions to be determined with a weighted sum. The resulting output from this model demonstrates the necessity of curbing emissions from both burning coal as well as transporting it. In terms of resilience, these results demonstrate how modern infrastructure has developed throughout a long history of relying on inefficient technology and unsustainable energy sources. Not only is it necessary to fortify the infrastructure we rely on, but also to optimize it for resilience in the long-run, paving the way to establishing sustainability.

Adaptation of Manufacturing Systems to Climate Change.

Kyuha Lee[1], *Sami Khanal*[2], *and Bhavik R. Bakshi*[1]
(1)Department of Chemical and Biomolecular Engineering, The Ohio State University, Columbus, OH, (2)Department of Food, Agricultural and Biological Engineering, The Ohio State University, Columbus, OH

Fossil fuel power generation and manufacturing plants are one of the major contributors to greenhouse gas (GHG) emissions, and thus to climate change. They rely heavily on water resources, both for generating steam and cooling the process. However, water resources could be affected by drought and flooding under future climate change due to the projected increase in the variability of temperatures and precipitation. To combat climate change and its impacts, there is a need for implementation of technologies and policy changes that mitigate GHG emissions.

Representative concentration pathway (RCP) scenarios define future GHG emissions trajectories depending on the level of mitigation. RCP 4.5 is a low emissions scenario with mitigation strategies to limit global warming in 2100 to 2 degrees Celsius above pre-industrial levels (1850-1900). On the other hand, RCP 8.5 is a high emissions scenario with no mitigation, which will result in approximately 4-degree warming in 2100.

In this work, we investigate how urea manufacturing processes and supply networks could be affected by future changes in climate and how they could adapt to maintain their productivity. To mitigate and adapt to climate change, we examine the effectiveness of technologies that help reduce GHG emissions and water consumption. For example, green urea production could employ water instead of methane as feedstock to provide hydrogen to urea since the electrolysis of water generally has a smaller carbon footprint than the conventional steam methane reforming. Another adaptation option could include the use of renewable energy sources instead of fossil fuels.

RESILIENCE IN COMPLICATED AND/OR COMPLEX SYSTEMS

Optimal Design of Supply Chains with Facility Disruptions.

John M. Wassick[1] *and* ***Ignacio E. Grossmann***[2]
(1)The Dow Chemical Company, Midland, MI, (2)Department of Chemical Engineering, Carnegie Mellon University, Pittsburgh, PA

We first describe the importance of the performance of supply chain for companies' competitiveness in the process industries. Major issues that impact, the performance of supply chains are uncertainties in product demand, operating costs, and reliability of facilities. With the recent COVID pandemic the importance of anticipating and responding to disruptions in supply chains has greatly increased. Such disruptions, which can occur globally, can have far ranging negative impact on servicing customers. In order to protect against the effects of such events, supply chain designs must anticipate disruptions and supply chain operations must be agile in their response to disruptions. We review several approaches used at Dow Inc to address supply chain disruptions. One such effort has been a collaboration with the Center of Advanced Process Decision-making at Carnegie Mellon, which we describe in this presentation.

We develop a mathematical model for the optimization of the supply chain design under random facility disruptions. We formulate this problem as a multistage stochastic programming with recourse. We consider the supply of a single commodity from a fixed set of production facilities, passing through distribution centers, and serving a fixed set of customers with deterministic demand. Lead times are considered between facilities. The objective is to select among the set of candidate distribution centers and design their capacity in order to minimize the investment cost and the expected operational cost of satisfying the customers demand. We develop a multi-period formulation where the first-stage variables correspond to the selection of distribution centers and their capacities; the recourse variables that are selected in the different time periods correspond to the inventory level at each distribution center, the amounts transported from production facilities to distribution centers, the amounts transported from distribution centers to customers, and penalties for unsatisfied demand. Simulation results show the economic advantages of the stochastic programming approach over the design based on deterministic supply. Furthermore, the periodic review of inventory is found to be well suited for the design stage of supply chains.

From Newton to Shannon and Back Again: Information Mechanical Thermodynamics Characterization of Resilience at the Cold Food Storage Node of the US Food Supply Chain.

Richard Donovan

School of Engineering and School of information and Computer Science, University of California, Irvine, Irvine, CA

The US food web is a complex adaptive system coupling human activities to natural systems through a vast network encompassing the kitchen gardens of urban and rural families across the country to the agro-industrial farm factories of the Great Plains. It is an intricate web of technologies, energy and water infrastructures, policies, ecosystems, people and their ghosts (i.e. traditions.) The claim is that this network is fundamentally connected via the exchange of information at scales ranging from microbial communities supporting Southern CA winter vegetable production to global atmospheric rivers transporting water, nutrients and soil across the globe. To study this claim the existence of unique subsystems (e.g. the nationwide cold food transportation and storage network) that can be rationally characterized using emerging methods of complex systems analysis are proposed. Furthermore, these methods can be applied at the cold food storage nodes of the national food supply chain to create tools for characterizing the resilience of the overall US food web. The proposed methods and resulting tools will leverage emerging perspectives regarding Thermo-Information Mechanical (TIM) systems such as Correlation Powered Information Engines that capitalize on information flows that produce entropy gradients and associated entropic forces that can bind deeply inner connected networks in a manner that is analogous to Thermo-Newtonian Mechanical (TNM) systems. In this manner we hypothesize that the US food web can be characterized as a TIM system with dynamical properties analogous to TNM systems. As with TNM systems (e.g. acoustic wave transmission through multiphase materials), when perturbations are applied to a TIM system the resulting dynamics can reveal internal structures and can be used to characterize strength, ductility, and toughness/resilience of these systems. Furthermore, we propose that the impact of the global COVID-19 Pandemic represents a unique naturally occurring multi-spectral impulsive force to this vast supply chain that can reveal heretofore unknown internal structures and serve to characterize resilience of the complex US food web and similarly complex supply chains to generalized impulsive forces associated with all manner of natural disasters.

Design and Planning of Resilient Supply Chain.

Ana Barbosa-Póvoa

Engineering and Management, Instituto Superior Técnico, Lisbon, Portugal

Supply chains operate more and more over a global market, under constant changes caused by technological innovations, demand volatility and potential disruptions caused by unexpected natural causes or man-made disasters such earthquakes, fires or the current Covid-19 pandemic. All these events have a low probability of occurrence but when happening may cause a significant business impact. Supply Chain Management should then adopt strategies to improve their ability to respond rapidly and cost effectively to unpredictable changes. In order to do that, decision makers have to incorporate the concept of SC resilience when designing and planning such systems. The need of accounting for resilience, under the threat of foreseeable disruptions is however a challenge that still lacks quantitative decision support models to inform the involved decisions. Additionally, the combination of resilience with sustainability concerns should also be at stake, adding more complexity to the already complex problem.

On this set this talk focus on the design and planning of resilient supply chain systems aiming to provide some insights on how to incorporate resilience in such systems while also exploring green concerns. Indicators are discussed to assess resilience and a mathematical model to design resilience supply chain is presented.

The solution of some supply chain case studies under diverse disruption events is discussed helping to conclude on the main supply chain characteristics that should be explored to potentiate resilient supply chain.

Resilience of Interconnected Networks in a Water-Energy Nexus.

Spyridon D. Tsolas *and M. M. Faruque Hasan*
Artie McFerrin Department of Chemical Engineering, Texas A&M University, College Station, TX

A water-energy nexus (WEN) consists of two interconnected water and energy networks where the energy sources depend on the water network, and vice versa. Disruptions in one network affect both networks. For example, temporal water shortages can cause capacity reduction or even shutdown of power stations. Optimizing WEN solely based on minimal costs may not be fully resilient to such disruptions. A fully resilient design, on the other hand, is capable of meeting the water and energy demands under any disruptions, but may require excess capacities and costly overdesigns. Therefore, it is important to characterize different levels of resilience of interconnected networks and strike a balance between the desired resilience, demand satisfaction, and cost. In terms of methodology, existing graph-theoretical metrics can quantify resilience of a single network based on the network topologies using the adjacency of the graph nodes, edges and their weights. For interconnected networks, however, we cannot rely on network topology attributes alone, and need to also consider design and operational attributes. To address these challenges, we use 'minimum cost of resilience' (MCOR) to characterize the resilience of interconnected networks. MCOR is defined as the minimal additional investment, operating expenses and penalties that would allow a network to meet the demands under any disruption events. To obtain a resilient WEN design with MCOR, we formulate the problem as a mixed-integer linear program (MILP). The feasibility of the network is explicitly considered via a multi-scenario expansion for all potential disruption scenarios. Every disruption scenario corresponds to the failure of a single connection within the nexus. The degree of resilience is a decision variable assuming that the unsatisfied demands are met by external grids with penalties incurred for the additional external supply. From the results, we observe three regimes of resilience: (i) for low penalties, all demands are satisfied from external supplies without the need of a network; (ii) for moderate penalties, the optimal operation uses both WEN and external grids to meet the consumer demands; and (iii) for large penalties, it is more cost-effective to employ a fully resilient network with MCOR rather than depending on external supplies.

An Optimization Approach for Green Resilient Supply Chain.

João Pires Ribeiro[1] *and Ana Barbosa-Póvoa*[2]
(1)CEGIST, Lisbon, Portugal, (2)Engineering and Management, Instituto Superior Técnico, Lisbon, Portugal

COVID Pandemic showed the whole globe the dangers of running a non-resilient business. Companies have faced the same disruptive scenarios, however the consequences changed. For some, the changes to steady-state were too hard to bear and bankruptcy was the only option left. For some, their operation was able to cope with the aggression and withstand the negative period. Now, focus must be on how will companies adapt to the post-pandemic world and how can academics provide the best tools for more resilient systems, taking advantage of the opportunity to create a more sustainable Supply Chains.

Most disruptive scenarios, experienced in the pandemic and consequent lockdown, can be categorized in three types of disruptions. Supply: Some raw materials producers stop due to imposed stoppages (eg. Italy or China). Production: Factories are forced to stop due governmental impositions or an outbreak in the workforce, a scenario that happened almost worldwide. Transportation: Due to limitations in the free movement, although mainly

between countries, affected several companies. Even with products being assembled, there is no possible way to move products downstream.

Considering the objectives for the future and the constraints for companies, an optimization model is presented that accounts for the green objectives while maintaining a highly responsive SC ensuring economic sustainability.

The environmental quantification is implanted in the mathematical model by considering CO2 emissions as costs, linked with the European Union Emissions Trading Scheme. With this, CO2 emissions are associated with a direct cost established by the economic trades, turning it a commodity.

As main conclusion it can be said that Closed-Loop SC allow for better resilient capabilities, coupling in a good tradeoff the green objective, economic return and the need for customer satisfaction.

SAFETY IN RESILIENCE

Engineering for Resilience

Ali Mosleh
University of California, Los Angeles

This Talk Will Offer a Perspective on Principles of “Engineering for Resilience” in the Context of Complex Infrastructure Systems. Reflecting on Challenges Highlighted By Past Events Impacting the Lifeline Systems, and the Projected Complexities of Emerging Infrastructure Systems, the Talk Will Provide an Assessment of the Merits and Limitations of Current Approaches to Modeling and Analysis of Infrastructure Resilience and Offer Possible Pathways to Leveraging Analytical and Technical Means to Ensure Higher Levels of Resilience of Complex Interconnected Infrastructure Systems

Optimizing Efficiency-Robustness Trade-Offs in Complex Systems for Safety and Sustainability.

Venkat Venkatasubramanian
Department of Chemical Engineering, Columbia University, New York, NY

Recent systemic failures, such as the COVID-19 pandemic and Boeing Max 8 disaster, continue to remind us of the fragility of complex sociotechnical systems. Although these failures occurred in different domains, there are common failure mechanisms that often underlie such events. Hence, it is important to study these disasters from a unifying systems engineering perspective so that one can understand the commonalities as well as the differences to prevent or mitigate future events. We have developed a new conceptual framework that systematically identifies the failure mechanisms in a sociotechnical system, across different domains. Our analysis includes multiple levels of a system, both social and technical, to identify the potential failure modes of equipment, humans, policies and institutions. In this talk, I will present an overview of this conceptual framework and discuss the trade-offs we need to make among efficiency, resilience, and cost for the long-term sustainability of such systems.

Survivability-Aware Resilient Supply Chains.

Spyridon D. Tsolas, Akshay Punnoose, and ***M. M. Faruque Hasan***
Artie McFerrin Department of Chemical Engineering, Texas A&M University, College Station, TX

The survivability is defined as the maximum duration for which a network is able to meet the customer demands while maintaining at least a specified (positive/negative) cash flow when facing a continued disruption over a sustained time period. Pandemic-induced lockdowns and restrictions on commercial activities, disaster (e.g., hurricane, flood), war, conflicts and sanctions are examples of continued disruptions, which depending on the duration, can severely impact the global profitability as well as the local survivability of a supply chain that spans across multiple regions, countries or continents. Here, we address the survivability of both independent and interdependent networks during continued disruptions. It is important to examine the survivability of regional supply chains when they are cut off from external supplies. For a given network with known demands, both internal and external supplies, and installed generation, transportation and storage capacities, we assess its survivability in the face of continued disruptions and identify the most critical nodes and arcs in the network. For the grassroot design of new multi-regional supply chains, we apply a mathematical programming-based formulation to maximize the global profitability while ensuring local survivability. For redesigning supply chains, we investigate the optimal retrofitting strategies to improve the survivability under a budget constraint. Higher budget limitations lead to lower total network cost but also low resulting survivability. On the contrary, higher penalization of internal demand violations leads to increased infrastructure provisions and increased survivability.

PANEL: TRANSFORMATION TOWARDS RESILIENCE- EMERGING TRENDS

Outperforming Organizations Are Resilient and Agile.

Nicholas Bahr Sr.

DuPont Sustainable Solutions, Abu Dhabi, United Arab Emirates

Surviving a crisis requires adaptability and agility – attributes that businesses cannot develop on the spur of the moment, but that need to be built into their ecosystem. Organizations that outperform others in difficult times do more than just prepare emergency response plans, they anticipate future vulnerabilities and design flexibility and responsiveness into their management systems. COVID-19 is not the first crisis the world has faced, and it won't be the last. Revolutions, wars, the Great Depression, the OPEC oil price shock, the Dot-com bubble, and the financial crisis of 2008 have all quickly sorted winners from losers. Considering that the average tenure of companies on Standard & Poor's 500 has slipped from 37 years in 1980 to a projected 12 years by 2027, 75% of companies currently listed on the S&P 500 are likely to have disappeared in seven years' time. Nicholas Bahr's talk with focus on this subject and define the three key building blocks for resilience and briefly cite some successes.

Effective Energy Efficiency Solutions for a Sustainable Future.

Johan Ulloa

Constellation, Baltimore, MD

While budget cuts and finite resources can often act as hurdles to enacting energy efficiency improvements, these developments can produce long-term and unmatched benefits that significantly reduce overall energy expenses and improve the energy-related equipment, infrastructure, and systems at various facilities. Constellation, one of the leading energy providers in the country, helps facilities achieve their sustainability goals, develop energy resiliency, and manage their costs and capital needs.

Johan Ulloa, Distributed Energy and Energy Efficiency Manager at Constellation can discuss case studies that highlight how the right energy efficiency solutions can reduce overall energy expenses and improve infrastructure and management systems. Johan is well-positioned to discuss and provide guidance on how to best address energy challenges while smartly integrating sustainable energy upgrades.

Additionally, as decentralized forms of energy production such as solar, cogeneration, fuel cells and batteries become more prevalent and integral to power markets, customers are increasingly interested in exploring and incorporating these options into their energy mix. The adoption of distributed energy resources requires a better understanding of how to best incorporate these renewable energy options in way that meets sustainability benchmarks, business objectives and customer preferences. As distributed generation options continue to draw interest from a wide range of residential and business customers, it is also critical to examine how exactly these developments will influence the future of the traditional energy grid.

With experience managing large distributed energy projects, commercial transactions, and partnerships across the country, Johan can also speak to distributed energy trends that are causing industry-wide disruption. Johan's expertise is providing customers with guidance on how to integrate energy upgrades that benefit the environment while saving long-term costs. He can also provide insight on how these innovative solutions offered by leading energy providers like Constellation are addressing the changes in supply and

SHORT PRESENTATIONS

Building Resilience through Innovating Waste Management.

Andrea Cecchin
North Dakota State University, Fargo, ND, USA

A growing number of studies and technological developments are opening new opportunities for recycling wastes (e.g. plastics, glass, tires, fibers) as construction materials. As several studies have pointed out, poor communities are disproportionately affected by natural hazards (e.g. earthquakes, flooding, landslides) and the low quality of housing is one of the main causes of such high level of vulnerability. Therefore, having access to better construction materials can positively impact the quality of housing and reduce, to some extent, the community's vulnerability to natural disasters. To seize this opportunity on is also essential to design and develop policies and waste management schemes able to address multiple instances coming from all stakeholders involved, in particular policymakers, industry and local communities. This transdisciplinary research project identifies a new governance model to introduce a specific urban waste - scrap tires - as a construction material to improve the resilience of informal housing and settlements to natural disasters. Such a governance system - built on the adaptive governance framework - was designed and tested on a couple of real-world experiments involving low-income communities in Ecuador by employing a community-based participatory research approach. National policymakers, tire producers and importers, waste management companies, NGOs, academia and local communities worked together to carry out a post-disaster reconstruction project and a disaster risk reduction initiative. One of the results of the study was a new national waste policy proposal and waste management scheme aimed at integrating social sustainability into waste management. Overall, the research attempted to increase the sustainability and resilience of: (1) the national waste management system, by reducing the environmental impact of waste generation; (2) industry, by diversifying the viable recycling options to improve the waste management of end-of-life products and creating new opportunities for CSR programs; and (3) local communities, by improving the resilience of housing and urban settlements to natural disasters. This action research demonstrated that waste management strategies and policies can become an opportunity to address relevant social sustainability issues, in particular in emerging economies or low-income communities.

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