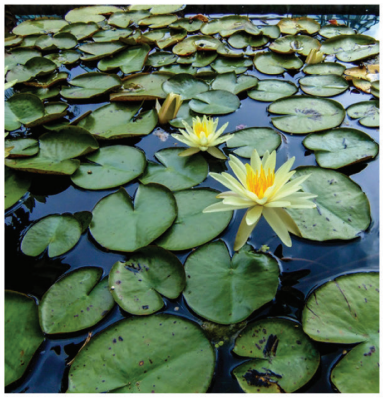
ESS:M&R3 Symposium Program

February 18 - 19, 2017

ENGINEERING SOLUTIONS FOR SUSTAINABILITY: MATERIALS AND RESOURCES 3

Toward a Circular Economy



Colorado Convention Center 700 14th Street Denver, CO 80202

ACKNOWLEDGEMENTS

Symposium Chairmen

John Craynon, Ph.D., Senior Mining Engineer, Export-Import Bank of the United States and Chair of the SME Sustainable Development Committee

Brajendra Mishra, Ph.D., Professor and Director, Center for Resource Recovery and Recycling, Worcester Polytechnic Institute, 2011 AIME President and 2006 TMS President

Organizing Committee

Lucy Alexander, B.S. Chemical Engineering, MAIChE, IfS

Dayan Anderson, Senior Mining Engineer, Micon International, Ltd.

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Jonathan Motherwell, P.E., Jonathan T. Motherwell and Associates, LLC

Carol Russell, Environmental Protection Agency (retired)

Emily Sarver, Ph.D., Assistant Professor, Mining and Minerals Engineering, Virginia Polytechnic Institute and State University

Deborah J. Shields, Ph.D., Professor, Colorado State University and Politecnico di Torino

Nikhil Trivedi, Ph.D., IDEKIN International, 2016 AIME President and 2010 SME President

LOGISTICS

Conference Location Information

- The event is at the Colorado Convention Center located at 700 14th St, Denver, CO 80202.
- Meals will be in Room 702.
- Talks will be in Room 709.
- The poster session and networking reception will be in Rooms 705-707.

Please Take Note

- Due to the high altitude and arid climate of Denver, please be sure to drink plenty of water and get plenty of rest to help avoid altitude sickness.
- Attendees of the Symposium will receive a digital copy of the Proceedings by mail in August. Please ensure the address on our roster at the event is the correct one to get this to you at that time. They will also be available for purchase by non-attendees at SME's Online Store (https://smemi.personifycloud.com/personifyebusiness/default.aspx?tabid=54).
- Presenters should have submitted their draft manuscript (or slides) and copyright assignment at www.essmandr3.org.
- Poster presenters are also invited to submit a one-page extended abstract of their talk. Hard copies of guidelines and the Copyright Assignment form will be available at the event.
- Each attendee can receive a PDF Certificate of attendance with 16 Professional Development Hours (PDH). Sign up for $25 at registration (self-tracked/printed at kiosks throughout the conference or afterward online).
- For details about past or future Engineering Solutions for Sustainability: Materials and Resources events, see http://aimehq.org/programs/collaborative-efforts/sustainability.

SPONSORS

CR3 - NSF Center for Resource Recovery & Recycling

The Center for Resource Recovery and Recycling (CR^3) is committed to being the premier cooperative research center focused on sustainable stewardship of the earth's resources.

Our focus is on helping industry address a pivotal societal need – the need to create a sustainable future. At CR^3 you will advance technologies that recover, recycle and reuse materials throughout the manufacturing process. These advancements will help your business reduce energy costs and increase profitability, while protecting our natural resources.

The Center for Resource Recovery and Recycling is a multi-university, member-driven collaborative. Four of the world's leading universities in materials engineering steer CR^3, ensuring that it is making a difference globally.

Worcester Polytechnic Institute (WPI) is one of the best technological universities in New England and one of the nation's earliest technological universities. World renowned faculty lead students and industry partners in a number of cutting-edge research areas, resulting in breakthroughs and innovations in such fields as materials processing, biotechnology, fuel cells, information security, and nanotechnology. Colorado School of Mines (CSM) is a public teaching and research university devoted to engineering and applied science, with special emphasis on the development and stewardship of the earth's natural resources. CSM is a leading educational institution in process metallurgy and rare earth metal. KU Leuven is one of the leading European universities where internationally acclaimed research, high-quality education, and societal outreach meet. Resource efficiency is a flagship research area with focus on critical metal recycling, use of secondary resources into building materials, enhanced landfill mining and policy research. The University of Tokyo is recognized globally as a leading research university, and a true partner in CR3's quest to provide for a more sustainable future. Established in 1877 as the first national university in Japan, U Tokyo has gained worldwide recognition for the work it is doing to bring research and academia together, specifically in the area of addressing depletion of our natural resources and damage to the environment.

CSM - Colorado School of Mines

The Humanitarian Engineering program is training the next generation of engineers to use engineering to promote corporate social responsibility and the social license to operate. At CSM we are breaking new ground by bringing engineers and social scientists together to create the first CSR curriculum specifically designed for multiple disciplines, from petroleum and mining engineering to environmental engineering. Our faculty collaborate with programs and centers across campus, including a ConocoPhillips Center for a Sustainable WE2ST student research project on community acceptance of unconventional energy in Colorado's Front Range. Our students learn how to *create shared value for companies and communities* through real world engineering projects with CSM faculty, alumni, companies, graduate students and communities. In one project, students partnered with an international mining company to foster more sustainable artisanal mining practices in Latin America. Training in CSR propels our graduates to careers in the world's leading energy and mining companies. The strength of our program rests on our academic and corporate partners and sponsors, ranging from the National Science Foundation to the Shultz Family Fund. We invite collaborations on student design projects, internships, class lectures, financial support and more.

PLANNING PARTNERS

AIME - American Institute of Mining, Metallurgical and Petroleum Engineers

One of 5 engineering Founder Societies, AIME was founded in 1871 by 22 mining engineers in Wilkes-Barre, Pennsylvania. AIME was one of the first national engineering societies established in the United States, and, along with ASCE (civil), ASME (mechanical), IEEE (electrical), and AIChE (chemical), it is known as an Engineering Founder Society. Together, the engineering Founder Societies form the United Engineering Foundation (UEF).

AIME has 4 Member Societies representing over 200,000 professionals worldwide, including: SME (Society for Mining, Metallurgy, and Exploration), TMS (The Minerals, Metals, and Materials Society), AIST (Association for Iron & Steel Technology), SPE (Society of Petroleum Engineers).

AIME's Mission is to support its Member Societies. We fulfill this mission by exercising fiscal responsibility, distributing funds, facilitating interaction with the relevant scientific and engineering community, encouraging collaboration among the Member Societies and by honoring the legacy and traditions of AIME. Our vision is to honor our legacy as a valued partner with our Member Societies.

SME - Society for Mining, Metallurgy & Exploration

The Society for Mining, Metallurgy & Exploration Inc. (SME) is a professional society (nonprofit 501(c)(3) corporation) whose more than 15,000 membership represents all professionals serving the minerals industry in more than 100 countries. SME members include engineers, geologists, metallurgists, educators, students and researchers. SME advances the worldwide mining and underground construction community through information exchange and professional development. SME's staff is located in Englewood, Colorado.

TMS - The Minerals, Metals and Materials Society

Headquartered in the United States but international in both its membership and activities, The Minerals, Metals & Materials Society (TMS) is a rare professional organization that encompasses the entire range of materials and engineering, from minerals processing and primary metals production to basic research and the advanced applications of materials.

In support of its Mission Statement and Strategic Plan, the society provides forums for the exchange of information; promotes technology transfer; promotes the education and development of current and future professionals; represents the profession in the accreditation of educational programs and in the registration of professional engineers (a U.S.-grounded activity); encourages professionalism, ethical behavior, and concern for the environment; and stimulates a worldwide sense of unity in the profession.

To reflect TMS' commitment to ethical professional behavior, the Society has endorsed the National Society of Professional Engineers (NSPE) Code of Ethics, which sets the standard for our members.

AIST - Association of Iron and Steel Technology

The Association for Iron & Steel Technology (AIST) is a non-profit organization with 17,500 members from more than 70 countries. With 30 Technology Committees and 22 Local Members Chapters, AIST represents an incomparable network of steel industry knowledge and expertise.

Our mission is to advance the technical development, production, processing and application of iron and steel.

The vision of AIST is to be a global leader in networking, education and sustainability programs for advancing iron and steel technology.

SPE - Society of Petroleum Engineers

SPE is the largest individual-member organization serving managers, engineers, scientists and other professionals worldwide in the upstream segment of the oil and gas industry.

In 1957, the organization was officially founded as SPE, a constituent society of the American Institute of Mining, Metallurgical and Petroleum Engineers (AIME). SPE became a separately incorporated organization in 1985.

The SPE Board of Directors is the policy-making and governing body of SPE. SPE board committees oversee many of SPE's administrative and operating responsibilities. The board retains final authority on all SPE matters, including any actions the board committees may take.

More than 168,000 members in 144 countries participate in 207 sections and 368 student chapters. SPE's membership includes more than 68,000 student members.

SPE's mission is to collect, disseminate, and exchange technical knowledge concerning the exploration development and production of oil and gas resources, and related technologies for the public benefit; and to provide opportunities for professionals to enhance their technical and professional competence.

Our vision is to enable the global oil and gas E&P industry to share technical knowledge needed to meet the world's energy needs in a safe and environmentally responsible manner.

ASCE - American Society of Civil Engineers

The American Society of Civil Engineers represents more than 150,000 members of the civil engineering profession in 177 countries. Founded in 1852, ASCE is the nation's oldest engineering society.

ASCE stands at the forefront of a profession that plans, designs, constructs, and operates society's economic and social engine – the built environment – while protecting and restoring the natural environment.

Through the expertise of its active membership, ASCE is a leading provider of technical and professional conferences and continuing education, the world's largest publisher of civil engineering content, and an authoritative source for codes and standards that protect the public.

The Society advances civil engineering technical specialties through nine dynamic Institutes and leads with its many professional- and public-focused programs.

AIChE - American Institute of Chemical Engineers

AIChE is the world's leading organization for chemical engineering professionals, with more than 50,000 members from over 100 countries. AIChE has the breadth of resources and expertise you need whether you are in core process industries or emerging areas, such as translational medicine.

As a member, you can access information on recognized and promising chemical engineering processes and methods. Connect with a global network of intelligent, resourceful colleagues and their shared wisdom. Find learning opportunities from recognized authorities. Move forward professionally with AIChE and enrich the world we live in.

PROMOTIONAL PARTNERS

AAES - American Association of Engineering Societies

The American Association of Engineering Societies (AAES) is a multidisciplinary organization of engineering societies dedicated to advancing the knowledge, understanding, and practice of engineering. AAES member societies represent the mainstream of U.S. engineering — engineers in industry, government, and academia.

The history of AAES starts in 1979 in New York. Today its office and staff are located in Reston, VA. AAES is a nonprofit organization that operates within a vision, mission, and engineer's preamble.

AEG - Association of Environmental & Engineering Geologists

In June 1957, 13 local engineering geologists met in Sacramento, CA, to discuss the need for organization of a society in the specific field of engineering geology. In 1964, AEG was accepted as a member society of the American Geological Institute.

On September 22, 2005, the Past Presidents unanimously petitioned the Executive Council and Board of Directors to have the Association's name changed to the Association of Environmental & Engineering Geologists. The Association has been serving members of both the environmental and engineering geology for a number of years, and the name change serves to provide formal recognition of this support.

Our membership is presently located in 15 countries. In the United States, AEG's membership comes from each of the 50 states, the District of Columbia and Puerto Rico. The membership of the Association of Environmental & Engineering Geologists continues to grow, as the field of Engineering Geology and Environmental Geology gains greater recognition and the need for our organization becomes more apparent. Ever-increasing interest is being shown by geologists from countries around the world as the importance of applied geology, in both the development and restoration of the earth, gains international recognition.

CGS - The Canadian Geotechnical Society

The Canadian Geotechnical Society is the leading organization for geotechnical engineering and related geoscience in Canada. The CGS is dedicated to the advancement of knowledge and the creation of opportunities to exchange information among individuals from academia (both faculty and students), consulting, government, industry, contractors, and various providers of geotechnical-related products and services.

With approximately 1,400 members across Canada and around the world, the CGS is a driving force in the geotechnical profession by providing opportunities for members to upgrade their skills, to present research and case histories, and to connect with other geotechnical professionals locally, nationally, and internationally.

EEGD - The Environmental & Engineering Geology Division

The Environmental & Engineering Geology of GSA is the oldest engineering geology organization in the United States. EEGD is proud to have 3100+ members as of December 2015. We are the only GSA division to have our own publications series and we support state of the art presentations at our meetings. Since engineering geologists use knowledge within all fields of geology in their application of our science to benefit society, we are truly the interdisciplinary division.

IAEG - International Association for Engineering Geology and the Environment

Engineering Geology is the science devoted to the investigation, study and solution of the engineering and environmental problems which may arise as the result of the interaction between geology and the works and activities of man as well as to the prediction and of the development of measures for prevention or remediation of geological hazards. *(IAEG statutes, 1992)*

The International Association for Engineering Geology and the Environment (IAEG) was founded in 1964 and is affiliated to the International Union of Geological Sciences (IUGS). IAEG is a worldwide scientific society with more than 5,200 members and 59 national groups. The official languages of the IAEG are English and French.

The aims of the International Association for Engineering Geology and the Environment are: to promote and encourage the advancement of Engineering Geology through technological activities and research, to improve teaching and training in Engineering Geology, and to collect, evaluate and disseminate the results of engineering geological activities on a worldwide basis.

PROGRAM - DAY 1

7:00-8:00a Registration/Breakfast

8:00-8:30a WELCOMES AND CONVENING

- **Nikhil Trivedi**, 2016 AIME President
- **Brajendra Mishra,** Worcester Polytechnic Institute (WPI), and **John Craynon**, Export Import Bank of the United States, ESS:M&R3 Co-Chairs

8:30-10:30a SESSION 1 – SUSTAINABLE DEVELOPMENT AND THE CIRCULAR ECONOMY

Goal: Make "circular economy" a part of everyone's working vocabulary. Develop a foundation and common terms to help all see the big picture and how the smaller pieces fit into the puzzle.

Moderator: Jessica Kogel, National Institute for Occupational Safety and Health (NIOSH)

- ***Maja Johannessen***, ***Ellen MacArthur Foundation:*** What is the circular economy?
- ***Florian Kongoli, Flogen:*** Role of engineering sciences on sustainable solutions toward a circular economy
- ***Diran Apelian, WPI:*** Circular economy – A pathway to resource recovery and recycling
- ***Carol Russell, EPA (retired) and Deborah Shields, Colorado State University (CSU):*** International challenges in a global circular economy

10:30-10:45a Break

10:45a-12:15p SESSION 2 – CASE STUDIES: CHALLENGES & SUCCESSFUL BUSINESS MODELS

Goal: Bring philosophical concepts to practical levels. Learn from firms which have been trying to implement these concepts and hear how it has gone and how to implement best practices.

Moderator: Jonathan Motherwell, JTM and Associates, LLC

- ***Jill Cooper Anadarko:*** How Anadarko incorporates the circular economy into its business model
- ***Bob Bassett, Holland and Hart:*** The Model Mine Development Agreement (MMDA) and sustainability in mining
- ***Rick Wagner, Chevron Phillips:*** Fueling the sustainability journey – Top 3 elements for success

12:15 -1:15p Lunch

1:15-2:45p SESSION 3 -- Educating the Future Engineer

Goal: Discuss challenges that need to be addressed by academia to better prepare future engineers to more effectively promote and implement the benefits of a circular economy through incorporation of appropriate curricula in addition to the more standard, historical technical focus areas.

Moderator: Deborah Shields, CSU

- ***Jeff Fergus, Auburn (co-authors Brian K. Via, M. Soledad Peresin, Nanette E. Chadwick):*** Introducing the circular economy to undergraduate students
- ***Brajendra Mishra, WPI:*** Improvement in resource productivity through corrosion engineering education
- ***Catherine Mulligan, Concordia:*** An interdisciplinary research and training program in sustainability - CIWESS
- ***Jessica Smith, Colorado School of Mines (CSM) (co-authors Nicole Smith, Carrie McClelland, Linda Battalora):*** Where are the people? Including social sustainability in the circular economy

2:45-3:00p Break

3:00-4:30p SESSION 4 – Water

Goal: Water is at the core of so many processes along a product or asset life cycle, so it is important that everyone understand these resulting challenges, especially given the emotional and local/regional factors that are integrated as part of this important, strategic topic.

Moderator: Carol Russell, EPA (retired)

- ***Will Sarni, Water Foundry:*** Innovation and the Energy - Water - Food Nexus
- ***Eleanor Allen, Water For People:*** How the global sustainable development goals can help promote CSR
- ***Stephen Northey, Monash University (co-authors Maureen Upton, Patrick Williamson, David Hoekstra):*** Water footprinting - Communicating mine site water performance in a circular economy
- ***Joe Lima, Schlumberger:*** Incorporating sustainability practices to reduce water in upstream oil and gas development

4:30-5:00p REVIEW OF DAY 1

- **Brajendra Mishra,** Worcester Polytechnic Institute (WPI), and
  John Craynon, Export Import Bank of the United States, ESS:M&R3 Co-Chairs

5:00-7:00p SESSION 5 – POSTER SESSION AND NETWORKING RECEPTION

- ***Sumedh Gostu, WPI (co-author Brajendra Mishra):*** Investigation of carbon-based reductant, low-temperature process for conversion of hematite in red-mud to magnetite
- ***Mark Strauss, WPI:*** Recovery of rare earths from waste fluorescent lamps
- ***Sean Kelly:*** Auto-Al scrap material flow analysis with compositional projections
- ***Myungwon Jung, WPI:*** Recovery of vanadium from oil fly ash
- ***Mikaela DeRousseau, WPI:*** Battery disassembly in support of material reuse
- ***Hyunju Lee, WPI (co-author Brajendra Mishra):*** Recovery of valuable metals from flue dust and other fines from mechanical treatment of e-scrap
- ***Remya Narayanan, WPI (co-authors Nikolaos Kazantzis, Marion Emmert):*** Rare earth metals recovery from bauxite residue
- ***Christina Suarez, CSM:*** Greenhouse Gases, a Carbon-Constrained Regulatory Environment, and the Oil and Gas Industry: How Will We Maintain Our Social License to Operate?
- ***Rosalie O'Brien, CSM:*** Constructed Wetlands and Other Produced Water Treatment Technology Opinions from Stakeholders in Oil and Gas Impacted Communities
- ***Kekahu Aluli, CSM:*** Cedarville Rancheria Geothermal End Uses Challenge: Working with Indigenous Communities on Sustainable Development Solutions
- ***Micaela and Michelle Pedrazas Hinojosa, CSM:*** Technology, Training, and Capacity Building in Artisanal and Small-scale Gold Mining: Using Mobile Training Units to Promote Cleaner, Safer, and More Sustainable Livelihoods in Peru and Bolivia

PROGRAM - DAY 2

7:00-8:00a Registration/Breakfast

8:00-10:00a SESSION 6 –BUILDING BLOCKS FOR THE CIRCULAR ECONOMY

Goal: Understand critical facets of making a circular economy work.

Moderator: Roland Moreau, ExxonMobil (retired)

- ***Linda Battalora, CSM:*** Stakeholder Engagement: "Have you been to a wedding lately?"
- ***Atalay Atasu, Georgia Tech:*** 4 Obstacles on the Way to a Circular Economy
- ***Jeff Keaton, ASCE:*** Regulatory-ready Sustainability vs. Sustainability-ready Regulators?
- ***Flora Moon, Expressworks:*** Integration into a Company's Business Plan

10:00-10:15a Break

10:15-11:45a SESSION 7 – SYSTEM IMPLEMENTATION

Goal: Learn some concepts and expectations to be integrated in sustainable business.

Moderator: Jeff Keaton, ASCE

- ***Janet Peargin, Chevron:*** Do more with less – design for the triple bottom line for sustainable development and footprint optimization
- ***Tatiane Marin (co-author Jacopo Seccatore), University of São Paulo***: Economic viability of responsible small-scale mining
- ***Mark Caffarey, Umicore (co-authors Colton Bangs, Christina Meskers, Thierry Van Kerckhoven):*** Circular economy for electronics gold mine or race to the bottom
- ***Kimberly Martin, Arizona State University (co-authors Ranjiv Gupta, Hamed Khodadadi T.):*** Alternatives to deep foundations to enhance sustainability of infrastructure projects

11:45a-12:45p Lunch

12:45-3:15p SESSION 8 – ENVIRONMENTAL/WASTE

Goal: Discuss how environmental and waste management have evolved over recent time beyond the standard recycle/reuse mindset to require a more comprehensive understanding of the overarching processes associated with environmental protection and waste minimization/optimization.

Moderator: Jeff Fergus, Auburn University

- ***Nicole L. Villamizar, EPA Office of Resource Conservation & Recovery:*** U.S. EPA's efforts to advance sustainable materials management
- ***Eric Peterson, Idaho National Laboratory:*** Metals recovery and recycling
- ***Flora Moon, Expressworks (co-author Sophie Theys, Bureau Veritas):*** Waste as a useful circular economy indicator
- ***Emmanuel Atta-Obeng, West Virginia University (co-authors Benjamin E. Dawson-Andoh, Mohindar S. Seehra, Usha Geddam; Johannes Leisen, GA Institute of Technology :*** Characterization of green carbons produced by the hydrothermal carbonization of a biorefinery lignin waste-stream
- ***Sean Monkman, Carbon Cure (co-author Mark MacDonald):*** More sustainable concrete using waste cement industry CO2
- ***Sean Kelly, WPI (co-author Diran Apelian):*** Value creation through enabling technologies to up-cycle aluminum scrap

3:15-3:30p Break

3:30-5:00p SESSION 9 – FUTURE VISIONS FOR THE CIRCULAR ECONOMY

Goal: Interactive sharing on ESS:M&R3 learnings and engineering solutions to move us further toward a circular economy. Vision from the different stakeholder perspectives.

Moderator: Nikhil Trivedi, IDEKIN International

- ***Linda Battalora, CSM:*** Hydrocarbon development and the sustainability lifecycle: What is the role of the Citizen Engineer?
- ***Lucy Alexander (author Dale Keairns), AIChE:*** The Food-Energy-Water Nexus and a Circular Economy
- ***Andrew Mangan, United States Business Council for Sustainable Development:*** A rapidly expanding cloud-based industrial material reuse platform
- ***Robert Dowling, rePurpose:*** Towards a sustainable future - Opportunities for impact in an already circular economy

5:00-5:30p CONFERENCE WRAP-UP AND FUTURE PLANS FOR ESS:M&R

Goal: Develop Top 10 Takeaways

- **Brajendra Mishra,** Worcester Polytechnic Institute (WPI), and
  John Craynon, Export Import Bank of the United States, ESS:M&R3 Co-Chairs
- **Nikhil Trivedi**, 2016 AIME President

WELCOME/CONVENING

Nikhil Trivedi, IDEKIN International

Nikhil Trivedi has 35 years of business experience---in research and development, engineering, operations, administration and general management and consulting. He has served as vice president of research and development and chief technology officer of Pfizer Minerals Inc. and Minerals Technologies, Inc. from 1987 to 2001. Additionally, between 1994 and 2001 he established and built up a powerful technical group in Finland to support the company's European businesses.

Following his retirement in 2002 from Minerals Technologies Inc., Nikhil established IDEKIN INTERNATIONAL, a firm specializing in developing technology transfer opportunities and providing optimizations for chemical and mineral processes. His clients include corporations in the chemical process industries and mining industry worldwide.

Nik graduated with a Bachelor of Science degree in Chemistry from Bombay University and earned a Master of Science in Metallurgical Engineering from University of Nevada. His Ph. D. degree in Chemical Engineering is from University of Minnesota. University of Nevada awarded him Outstanding Alumni Award in 1995.

Nikhil has been an active member of The Society for Mining, Metallurgy and Exploration Inc (SME), served twice on its Board of Directors and was elected President of SME in 2010. He has also served on the Board of Directors of Industrial Minerals Association of Europe (1991-2001), Calcium Carbonate Association of Europe (1993-2001) United Way of the Greater Lehigh Valley (2001), and Easton Hospital's Valley Health Foundation (1999-2002). He is an Honorary member of AIME, Distinguished member of SME and a recipient of AIME's Hal William Hardinge Award.

Nikhil is 2016 President of American Institute of Mining, Metallurgical and Petroleum Engineers (AIME).

Brajendra Mishra, WPI

Dr. Mishra is the Kenneth G. Merriam Distinguished Professor of Mechanical Engineering and Director of the Metal Processing Institute at the Worcester Polytechnic Institute [WPI]. Dr. Mishra is the Director of the National Science Foundation's Industry/University Collaborative Research Center on Resource Recovery & Recycling – the first National Center of its kind. Brajendra received his Bachelor of Technology [1981] degree in Metallurgical Engineering from the Indian Institute of Technology in Kharagpur, India and his M.S. [1983] and Ph.D. [1986] in Materials Science from the University of Minnesota in Minneapolis. Prior to joining WPI, Prof. Mishra was a Professor of Corrosion and Physico-chemical Processing in Metallurgical & Materials Engineering at the Colorado School of Mines [CSM]. Dr. Mishra served as a Distinguished Chair Professor of Chemical Engineering at the Petroleum Institute in Abu Dhabi for six months. Dr. Mishra has authored over 500 technical publications in refereed journals and conference proceedings. He holds six patents and has authored/edited 19 books. He is a Fellow of ASM (2001) and TMS (2016). Mishra received the Distinguished Service Award from the Minerals Metals & Materials Society (2010) and the highest award of Honorary Membership form the Indian Institute of Metals (2008). Brajendra served as the 2006 President of The Mineral, Metals & Materials Society (TMS) of AIME and the 2011 President of American Institute of Mining, Metallurgical & Petroleum Engineers. Dr. Mishra received the Presidential Citation of AIME in 2015. Brajendra believes that an academic institution is for the education, growth and nurturing of students – both undergraduates and graduates. Student involvement in research activities is the part of education that allows them to be in concert with the state-of-the art in their field of profession.

John Craynon, Export Import Bank of the United States

Dr. John R. Craynon, P.E. has been Senior Mining Engineer in the Engineering and Environment Division of the Export-Import Bank of the United States since April 2016. In this role he provides technical expertise for risk management of mining and related projects in the Bank's portfolio. Previously, he was Director of Environmental Programs and Project Director for the Appalachian Research Initiative for Environmental Science at the Virginia Center for Coal and Energy Research at Virginia Tech, from March 2011 until April 2016. In addition, Dr. Craynon is the Principal of CWP, a consulting firm, based in Shawsville, Virginia. His government career prior to joining academia, which spanned nearly 28 years, focused on mining and the environment and the technical, legal, and public policy issues related to mining. His work related to diverse topics such as coal mining, mine waste management, cleanup of contaminated sites, coal combustion byproducts, underground mine mapping, acid mine drainage, subsidence, hydrology, stream restoration, reforestation, sustainable reclamation and invasive species issues. His research program and consulting interests also include stakeholder involvement, resource and market characterization and the analysis of regulatory and legal frameworks for energy and minerals development.

Dr. Craynon has bachelor, masters and doctorate degrees in Mining and Minerals Engineering from Virginia Tech and has a graduate certificate in Natural Resources and a Professional Certificate in International Sustainability Consulting also from Virginia Tech. He is an active member of a number of professional societies and organizations. Dr. Craynon was a member of the Committee on Geological and Geotechnical Engineering at the National Academies, has served as Chair of the Society of Mining, Metallurgy and Exploration's Sustainable Development committee and has served on various technical and organizing committees for national and international conferences. He has authored and edited numerous scientific and government publications during his career.

SESSIONS

(Listed in order of presentation)

SESSION 1 – SUSTAINABLE DEVELOPMENT AND THE CIRCULAR ECONOMY

Moderator: Jessica Kogel, National Institute for Occupational Safety and Health (NIOSH)

Jessica Kogel is NIOSH Associate Director for Mining. In this role, Dr. Kogel leads the development and implementation of a dynamic research program focused on ensuring the health and safety of mine workers. She also works to ensure the program continues to have the resources needed to carry out its responsibilities of conducting a multi-faceted and impactful research agenda. Dr. Kogel brings with her over 25 years of experience and has held a number of senior positions in the mining industry. Prior to joining NIOSH, she was the Senior Manager for Mining and Geology at Imerys S.A., a French multinational company which specializes in the production and processing of industrial minerals. In addition to serving on the NORA Mining Sector Council, Dr. Kogel serves on the editorial board of the Mineral and Metallurgical Processing Journal. She is the author of numerous articles in minerals research. She holds four patents in the field of minerals geology.

She has been actively involved in professional organizations, serving as president of the Society of Mining, Metallurgy and Exploration (SME) in 2013 and continues to serve on the Board of Trustees of the SME Foundation. She is also the Vice-Chairman of the Board of the National Mining Hall of Fame and Museum. Dr. Kogel received a Bachelor of Arts degree in Earth Science from the University of California at Berkeley, a Master of Science degree in Geology from Indiana University in Bloomington, Indiana, and a Doctor of Philosophy degree in Geology also from Indiana University. (NIOSH)

Maja Johannessen, Ellen MacArthur Foundation

Maja joined the Ellen MacArthur Foundation in 2015 where she since has been managing the Circular Economy 100 (CE100) Governments and Cities network. Apart from being the point of contact for the members she focuses on supporting public bodies and business support organisations in driving circular economy initiatives. Maja is originally Danish and her previous background is in strategic energy planning.

The Ellen MacArthur Foundation was established in 2010 with the aim of accelerating the transition to the circular economy. Since its creation the charity has emerged as a global thought leader, establishing the circular economy on the agenda of decision makers across business, government and academia. The Foundation's work focuses on five interlinking areas: Education, Business & Government, Insight & Analysis, Systemic Initiatives and Communications.

What is the Circular Economy?

A circular economy is one that is restorative and regenerative by design, and which aims to keep products, components and materials at their highest utility and value at all times, distinguishing between technical and biological cycles. But what does that mean in practise? Supported by a range of practical case examples the Ellen MacArthur Foundation will in session share their perspective on what is to be understood when talking about the circular economy and why it is so interesting from a business perspective.

Florian Kongoli, Flogen

Dr. Florian Kongoli (BSc, MSc, PhD) is CEO of FLOGEN Technologies Inc., in USA and Canada and Chairman of FLOGEN STAR OUTREACH.

He has gained about 20 years of rich scientific and technology experience through numerous invited engagements in all continents. He has worked with more than 47 well-known chemical and metallurgical companies and several well-known universities around the world.

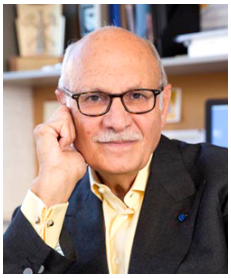
Dr. Kongoli has published 29 books and about 100 scientific articles in the last 5 years and has delivered in numerous countries about 130 plenary, keynote and invited presentations as well as articles, technical reports and research presentations. He has served in many leadership positions in national and international organizations. He is Editorial Board member of several International Journals. He has organized several major successful International Symposiums mainly dedicated to famous scientists.

Role of Engineering Sciences on Sustainable Solutions Toward a Circular Economy

Sustainable solutions for a circular economy should be a prerequisite criteria in evaluating the objectives and outcomes for any project in any field of life. For heavy multibillion dollar industries of metals and materials extraction these constitute major criteria since their impact in the world is much more pronounced.

Although the products of metals extraction industries are tremendously used in all aspects of modern life, confusion exists in the perception of the society about on their role on circular economy solutions. They are perceived by the public as polluters that impede the sustainable development.

This plenary paper will give an overview of various aspects of sustainability solutions for a circular economy. The important role of extraction technologies and that of engineers and scientists in this direction is shown. The need for better society recognitions of scientists and engineers is particularly emphasized.



Diran Apelian, WPI

Diran Apelian is the Founding Director of the Metal Processing Institute at WPI. He received his B.S. degree from Drexel University (1968) and his Sc.D. degree from MIT (1972). He is an elected member of the National Academy of Engineering (USA), and is the recipient of many honors and awards. He has over 700 publications to his credit, 12 books and many patents. He was past president of TMS (2008), and is Chairman of ASM Foundation Board (overseeing all material camps for students and teachers). Apelian is also Distinguished Visiting professor at University of California (Irvine) during the winter terms. In 2016 Apelian and three colleagues at WPI received the Gordon Prize in Innovations in Engineering Education. He is a Fellow of TMS, APMI and ASM.

Circular Economy – A Pathway to Resource Recovery and Recycling

The 21st Century is the Innovation era and the onset of the Fourth Industrial Revolution. This is the era when we will witness a major shift in the organization of global value chains. As Klaus Schwab, founder of the World Economic Forum has stated – *"This is the era in which virtual and physical systems of manufacturing will globally cooperate with each other in a flexible way".* In brief, this is the era of innovation. In this presentation, Prof. Apelian will highlight the context of the paradigm shifts we are witnessing, and propose pathways to move forward. The focus of the presentation is on the circular economy as the way to create value in our waste streams and develop sustainable business models in order for the solutions for sustainability be sustainable and feasible.

Carol Russell, EPA (retired) and Deborah Shields, Colorado State University

Carol Cox Russell recently retired from the U.S. Environmental Protection Agency where she focused on environmental effects of resource extraction, mining and oil and gas. In her thirty-year environmental career she has served as the co-chair of EPA's National Mining Team, Chief of the Water Quality Unit, Community Involvement Team Leader and Tribal Team Leader. In particular, she provided technical expertise to various EPA programs and international entities regarding resource extraction. Professionally she served as chair of the Sustainability Committee for the Society of Mining Engineers and on the World Federation of Engineers Sustainability Task Force. She has a B.S. in geology from Fort Lewis College, a B.S in biology from the University of Oregon, a master's degree in Environmental Policy and Management from the University of Denver and post-graduate work at Purdue and Colorado School of Mines. She also taught Sustainable Public Policy as an adjunct professor at the University of Denver.

Deborah J. Shields, Ph.D., is a Faculty Affiliate in the Dept. of Economics at Colorado State University and a Visiting Professor at the Polytechnic University of Turin, IT, in the Dept. of Land, Environment and Infrastructure Engineering. Her research foci are minerals in sustainable development, mineral policy, and integrated sustainability assessments. She has published over 100 peer reviewed journal articles, book chapters and conference papers. She previously worked for the US Government, first with the US Bureau of Mines and later with the U.S. Forest Service, Research and Development Division, where she directed the agency's mineral policy research program. She holds a M.Sc. in Mineral Economics from Colorado School of Mines and a Ph.D. in Natural Resources Management from Colorado State University.

International Challenges in a Global Circular Economy

We now live in the anthroposphere, a world where there is human presence in all the Earth's systems, a presence that is recognized as not always benign. Ecosystems have been degraded and there are valid concerns about the availability of adequate materials and resources to support the sustainable development of societies. Dealing with

these issues will necessitate increased resource efficiency, decreased waste, and avoidance of pollution, a decoupling of economic growth from negative environmental and social impacts. The circular economy concept provides a framework for addressing these problems with a systems perspective. However, since material and resource flows are also global, solutions will not be found without innovation coupled with international cooperation and collaboration. In this paper we will describe ongoing activities within the United Nations, the OECD, the European Union as teams of nations set out data needs and provide information to support progress toward a circular global economy.

SESSION 2 – CASE STUDIES: CHALLENGES & SUCCESSFUL BUSINESS MODELS

Moderator: Jonathan Motherwell, JTM and Associates, LLC

Jonathan Motherwell is a consulting engineer with more than 35 years of experience in the civil and environmental engineering fields. He has worked on numerous global projects related with the oil and gas, mining, power, and chemical manufacturing industries. Since the mid-1990s, Jonathan has focused on project siting, development and construction in a sustainable manner which integrates engineering, environmental and social issues. This includes satisfying the environmental and social performance standards of the International Finance Corporation (IFC), a member of the World Bank Group.

His projects / clients range from the Chad-Cameroon oil development (ExxonMobil), the Bolivia to Brazil gas pipeline (Consortium including Petrobras), the Jubilee deepwater development (Tullow Oil Ghana) to currently the Mozambique LNG development (Anadarko).

Jonathan received an MSCE degree from the University of Texas at Austin and a BSCE degree from the Missouri University of Science & Technology. He is a registered professional engineer in the State of Texas and an active member of the Society of Petroleum Engineers (SPE) and the American Society of Civil Engineers (ASCE).

Jill Cooper, Anadarko

Jill Cooper is a Corporate HSE Manager of Data Advocacy and Reporting for Anadarko Petroleum Corporation and works on global health, safety, and environmental matters for the company. She received her MBA in International Business at Thunderbird School of Global Management and continued on to receive her JD in Environmental Law at the University of Colorado Law School (1996). She has since then held several positions including the Senior Advisor to the Executive Director on environmental matters, Director of the Sustainability Division and Legal Administrator for the Air Pollution Control Division at the Colorado Department of Public Health & Environment. She also practiced environmental, natural resource and sustainability law as an Attorney with Faegre & Benson LLP. Ms. Cooper was the Group Lead in the divisional environmental program for Encana Oil & Gas Inc., which included air, water, waste, land, wildlife, and sustainability. She specializes in sustainability, environmental and regulatory legal, management as well as oil and natural gas.

How Anadarko Incorporates the Circular Economy into its Business Model

The oil and natural gas industry was designed around the "life-cycle" concept. Recognizing how this is an "organic" aspect to our business, can take some time and discussion. Anadarko will present on how "cradle to cradle" operations are possible in our industry, in fact, many companies are already accomplishing aspects of the circular economy. Jill Cooper, HSE Manager of Advocacy & Reporting, will present on how we consider air, water, land, and waste in the aspects in operational decisions, as well as our programs related to social matters.

Recognizing that their best spokespeople in the communities where they live and work are their employees, and as a proactive measure to help address emerging local and state legislative challenges, Anadarko Petroleum Corporation launched its Employee Ambassador and Advocate Program in January 2014. This effort was developed

to inform, empower and activate Anadarko's Colorado-based employees to engage with their neighbors and communities. Additionally, it aims to share information on a person-to-person platform about the company and the state's oil and natural gas industry, and how it responsibly finds, develops and produces the energy we all need. She will also provide an overview of Anadarko's Employee Ambassador and Advocate Program and discuss lessons learned. She will also offer information around the continued efforts utilizing legislative outreach, social media, sustainable relationship building and managed deployment efforts."

Bob Bassett, Holland and Hart

Robert Bassett is the Mining Team Leader at the law firm Holland & Hart, LLP. Bob provides clients with the practical solutions they need for financing and developing their mining projects. He represents clients in complex transactions involving coal, copper, gold, industrial minerals and uranium mines and companies in the U.S., Latin America and Africa. Bob is an adjunct professor at the University of Denver, College of Law in international mining law and policy (since 1997), and has been a lecturer at the Centre for Energy, Petroleum and Mineral Law and Policy at the University of Dundee, Scotland.

The Model Mine Development Agreement (MMDA) and Sustainability in Mining

The International Bar Association's Model Mine Development Agreement project surveyed 80+ agreements between private companies and governments for developing mines in jurisdictions that lacked mature mining codes. The 2011 result of the project, MMDA 1.0, provides an agenda for negotiating agreements after successful exploration, contains examples of provisions in use around the world, and is a tool for drafters of all mining agreements. MMDA 1.0 reflects practices of sustainability, transparency and social responsibility in the mining industry and foreshadows the inclusion of circular economy concepts.

Rick Wagner, Chevron Phillips

Rick Wagner has over 25 years of experience in the petrochemical industry for Chevron Phillips Chemical Company LP. Currently, he is Chevron Phillips Chemical's Sustainability Manager. Prior roles have been in polyethylene sales, application development, and product development and as a refinery chemist.

Most recently Rick has spoken at conferences examining the business case for Sustainability, stakeholder engagement and "a vision for plastics recovery".

He serves as the Team Leader for the Plastics Energy Recovery Team and a member of the Value Chain Outreach Committee, Plastics Packaging Team and Flexible Films Recycling group of the American Chemistry Council. He also represents the World Plastic Council in the Trash Free Seas Alliance.

As an Honored Service Member of the Society of Plastics Engineers, Rick was a founding member of the Flexible Packaging Division and has served as a leader in various International, Divisional and Local roles.

Rick received his Bachelors of Science in Chemistry from San Diego State University.

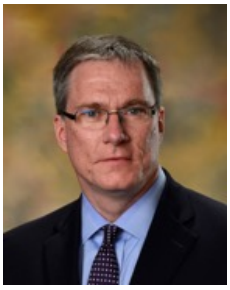
Fueling the Sustainability Journey – Top 3 Elements for Success

To drive sustainability into a company's everyday business practice, a company must have leadership commitment, a clear business strategy and transparent dialogue with stakeholders. With these basic building blocks, corporate culture can learn to recognize opportunities and then take action, increasing the momentum along its sustainability journey. This presentation follows Chevron Phillips Chemical Company's path through this model.

SESSION 3 -- EDUCATING THE FUTURE ENGINEER

Moderator: Deborah Shields, Colorado State University

Deborah J. Shields, Ph.D., is a Faculty Affiliate in the Dept. of Economics at Colorado State University and a Visiting Professor at the Polytechnic University of Turin, IT, in the Dept. of Land, Environment and Infrastructure Engineering. Her research foci are minerals in sustainable development, mineral policy, and integrated sustainability assessments. She has published over 100 peer reviewed journal articles, book chapters and conference papers. She previously worked for the US Government, first with the US Bureau of Mines and later with the U.S. Forest Service, Research and Development Division, where she directed the agency's mineral policy research program. She holds a M.Sc. in Mineral Economics from Colorado School of Mines and a Ph.D. in Natural Resources Management from Colorado State University.



Jeff Fergus, Auburn (co-authors Brian K. Via, M. Soledad Peresin, Nanette E. Chadwick):

Jeffrey W. Fergus is a professor of materials engineering and associate dean for program assessment and graduate studies in the Samuel Ginn College of Engineering at Auburn University. He has a B.S. in metallurgical engineering from the University of Illinois and a Ph.D. in materials science and engineering from the University of Pennsylvania. His research interests are in high temperature and electrochemical application of materials, including batteries, fuel cells, thermoelectric devices and gas turbine engines. He has developed or taught several sustainability related courses or undergraduate students.

Introducing the Circular Economy to Undergraduate Students

As available resources become limited and environmental regulations become more stringent, consideration of the circular economy becomes increasingly important in product design and manufacturing. Ideally, such sustainability-related topics would be integrated into existing curricula, but because of academic requirements, marketability and other constraints, alternate strategies are needed to reach different groups of students. In this presentation, different approaches for introducing students to the circular economy ranging from one-credit- hour courses to university-wide minors to interdisciplinary degree programs will be discussed.

Brajendra Mishra, WPI

Dr. Mishra is the Kenneth G. Merriam Distinguished Professor of Mechanical Engineering and Director of the Metal Processing Institute at the Worcester Polytechnic Institute [WPI]. Dr. Mishra is the Director of the National Science Foundation's Industry/University Collaborative Research Center on Resource Recovery & Recycling – the first National Center of its kind. Brajendra received his Bachelor of Technology [1981] degree in Metallurgical Engineering from the Indian Institute of Technology in Kharagpur, India and his M.S. [1983] and Ph.D. [1986] in Materials Science from the University of Minnesota in Minneapolis. Prior to joining WPI, Prof. Mishra was a Professor of Corrosion and Physico-chemical Processing in Metallurgical & Materials Engineering at the Colorado School of Mines [CSM]. Dr. Mishra served as a Distinguished Chair Professor of Chemical Engineering at the Petroleum Institute in Abu Dhabi for six months. Dr. Mishra has authored over 500 technical publications in refereed journals and conference proceedings. He holds six patents and has authored/edited 19 books. He is a Fellow of ASM (2001) and TMS (2016). Mishra received the Distinguished Service Award from the Minerals Metals & Materials Society (2010) and the highest award of Honorary Membership form the Indian Institute of Metals (2008). Brajendra served as the 2006 President of The Mineral, Metals & Materials Society (TMS) of AIME and the 2011 President of American Institute of Mining, Metallurgical & Petroleum Engineers. Dr. Mishra received the Presidential Citation of AIME in 2015. Brajendra believes that an academic institution is for the education, growth

and nurturing of students – both undergraduates and graduates. Student involvement in research activities is the part of education that allows them to be in concert with the state-of-the art in their field of profession.

Improvement in Resource Productivity by Life Extension through Corrosion Education

Materials are non-renewal resources that are created through an 'unnatural' process. Simple methods to extend the life of materials enhance the resource productivity. Corrosion costs the U.S. over $300 billion per year and also produces significant safety hazards. Corrosion protection technology utilizes metallurgy, material chemistry and physics as well as electricity to prevent or control corrosion degradation and therefore, the education of corrosion science & engineering is directly linked to improving material life. Education in corrosion Control applies these sciences to control the chemical and mechanical aspects that are involved in the deterioration of properties.

Catherine Mulligan, Concordia

Dr. Catherine N. Mulligan, Eng. obtained her B.Eng and M.Eng. degrees in chemical engineering and a Ph.D. in geoenvironmental engineering, all from McGill University. She worked for the Biotechnology Research Institute and then SNC Research Corp of SNC Lavalin before joining Concordia University in 1999. She currently holds a Concordia Research Chair in Geoenvironmental Sustainability (Tier I) and is Full Professor in the Dept. Building, Civil and Environmental Engineering. She has authored more than 95 refereed papers, (co)published 6 books, holds three patents and has supervised to completion more than 55 graduate students. She established and is the Director of the Concordia Institute of Water, Energy and Sustainable Systems. The Institute trains students and performs research into new technologies and solutions for environmental sustainability.

An Interdisciplinary Research and Training Program in Sustainability – CIWESS

Engineers must be able to work in multidisciplinary teams incorporating public policy, economics, and social responsibility. In light of the above, Concordia University has established the Concordia Institute for Water, Energy, and Sustainability Engineering (CIWESS) that provides a unique interdisciplinary training in water, energy and sustainability engineering. The specific objectives of this program are: To catalyze, through collaboration, internships, enhanced research opportunities in sustainability; to train highly qualified personnel in an interdisciplinary manner for public, parapublic and industrial sectors; to maintain and enhance interdisciplinary areas of teaching and research; and to attract external research funding and foster relationships with external researchers and internal Concordia researchers with similar interests. Examples of the research and training will be provided, showing the importance of this type of education and research.

Jessica Smith, CSM (co-authors Nicole Smith, Carrie McClelland, Linda Battalora)

Jessica M. Smith joined the faculty of Mines in 2012 as the Hennebach Assistant Professor of Energy Policy in Liberal Arts and International Studies. She is an anthropologist with two major research areas: 1) the sociocultural dynamics of extractive and energy industries, with a focus on corporate social responsibility, social justice, labor, and gender and 2) engineering education, with a focus on socioeconomic class and social responsibility. She is the author of Mining Coal and Undermining Gender: Rhythms of Work and Family in the American West (Rutgers University Press, 2014), which was funded by a fellowship from the National Endowment for the Humanities. In 2016 the National Academy of Engineering recognized her Corporate Social Responsibility course as a national exemplar in teaching engineering ethics. She co-organized the 2016 Energy Ethics: Fragile Lives and Imagined Futures conference at the University of St. Andrews. She is a Faculty Affiliate of the Center for Science & Technology Policy Research at the University of Colorado. Professor Smith holds a PhD in Anthropology

and a certificate in Women's Studies from the University of Michigan and bachelor's degrees in International Studies, Anthropology and Latin American Studies from Macalester College.

Where are the people? Including Social Sustainability in the Circular Economy

How do social concerns fit into the circular economy, and how can we educate the next generation of engineers to integrate social concerns into their professional practice? Most conceptions of the circular economy highlight the environmental dimensions of sustainability, such as reduction of materials use or the carbon emissions, perhaps because these are more easily controllable and measurable in a quantifiable way. This paper shares our efforts at the Colorado School of Mines to teach engineering students to approach engineering problem definition, solution and design from a sociotechnical, rather than just technical perspective.

SESSION 4 – WATER

Moderator: Carol Russell, EPA (retired)

Carol Cox Russell recently retired from the U.S. Environmental Protection Agency where she focused on environmental effects of resource extraction, mining and oil and gas. In her thirty-year environmental career she has served as the co-chair of EPA's National Mining Team, Chief of the Water Quality Unit, Community Involvement Team Leader and Tribal Team Leader. In particular, she provides technical expertise to various EPA programs and international entities regarding resource extraction. Professionally she served as chair of the Sustainability Committee for the Society of Mining Engineers and on the World Federation of Engineers Sustainability Task Force. She has a B.S. in geology from Fort Lewis College, a B.S in biology from the University of Oregon, a master's degree in Environmental Policy and Management from the University of Denver and post-graduate work at Purdue and Colorado School of Mines. She also taught Sustainable Public Policy as an adjunct professor at the University of Denver.

Will Sarni, Water Foundry

Will has been providing consulting services to private and public-sector enterprises for his entire career, with a focus on developing and implementing corporate-wide sustainability and water strategies. He has worked with companies across a range of industry sectors in evaluating the technical viability and market potential of innovative water technologies, market entry strategies and supporting M&A programs.

An internationally recognized thought leader on water strategies, Sarni is a columnist on sustainability and water strategies for GreenBiz and OOSKA News and has authored numerous articles and presented on the value of water, water technology innovation, agriculture and the Internet of Things and the energy water food nexus.

He is the author of: "*Corporate Water Strategies"* (Earthscan 2011, and in Chinese by Shanghai Jiao Tong University Press 2013); *"Water Tech – A Guide to Investment, Innovation and Business Opportunities in the Water Sector"* (Sarni, W. and Pechet, T., Routledge 2013); and *"Beyond the Energy – Water – Food Nexus: New Strategies for 21st Century Growth"* (Dō Sustainability 2015). He is currently working on the forthcoming books, *"Water Stewardship and Business Value: Tapping the Full Value of Water Stewardship"* (Sarni, W., Orr, S. and Grant, D., Earthscan 2017) and "*Public Policy Innovation at the Energy, Water, Food Nexus: 21st Century Solutions to 19th Century Public Policy and 20th Century Infrastructure"* (Sarni, W. and Koch, G., Greenleaf Publishing 2017).

Sarni is a Board Member of The Water Footprint Network and 10.10.10.org and Founder of WetDATA.org. He was a 2016 X-PRIZE Bold Visioneer for the Safe Drinking Water Team and is on the Scientific Program Committee for Stockholm World Water Week; Executive Council of NOAA's National Integrated Drought Information System (NIDIS); Editorial Board of the *Journal of Water Security*; Water Working Group for the Business and Industry Advisory

Committee (BIAC) to the OECD; and a Technical Advisor for the Climate Bonds Initiative: Nature- Based Solutions for Climate and Water Resilience.

Innovation and the Energy - Water - Food Nexus

The energy – water – food nexus provides an opportunity for innovation in technology, partnerships, business models and funding. Examples of innovation platforms such as X-Prize, 101010 and House of Genius will be presented along with examples of innovation at the energy – water – food nexus.

In particular, innovation in providing access to safe drinking water will be presented – to "democratize" access to safe drinking water. Stakeholders need 21st Century technology solutions to achieve SDG 6.1 Accelerating technology innovation coupled with catalyzing an ecosystem of stakeholders to fund and deploy these technologies shows promise in ensuring universal access to safe drinking water. Technology innovation and entrepreneurs outside the traditional water sector can bring new ideas and strategies to address the poor access to safe drinking water.

Eleanor Allen, Water For People

Eleanor Allen is the CEO of Water For People, a global nonprofit working in nine countries in Africa, Latin America, and India to help develop sustainable water and sanitation services. It is recognized as an innovative leader in the water, sanitation and hygiene sector through its innovative approach to development, which brings together local entrepreneurs, technology, governments, and communities to create quality, reliable and lasting systems and services.

Prior to Water For People Eleanor was the Global Director of Water at Arcadis and the Latin America Director of Water at CH2M. She is a professional engineer experienced in leading multi-cultural, global teams in delivering rural and urban infrastructure programs and managing regional and global operations. In 2016 Eleanor did a TEDx talk on Why Water Is a Women's Issue. In 2016 Eleanor also won the Denver Outstanding Women in Business Award in Architecture, Engineering and Construction. She is distinguished alum at the University of California at Berkeley Academy for Civil and Environmental Engineering and is on the advisory board at the University of Colorado Mortenson Center for Engineering in Developing Communities. She has lived and worked in many different countries and speaks four languages.

How the Global Sustainable Development Goals Can Help Promote CSR

The Global Sustainable Development Goals (SDG) were adopted by 193 countries in 2015. All 17 SDGs represent ripe business opportunities, especially SDG #6 – *ensure availability and sustainable management of water and sanitation for all*. Policies and global investment will be channeled in this direction, which creates business opportunities for water and sanitation technologies and innovation. The need to manage water sustainably also acts as an incentive to improve business practices and enhance corporate social responsibility (CSR) programs, especially if they can become more impactful globally to create greater value for society, the planet and the bottom line.

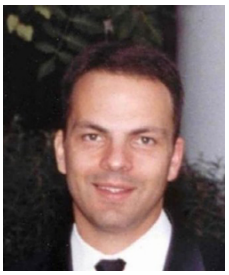
Stephen Northey, Monash University (co-authors Maureen Upton, Patrick Williamson, David Hoekstra)

Stephen Northey is based at Monash University in Melbourne, Australia where he is currently completing a doctorate focused upon quantifying water consumption and risks in the mining industry. Stephen also acts as an associate for SRK Consulting to provide clients with detailed water footprint assessments of mining operations, as a means to improving understanding of water resource impacts and to provide transparency to social license to operate discussions. Prior to this Stephen worked at CSIRO as part of their process evaluation team, where he

performed life cycle assessment and techno-economic evaluations of mining and metal production processes in the copper, gold, nickel and rare earth industries.

Water Footprinting - Communicating Mine Site Water Performance in a Circular Economy

Achieving the aspirations of a circular economy requires standardized metrics to measure progress in energy, water, material and resource efficiency. The recently developed ISO14046 standard for water footprinting provides a framework for evaluating water use impacts consistently throughout supply chains and is aligned with life cycle assessment methodology. Complementing this are the impact characterization methods for water use occurring in different regions that have been developed by the UNEP-SETAC Working Group for Water Use in Life Cycle Assessment. The use of these methods by the mining industry requires careful judgement due to the large variability in water use between mines. Nevertheless, the ability to clearly demonstrate water efficiency and performance to industry stakeholders provides benefits for those who adopt these methods.



Joe Lima, Schlumberger

Joe Lima joined Schlumberger in 1989 as a Sand Control Field Engineer working in the Gulf of Mexico, USA. Over the past 26 years, he has held various technical, marketing and management roles across cement, stimulation and other oilfield services with global responsibilities.

In his current role, Lima leads Schlumberger's environmental sustainability strategy, which includes ongoing technology development and application with a focus on reducing various aspects of wellsite footprint.

Previously, Lima served as the Environmental Solutions Manager for Schlumberger Well Services where he was focused on global implementation of high performance hydraulic fracturing fluids that exceed US drinking water quality standards as well as developing Schlumberger's global chemical disclosure process.

Lima has served on the Boards of Colorado Oil and Gas Association, Interstate Petroleum Association of Mountain States and California Independent Petroleum Association.

He holds a Bachelor's of Science Degree in Petroleum Engineering.

Incorporating Sustainability Practices to Reduce Water in Upstream Oil and Gas Development

SESSION 5 – POSTER SESSION AND NETWORKING RECEPTION

Christina Suarez, CSM

Christina Suarez is an aspiring petroleum engineer at the Colorado School of Mines (CSM). Having been awarded undergraduate research by the school's petroleum engineering department, she has had the opportunity of working with a distinguished CSM professor to investigate the field of corporate social responsibility and sustainability in the Oil and Gas Industry. Passionate about the world of petroleum and energy, Christina hopes to one day contribute to providing the world with energy more efficiently and safer than ever before.

Greenhouse Gases, a Carbon-Constrained Regulatory Environment, and the Oil and Gas Industry: How Will We Maintain Our Social License to Operate?

This study is an overview of the synergy of the oil and gas industry, regulators and the community in addressing Climate Change and reducing GHG gases (GHGs). thereby protecting the environment. In addition to identifying specific GHG regulations, this project dives into the science behind climate change and describes successful oil and gas projects and mitigation of climate change during the project lifecycle. Industry's commitment to the

environment is demonstrated through support of policies, developing safe, efficient technologies and procedures, and investing in research that further benefit the environment. Recommendations for the improvement of GHG mitigation as well as the relationship between industry and the community are provided.

Rosalie O'Brien, CSM

Rosalie O'Brien is currently a junior at the Colorado School of Mines pursuing a degree in Environmental Engineering with a minor in Humanitarian Engineering. Her interest in oil and gas started with an internship in the industry, where she worked in both a corporate setting and a field position on environmental monitoring. After over a year of working for a corporation, she transitioned into research for the ConocoPhillips WE2ST Center, where she focuses on the social dimensions of produced water treatment technologies. Through her coursework and participation as a Humanitarian Engineering Shultz Scholar, she continues to develop a passion for corporate social responsibility and the role of community engagement in the oil and gas sector.

Constructed Wetlands and Other Produced Water Treatment Technology Opinions from Stakeholders in Oil and Gas Impacted Communities

Allocation of billions of gallons of water for hydraulic fracturing spurs controversy among stakeholders of the oil and gas industry. To reduce this freshwater consumption, industry professionals are investing in technologies for produced water treatment, such as constructed wetland cells for biological contaminant attenuation. Yet for this technology to be feasible, it must also be socially acceptable to the communities where it will be placed. Characterization of social perceptions, concerns, and knowledge base about these technologies remains nonexistent. However, the continued development and implementation of produced water reclamation strategies relies on the social implications expressed by community stakeholders. ArcGIS analyses of collected parameters from Colorado communities unveiled three appropriate communities where ethnographic methods will be used to understand existing opinions about novel treatment techniques.

Kekahu Aluli, CSM

Kekahu Aluli is a student studying Mechanical Engineering at the Colorado School of Mines. At Mines, he discovered a passion for Humanitarian Engineering, and since has declared a minor in that area of study. Growing up in Hawai'i has given him first hand experience with development on indigenous land. In a partnership with the Division of Energy and Minerals Development, he is currently working on a Senior Design project that is collaborating with an indigenous tribe seeking to develop a local geothermal resource. Kekahu is also an active member of the Protect Kaho'olawe Ohana, which is a native Hawaiian grass roots organization that is dedicated to the island of Kaho'olawe and practicing the principals of Aloha 'Āina.

Cedarville Rancheria Geothermal End Uses Challenge: Working with Indigenous Communities on Sustainable Development Solutions

Many native American tribes are sitting atop lands that hold natural resources and other precious metals. Whereas many of these groups of people choose to take a more traditional linear approach of the development of extractive industries, the Northern Paiute Tribe has chosen to take a different approach that resonates with the circular economy. Instead they have chosen to develop a renewable geothermal source located on the reservation. In a partnership with the Division of Energy and Minerals Extraction (DEMD), my Senior Design group at the Colorado School of Mines is working to assist the tribe in their efforts to further develop this renewable resource. The major goal of this project is to ensure that end product will work to directly benefit the people of the Cedarville Rancheria. In order to tackle this goal, our methodology included stakeholder mapping, site visits to meet the tribe, iterative design practices with tribe feedback, and presentations of final solutions. This poster serves to highlight team GEOPamaka's ongoing efforts to work with the tribe in an attempt to ensure maximum benefit to their community and people.

Micaela and Michelle Pedrazas Hinojosa, CSM

Micaela Pedrazas is a senior in Geophysical Engineering minoring in Humanitarian Engineering at the Colorado School of Mines. She presides over the Society of Students Geophysicists and is a Schultz Scholar for the Humanitarian Engineering Department. Micaela is doing research under the supervision of Dr. Nicole Smith on the efficacy of mobile training units as a pathway to cleaner, safer, and more sustainable ASGM-based livelihoods in selected sites in Peru and Bolivia. Micaela travelled to Peru to lead a stakeholder workshop and arrive in shared goals with community members and project partners. She also investigates the relationship between water and non-conventional energy using satellite data for the ConocoPhillips WE2ST Research Center. She is also developing a dust monitor to be used near and at mine sites.

Michelle Pedrazas is a senior in Geophysical Engineering minoring in Humanitarian Engineering at the Colorado School of Mines. She presides over the International Student Council and is a Schultz Scholar for the Humanitarian Engineering Department. Michelle is doing research under the supervision of Dr. Nicole Smith on the efficacy of mobile training units as a pathway to cleaner, safer, and more sustainable ASGM-based livelihoods in selected sites in Peru and Bolivia. Michelle travelled to Peru to lead a stakeholder workshop and arrive in shared goals with community members and project partners. She is also developing a dust monitor to be used near and at mine sites.

Technology, Training, and Capacity Building in Artisanal and Small-scale Gold Mining: Using Mobile Training Units to Promote Cleaner, Safer, and More Sustainable Livelihoods in Peru and Bolivia

Artisanal and small-scale gold mining (ASGM) is the largest source of anthropogenic global mercury emissions worldwide. Unlike other industrial uses of mercury, most of what is used by ASGM ends up in the environment. This project examines the efficacy of mobile training units as a pathway to cleaner, safer, and more sustainable ASGM-based livelihoods in selected sites in Peru and Bolivia. We apply a participatory action research framework to identify the opportunities and challenges associated with using mobile training units to reduce mercury use while introducing and improving technology, conducting trainings, and building capacity. This approach is intended to gain a comprehensive understanding of the local social, political and economic contexts, and involve community members as active participants in identifying and designing sustainable ASGM practices.

Sumedh Gostu, WPI (co-author Brajendra Mishra)

Sumedh Gostu is a PhD student studying at the Metal Processing Institute, Worcester Polytechnic Institute where he applies his educational background in Material Science, Metallurgy and chemical processing to address issues of sustainability and waste management. Sumedh possesses proficiency in Pyrometallurgy, Hydrometallurgy, Mineral processing, Materials Science and is actively involved in the Society of Mining Metallurgy and Exploration, The Minerals, Metals and Materials Society, annual society meetings and various conferences.

Sumedh is working to devise a low temperature process mechanism to extract Iron, Aluminum, Titanium and rare earth metals from the Industrial waste 'Red-Mud'. The project's aim is to address the issues of sustainability, value addition of waste through metallurgical concepts. The research is a part of CR3 (Centre of Resource Recovery and Recycling research)/ IUCRC/ NSF initiative.

Investigation of carbon-based reductant, low-temperature process for conversion of hematite in red-mud to magnetite

The alkaline residue red-mud is generated at a rate of 120 million tons per annum from current day primary alumina refineries, total accumulation being 3 billion tons world-wide. Due to lack of commercial utilization, vast amounts of untapped residue are landfilled, discharged in water bodies. The research reported focuses on extraction of metallic values namely Iron, Aluminum and Titanium from Jamaican red-mud, thereby contributing to environment and resource sustainability. The hematite in red-mud was converted to magnetite using a gaseous reduction route. Optimum conditions for reduction achieved were: a processing temperature of 540^{o}C ± 10^{o}C,

partial pressures CO(g) and CO_2(g) each of 0.070atm ± 0.001atm./ inert diluent-gas: N_2(g), for a conversion-time of 30min. Initial magnetic separation tests wet and dry on reduced magnetite are also reported.

Mark Strauss, WPI

Mark Strauss is a PhD student studying at the Department of Materials Science and Engineering at Worcester Polytechnic Institute. He is passionate about creating extractive metallurgical innovations to advance sustainability, clean energy technology, and materials independence.

His research experience involves the primary and secondary production critical materials using hydrometallurgical techniques. His undergraduate research involved by-product recovery of rare earths from copper leach solutions at University of Arizona. His master's research in entailed recycling fluorescent lights at Colorado School of Mines. In addition, his current PhD graduate research is continuing to study the separation and purification rare earths from waste fluorescent lights.

Mark is currently researching methods to produce a native and high purity source of europium and yttrium oxide.

Recovery of rare earths from waste fluorescent lamps

Europium and yttrium are critical materials required for LED, florescent lamp, and flat panel display production. More than 8000 tons of material from end-of-life lamps are sent to the landfill each year in the form of phosphor dust. Based on the average composition of phosphor dust, a resource of 50 tons a year of europium oxide and 800 tons a year of yttrium oxide are available in the United States. Recycling europium and yttrium from waste lamp phosphors is an innovative method to supply them to high technology applications. Phosphor powder from recycled lamps is retorted, sieved, and selectively leached to produce a salable, mixed, semi-pure europium and yttrium oxide product. After conducting an economic analysis, the NPV for the process was $19.4 million dollars. The break-even price for yttrium oxide is $15.4 per kg yttrium oxide and $420 per kg europium oxide based on China FOB rare earth prices.

Sean Kelly, WPI

Sean Kelly received his B.S. from Worcester Polytechnic Institute in Biomedical Engineering in 2014. He received his M.S. in Material Science and Engineering in February 2016 working with Dr. Diran Apelian in the Center for Resource Recovery and Recycling. His research focused on automotive scrap characterization to optimize the recycling process as a function of polymeric and metallic composition.

Sean is currently a PhD candidate aiming to project the future material flows of automotive aluminum scrap through the secondary aluminum production industry. He plans on projecting how the increase of aluminum use in the automotive sector will alter the bulk chemical composition of auto-shred scrap mixtures. He will consider the increase of aluminum component dismantling and the capabilities and efficiencies of optoelectronic.

Auto-Al scrap material flow analysis with compositional projections

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Myungwon Jung, WPI

Recovery of Vanadium from Oil Fly Ash

Mikaela DeRousseau, WPI

Battery Disassembly in Support of Material Reuse

Hyunju Lee, WPI ***(co-author Brajendra Mishra)***

Recovery of Valuable Metals from Flue Dust and Other Fines from Mechanical Treatment of E-scrap

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Remya Narayanan, WPI ***(co-authors Nikolaos Kazantzis, Marion Emmert)***

Rare Earth Metals Recovery from Bauxite Residue

SESSION 6 –BUILDING BLOCKS FOR THE CIRCULAR ECONOMY

Moderator: Roland Moreau, ExxonMobil (retired)

Roland Moreau is the current Vice President of Finance for the SPE International Board of Directors, as well as President-Elect Designate on the Board of Trustees for the American Institute of Mining, Metallurgical, and Petroleum Engineers (AIME). Previously, he served as the Health, Safety, Security, Environment & Social Responsibility (HSSE-SR) Technical Director on the SPEi Board. Roland retired from ExxonMobil in 2014 after 34 years of service, with most of that time focused in the area of HSSE.

Linda Battalora, CSM

Dr. Linda Battalora is a Teaching Professor in the Petroleum Engineering Department at the Colorado School of Mines. She earned her B.S. and M.S. degrees in Petroleum Engineering from Mines, her J.D. from Loyola University New Orleans School of Law, and her Ph.D. in Environmental Science and Engineering from Mines. She teaches Reservoir Fluid Properties, Multidisciplinary Petroleum Design, Field Session, Graduate Petroleum Seminar, and Environmental, Energy and Natural Resources Law. Linda is an active member of the SPE and currently serves as the co-chair of the Sustainable Development Technical Section Steering Committee. She is also a member of multiple professional organizations and bar associations, and is the recipient of multiple industry recognition awards.

Stakeholder Engagement: "Have you been to a wedding lately?"

Stakeholder engagement is the key to maintaining our social license to operate. Many levels of communication are required in stakeholder engagement including informing the project stakeholders, consulting with them, creating permanent dialogue forums, collaboration in decision-making, and final decision making. Stakeholder mapping by criteria (knowledge, influence, necessity, willingness, legitimacy, and net cost/benefit) is one tool to assist us in securing a strong engagement with our stakeholders. Stakeholder network mapping is another tool that allows us to anticipate problems, identify opportunities, and develop strategies throughout the project lifecycle.

Atalay Atasu, Georgia Tech

Dr. Atalay Atasu's research focus is on sustainable operations management, and his interests include product recovery economics, extended producer responsibility and environmental regulation. His research appeared in Management Science, Manufacturing and Service Operations Management, Production and Operations Management, Journal of Industrial Ecology, and California Management Review. He is the recipient of a number of awards, including the Wickham Skinner Best Paper Award (winner 2007, runner up 2014), Wickham Skinner Early Career Research Award (2012), and Paul Kleindorfer Award in Sustainability (2013). He is senior editor for POMS' Sustainable Operations and Industry Studies and Public Policy Departments.

4 Obstacles on the Way to a Circular Economy

The concept of circular economy is part of a grand, sweeping vision, which requires advance critical thinking on how to operationalize and implement the concept on the ground. In this talk, we discuss possible implementation challenges for the industry and policy makers. We argue that the industry is advised to carefully analyze business models and understand where the costs and benefits from circular business models are and to whom their benefits and costs apply. Likewise, lawmakers will need to pay particular attention to existing scientific research to realize possible implementation related obstacles and seek solutions accordingly.

Jeff Keaton, ASCE

Jeffrey R. Keaton specializes in quantifying hazardous natural processes for siting and design of all types of facilities in all geologic environments. He has degrees in Geological Engineering, Engineering, and Geology. He has been employed by consulting firms for over 45 years, and in Amec Foster Wheeler's Los Angeles office of since July 2005 where he is a Principal Engineering Geologist. He is registered in several states as an Engineer and as a Geologist; he holds the Envision® Sustainability Professional credential from the Institute for Sustainable Infrastructure and is a Diplomate in Geotechnical Engineering of the Academy of Geo-Professionals. He is a member of SME-AIME, ASCE and its Committee on Sustainability, and the editorial board of ICE's *Engineering Sustainability*, which is published in the U.K.

Regulatory-ready Sustainability or Sustainability-ready Regulators?

Standards and regulations could stifle innovation needed to advance sustainable principles. Regulations typically are indexed to minimum values of key parameters, and owners are accustomed to paying for the minimum. Consultants and contractors are conditioned to provide low-bid estimates and perform at the lowest level that will meet the standard of care, or not be selected for the work. Innovative ideas tend to be dismissed because they result in costs that exceed low bid, even if they result in lower life-cycle costs, because most "projects" are defined as "design and construction" and treated separately from "operation and maintenance". Owners reject new ideas because regulators' review questions delay construction. Both regulatory-ready sustainability and sustainability-ready regulators are needed to advance innovative ideas.

Flora Moon, Expressworks

Flora Moon has had a diversified 25-year consulting career in oil and gas, technology, media and communications. She is the Sustainability Practice Director for Expressworks, a change management consultancy. Flora serves on the Board of Directors of the SPE Sustainable Development Technical Section (SDTS) and co-chairs its Performance Subsection. Her oil and gas clients have included operator, service and chemical companies. Her recent focus has been Sustainability, HSSE and organizational capability. Flora is formerly an award winning filmmaker who has worked with US and international Broadcast and Cable Networks and later worked on startup teams for technology companies including TimeWarner.

Integration of Concepts into a Company's Business Plan

Moving from current state to next state in business is facilitated or operationalized through the planning process. Before jumping into planning, however, there must be a determination of what's at stake, who needs to be part of planning, as well as roles and responsibilities of all parties. Definition of what success looks like before you start helps align effort and expectation. Understanding organizational capability and culture will help in creating more successful plans. Clarity for yourself, your organization and other stakeholders before you embark on planning will go a long way to realizing success.

SESSION 7 – SYSTEM IMPLEMENTATION

Moderator: Jeff Keaton, ASCE

Jeffrey R. Keaton has been employed by consulting firms for over 45 years. His education is in engineering and geology, and he is licensed as an engineer and geologist. He is a member of the *Society of Mining, Metallurgy, and Exploration* of AIME and represented SME-AIME on *ABET's Engineering Accreditation Commission* from 2007-2012. He holds the Envision™ Sustainability Professional credential from the *Institute for Sustainable Infrastructure*. He is a Fellow of the American Society of Civil Engineers and a member of its *Committee on Sustainability* and chair of its *Advocacy & Communications Subcommittee*. He also serves on the editorial board of *Engineering Sustainability*, a journal published in the UK by the *Institution of Civil Engineers*.

Janet Peargin, Chevron

As Manager of the Footprint Program for Chevron's Tight Rock Unconventional resources, Janet applies Sustainability concepts and Triple Bottom Line-thinking in planning, design, and decisions to reduce cost, improve performance, and add value for the company, the community and the environment.

Janet graduated from Vanderbilt University with a degree in Environmental Engineering and she possesses 35 years of experience in O&G facilities design, HES management and metrics, strategy & planning, change management, corporate responsibility, and regulatory affairs and policy development. Janet chairs the API Risk Management Task Force and the API Air Toxics Task Force and is a member of the API Pollution Prevention Task Force and Refinery Environmental Control Workgroup while also serving as API Representative, EPA Federal Advisory Committee on Industrial Combustion Coordinated Rulemaking.

Do More with Less – Design for the Triple Bottom Line for Sustainable Development and Footprint Optimization

As the engineering systems applied to produce energy get more complex, we must seek to create less wasteful designs, processes, and systems. And we must better account for the "costs and benefits" of hard-to-value drivers (social, environmental, broader economic). This presentation will discuss how we apply sustainable development and footprint optimization concepts to developing tight rock (shale)-based oil and gas reservoirs.

In planning, design, and decision-making we address social, environmental and economic factors to reduce risk, improve performance and create value for the company, the environment and stakeholders. We manage our "footprint" as a system of materials and energy that changes over time. ISO life cycle assessment is used to model our footprint and understand the environmental tradeoffs of different alternatives. This presentation will define key concepts that guide our thinking, outline the questions we ask, and highlight some success stories and learnings from implementing "triple bottom line" thinking.

Tatiane Marin, University of São Paulo *(co-author Jacopo Seccatore)*

Tatiane Marin is currently Professor of the Post-graduate Mineral Engineering Program at the Polytechnic School of the University of São Paulo, Brazil. She is a Mining and Safety engineer and holds a PhD in Mineral Engineering based on her research on financial aspects of sustainable small-scale mining. She is a specialist in mine planning, mine design and simulation.

Economic Viability of Responsible Small-scale Mining

Artisanal (ASM) and Small-Scale Mining (SSM) are well-known sources of concern, but they can play a positive role in the sustainable development of an area. It has been demonstrated that SSM can be performed responsibly. Capital investment is needed for this. We propose an approach based on investment risk reduction: proving, in the early stages of the business, a minimum mineral reserve (MMR) able to rapidly return the investment committed. We show a practical methodology for the estimation of the MMR and we undertake a realistic analysis of economic feasibility for a SSM unit in Ecuador, through a cash flow analysis of various scenarios of investment strategy. Results show that the MMR approach is always more attractive in terms of NPV, IRR, and payback time.

Mark Caffarey, Umicore ***(co-authors Colton Bangs, Christina Meskers, Thierry Van Kerckhoven)***

Mark Caffarey is Executive Vice-President for Umicore USA Inc. He is based in Raleigh, NC. He graduated with a degree in Chemical Engineering from Brussels University in 1983. After graduation, he joined Umicore in 1984. He served as the department head for Special Materials in Hoboken, Belgium from 1990-1994. Following that, he was the General Manager of Cobalt Products in Maxton, NC from 1994-1998. Currently he is serving as President of Umicore Marketing Services USA in Raleigh, NC (1998-present). He also serves as Executive Vice President for Umicore USA, Autocatalyst and Battery Recycling USA (2008-present).

Circular Economy for Electronics Gold Mine or Race to the Bottom

While the challenges to electronics recycling economics posed by product trends (e.g. declining material weight, declining precious metal content, and more) is generally well known within the recycling industry, the “e-waste gold rush” is still alive and well to the outside world. Underappreciation or misunderstanding of these key product trends is one reason this divide exists, though there are likely several others. What is certain is that this has led to a precarious situation in which outside investment has continued to pour in despite declining capacity utilizations and bankruptcies. Hence, the key issue has become how to prevent a “race to the bottom” while continuing to move toward a circular economy for electronics. The solutions must address the challenge from a systems perspective and should focus first and foremost on collecting and keeping material within the formal recycling chain to ensure that the high-quality recycling processes that already exist can be utilized to their full capacity.

Kimberly Martin, Arizona State University ***(co-authors Ranjiv Gupta, Hamed Khodadadi T.)***

Kimberly Martin, PE is a graduate researcher at Arizona State University. She spent nine years as a geotechnical engineer at ExxonMobil working on onshore and offshore development projects all over the world. She decided to return to graduate school to pursue her doctorate degree in 2016. Her research interests include investigating sustainable materials and methods for geotechnical engineering, specifically through bio-inspired processes as part of the NSF Center for Bio-mediated and Bio-inspired Geotechnics (CBBG).

Alternatives to Deep Foundations to Enhance Sustainability of Infrastructure Projects

Deep foundations (e.g., driven piles) are required when shallow foundations (e.g., strip footings) do not have the required capacity or would settle significantly as deep foundations transmit loads to deeper, competent soils. Deep foundations are often 100 feet long or more and 5-10 feet in diameter, thus requiring large volumes of concrete and steel to be constructed. While it is possible to salvage the material of the super-structure at the end of a project’s life, the materials used for deep foundations are buried underground and most often lost to the economy. This paper presents the applicability of alternative materials and methods (e.g., recycled materials or bio-inspired processes) for ground modification to enhance the sustainability of infrastructure projects.

SESSION 8 – ENVIRONMENTAL/WASTE

Moderator: Jeff Fergus, Auburn University

Jeffrey W. Fergus is a professor of materials engineering and associate dean for program assessment and graduate studies in the Samuel Ginn College of Engineering at Auburn University. He has a B.S. in metallurgical engineering from the University of Illinois and a Ph.D. in materials science and engineering from the University of Pennsylvania. His research interests are in high temperature and electrochemical application of materials, including batteries, fuel cells, thermoelectric devices and gas turbine engines. He has developed or taught several sustainability related courses or undergraduate students.

Nicole L. Villamizar, U.S. EPA Office of Resource Conservation & Recovery

Nicole Villamizar joined the U.S. EPA's Office of Resource Conservation and Recovery in 2006 as a Presidential Management Fellow. Nicole's primary focus areas at the EPA have included advancing sustainable materials management through the recycling and reuse of non-hazardous industrial secondary materials (such as coal ash, spent foundry sand, and construction and demolition debris), as well as advancing sustainable management of electronics. During her time at the EPA, Nicole has developed and launched a number of voluntary public-private partnerships, including the Sustainable Materials Management Electronics Challenge, a national program encouraging electronics manufacturers and retailers to increase the collection and responsible recycling of e-waste through the use of third-party certified recyclers. Nicole is also currently leading the Sustainable Materials Management program's efforts to implement its FY 2017 – FY2022 Strategic Plan. Nicole holds an M.P.A. degree in Environmental Science and Policy from Columbia University and a B.A. degree in Political Science from Brandeis University.

U.S. EPA's Efforts to Advance Sustainable Materials Management

The Resource Conservation & Recovery Act provides the legislative basis for EPA's Sustainable Materials Management (SMM) Program, setting a strong preference for resource conservation and recovery over disposal. EPA's *SMM: The Road Ahead* (2009) provided a life-cycle based analytical framework for moving toward SMM. The *Road Ahead* serves as the foundation for EPA's current SMM Program, which is focused on advancing SMM in the built environment (buildings, roads, bridges, and other infrastructure), reducing food loss and waste in the U.S by 50% by 2030, and increasing the recovery of packaging materials. EPA also provides estimates of national generation and recovery rates for municipal solid waste and construction and demolition debris in the U.S, and develops tools to support the environmentally responsible beneficial use of industrial non-hazardous secondary materials. International efforts include collaboration with the G7 Alliance on Resource Efficiency. This presentation will provide an overview of EPA's SMM Program, including an historical perspective on the evolution of EPA's waste/end-of-life focused efforts to current activities implementing EPA's FY17-2022 SMM Strategic Plan.

Eric Peterson, Idaho National Laboratory

Eric Peterson leads the Process Science and Technology Business Area at Idaho National Laboratory and is Divisional Laboratory Fellow at the Laboratory, where he has spent the past 27 years performing research on polymeric and related materials. His research has varied from the most fundamental understanding of molecular interactions to construction and proving of pilot facilities using the materials that he has been active in developing. His research emphasis is understanding of inter- and intra- molecular interactions that lead to interesting structure property relationships in polymer and solid state materials. Dr. Peterson received undergraduate education in chemistry and biology at Concordia College in Moorhead, MN, his Ph.D. from Montana State University in Bozeman, MT, and did postdoctoral training in polymers at University of Missouri-Rolla

and solid phase inorganic chemistry at the Ames Laboratory. Eric has authored/coauthored 92 peer reviewed archival articles, 26 peer reviewed DOE reports, 2 book chapters, 4 classified reports, and has authored/coauthored 14 issued US Patents with 5 patents pending.

Metals Recovery and Recycling

Reduce, Reuse, Remanufacture, Recycle! Is recycling the simple solution to all our environmental woes, or a feel-good waste of time and money? When considering the impacts of metals production, we can easily come up with problem after problem. But what about the other side? The simplest rebuttal to not mining is - we need metal, therefore we need mines! Is it so simple? The continual creation of new mines is polluting in the short term, and unsustainable in the long term. There are two different, and complementary, solutions to the environmental (and ultimately economic) problems associated with metals mining. The first is improved regulation and oversight of existing and future mines (not the topic of this talk), and the second is for society to reduce demand for metals in the first place, through a combination of recycling, more efficient production methods, and smarter product design. The environmental impact of mining may be reduced by recycling, and is a necessary part of a circular economy. But, how do we efficiently collect, process, and recycle all of these metals? Under current economic conditions, many metals are more economical to extract from the earth than to recycle, mostly because the price of these metals doesn't reflect all costs of production. This talk will reflect upon metals recovery and recycling from the author's perspective.

Flora Moon, Expressworks (co-author Sophie Theys, Bureau Veritas)

Flora Moon has had a diversified 25-year consulting career in oil and gas, technology, media and communications. She is the Sustainability Practice Director for Expressworks, a change management consultancy. Flora serves on the Board of Directors of the SPE Sustainable Development Technical Section (SDTS) and co-chairs its Performance Subsection. Her oil and gas clients have included operator, service and chemical companies. Her recent focus has been Sustainability, HSSE and organizational capability. Flora is formerly an award winning filmmaker who has worked with US and international Broadcast and Cable Networks and later worked on startup teams for technology companies including TimeWarner.

Sophie Theys is Asset Integrity Services Manager at Bureau Veritas, a testing, inspection and certification (TIC) company. Sophie Theys comes with 20 years of experience in the upstream and midstream oil and gas sector with a unique mix of project management, technical and field experience. She has lead efforts in optimising water usage, monitoring CO2 capture & storage, ensuring well integrity and is now providing solutions for assets to live longer without impacting safety or the environment. She has a general engineering degree from Ecole Polytechnique Feminine (France) and a master in petroleum engineering from Texas A&M University (USA). She is currently part of the technical board of EUROGIA2020 (promoting low-carbon energy technologies) and co-leads the "fit-for decision metrics" workscope of SPE's Sustainable Development Technical Section. As such, with Flora Moon, she is investigating meaningful indicators to help decision makers create a sustainable future for their business, society and the environment.

Waste as a Useful Circular Economy Indicator

Waste is often defined as unwanted or unusable material that is generated in business and is discarded. The authors advocate an approach that prevents or reduces waste creation at every step in a process. The authors present their rationale and methodology employed in the creation of a useful waste circular economy indicator applicable to all industries, with examples from the oil and gas sector. The indicator can be useful in helping engineers examine each process and system to design opportunities to increase resource intensity and reduce costs across entire asset and product lifecycles.

Sean Monkman, CarbonCure Technologies (co-author Mark MacDonald)

Sean Monkman is the Vice President of Technology Development for CarbonCure Technologies. He oversees the company's research and intellectual property efforts as they develop carbon utilization technologies to bring more sustainable concrete to the built environment. His career has included 26 years of materials science experience, with the last 23 years spent working in concrete materials. Sean holds a Doctoral degree in Civil Engineering from McGill University. He is active within the American Concrete Institute on the Materials, Nanotechnology and Sustainability committees. Sean has authored more than a dozen papers on beneficial carbon dioxide utilization in concrete production and is a co-inventor on 30 patents related to the work.

More Sustainable Concrete Produced Using Waste Cement Industry CO_2

Concrete is the world's most important and most widely used building material. Cement production is one of the most significant industrial sources of CO_2 emissions. The capture of cement industry CO_2 for upcycling in downstream
value-added concrete applications is a viable, synergistic and beneficial approach.

The beneficial use of carbon dioxide in concrete production has been investigated through lab and industrial studies. Retrofit applications have been developed for masonry block production, ready mix concrete production, and concrete wash water beneficiation.

Concrete masonry blocks produced using a CO_2 injection applied during mixing means that carbon dioxide is locked into the concrete, the block compressive strength increases and the absorption decreases. A ready mix implementation uses an optimum dose of carbon dioxide to increase the compressive strength of the concrete thereby allowing producers to optimize their mix designs (for example, reducing the cement loading and using the CO_2 to restore the reduced strength) to create reduced carbon footprint of concrete without compromising performance. High solids concrete wash water can be beneficiated for reuse through treatment with CO_2. The process eliminates issues associated with reusing waste water in concrete (accelerated set, increased water demand), leads to reduced use of fresh water and offers sequestration of carbon dioxide.

Sean Kelly, WPI (co-author Diran Apelian)

Sean Kelly received his B.S. from Worcester Polytechnic Institute in Biomedical Engineering in 2014. He received his M.S. in Material Science and Engineering in February 2016 working with Dr. Diran Apelian in the Center for Resource Recovery and Recycling. His research focused on automotive scrap characterization to optimize the recycling process as a function of polymeric and metallic composition.

Sean is currently a PhD candidate aiming to project the future material flows of automotive aluminum scrap through the secondary aluminum production industry. He plans on projecting how the increase of aluminum use in the automotive sector will alter the bulk chemical composition of auto-shred scrap mixtures. He will consider the increase of aluminum component dismantling and the capabilities and efficiencies of optoelectronic sorting systems.

Value Creation Through Enabling Technologies to Up-cycle Aluminum Scrap

Many forms of aluminum scrap are down-cycled at end-of-life. Unfortunately, end-of-life processing of products containing aluminum is not optimized to allow for maximized reuse opportunities. By not creating value in our waste or scrap streams, one down-cycles rather than up-cycle, resulting in scrap surpluses and diminishing domestic utilization. The recycling loops of many old aluminum scrap classes are extensively open (not closed loop). With the advent of optoelectronic sorters and other enabling technologies, we can now up-cycle, create value from scrap;

these developments have transformed how one deals with end-of life of products. The presentation will review these developments; investigating the capabilities and limitations of metallic sorting systems and characterizing mixed scrap classes to enhance end of life recycling rates.

Emmanuel Atta-Obeng, West Virginia University (co-authors Benjamin E. Dawson-Andoh, Mohindar S. Seehra, Usha Geddam; Johannes Leisen, GA Institute of Technology)

Born and raised in Ghana, Emmanuel has been captivated by nature and forest products since college and became focused on Forest Resource Science as a PhD student at West Virginia University. His interests lie in researching alternative uses for biorefinery waste products. He focuses on producing carbonaceous materials from lignin and hemicelluloses using a low temperature, low energy process called hydrothermal treatment. These carbonaceous materials can be exploited several ways including energy storage, soil amelioration, water purification, catalyst supports etc. Emmanuel has a B.S in Natural Resources Management from Ghana and a M.S in Forest Products from Auburn University, Al.

Characterization of "Green Carbons" Produced by the Hydrothermal Carbonization of a Biorefinery Lignin Waste-Stream

"Green carbons" were synthesized from organosolv lignin, a bio-refinery waste-stream, using a hydrothermal carbonization (HTC) process between 200 ^{o}C and 350 ^{o}C. Results from this study showed that up to 300 ^{o}C, the lignin structure was only slightly altered by hydrothermal process. Major structural transformations occurred at 350 ^{o}C, with the carbonaceous materials showing both open and closed vesicles. There was a gradual decrease in amounts of oxygenated aromatics, methoxyl and aliphatic substructures with increasing temperature. The evolution of an enhanced aromatic structure at 350 ^{o}C was depicted by quantitative peak analysis of direct polarization (DP) nuclear magnetic resonance (NMR) spectra, as well as FTIR analysis. Hydrothermal carbons were more thermally stable, with O/C and H/C ratios between 0.1- 0.4 and 0.3 - 1.1 respectively.

SESSION 9 – FUTURE VISIONS FOR THE CIRCULAR ECONOMY

Moderator: Nikhil Trivedi, IDEKIN International

Nikhil Trivedi has 35 years of business experience---in research and development, engineering, operations, administration and general management and consulting. He has served as vice president of research and development and chief technology officer of Pfizer Minerals Inc. and Minerals Technologies, Inc. from 1987 to 2001. Additionally, between 1994 and 2001 he established and built up a powerful technical group in Finland to support the company's European businesses.

Following his retirement in 2002 from Minerals Technologies Inc., Nikhil established IDEKIN INTERNATIONAL, a firm specializing in developing technology transfer opportunities and providing optimizations for chemical and mineral processes. His clients include corporations in the chemical process industries and mining industry worldwide.

Nik graduated with a Bachelor of Science degree in Chemistry from Bombay University and earned a Master of Science in Metallurgical Engineering from University of Nevada. His Ph. D. degree in Chemical Engineering is from University of Minnesota. University of Nevada awarded him Outstanding Alumni Award in 1995.

Nikhil has been an active member of The Society for Mining, Metallurgy and Exploration Inc (SME), served twice on its Board of Directors and was elected President of SME in 2010. He has also served on the Board of Directors of Industrial Minerals Association of Europe (1991-2001), Calcium Carbonate Association of Europe (1993-2001) United Way of the Greater Lehigh Valley (2001), and Easton Hospital's Valley Health Foundation (1999-2002). He is an Honorary member of AIME, Distinguished member of SME and a recipient of AIME's Hal William Hardinge Award.

Nikhil is 2016 President of American Institute of Mining, Metallurgical and Petroleum Engineers (AIME).

Linda Battalora, CSM

Dr. Linda Battalora is a Teaching Professor in the Petroleum Engineering Department at the Colorado School of Mines. She earned her B.S. and M.S. degrees in Petroleum Engineering from Mines, her J.D. from Loyola University New Orleans School of Law, and her Ph.D. in Environmental Science and Engineering from Mines. She teaches Reservoir Fluid Properties, Multidisciplinary Petroleum Design, Field Session, Graduate Petroleum Seminar, and Environmental, Energy and Natural Resources Law. Linda is an active member of the SPE and currently serves as the co-chair of the Sustainable Development Technical Section Steering Committee. She is also a member of multiple professional organizations and bar associations, and is the recipient of multiple industry recognition awards.

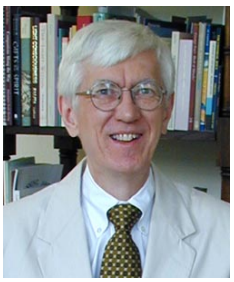
Hydrocarbon Development and the Sustainability Lifecycle: What is the Role of the Citizen Engineer?

In discussions on the broad potential value of sustainability to the hydrocarbon development project lifecycle, the role of the Citizen Engineer has emerged. The trending focus on the integration of technical and non-technical aspects underscores the role of the Citizen Engineer in risk identification and management. Can we adequately define the role of Citizen Engineer to improve our risk analysis and stakeholder engagement?

Lucy Alexander (author Dale Keairns), AIChE

Lucy Alexander is an Engineering Specialist at the Institute for Sustainability (IfS), a Technical Entity of the American Institute of Chemical Engineers (AIChE). In her role, Lucy works with IfS and AIChE volunteers and leadership, as well as outside government organizations, NGOs, industry and academia to develop initiatives that foster innovation and collaboration, and serve AIChE and IfS membership, the chemical engineering and sustainability professions, and society. Since beginning her career at AIChE in 2013, Lucy has implemented and supported over 30 conferences, workshops and projects across the AIChE Technical Entities locally and internationally.

Lucy graduated from Cornell University with a B.S. in Chemical Engineering. Prior to joining AIChE, she worked as Process Engineer in Spanish-based engineering, procurement and construction contractor Tecnicas Reunidas, S. A. in Madrid, Spain.



Dr. Keairns has over 40 years of experience in industry, consulting, teaching and service through professional society initiatives. The last ten years have focused on energy systems analysis and planning activities to guide technology research and development needs for the Nation's energy future, supporting energy research programs, management responsibility for strategic energy projects, and supporting the development of technology roadmaps for future energy systems. This work was carried out through a support contract to the Department of Energy National Energy Technology Laboratory and commercial projects. Prior to this, he had 32 years experience with Westinghouse as a senior executive leading the development and commercialization of technology to meet emerging energy and environmental needs. Dr. Keairns holds a B.S. in Chemical Engineering from Oklahoma State University and M.S. and PhD degrees in Chemical Engineering from Carnegie Mellon University.

The Food-Energy-Water Nexus and a Circular Economy

The Food-Energy-Water Nexus is used to describe the complex interconnected nature of food, energy and water resources, each a complicated system. Addressing the Nexus challenge requires considering the interactions between multiple dimensions and

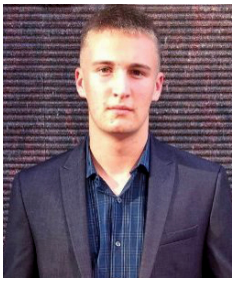
scales. Given abundant resources, economic growth has been based on the linear model of taking these and other resources, using the resources, and disposing of the waste streams and products when no longer needed. There is growing recognition that food, energy, and water resources must be managed as an integrated system. The circular economy is used to describe an alternative to the linear model and seeks to remove waste. Similar to the Nexus, there is a growing recognition that there are environmental and business benefits by moving away from the linear economy model and reinventing the value proposition. Addressing the challenges associated with the Nexus and a circular economy will lead to technology innovation and innovations in business, social, and institutional structures. What are the lessons from thinking about the Nexus and a circular economy? What are the implications for process design, plant design, infrastructure, business markets, and institutions? How will we respond?

Andrew Mangan, United States Business Council for Sustainable Development

Andrew Mangan is co-founder and executive director of the United States Business Council for Sustainable Development. Mr. Mangan holds a masters degree from Columbia University Graduate School of Journalism, where he attended the Columbia School of International and Public Affairs as an International Fellow. He currently serves on the board of the Foundation for Sustainable Development, is a member of the Education Committee for the International Society of Industrial Ecology, and a member of the Advisory Committee for the Environmental Science Institute at the University of Texas at Austin.

A Rapidly Expanding Cloud-based Industrial Material Reuse Platform

The Materials Marketplace is an award-winning regional and national platform that facilitates company-to-company industrial reuse. Traditional and non-traditional industrial waste streams are proactively matched with new product and revenue opportunities, ultimately enabling the culture shift to a circular, closed-loop economy. In addition to diverting waste from landfills, these recovery activities generate significant cost savings, energy savings, and create new jobs and business opportunities. Marketplace platforms are currently deployed at the national level in the US, at the state level in Ohio and Tennessee -- with plans for scaling to all 50 states -- and in Turkey, in cooperation with the European Bank for Reconstruction and Development.



Robert Dowling, rePurpose

Robert is an entrepreneur, humanitarian, and academic whose projects aim to have a social impact. His current impact enterprise, *rePurpose*, is a platform that aims to double the income of those living in dense urban slums by better connecting trash pickers to the recycling companies that demand their product. He also serves on the *Wharton – World Bank Ideas for Action Incubator* and as a judge and board member for the *Power African Youth Entrepreneur Drive*, a pitch competition sponsored by the African Union to bring entrepreneurs of the diaspora back to the continent. Robert's involvement on Penn's campus include founding the Penn Diplomacy and Policy Council (PennDPC.com), doing robotics research at the GRASP Lab involving applications of quadrocopter drones, and Penn's Mock Trial Team. He is an award winning and All-American Model United Nations delegate. As a humanitarian, Robert is on the Disaster Action Team with the American Red Cross and an International Disaster Response Operator with Team Rubicon. He is a StartingBloc Social Innovation Fellow, a Management and Technology Fellow, and an Andhra Pradesh Entrepreneurship and Innovation Fellow who is taking a year off from Penn to build economies and impact oriented organizations around the world. Robert's background in the conference organization and debate, combined with his training in National Security Policymaking at the Kennedy School of Government and his cyber security and operational security at the Department of Homeland Security makes him knowledgeable in international relations. Robert is training for Commission in the US Marine Corps while studying electrical engineering, finance, and global analysis at the University of Pennsylvania's Jerome Fisher Program in Management and Technology, a coordinated dual degree

program between Penn Engineering and The Wharton School. He hopes to remain at Penn for a fifth year and pursue a Master's of Science in Engineering in Robotics and a Master's in Law focused on technology and policy.

Towards a Sustainable Future: Opportunities for Impact in an Already Circular Economy

The World Bank Estimates that 1% to 2% of the global population --hundreds of millions of people --earn their income through picking trash in the world's waste dump sites. They are living invisibly in the dense urban slums on the outskirts of our major cities. Trash Pickers are reliant on established supply chains to deliver the products they collect in the trash sites to the recycling companies who turn it into the everyday goods we use around the world. These supply chains erode the income of the trash pickers with each transaction, and can retain up to 95% of the income trash pickers should be taking home. Engineers have the incredible opportunity to build for impact, design systems that benefit those on the bottom, and solve some of the world's greatest humanitarian crises through rethinking traditional models and disrupting economies and livelihoods so far removed from our own. rePurpose founders Robert Dowling and Peter Wang Hjemdahl will help close the conference with a narrative of the potential of engineering and who we can impact when we build together.

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