Ammonia Energy Conference 2020

Handbook

KEYNOTE (16 Nov, 10-11pm GMT) – Alex Tancock (MD, InterContinental Energy)

Green ammonia at Oil and Gas scale

Moderated by Trevor Brown (AEA)

PANEL #1: AMMONIA CRACKING (17 Nov, 1-2:30pm GMT)

Bill David (STFC), Joe Beach (Starfire Energy), Michael Dolan (Fortescue), Gennadi Finkelshtain (GenCell Energy), Josh Makepeace (University of Birmingham), Camel Makhloufi (Engie)

PANEL #2: A FUEL STANDARD FOR AMMONIA (17 Nov, 3:30-5pm GMT)

Ron Stanis (GTI), Dorthe Jacobsen (MAN ES), David Richardson (Airgas), Eric Smith (IIAR), Rob Steele (EPRI)

PANEL #3: CERTIFICATION OF LOW-CARBON AMMONIA (PRODUCERS) (17 Nov, 7:45-9:15pm GMT)

Jonathan Lewis (CATF), Blake Adair (Nutrien), Tobias Birwe (thyssenkrupp), Rob Hanson (Monolith Materials), Krista Mann (Eneus Energy)

PANEL #4: AMMONIA INFRASTRUCTURE (18 Nov, 1-2:30pm GMT)

Daniel Morris (KBR), Michael Goff (Black and Veatch), Oliver Hatfield (Argus Media), Anthony Teo (DNV GL)

PANEL #5: NEXT GENERATION AMMONIA SYNTHESIS (18 Nov, 10-11:30pm GMT)

Sarb Giddey (CSIRO), Douglas Macfarlane (Monash University), Karthish Manthiram (MIT), Michael Stoukides (CERTH)

PANEL #6: MARITIME AMMONIA (19 Nov, 1-2:30pm GMT)

Sofia Furstenberg Stott (Furstenberg Maritime Advisory), Tue Johannessen (AP Moller Maersk), Katharine Palmer (Lloyds Register), Rob Stevens (Yara), Kazumasa Taruishi (NYK Group)

PANEL #7: THE AMMONIA TRANSITION (19 Nov,7:45-9:15pm GMT)

Stephen Crolius (Carbon-Neutral Consulting), Sammy van den Broeck (Yara), Ashraf Malik (CF Industries), Trevor Williams (Nutrien)

KEYNOTE: Alex Tancock (MD, InterContinental Energy)

Green ammonia at Oil and Gas scale

Trevor Brown is the Executive Director of the Ammonia Energy Association, a global trade association that promotes the responsible use of ammonia in a sustainable energy economy. The AEA aims to accelerate the energy transition by building connections across sectors and across continents, to support the adoption of ammonia as a carbon-free hydrogen-dense energy molecule. Previously, Trevor was a theater and film producer and later an independent ammonia industry analyst. Since 2012, he has been an agitator for the commercialization of sustainable ammonia synthesis technologies.

Alex Tancock is MD of InterContinental Energy. Alex has been a pioneer in the global renewables industry over the last twenty years and is a Co-Founder of InterContinental Energy, the world's largest green hydrogen developer. He has been involved in the development, construction, and operation of renewable energy projects - both onshore and offshore - in Europe and across the Asia Pacific region. After working for E.ON Renewables in the UK and Wind Prospect in Australia, he founded Wind Prospect in Hong Kong to address the growing Chinese renewables market. Following an asset buyout by CLP Group, one of the largest utilities in Asia, he started InterContinental Energy in 2014. With a successful track record as a Project Manager, Alex was the Project Director of the Asian RE Hub from its launch in 2014 until 2020, when he shifted to manage another of ICE's world leading projects. Alex holds a B.Sc. in Theoretical Physics from Imperial College and qualified as a Chartered Financial Analyst with the CFA Institute. He is also a Board Member of the Ammonia Energy Association.

Green ammonia at Oil and Gas scale

Green Ammonia demand will grow massively over the coming years as it takes a central role in decarbonization, particularly in hard to abate sectors. In order to meet this demand, the industry must respond with projects at oil and gas scale. This is the only way to deliver the volumes required to decarbonize and to do it at the prices needed to accelerate the energy transition. The project concept pioneered by Intercontinental Energy offers a way forward. This presentation will outline Intercontinental Energy's view of the green ammonia market and summarize the project template used throughout the global portfolio, followed by an overview of the company's most advanced project, the Asian Renewable Energy Hub, and highlights from lessons learned.

PANEL #1: AMMONIA CRACKING

Bill David is Professor of Energy Materials Chemistry in the University of Oxford, an STFC Senior Fellow at the Rutherford Appleton Laboratory and a Fellow of the Royal Society. His work involves the research, development and demonstration of renewable and sustainable chemical and electrochemical energy storage systems and the provision of clean renewable power. Bill is the lead author of the recent Royal Society Report on "Ammonia: zero-carbon fertiliser, fuel and energy store" and advocates transitioning through the lowest disruption routes that build upon existing international infrastructures to realise a real-zero emissions future this side of 2050.

Joe Beach is CEO & CTO of Starfire Energy. He received a PhD in Applied Physics from Colorado School of Mines and was previously a founder of a thin film CdTe solar panel start-up. Prior to shifting Starfire Energy's focus to ammonia fuel, he ran the company as a solar energy system design/build/repair business. He entered ammonia fuel development after realizing that wind and solar needed a carbon-free fuel to achieve energy dominance. His past volunteer activities included being a firefighter and medic. His past and current hobbies have included D&D, cross-country skiing, hang gliding, running, gardening, and winemaking.

Starfire Energy's ammonia cracking and cracked gas purification technology

Ammonia cracking is important for both combustion and fuel cell applications. Starfire Energy has verified that a blend of 70% ammonia + 30% cracked ammonia can burn well in a conventional natural gas burner with very low ammonia slip and acceptable NOx using a stoichiometric fuel-air mixture. A 10 MW turbine or internal combustion engine using such a blend will need about 1.44 tonnes of cracked ammonia per hour. Starfire Energy's monolith-supported cracking catalyst may be ideally suited for this application.

Fully cracked ammonia retains several thousand parts per million of ammonia due to thermodynamic limitations. Residual ammonia can damage proton exchange membrane devices. Starfire Energy's patented adsorption ammonia removal process can provide a cracked ammonia stream with nominally 0 parts per million ammonia, allowing it to be used in proton exchange membrane devices.

Gennadi Finkelshtain is the Co-Founder, CTO and VP R&D at GenCell Energy. A veteran fuel cell pioneer, Gennadi Finkelshtain has managed the production of more than 250,000 fuel cell devices. As the founder of More Energy, he developed the first commercial portable fuel cell. Having led projects for numerous global companies including HP, Kodak, and General Dynamics, Gennadi holds 40 patents in his name. He earned his M.Sc. in Power Engineering from the Leningrad Technological Institute.

GenCell's ammonia-fuelled, off-grid power generation solution

Josh Makepeace is Josh Makepeace is a UKRI Future Leaders Fellow and Lecturer in Materials Chemistry in the School of Chemistry at the University of Birmingham, UK. Originally from Australia, he did his PhD in Inorganic Chemistry at the University of Oxford, exploring solid-state hydrogen stores and the development of a new family of earth-abundant catalysts for decomposing ammonia to release hydrogen. He then worked on a STFC Innovations project at the Rutherford Appleton Laboratory developing a benchtop demonstration of ammonia to power using those same catalysts; this work continued during a Junior Research Fellowship at St John's College, University of Oxford. Josh has recently been involved in reviews of hydrogen storage approaches with colleagues from the International Energy Agency's Task 32 on the storage of hydrogen, and was a contributor to the Royal Society's recent policy briefing on "Ammonia: zero-carbon fertiliser, fuel and energy store".

Ammonia cracking: when, how, and how much?

Cracking ammonia to produce hydrogen underpins many of the fuel-based uses of ammonia, and as such is a lynchpin technology in the case for ammonia energy. While in many ways ammonia cracking is a mature technology, systems which are designed specifically for these applications are less common. In this presentation, a general overview of the potential roles of ammonia cracking in facilitating the use of ammonia for energy applications will be outlined, including a survey of established and emerging cracking and purification technologies. A forthcoming project to produce an AEA Ammonia Cracking Technical Paper will be introduced.

Camel Makhloufi is a Key Expert within the hydrogen team of ENGIE Lab CRIGEN, corporate R&D center of the ENGIE group dedicated to new gases and their usages. Camel is leading the R&D program related to the power-to-X pathway, helping to bridge the gap toward commercialization of various hydrogen related technologies and systems. He is coordinator of the C2FUEL project, Horizon 2020 funded European project promoting clean technologies in the area of Dunkirk. He is also principal investigator of various European projects dealing with innovative technologies for hydrogen production (electrolysis and steam methane reforming), storage (metal hydrides) and hydrogen carrier production, cracking and reforming. Camel is a member of the current Task 40 of IEA on hydrogen storage and liquid carriers and followed for ENGIE the task 38 on power-to-X. He provides on a daily basis his technical and business knowledge to assess potential of startups and technologies and participates as a technical and business advisor within hydrogen startups. Camel holds a PhD in process engineering from the Lorraine University dedicated to CO2 capture processes and intensification. He worked previously for several large companies like Alstom and General Electric.

Ammonia As Hydrogen Carrier to Unlock the Full Potential of Green Renewables

Michael Dolan was appointed Manager Hydrogen of Fortescue Metals Group in May 2020, after joining the Company in January 2019 to support Fortescue's efforts to decarbonise and establish an Australian hydrogen industry for domestic and international markets. He joined Fortescue after a distinguished career in research and development with the Commonwealth Scientific and Industrial Research Organisation (CSIRO) – Australia's national science agency. Michael holds a Bachelor of Science (Honours), Ph.D. and MBA.

Ammonia as a fuel for Low-Carbon Mining

PANEL #2: A FUEL STANDARD FOR AMMONIA

Ron Stanis is Institute Engineer and Manager of Process Engineering at the Gas Technology Institute. He received his Bachelor's Degree from Rose-Hulman Institute of Technology in Chemical Engineering and Mathematics and received his PhD in Chemical Engineering from Colorado School Mines. His PhD was focused on PEM fuel cell catalysts. Dr Stanis then completed at post-doctoral fellowship at Sandia National Laboratory and performed R&D on membranes and electrode layers for fuel cells as well as materials development for photovoltaics and water desalination equipment. He joined GTI in 2008 and worked with a highly innovative team developing materials and systems for gas separation and variety of electrochemical devices including flow batteries and PEM, AEM, Solid Oxide and direct methanol fuel cells. In 2014-2015 Dr Stanis transitioned his research to gas conversion technologies starting with electrochemical and then thermochemical systems. In 2018 Dr Stanis became the manager of the Process Engineering group at GTI. In addition to this role, Dr Stanis is GTI's representative for CISTAR and the Ammonia Energy Association. Dr Stanis leads GTI's gas-to-value strategic initiative and is the GTI Electrolysis technical subcommittee lead for a GTI/EPRI joint run program called LCRI or Low Carbon Resources Initiative.

Dorthe Jacobsen is the Principal Specialist within fuels and emissions at MAN Energy Solutions. Dorthe has worked at MAN ES for 20+ years in various positions in the Fuel, Emission Reduction Technology, Regulatory Affairs, Lube and Materials areas. She is a member of the ISO 8217 Working Group for an International standard for marine fuels, and the Ammonia Energy Association Working Group for Combustion and emissions. She is a member of CIMAC fuels, Chairman of CIMAC lubes and Man ES's company representative in Getting to Zero coalition. She is also part of leadership team at Man ES for Fuels and Technology workstream.

A marine fuel standard for Ammonia - an engine designers perspective

The presentation will discuss the challenges for operation on ammonia from an engine designers perspective and show the preliminary fuel standard for ammonia for the MAN Energy Solution ME-LGIA two-stroke engine. The presentation will also discuss drivers for change in the marine industry, and what is required for reaching zero-carbon shipping.

Dave Richardson is Eastern Region Sales Manager at Airgas, and currently manages ammonia sales for Airgas across the Eastern United States. His previous roles include the management of the operations team for Airgas on the west coast. Prior to Airgas, he worked as an analytical chemist/project manager for a Boulder Scientific Company, a specialty chemical manufacturer.

Ammonia Fuel Standard, where do we go from here?

A discussion focused on the path to creating an ammonia fuel standard. Exploring the current state of the Ammonia Fuel Product Standards, its parallels to the current ammonia industry, and the challenges that need to be overcome to develop a meaningful standard for all stakeholders in the ammonia fuel supply chain.

Eric Smith is Vice President and Technical Director of the International Institute of Ammonia Refrigeration. His main responsibilities include management of standards and guidelines development, consultation and assistance to IIAR committees, initiation and coordination of research projects, regulatory outreach, and advocacy. Eric develops the technical program for the annual conference and provides assistance to IIAR members and the public. He represents the IIAR in related organizations and public venues, writes and reviews technical articles for IIAR's publications, and shares in executive responsibilities. Eric is a registered engineer in many states, is LEED accredited, and is a voting member on several technical society committees.

IIAR Standards and Guidelines

The International Institute of Ammonia Refrigeration (IIAR) is a professional society and trade association dedicated to the use of natural refrigerants, the most prevalent of which is ammonia. IIAR members embrace the safe use of ammonia because of its energy efficiency, ease of use, and wide availability. Soon celebrating 50 years as a professional society, IIAR has developed numerous standards and guidelines that are recognized by government agencies, model codes, and associated organizations in the United States and internationally. Our member library contains hundreds of technical papers on a wide array of topics regarding the use of ammonia. This session will provide a brief overview of the standards and guidelines that IIAR has developed. These materials and the development process could serve as a template for similar efforts in the ammonia energy industry.

Rob Steele is Technical Executive of the Combined-Cycle Turbomachinery program (P79) at EPRI. He is involved with all aspects regarding industrial gas turbine research and development including hot section/combustor life cycle, compressor/turbine rotor life extension and durability, and combustor monitoring, tuning, and turndown. His expertise is in the area of fuels, combustion fundamentals, and gas turbine combustor design optimization with particular interest in carbon-free fuels, combustion driven pressure dynamics, combustor rig testing and instrumentation, and ultra-low emissions designs.

Low- Carbon Fuels for Power Generation

The EPRI-GTI Low Carbon Resources Initiative (LCRI) has nine technical subcommittees. The Power Generation subcommittee currently has 26 active members representing electric, gas and combined electric & gas utilities as well as two gas turbine Original Equipment Manufacturers (OEM). Studies, testing and demonstration projects utilizing hydrogen and ammonia as alternate low-carbon energy carriers dominates member interests with hydrogen being most significant. Next steps will include scoping specific topics for "no-regret" studies and soliciting inputs for creating a five-year power generation roadmap. Current position of the power generation company members:

1. **Alternate Energy Carrier (AEC).** Applied R&D on H2 and H2 blended with natural gas dominates member interest. Ammonia is also being studied with selected tests underway.

2. **Hardware.** Gas turbines (combined cycle and simple cycle) are of most significant interest with reciprocating engines next; R&D related to use of H2 in these equipment has priority over, for example, in power generation boilers. Boilers for industrial and commercial steam and CHP are not a current focus.

3. **Studies & Evaluations.** Studies including establishing laboratory data related to combustion phenomena (auto-ignition, flame stability, combustion dynamics, etc.) are being identified as pre-commercial R&D for pure and blended AEC, with reaction kinetics, associated reduced kinetics mechanisms and validation tests to follow; these fundamental experiments and correlations will also specifically address emissions (e.g., oxides of N2). We have determined that these academia-based efforts are a foundational pre-requisite for both AEC fuel standards and combustor designs.

4. **Demonstrations.** Tests to demonstrate H2 co-firing and ammonia in simple cycle gas turbines are being considered. Desire to host pilot demonstrations is dependent on specific technologies (e.g., electrolyzers, power-to-gas) as well as upon future identification of demonstrations that would be compatible with member interest and site capabilities. We have one member that has 30 process steam boilers and is offering to use one of the units to demonstrate the use AEC-natural gas blended fuels.

PANEL #3: CERTIFICATION OF LOW-CARBON AMMONIA (PRODUCERS)

Jonathan Lewis is an attorney and climate specialist with the Clean Air Task Force, works with companies, governments, and citizen groups on state, national, and international initiatives to address climate change. Jonathan leads CATF's Bioenergy Project, which seeks to redirect the production and use of biofuels and biomass-based power so that they contribute to—rather than undermine—decarbonization and climate stability. He also works with the Advanced Energy Systems Project to promote the development of zero-carbon fuels for transportation, power generation, and industry. Jonathan previously coordinated CATF's effort to accelerate the deployment of climate-friendly energy technologies by facilitating partnerships between cutting-edge energy companies and institutions in China and the United States.

Blake Adair is a Chemical Engineer and Lean Six Sigma Master Black Belt, passionate about affecting change in the Agriculture industry in line with the UN's sustainable development goals. He learned the challenges faced by agricultural business's early in his career during a work placement with Engineers Without Borders in Ghana. Working alongside incredible entrepreneurs, he witnessing first hand their work ethic, courage and willingness to takes risks in spite of any headwinds which has influenced his career thus far. Most recently, Blake has been focused on the commercialization of a new phosphate product (MAP+MST®) that efficiently delivers sulfur to crops while minimizing the risks of its loss into waterways and groundwater. He has also been an active participant in the development of a Technology Roadmap for the Nitrogen Fertilizer Industry, in concert with the International Fertilizer Association (IFA) and The International Energy Agency (IEA). Blake will be leading the AEA's Low Carbon Ammonia Certification effort.

Low Carbon Ammonia at Nutrien

Nutrien is currently a world leader in the production of low carbon Ammonia today. A market premium for low carbon ammonia is critical to spur investment and deployment of transformative technologies, which will not only provide low carbon Ammonia as a fuel, but support decarbonization of the fertilizer industry as well. The development of a forward-looking certification process, based on sound science, is critical to developing this market.

Tobias Birwe is Head of Sales, Fertilizer and Methanol at thyssenkrupp. Tobias has been working at thyssenkrupp Industrial Solutions AG since 2003, working on large scale EPC jobs in fertilizer industry. He started his career as process engineer developing ammonia plants based on thyssenkrupp's Uhde ammonia technology. After spending about one year in Saudi-Arabia on a commissioning job for Ma'aden 1 ammonia complex he joined the sales department. Since 2015 he is heading the sales department in the Operating Unit Fertilizer and Methanol. He holds a diploma in Industrial Engineering (Dipl. Wirtsch.Ing.) from TU Braunschweig.

Building a sustainable industrial and energy infrastructure

Adjacent to its steel manufacturing plant in Duisburg, Germany thyssenkrupp has established multi-million dollar testing facility for different kinds of Carbon-2-Chem solutions using the offgases from blast furnaces and coke plants, cleaning and separating those gases into its different components and further processing the components to different chemical products such as ammonia and methanol. Major contributor is also the element hydrogen, which is produced in electrolysis unit based on thyssenkrupp's Uhde technology. This testing facility focuses mainly on recycling the offgases to maximum extent resulting in most sustainable production processes.

Rob Hanson is the co-founder and chief executive officer of Monolith, where he leads the development of next-generation technology for producing low cost, low emission hydrogen, ammonia, and solid carbon products. Prior to Monolith, Hanson served as the global director of product management for AREVA Solar, the solar division of the world's largest nuclear company. He has a master's degree in mechanical engineering from Stanford, and has been a guest lecturer at Stanford, UNL, Foothill College and the University of Saskatchewan on topics ranging from thermodynamics to entrepreneurship.

Low Carbon Ammonia via Methane Pyrolysis

Splitting methane into hydrogen and carbon (methane pyrolysis) allows for the utilization of one of the largest energy reserves on our planet (natural gas) without emitting carbon dioxide, since only the hydrogen is oxidized to release energy, while the carbon is permanently sequesters as a solid product often replacing products that have their own GHG emissions. If you split biogenic methane (that produced from the anaerobic digestion of biomass), carbon dioxide is pulled out of the atmosphere resulting in a carbon negative process for making hydrogen (and in turn ammonia), and presenting a long term opportunity to begin drawing CO2 from the atmosphere at Gigatons per year scale. Monolith is the world leader in hydrogen production via methane pyrolysis, and the only company that is doing it at scale today.

Krista Mann is currently leading US Operations for Eneus Energy, focusing on growing its activities in the US and elsewhere. Krista has 17 years of experience in the energy industry. Prior to joining Eneus, she focused primarily on wind energy, solar energy, and electric transmission development in the United States. More than 4 billion USD worth of Krista's projects are in operation or under construction today, including what were at the time the largest wind projects in each of several US states. Krista holds a Bachelor of Science degree in Electrical Engineering and a Master of Science degree in Finance.

Green[1] Ammonia Certification ([1]For discussion today)

PANEL #4: AMMONIA INFRASTRUCTURE

Daniel Morris is a Consultant – Energy Transition at KBR. Daniel has over 7 years' experience in the energy industry working on energy transition projects globally primarily in green hydrogen and green ammonia. He has a broad background in project development, transaction advisory and master planning. Daniel has served as a non-executive Director of the Ammonia Energy Association, steering key activities to promote and develop the sector. Daniel holds a M.Eng (Hons) Chemical Engineering Masters degree from the University of Manchester.

Ammonia Asset Transition for New Markets

With over $900 billion worth of assets at risk of being stranded by the energy transition, operators must act now in order to compete in the future. Ammonia, as an already widely traded commodity, may prove to be the vehicle to deliver decarbonised gas resources ahead of a completed transition. Reimagining how we deliver energy is essential to people, planet and economy. Blue ammonia offers a step to realise national gas monetization objectives with the utopia of green ammonia. This presentation with showcase the challenges and opportunities that await and how well we are prepared.

Michael Goff is a Technology Manager in Black & Veatch's Oil & Gas business. Dr. Goff's areas of expertise include ammonia, urea, gasification, syngas processing, hydrogen, methanol, and gas to liquids production. His responsibilities include ensuring appropriate technologies are applied to projects to provide commercial advantages to clients for revamp projects and grass roots projects. Dr. Goff oversees work in these specific technology areas for all projects, from preliminary feasibility studies through full service EPC. He reviews and approves all major process design parameters to ensure a quality design, serves as a technical consultant to upper management, and is responsible for staying abreast of and evaluating emerging technology and maintaining the company's position in the technology area.

Distribution of Ammonia as an Energy Carrier

Ammonia can be used as an energy carrier to produce a low carbon fuel that can be transported around the globe. Infrastructure for transporting ammonia is already in place, but as more ammonia is used as an energy source, addition transportation capacity will be required. This presentation will discuss technical and economic data for ammonia distribution. The focus will be on pipeline and ocean transport. A perspective will be provided to identify the typical required infrastructure to produce, store and distribute of the ammonia for the equivalent power plant energy requirement.

Oliver Hatfield is VP Business Development for Argus Media in London. Oliver joined Argus in October 2018 following its acquisition of Integer Research, where he spent 15 years as head of the fertilizer market research team. Oliver has more than 20 years of experience in business analysis and consulting, and he was also one of the founders of Integer. Oliver has worked extensively on multi-client and bespoke fertilizer market analysis studies, covering market forecasts, strategy, due diligence, market entry and project feasibility. He has worked as an analyst on all the key fertilizer and related chemical markets: nitrogen, phosphates, potash, sulphur and sulphuric acid. Oliver is a graduate of economics and development economics from the University of Manchester in the UK.

A review of global ammonia supply

The presentation will provide an overview of global ammonia supply. It will consider the geography and orientation of the current stock of supply, including captive use, merchant availability and proximity to seaborne markets. It will examine the extent to which there is currently spare ammonia capacity, and the responsiveness of supply to demand growth in different timeframes.

Anthony Teo is Technology and LNG Business Development Director at DNVGL. He brings more than 21 years of maritime experience and 18 years of experience in DNV GL. Currently based in Houston, he is responsible for business development with a strong focus on new technology for maritime application, LNG as a marine fuel, Gas ships, energy efficiency and hybrid ships/ technology.

Ammonia as Alternative Maritime fuel

Global shipping will by 2050 need to reduce the GHG emissions by 50% compared to the 2008 baseline, according to one of the targets set by the IMO, as well as a goal of being GHG neutral by the end of the century. The adoption of carbon neutral fuels will be a key enabler to achieve this goal. This presentation will consider these issues and suggest a process and pathway to overcome regulatory barriers, safety, and infrastructure for ammonia that needs to be addressed to facilitate the use of ammonia as a fuel in shipping.

PANEL #5: NEXT-GENERATION AMMONIA SYNTHESIS

Sarb Giddey is Principal Research Scientist, and Group Leader in the Energy Technologies Program at Commonwealth Scientific and Industrial Research Organisation (CSIRO). Dr Giddey's group performs R & D in the areas of hydrogen related technologies, battery storage and alternative fuels IC engines. Dr Giddey has over 20 years R & D experience in hydrogen and fuel cell technologies. He has strong interests in distributed energy generation and hydrogen-based hybrid energy solutions. Dr Giddey has led several multi-million-dollar industrial projects in the area of renewable hydrogen and ammonia production. He has co-authored more than 65 journal publications, 3 patents, 4 book chapters, made several invited presentations and has served as chairperson at several international conferences.

Doug MacFarlane is a Sir John Monash Distinguished Professor and an Australian Laureate Fellow at Monash University's School of Chemistry. He is also leader of the Energy Program in the Australian Centre for Electromaterials Science. He was the Australian Academy of Science's Craig Medallist 2018 and winner of the Victoria Prize for Science and Innovation 2018. His interests cover a broad range of materials chemistry and electrochemistry for renewable energy generation and storage. He has published more than 700 papers and 30 patents and these have been cited more than 55,000 times (h-index 111). Professor MacFarlane was elected to the Australian Academy of Science in 2007 and the Academy of Technological Sciences and Engineering in 2009. He is a member of the Scientific Advisory Board of Cap-xx Ltd and has previously been the Chair of the Scientific Advisory Board of Ioteq Ltd.

Whither Aqueous Electro-reduction of Nitrogen to Ammonia?

Electrochemical reduction of N 2 (NRR) is widely recognised as an alternative to the traditional Haber-Bosch production process for ammonia. The high-energy efficiency, low-cost variant of this process involves an aqueous electrolyte and there is now a substantial literature on this topic. However, though the challenges of NRR experiments have become better understood, the reported rates in these aqueous solution studies are often too low to be convincing that reduction of the highly unreactive N 2 molecule has actually been achieved. Unfortunately, there are many possible impurity sources that can interfere with robust measurements. In this presentation we will discuss the issues arising and critically reassess the status of this field of NRR reports, describing several experimental case studies of potential false-positives. It seems the Holy Grail of low cost production of ammonia in aqueous media remains elusive.

*Choi, J., Suryanto, B.H.R., Wang, D. et al. Identification and elimination of false positives in electrochemical nitrogen reduction studies. Nat Commun **11,** 5546 (2020)*

Karthish Manthiram is the Theodore T. Miller Career Development Assistant Professor at MIT. The Manthiram Lab at MIT is focused on synthesizing critical chemicals and materials using carbon dioxide, nitrogen, water, and renewable electricity. Karthish received his bachelor's degree in Chemical Engineering from Stanford University in 2010 and his Ph.D. in Chemical Engineering from UC Berkeley in 2015. After a one-year postdoc at the California Institute of Technology, he joined the faculty at MIT in 2017. Karthish's research has been recognized with several awards, including the NSF CAREER Award, DOE Early Career Award, 3M Nontenured Faculty Award, American Institute of Chemical Engineers 35 Under 35, American Chemical Society PRF New Investigator Award, Dan Cubicciotti Award of the Electrochemical Society, and Forbes 30 Under 30 in Science. Karthish's teaching has been recognized with the C. Michael Mohr Outstanding Undergraduate Teaching Award, the MIT Chemical Engineering Outstanding Graduate Teaching Award, and the MIT Teaching with Digital Technology Award. He serves on the Early Career Advisory Board for ACS Catalysis and on the Advisory Board for both Trends in Chemistry and the MIT Science Policy Review.

Electrification of Ammonia Synthesis

Near-term prospects for decarbonized ammonia synthesis rely on conventional thermochemical Haber Bosch coupled to either electrochemical hydrogen production or methods of mitigating carbon emissions, such as carbon capture and storage. Thermochemical Haber Bosch requires high temperatures to achieve significant rates of ammonia synthesis and high pressures in order to achieve reasonable conversions of nitrogen and hydrogen to ammonia. Next-generation electrically-driven routes raise the prospect of using voltage in the place of temperature and pressure – an ambient pressure and room temperature route through which renewable electricity can be used to convert nitrogen and hydrogen to ammonia.

Electrically-driven routes for nitrogen fixation remain relatively immature and there are significant technical challenges to be overcome in order to achieve high rates and energy efficiencies. Our lab has developed a semi-batch lithium-mediated approach to ammonia synthesis, achieving the highest rates of nitrogen fixation at ambient conditions. Specifically, we have developed a gas diffusion electrode technology which allows for significantly improved rates of nitrogen fixation with suppression of competing hydrogen evolution. We will discuss these technical advances in the context of remaining challenges for future methods of electrically-driven ammonia synthesis.

*Lazouski, N., Chung, M., Williams, K. et al. Non-aqueous gas diffusion electrodes for rapid ammonia synthesis from nitrogen and water-splitting-derived hydrogen. Nat Catal **3,** 463–469 (2020)*

Michael Stoukides is a Professor of Chemical Engineering at the Aristotle University in Thessaloniki, Greece. Michael received his Diploma of Chemical Engineering from the National Technical University of Athens, in 1978 and his PhD from MIT in 1982. In 1982, he joined the Chemical Engineering Department of Tufts University as an Assistant Professor. In 1988, he was tenured and promoted to Associate Professor. For about one decade he conducted research

in the areas of heterogeneous catalysis, chemical reaction engineering, high temperature electrochemistry and incineration of toxic chemicals. In 1993, he moved to Greece to continue his career under two affiliations: Associate Professor of Aristotle University (AUTH) and Researcher at the Chemical Process Engineering Research Institute (CPERI), both at Thessaloniki. Starting in early 90's, in addition to heterogeneous catalysis and reaction engineering, he added to his research scope the study of the properties and applications of solid electrolytes In 1997 he was promoted to a full professor at the Chemical Engineering Department of AUTH and to a senior researcher at CPERI.

Alternatives to Ammonia Synthesis: An Electrochemical Haber-Bosch Process

Several alternatives to the existing process for ammonia synthesis, the Haber-Bosch Process, have been proposed in the past two decades, including the electrochemical synthesis in aqueous, molten salt or solid electrolyte cells. The present work reviews results of recent efforts (last 3 years) for the electrochemical synthesis of ammonia. An Electrochemical Haber-Bosch Process is also demonstrated. The proposed $BaZrO_3$ - based protonic ceramic membrane reactor combines hydrogen production via the reactions of methane steam reforming and water-gas shift at the anode (Ni-composite) with ammonia synthesis from N 2 and protons (H +) at the cathode (VN-Fe). Hydrogen extraction from the steam reforming compartment, enhances the thermodynamically limited methane conversions, whereas 5-14% of the protons pumped to the cathode, are converted to ammonia. The NH 3 synthesis reactor is combined with a protonic ceramic fuel cell to recover electricity and separate nitrogen from ambient air by exploiting by-product hydrogen.

*Kyriakou V., Garagounis I., Vourros A. et al. An Electrochemical Haber-Bosch Process. Joule **4**, 142-158 (2020)*

PANEL #6: MARITIME AMMONIA

Sofia Fürstenberg Stott is a leading figure in the innovation- and sustainability sphere of the maritime industry. Through *Fürstenberg Maritime Advisory*, a member of the *Getting To Zero Coalition*, she and her partner focus on providing strategic pathways for the transformational journey towards decarbonisation, combining insights of innovation management, industry collaboration, operational risk management and intercultural communication. Some of her latest accomplishments include developing *Nor-Shipping*'s new concept exhibition *Blue Economy*, and launching its first *Opening Oceans Conference*, connecting the wider ocean industries in such context for the first time. She has had significant presence in the Nordics for soon 15 years, through her tenure as Innovation Portfolio Manager with *Maersk*, and as a green shipping spearhead with *DNVGL*. She holds an MBA in Shipping & Logistics from Copenhagen Business School, an MSc in Chemical Engineering from Lund University, and was part of the first cohort to finish the Top Tech Executive Innovation Program at Haas Business School back in 2009.

Tue Johannessen is Head of Maritime Application and Viability at the recently established Center for Zero Carbon Shipping. Before this, he worked at A.P. Moller – Maersk having the R&D lead in Project Zero – a project leading to the formation of the center. Earlier in his career, Dr. Johannessen was co-founder and CTO of the cleantech company, Amminex, industrializing an ammonia-based emissions control solution. Amminex was a spin-out from the Technical University of Denmark where he until 2005 was Assoc. Prof. at Department of Chemical Engineering.

Ammonia & maritime decarbonization

Katharine Palmer is the global head of sustainability for Lloyd's Register Marine and Offshore Business. With over 17 years' experience in the shipping industry she is an established influencer and thought leader in relation to climate change, decarbonisation and potential energy transition pathways within the maritime segment. In her current role she provides advice and insight to a wide range of marine stakeholders including financiers, charterers, shipowners and regulators on sustainability leading practice and future strategies. Katharine qualified with a BSc (Hons) in Environmental Science from the University of Leeds, UK and a MSc in Environmental Biogeochemistry from the University of Newcastle upon Tyne, UK. Katharine has held a number of positions on external industry bodies throughout her career and is currently the co-chair of the IMarEST Technical Leadership Board since 2016, Trustee for the Sustainable Shipping Initiative, member of the UK Department for Transport Net Zero Transport Board and represents LR at the Getting to Zero Coalition, UNGC, UNEP sustainable blue economy finance initiative and the Ammonia Energy Association.

Ammonia as a fuel – building the business case

The successful substitution of current fossil-based fuels by zero-carbon energy sources is dependent on a combination of policy / regulation, investment and commercial business model development and fuel / technology development that will evolve over the coming years. The evolution of both the energy system and the shipping system that is needed, and associated timescales of development, investment and asset life, means that there are steps that need to be initiated now, and work carried out throughout this decade, even though the transition may not be completed for a couple of decades. This presentation looks at the Technology readiness, investment readiness and community readiness of Ammonia as a marine fuel and what needs to be done to build the business case.

Rob Stevens is VP Ammonia Energy and Shipping Fuel at Yara International. Rob has an MSc in chemical engineering and a PhD in Applied Thermodynamics from Delft University of Technology, the Netherlands. Rob started his career in Yara in product and technology development for fertilisers. Since then Rob held several management positions in Yara production (Urea, ammonia and nitric acid), of which 10 years in ammonia, including the General Manager role at Yara Pilbara, Western Australia. Currently Rob works as VP Ammonia Energy and Shipping Fuel in the Climate Neutrality team, with a focus to bring green ammonia at scale, contributing to the Yara target of climate neutrality by 2050 in the full the value chain.

Ammonia Energy Scale-up challenge

Yara was founded in 1905 to solve famine in Europe, through the production of mineral fertiliser from renewable energy. Today's challenges have not changed and Yara's mission is to responsibly feed the world and protect the planet. Producing renewable ammonia has been done before, and the transitional cost and CO2 gap can be closed in public-private partnership. Yara recognizes that collaboration and innovation along the value chain is essential to move into the future, reducing emissions in agriculture (digital farming, circular economy and nitrate-based products). Being one of the largest ammonia producers and the truly global leader in ammonia supply and trade, Yara believes that ammonia is the key molecule as energy carrier to facilitate the energy transition in production, logistics and as shipping fuel.

Kazumasa Taruishi is Vice President at NYK Energy Transport (USA) Inc. He's a senior-level manager with about twenty years' business experience in international shipping including ship investment planning, corporate strategy planning, project financing and container terminal business. Kazumasa joined NYK Line in Tokyo in 2003. In 2018, Kazumasa was seconded to NYK Energy Transport (USA) based in Houston, Texas as Vice President of business development. NYK Line, as leader in global marine transport, has been making efforts to promote de-carbonization through technical and commercial development that contributes to energy savings and reduction of greenhouse gas (GHG). Renewable hydrogen is one of the effective solutions for achieving de-carbonization in the shipping industry. Kazumasa is responsible for

business development of emerging supply chain of renewable hydrogen/Ammonia from North and South America.

De-carbonization of Ocean-going Vessels

Most of world trade is supported by ships. In fact, nearly 200 times cargos are carried by ships than air. And, about 800 million tons of CO2 are emitted in the world ocean by whole shipping industry every year. NYK Group as one of the world's leading marine transportation company is committed to our efforts for GHG emission reduction. We are operating over 700 ocean-going vessels.

PANEL #7: THE AMMONIA TRANSITION

Stephen Crolius is President and Co-Founder of Carbon-Neutral Consulting, President of the Ammonia Energy Association, and Co-Director of the Vehicle-to-Grid EV School Bus Initiative. Steve has 34 years of experience as a business strategy professional at The Boston Consulting Group, the strategy boutiques Telesis and Alliance Consulting Group (at both of which he served as a Partner), and in subsequent roles. Throughout his career, he has focused on growth strategies driven by technology innovation. His interest in the economic implementation of alternative energy technologies led him to join the William J. Clinton Foundation's Climate Initiative (CCI) in 2006. He served as the Director of CCI's Transportation Program from 2008 until he left the Foundation in 2013.

Ashraf Malik is Senior VP of Manufacturing and Distribution at CF Industries. He assumed this role in September 2019, with accountability for the company's manufacturing, corporate engineering, environmental health and safety, and distribution facilities. Prior to his current role, he served as vice president, site operations, since 2012. Mr. Malik has more than 30 years of experience within the chemicals industry, having worked in senior roles for GrowHow UK, Terra Industries and ICI PLC. He is a member of the Institute of Engineering & Technology, London, and the UK Engineering Council. He is a chartered engineer and holds a first-class honours degree in Control, Instrumentation & Systems Engineering from The City University, London.

CF's Commitment to Clean Energy Economy - Clean Fuels for a Sustainable World

Hydrogen has emerged as a leading clean energy source to help the world achieve net-zero carbon emissions by 2050. Ammonia is one of the most efficient ways to transport and store hydrogen and is also a fuel in its own right. CF is the world's largest producer of ammonia and is uniquely positioned, with an unparalleled asset base and technical knowledge, to serve this anticipated demand. We are announcing our commitment to decarbonize the world's largest ammonia production network, positioning CF at forefront of clean hydrogen supply. We have also announced a new green ammonia project at our Donaldsonville Nitrogen Complex.

Sammy van den Broeck is the VP Climate Neutrality at YARA International. He holds a M.Sc. degree in bio engineering and a Masters in management. He has worked for Yara since 2004. He held several position in Ammonia Production management, Innovation Management and acted as VP Product Management in Sales & Marketing. Since 2019, he is VP Climate Neutrality, leading and coordinating Yara's roadmap towards a low-carbon future, as well as overseeing the clean ammonia project portfolio.

The Clean Ammonia Transition @ Yara

Yara is one of the world's largest ammonia producers, and the largest trader and shipper of ammonia around the world. We see green ammonia as key molecule to decarbonize the food chains, as well as the ultimate zero-carbon shipping fuel. To provide proof of concept, different large commercial demonstration projects are in the pipeline. The green projects are based on hydro, off-shore wind and solar, while solutions for blue and grey ammonia can be suitable during the transition period. Several framework conditions for success will be discussed.

Trevor Williams is the Senior Vice President of Nitrogen Operations at Nutrien – responsible for the safe, reliable and efficient operation of Nutrien's Nitrogen Manufacturing Facilities across Canada (4), United States (6), Trinidad (1) and Argentina (1). He is a member of the Nitrogen Senior Leadership team, providing input and direction regarding the strategic development and tactical execution of the Nitrogen business plan. He led the integration of the two legacy Nitrogen Operations groups, bringing together two diverse teams into one integrated and aligned organization. Trevor joined Agrium in 2011 after an 18-year career in the petrochemical business. His roles at Agrium included Vice President, Engineering and Organizational Effectiveness; General Manager, Canadian Nitrogen; and Site Leader, Carseland Nitrogen Operations. Prior to this, Trevor held engineering, leadership and management roles at Nova Chemicals.

Start of the Journey - A Carbon Capture Success Story

Carbon Capture, Utilization and Storage (CCUS) has proven to be an important and effective step in helping organizations achieve their global climate change goals. This presentation will provide an overview of a strategic success story, highlighting the importance of partnering with key stakeholders, taking a concept and turning it into an operational reality.