UNIVERSITY OF WATERLOO | FACULTY OF ARTS

WATERLOO INSTITUTE FOR nanotechnology

# ALTERNATE ENERGY AND THE HYDROGEN ECONOMY WORKSHOP PROGRAM

APRIL 5, 2023 | 10:30AM

QNC 1501

# AGENDA

## 5 APRIL EST

**JOIN ONLINE**

| Start | End | Event | Location |
|---|---|---|---|
| **10:30** | **10:45** | **Territorial Acknowledgement and Welcoming Remarks** | **QNC 1501** |
| 10:30 | 10:35 | Bernard Duncker, Associate Vice President of Research and International | |
| 10:35 | 10:40 | Sushanta Mitra, Executive Director, Waterloo Institute for Nanotechnology | |
| 10:40 | 10:45 | Ramona Bobocel, Interim Associate Dean of Research, Faculty of Arts | |
| **10:45** | **11:55** | **Presentations** | **QNC 1501** |
| 10:45 | 10:50 | Anna Ferrer (Arts - Virtual) | |
| 10:50 | 10:55 | Xianguo Li (WIN/MME) | |
| 10:55 | 11:00 | Jeff Gostick (WIN/ChE) | |
| 11:00 | 11:05 | Vassili Karanassios (WIN/Chem) | |
| 11:05 | 11:10 | Derek Schipper (WIN/Chem) | |
| 11:10 | 11:15 | Ashley Mehlenbacher (Arts) | |
| 11:15 | 11:20 | Eric Croiset (WIN/ChE) & Cecile Devaud (MME) | |

# AGENDA

## 5 APRIL EST

| Start | End | Event | Location |
|---|---|---|---|
| **11:20** | **11:30** | **Morning Break** | |
| 11:30 | 11:35 | Kevin Musselman (WIN/MME) | |
| 11:35 | 11:40 | Anindya Sen (Arts) | |
| 11:40 | 11:45 | John Wen (WIN/MME) | |
| 11:45 | 11:50 | XiaoYu Wu (WIN/MME) | |
| 11:50 | 11:55 | Eihab Abdel-Rahman (WIN/SDE) | |
| **12:00** | | **Closing Remarks and Next Steps** | **QNC 1501** |
| | | Sushanta Mitra & Ramona Bobocel | |
| **12:05** | | **Networking Lunch** | **QNC 1501** |

# PRESENTERS

## Ana Ferrer

Professer
Department of Economics,
University of Waterloo

I graduated from Boston University in 1999 and am currently a full professor at the University of Waterloo. My research career developed in Canada and focuses on labour markets, with an emphasis on immigration and family outcomes. I am a member of the Board of the Canadian Labour Economics Forum (CLEF) and Assistant Treasurer of the Canadian Economic Association. I am also a Research Fellow at IZA, the German-based Institute for Labour Economics, and an external Research Fellow at the Centre for Research and Analysis of Migration (CReAM) at the University College of London. Although I have no expertise in Hydrogen markets, I am very interested in everything that has the potential to change labour markets.

## RESEARCH EXPERTISE:

Labour economics, immigration economics, family economics

## TOPIC INTEREST:

Traditionally jobs in the energy sector have been seen as well paid, but requiring relatively low levels of human capital, being not family friendly and hence discriminatory against women and (sometimes) immigrants. Initially, I would be interested in tracking the potential effect of the Hydrogen economy in creating “good jobs”, jobs that offer career opportunities, are flexible and accessible for all demographics.

# PRESENTERS

## Xiangou Li

Waterloo Institute for Nanotechnology
Dept. of Mechanical and Mechatronics Engineering,
University of Waterloo

Dr. Xianguo Li is a Professor of Mechanical and Mechatronics Engineering at the University of Waterloo. He received his Bachelor of Engineering degree from Tianjin University, China, in 1982, Masters and PhD degree from Northwestern University, Evanston, Illinois, USA, in 1986 and 1989, respectively. His field of research interest and activities is in the area of hydrogen generation and fuel cells, liquid fuel atomization and sprays, and green energy systems. He has published extensively, including over 230 peer-reviewed journal articles; three edited books, and Principles of Fuel Cells, the world's first textbook on fuel cells. Dr. Li serves as the editor in chief for the International Journal of Green Energy, Field Chief Editor for the journal Frontiers in Thermal Engineering, and also on the editorial/advisory board for many journals, book series, encyclopedia and handbooks. He established the International Green Energy Conference (IGEC) series and World Fuel Cell Conference series, and serves as Vice President, Technical Program, Canadian Society for Mechanical Engineering (CSME); President of the Fuel Cell Division, International Association for Hydrogen Energy; and President of the International Association for Green Energy. He is a fellow of Canadian Academy of Engineering, Engineering Institute of Canada, and CSME.

## PRESENTATION:

### Hydrogen: Its Clean Generation and Utilization

Hydrogen is considered essential for the decarbonization of end uses where other options are less mature or costlier, including four of the most energy-intensive industries (ion and steel, chemicals and petrochemicals, cement and lime, and aluminium) and three key transport sectors (road freight or long-haul transport, aviation, and shipping), and seasonal energy storage. By 2050 hydrogen is expected to contribute up to 18-24% of final global energy use (today's annual global hydrogen production is equivalent to less than 3% of global total energy demand). Production of hydrogen from water electrolysis is desired (green hydrogen), however water electrolysis requires significant amount of noble metals such as Iridium and platinum, several times more than what is needed to meet hydrogen demand in EU countries alone. Today 96% of the global hydrogen is produced from fossil fuels, and hydrogen production from fossil fuels is the most economic and commercially viable option. Considering rich natural resources in fossil fuels for Canada, production of hydrogen from fossil fuels coupled with either carbon capture, utilization and storage (CCUS) and/or value-added carbon products will provide best value for Canada and global climate change mitigation. Hydrogen utilization for the key transport sectors will be instrumental for these hard-to-decarbonizing sectors to achieve zero emissions by 2050, the technology for hydrogen utilization include hydrogen fuel cells and hydrogen combustion engines.

# PRESENTERS

## Jeff Gostick

Waterloo Institute for Nanotechnology
Dept. of Chemical Engineering,
University of Waterloo

Jeff Gostick is the Azzam-Dullien Professor in Chemical Engineering at the University of Waterloo where he runs the Porous Materials Engineering & Analysis Lab. His research is centered around understanding the structure-performance relationship in porous electrodes used in hydrogen fuel cell, redox flow systems, zinc-air cells, Li-ion batteries, and super-capacitors. His group uses a combination experimental characterization, novel production methods, and advanced custom computational tools. He is the lead developer of the open-source pore network modeling project OpenPNM (openpnm.org), as well as PoreSpy, a tool for porous media image analysis (porespy.org). Prof Gostick is a licensed professional engineer, has published over 90 journal articles, and was recently named an Emerging Leader by the Canadian Society for Chemical Engineering.

# PRESENTERS

## Vassili Karanassios

Waterloo Institute for Nanotechnology
Department of Chemistry,
University of Waterloo

Vassili Karanassios is a Professor of Chemistry at the University of Waterloo (Ontario, Canada) and a co-founder of a degree-program in nano-technology engineering at the same University. Professor Karanassios received his Ph. D. from the University of Alberta (Edmonton, Canada) and was a Post Doctoral Fellow at McGill University (Montreal, Canada). In 2009, he held a Leverhulme award in the UK where he was a visiting Professor in Chemistry (Sheffield University), an Overseas Fellow of Churchill college (Cambridge University, UK), and a visiting Professor of Engineering (Cambridge University, UK) in the Center for Advanced Photonics and Electronics (CAPE). Professor Karanassios and his group published (among others) on microfluidics and nanofluidics, on 3D printing and on rapid prototyping, on spectral interference correction using Artificial Neural Networks (ANNs) and Deep Learning, and on smartphone-enabled data acquisition and signal-processing from a variety of sensors for on-site chemical analysis and (potentially) for IoT applications.

## PRESENTATION:

### Hydrogen and triboelectrics to power portable sensors and micro- and nano-instruments for measurements on-site or for monitoring remote locations

Driven by demands arising from climate change and by the necessity of meeting sustainable development goals, there is an urgent need to monitor physical and chemical parameters on-site. To meet these demands and goals, we are developing and characterizing portable measurement systems that are operated using hydrogen or are powered by employing triboelectric approaches. In this presentation, these approaches will be briefly described and collaborations will be sought.

# PRESENTERS

## Derek Schipper

Waterloo Institute for Nanotechnology
Department of Chemistry,
University of Waterloo

Derek Schipper is an assistant professor and Tier II Canada Research Chair in Organic Materials Synthesis at the University of Waterloo, Ontario, Canada. He received his Bachelor of Science degree from the University of Prince Edward Island which was followed by his doctoral studies at the University of Ottawa. Subsequently, he carried out his postdoctoral work at the Massachusetts Institute of Technology before beginning his independent career in late 2013. Since then, his research activities are focused on tackling synthetic challenges in the context of conjugated organic materials.

# PRESENTERS

## Ashley Mehlenbacher

Canada Research Chair,
Co-Director, TRuST
University of Waterloo

Ashley Rose Mehlenbacher is Canada Research Chair in Science, Health, and Technology Communication and the inaugural Co-Director, with Donna Strickland, for the Trust in Research Undertaken in Science and Technology (TRuST) network at the University of Waterloo. She is also a member of the Waterloo Climate Institute and Water Institute. Mehlenbacher's research investigates science communications expertise, and the ethical aspects of specialist/non-specialist communication. She is the PI of the CFI-funded Demos Lab, which focuses on issues of climate communication.

## PRESENTATION:

### Communication of Complex Information

Communication research and rhetorical studies of science reveal the complex situations new technologies enter. Risk perception, previous experience with technologies and, importantly, industries, as well as framing of issues, trust, dis/misinformation, etc., all shape the realities of these situations. Seeing communication as additive mistakenly overlooks the pragmatic ground of civic discourse as critical to social, economic, and policy change as well as environmental, technical, and scientific change itself. I work on projects that see the fundamental and foundational value of understanding the complex communication decisions we must make in science and technology as well as in broader stakeholder engagement.

# PRESENTERS

## Eric Croiset

Waterloo Institute for Nanotechnology
Dept. of Chemical Engineering,
University of Waterloo

Dr. Eric Croiset, PEng is a professor in Chemical Engineering, with research interests in sustainable energy systems, in particular CO2 capture, storage and utilization (CCUS), hydrogen/syngas production, sustainable chemical/fuels production (including aviation fuels), decarbonization of industrial processes, and more recently vapometallurgy processes to recover critical minerals (most notably nickel and cobalt) from “black mass“ (i.e. recycled batteries) and various ores. Beside his research activities, he has held several important administrative positions at the departmental level, having been Associate Chair Undergraduate Studies for four years, and then Chair for more than eight years.

## RESEARCH EXPERTISE:

**Decarbonization of energy systems, in particular CO2 capture, utilization and storage (CCUS) and hydrogen production/use.**

## TOPIC INTEREST:

1. Hydrogen utilization:
   - Use of hydrogen as feedstock, when combined with captured CO2 to produced fuels and chemicals. My research in this area has been mostly about process simulation and techno-economic analysis. An example is a WISA project on the production of aviation fuel from captured CO2 and hydrogen.
   - Use of hydrogen as heating source or reducing agent in industrial processes. An example is a current project in collaboration with the steel industry and collaborators at Strathclyde University in Glasgow, Scotland, where we are investigating the impact of replacing current fossil fuels by hydrogen in one furnace, in particular heat distribution, which is critical to the steel’s quality (UW collaborator: Cecile Devaud, MME).
2. Hydrogen production
   - Blue hydrogen, i.e. hydrogen production from natural gas (conventional way), with CO2 capture. Interest here is in techno-economic analysis, as well as in means to provide heat to the process (burning hydrogen or electrical heating).
   - High temperature H2O electrolysis in solid oxide electrolysis cells (SOEC). Two important benefits of SOEC are the higher electrolysis efficiency than low temperature ones, as well as the possibility of co-electrolyzing H2O and CO2 to produce H2 and CO, which in turn can be converted into fuels and chemicals.

Although, I have been working on the technological aspects of the above mentioned processes (along with some engineering economics), there are obviously other critical dimensions like life cycle analysis, social acceptability, policy, benefits to communities, legal, financing that are better tackled by non-engineers.

# PRESENTERS

## Cecile Devaud

Professor
Dept. of Mechanical and Mechatronics Engineering,
University of Waterloo

Dr. Cécile Devaud, PEng is a professor in Mechanical and Mechatronics Engineering (MME). Her research group focuses on Computational Fluid Dynamics (CFD) for sustainable energy problems, in particular related to turbulent reacting flows with alternative fuels and pollutant formation. Further, she is also interested in fire and safety research working closely with the experimental research group at UW. Her research applications are diverse ranging from aero and automotive engines, industrial furnaces to fire scenario analysis. Currently, she is the Associate Chair Graduate Studies in MME.

# PRESENTERS

## Kevin Musselman

Waterloo Institute for Nanotechnology
Dept. of Mechanical & Mechatronics Engineering,
University of Waterloo

Dr. Musselman is an Associate Professor in the Department of Mechanical and Mechatronics Engineering and holds a University of Waterloo Endowed Chair in Nanotechnology. He received his doctoral and postdoctoral training at the University of Cambridge before joining Waterloo in 2015, where he leads the Functional Nanomaterials research group. His research program focuses on the scalable synthesis of nanomaterials and using these materials to drive the understanding and development of next-generation functional coatings and devices. His group has developed spatial-atomic-layer-deposition technology that can produce large-area, pinhole-free, nanoscale, metal-oxide thin films on a variety of substrates (glass, wafers, plastics, fabrics). They have helped pioneer the integration of spatial-atomic-layer-deposition thin films into a variety of applications, including photovoltaics, chemical sensors, LEDs, memristors, high-frequency diodes, and antimicrobial coatings. A spatial-atomic-layer-deposition company, Nfinite Nanotechnology, was spun off from his lab and is developing barrier coatings for sustainable packaging to combat the global plastic waste problem.

## RESEARCH EXPERTISE:

Nanomaterials and their applications. Research topics relevant to this event:

- Perovskite solar cells for low-cost renewable energy
- Barrier coatings for sustainable packaging materials to combat plastic waste
- Chemical sensors for monitoring water and air quality

## TOPIC INTEREST:

My group is developing and commercializing technology to deposit ultrathin metal-oxide coatings that act as barrier layers to water vapor and oxygen. We are applying them to perovskite solar cells to improve the long-term stability of this low-cost photovoltaic technology. Our spinoff company, Nfinite (https://www.nfinitenano.com/), is applying the coatings to sustainable food packaging materials (paper, bioplastics, recyclable plastics) to eliminate landfill-bound plastics and their associated GHG emissions. I would like to connect with complementary expertise in:

- Product-life-cycle analysis, circular economy
- Degradation of these materials in the natural environment (e.g., compostability)
- Regulatory environment that will impact technology adoption (e.g., single-use plastic bans)
- Customer acceptance & adoption of new technology

# PRESENTERS

## Anindya Sen

Professor, Dept. of Economics
Associate Director, Cybersecurity and Privacy Institute (CPI)
University of Waterloo

Anindya Sen is Professor of Economics and Associate Director of the Cybersecurity and Privacy Institute (CPI) at the University of Waterloo. He has been at the University of Waterloo since nineteen ninety-nine. He received his Ph.D. from the University of Toronto. Prior to working at the University of Waterloo, Professor Sen worked as an economist at the Competition Bureau, Industry Canada. His research interests are the economics of public policy, with an emphasis on estimating the statistical effects of government intervention and imperfectly competitive market structures. He has published research on the relationship between market concentration and gasoline prices, the impacts of higher cigarette taxes on smoking, the effects of higher minimum wages on employment and poverty, and the consequences of incentive programs on electricity usage. Professor Sen's currently studies: the use of AI tools to study issues of societal importance; the implications of being a digital and AI based society; understanding trends in cybercrime; and constructing efficient models of data governance. He is passionate about mentoring students and helping them make the connection between their university degree and the real world.

## RESEARCH EXPERTISE:

Using advanced statistical methods to evaluate the societal impacts of government policies such as anti-covid19 policies, minimum wage, and cigarette taxes.

## TOPIC INTEREST:

I am interested in learning more about nanotechnology that could be used for environmental sustainability and engaging in cost benefit analysis that could quantify the societal benefits of technology that leads to better environmental impacts.

# PRESENTERS

## John Wen

Professor
Dept. of Mechanical and Mechatronics Engineering,
University of Waterloo

Prof John Wen is a Professor in the Department of Mechanical & Mechatronics Engineering and cross-appointed in the Department of Chemical Engineering at the University of Waterloo. JW is the director of the Waterloo Laboratory for Emerging Energy Research (LEER) and has already worked in a multidisciplinary team to develop novel energy technologies focusing on nanotechnology and renewables. JW's group has greatly contributed to developing new nanothermite (also called metastable intermolecular composite or MIC) microstructures and formulae and advancing understanding of their reaction mechanisms. The team fabricated, for the first time, multi-layered MIC thin films via vacuum filtration (to reveal the distinct reaction mechanisms of Al-CuO, Al-NiO, and Al-CNT-NiO composites) and core-shell colloid energetic micro- and nano- particles. They also pioneered in synthesizing and characterizing MIC composed of nano-Al and metal-oxide nanowire, multilayer nano-laminates, and core-shell Al/NiO particles. The newly fabricated composites were delivered to the potential user (DRDC, Valcartier, and Columbiad Launch Services) for testing in defence and space applications. Four provisional patents have been granted. Two patents were submitted. JW has published more than 100 referred journal articles and many conference papers.

## RESEARCH TOPICS:

1. Techno-economic analysis for hydrogen-burning power plant with onsite hydrogen production unit based on methane catalytic decomposition
2. Green hydrogen production: Analysis for different single or combined large-scale photovoltaic and wind renewable systems
3. Simulation and modeling of a combined biomass gasification-solar photovoltaic hydrogen production system for methanol synthesis via carbon dioxide hydrogenation
4. Safety guidelines for hydrogen storage infrastructure at airports (hydrogen leakage, sensing and low-concentration ignition)

# PRESENTERS

## XiaoYu Wu

Waterloo Institute for Nanotechnology
Dept. of Mechanical and Mechatronics Engineering,
University of Waterloo

Dr. XiaoYu Wu is an assistant professor in the Department of Mechanical and Mechatronics Engineering at the University of Waterloo. He received his B.Sc. and M.Sc. degrees from Zhejiang University, and Ph.D. from MIT. His research group, Greener Production Group, combines expertise in thermal science, material engineering and techno-economics to develop sustainable technologies for energy conversion and chemical production. Dr. Wu is an expert on hydrogen technology, energy storage, and ceramic membranes.

## PRESENTATION:

### Clean hydrogen and ammonia as energy carriers

In my group, we are studying the use of hydrogen and ammonia as energy carriers. Here, I will showcase several projects, including a techno-economics analysis on electrified ammonia production, comparing hydrogen and lithium-ion battery as an energy storage medium in 100% renewable micro-grids, an experimental study on solid state electrochemical cells for ammonia conversion, and evaluation of hydrogen's role to decarbonize cities. We seek collaborations to study the environmental impacts and policy implication of scaling up ammonia infrastructures to transport hydrogen, and other related topics.

# PRESENTERS

## Eihab Abdel-Rahman

Waterloo Institute for Nanotechnology
Dept. of Systems Design Engineering,
University of Waterloo

Eihab Abdel-Rahman is Professor of System Design Engineering and a member of WIN. A nonlinear dynamicist by training, his research interests are in micro and nano sensors and actuators. He has co-authored more than 250 journal and conference papers. Prof. Abdel-Rahman is a member of the American Society of Mechanical Engineers and the European Society of Mechanics, associate editor for the ASME journal “Computational and Nonlinear Dynamics”, and section editor-in-chief for the MDPI journal “Actuators”.

## PRESENTATION:

### Portable, Wearable GHG Sensors

Research: I am interested in developing and demonstrating micro sensors that can measure and track over time the local concentration of GHGs.

Collaboration: Economists and others interested in using measurements of GHG emissions to quantify the impact / efficiency of various climate change mitigation interventions.