THE CANADIAN SOCIETY FOR MECHANICAL ENGINEERING
LA SOCIÉTÉ CANADIENNE DE GÉNIE MÉCANIQUE
SPRING/PRINTEMPS 2022

BULLETIN

SPECIAL ISSUE ON

Climate Change & Sustainability

BULLETIN ADVERTISING RATES

Full page	$800
Half page	$500
Column	$400

Contact
bulletin@csme-scgm.ca

BECOME A CSME MEMBER

Fellow	$175
Member	$140
First year membership	$85
Student	FREE

CONTACT

www.csme-scgm.ca
www.facebook.com/CSMESCGM
Twitter: @CSME_SCGM
admin.officer@csme-scgm.ca
Phone: 613-400-1786

BY MAIL

Mohammud Emamally
Administrative Officer, CSME
P.O. Box 40140
Ottawa, ON K1V 0W8

CONTENT

SPRING/PRINTEMPS 2022

Guest Editor's Letter

WE WELCOME YOU TO ANOTHER ISSUE of the CSME *Bulletin*, this time dedicated to Climate Change and Sustainability. This issue marks the beginning of a new approach in editing the CSME *Bulletin*: Asking the experts. This issue is the first that is co-edited with CSME Technical Committee members, in this case, with the Environmental Engineering Committee, led by Prof. **Horia Hangan** and Prof. **Hassan Peerhossaini**. To make sure we provide the most up-to-date information in each issue, we will continue to approach CSME Technical Committee members to co-edit upcoming issues.

Impacts of climate change are happening now. In recent history, 2018 was the fourth-hottest year on record globally, the second-warmest year on record without an El Niño event, behind only 2017. All the years on record that were hotter or more disaster-filled came in the past decade. With the five warmest years on record happening during the past five years — and the 20 warmest occurring over the past 22 — a consistent warming trend couldn't be clearer. There is little doubt that the nexus climate-energy-environment is one of the most significant societal and economic issues that has been faced in the history of humankind. It is estimated that an increase of 2.5°C in the Earth's surface temperature could negatively impact the World's global GDP by 1.4%. With an estimated global GDP of $84.54 trillion (USD) in 2020, this would amount to approximately $1.18 trillion (USD) of damages per year! It is time to act, and mechanical engineers should be in the frontline combating climate change.

In this special issue of the CSME *Bulletin* four *feature articles* are contributed by Canadian specialist on the different aspects of climate change and sustainability. Dr. **Sylvie Leroyer** of Climate Change & Environment Canada shares her many years of experience in numerical weather prediction in urban areas. In his feature article, Dr. **Amir Aliabadi** of the University of Guelf proposes an advanced building energy model, a valuable complement to the city-scale weather modelling. Few higher education institutions have included climate change and sustainability in their engineering curriculum, these issues are largely left to geographers and social scientists. In her article, Dr. **Amanda Jang** of the University of British Columbia shows us the way to educate mechanical engineers to address the climate crisis and other sustainability challenges. **Caitlin Knapik** of BFC Technologies Inc. brings us to the amazing technology of cultured meat as a means of sustainable food production which, concomitantly contributes to climate change mitigation. Knapik, in a *Q&A feature*, also shares her opinion on different issues related to sustainability and climate change, seen by a young practitioner in process engineering. The *ME News* piece highlights new advancements in the area of biofuels.

Faculty spotlight features of this special issue are contributed by Dr. **Marina Freire-Gormaly** of York University and Dr. **XiaoYu Wu** of the University of Waterloo. Dr. Freire-Gormaly shows how new collaborative tools can help mechanical engineers achieve improved designs. She gives the example of aerosol dispersion in a closed environment, an issue of interest for the dispersion of COVID-19 virus. While Dr. Wu focuses on the capture and reuse of carbon dioxide by using mixed ionic-electronic conducting membranes, a crucial issue for climate change mitigation.

Updates are provided from the Editor of the CSME *Transactions,* the chairs of the *Technical* and *History* committees, and the CSME *Student Affairs and Young Professionals* committee. The *ME Chair's Corner* provides us with a glimpse of the Mechanical and Manufacturing Engineering Department at Ontario Tech University. Finally, the issue also takes the opportunity to celebrate the achievements of Drs. **Yovanovich** and **Salcudean**, which helped our community become what it is today, and to acknowledge the recipients of this year's CSME awards.

This year's CSME Congress will be held in-person, on June 5-8, 2022 at the University of Alberta. For this issue, we asked Dr. **Doucette**, chair of the Mechanical Engineering Department at University of Alberta, to provide an overview of the university, so that those attending the congress can hear his perspective of the hosting institution. Dr. **Hossein Rouhani** and Dr. **Andre McDonald**, co-chairs of the event, and the whole faculty look forward to hosting the CSME 2022 Congress.

The next CSME *Bulletin* issue will be titled **Fighting inflation, the future of manufacturing** and will be led by the Manufacturing and Robotics Technical Committees. Please let the CSME editors know your suggestions for future issues.

We hope you enjoy this issue of the CSME *Bulletin*.

Sincerely,
Editors and Guest Editors


POUYA REZAI, PhD, MCSME, P.Eng.
Editor-in-Chief CSME *Bulletin*
Associate Professor, Department of Mechanical Engineering, Lassonde School of Engineering
York University
prezai@yorku.ca


MARC SECANELL GALLART, PhD, MCSME
P.Eng., *Associate Editor* CSME *Bulletin*
Professor, Department of Mechanical Engineering
Faculty of Engineering, University of Alberta
secanell@ualberta.ca


HORIA HANGAN, PhD
Guest Editor CSME *Bulletin*
Professor and Canada Research Chair
Tier 1 in Adaptive Aerodynamics
Ontario Tech University
Professor Emeritus and Founding Director
WindEEE Research Institute
Western University


HASSAN PEERHOSSAINI, PhD
Guest Editor CSME *Bulletin*
Professor, Faculty of Engineering, Western University
Western Research Chair in Urban Resilience and Sustainability.

PHOTOS COURTESY OF THE RESEARCHERS

President's Message

Message de la présidente

We only have one earth....

Dear colleagues and members,

In the past two years, I have had the privilege of communicating with the CSME members through the *Bulletin*. This is my last message and I am excited that it is part of this issue highlighting Sustainable Development Goals (SDGs) which provide a tangible compass to guide our journey for a better future, with collective milestones and accountable measures. The complexity of the social and environmental challenges of our time requires innovative and creative approaches, finding original solutions using available resources at hand. The articles in this *Bulletin* offer original solutions to climate change crisis. They provide a wide range of approaches from numerical weather prediction, building energy modeling to cultured meat development with the focus on sustainability. I hope you enjoy them.

It is my pleasure to announce that the 2022 CSME International Congress will be held from June 5 to June 8, 2022 at the University of Alberta in person. The congress will have symposia in various fields related to Mechanical Engineering. The local organisers are expecting attendance in the range of 300, and plans are to present all 2020, 2021 and 2022 award winners with their medals and certificates. Next congresses will be in Sherbrooke, QC, Toronto, ON and Montreal, QC.

Thank you for your continuous support. Please join me to welcome Dr. **Aleksander Czekanski** as the next president of CSME starting June 2022.

MINA HOORFAR, PhD, P.Eng., FCSME
CSME *President*
Dean of Engineering and Computer Science
Professor, Mechanical Engineering
University of Victoria

Nous n'avons qu'une seule terre....

Chers collègues et membres,

Au cours des deux dernières années, j'ai eu le privilège de communiquer avec les membres de la SCGM par le biais du Bulletin. Ceci est mon dernier message et je suis ravie qu'il fasse partie de ce numéro mettant en lumière les Objectifs de développement durable (ODD) qui offrent une boussole tangible pour guider notre voyage vers un avenir meilleur, avec des jalons collectifs et des mesures responsables. La complexité des défis sociaux et environnementaux de notre époque nécessite des approches innovantes et créatives, trouvant des solutions originales en utilisant les ressources disponibles. Les articles de ce Bulletin proposent des solutions originales à la crise du changement climatique. Ils offrent un large éventail d'approches allant de la prévision numérique de la météo à la modélisation énergétique des bâtiments en passant par le développement de la viande cultivée en mettant l'accent sur la durabilité. J'espère que vous les appréciez.

J'ai le plaisir d'annoncer que le Congrès international de la SCGM 2022 se tiendra en personne du 5 au 8 juin 2022 à l'Université de l'Alberta. Le congrès offrira des symposiums dans divers domaines liés au génie mécanique. Les organisateurs locaux s'attendent à une participation d'environ 300 personnes et prévoient de présenter à tous les lauréats 2020, 2021 et 2022 leurs médailles et certificats. Les prochains congrès auront lieu à Sherbrooke, Toronto, et Montréal.

Merci pour votre soutien continu. Veuillez-vous joindre à moi pour souhaiter la bienvenue au Dr. Aleksander Czekanski en tant que prochain président de la SCGM à partir de juin 2022.

Mina Hoorfar, Ph.D., P.Eng., FSCGM
Présidente

Transactions of the Canadian Society for Mechanical Engineering (TCSME)

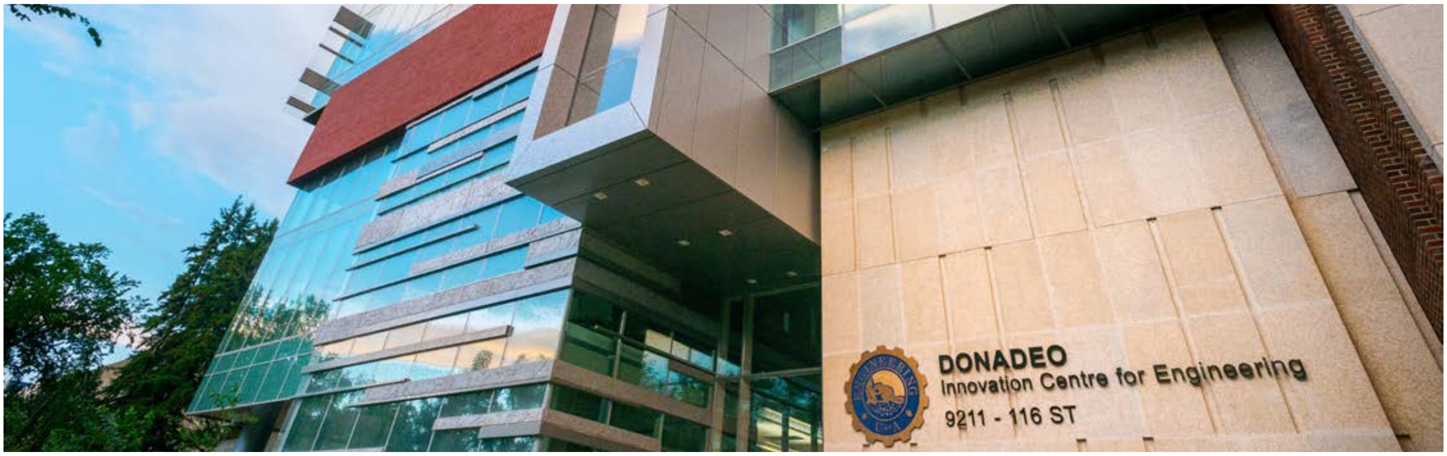
I am happy to report on the accomplishments of the *Transactions of the Canadian Society for Mechanical Engineering* (*TCSME*) for the year 2021. In 2021, we have published four issues with a total number of 56 articles. Also in 2021, based on the Web of Science, articles published either in 2019 or 2020 were cited 131 times which is a good indication that the impact factor for 2021 will be as high as the 2020 impact factor of 1.45. The manuscript submission rate is strong and growing and our overall acceptance rate is about 20%.

Concordia University Please support the journal by downloading and/or submitting articles to the *TCSME*. The journal can be accessed at the link:
www.nrcresearchpress.com/journal/tcsme.

MARIUS PARASCHIVOIU, PhD, FCSME, FEIC
Editor-in-Chief, TCSME
Professor, Mechanical, Industrial and Aerospace Engineering
Concordia University

PHOTO: SCHOOL OF ENGINEERING AT UBC OKANAGAN

2022 Congress at the University of Alberta



DR. JOHN DOUCETTE, PhD, P.Eng.
Professor and Chair, Department of Mechanical Engineering, University of Alberta

Dr. Doucette has served as Chair of the Department of Mechanical Engineering at the University of Alberta since 2017. In addition to his administrative role, he carries out research and teaching in the general area of operations research and optimization.

PHOTOS COURTESY OF THE UNIVERSITY OF ALBERTA

The University of Alberta, founded in 1908 and located in Edmonton, is recognized as one of the top research universities in Canada with its researchers being awarded over $500 million annually in research funding. The University's student body consists of over 40,000 students from over 150 countries, who take courses in more than 200 undergraduate programs and 500 graduate programs. University of Alberta graduates currently enjoy the second-best employment rate in Canada, with alumni now numbering more than 300,000.

Our Faculty of Engineering is one of the largest in North America, with over 4000 undergraduate students and 1500 graduate students in five departments: Chemical and Materials Engineering, Civil and Environmental Engineering, Electrical and Computer Engineering, Mechanical Engineering, and Biomedical Engineering. The Faculty's 200+ professors have one of the best publication rates and one of the highest levels of NSERC funding among Canada's engineering schools.

The University of Alberta's Department of Mechanical Engineering is home to approximately 1000 undergraduate students and over 400 graduate students. Our undergraduate programs emphasize a solid academic foundation and hands-on opportunities, with one or more design courses in each year. Undergraduate students can choose between traditional and co-op degrees, as well as an accelerated program and a biomedical engineering option. Among the wealth of extracurricular activities our undergraduate students participate in are student clubs in robotics, autonomous flight, rocketry, permaculture, hydrogen powered vehicles, biomechanics, and our flagship Formula SAE club (designing, building, and racing a Formula-style race car) and AlbertaSat club (designing and building Alberta's first satellite, Ex-Alta 1, which launched in 2017, and the upcoming Ex-Alta 2 satellite that is currently in development). We provide our students with a dynamic learning environment, and produce high quality graduates who are well prepared for careers in industry, government, and academia.

Graduate students can select MEng (course-based), MSc (thesis-based), and PhD programs in Mechanical Engineering and in Engineering Management. Our comprehensive graduate curriculum is oriented to providing MEng students with targeted advanced learning in a variety of disciplines including solid mechanics, thermo-fluids, and engineering management, and to preparing MSc and PhD students for specialized research in nearly the entire breadth of mechanical engineering and engineering management disciplines, and cutting edge interdisciplinary research that leverages collaborative partnerships across the sciences, medicine, dentistry, and business. Key aspects of our graduate programs include high level of research productivity and publication, professional development training, and high employment rates.

We have 50+ full-time professors who lead active research programs in fluid mechanics, computational fluid dynamics, microfluidics, thermodynamics, aerospace, robotics, mechatronics and controls, autonomous systems, sensors, nanotechnology, advanced manufacturing, Industry 4.0, mechanics of materials, composites and polymers, fracture mechanics, renewable energy, energy storage, energy economics, environment, combustion, HVAC systems, aerosols, biomechanics, rehabilitation, numerical analysis, quality and standards, safety and risk management, reliability, maintenance management, ergonomics, and engineering management. Our facilities are world class, among the best in Canada, and support internationally recognized and highly collaborative research programs.

We are pleased to host the CSME 2022 Congress, and look forward to welcoming delegates from across Canada and around the world. Edmonton and the University of Alberta are beautiful in June; I have no doubt that you will enjoy your visit here.

We are delighted to announce that the CSME 2022 Congress will be held on June 5 – 8, 2022 at the Faculty of Engineering of the University of Alberta in Edmonton (www.csmecongress.org).

This congress is composed of 16 symposiums: 1) Advanced Manufacturing, 2) Advanced and Future Energy Systems, 3) Biomechanics and Biomedical Systems, 4) Computational Mechanics, 5) Computational Fluid Mechanics, 6) Equity, Diversity, Inclusion and Decolonization (EDID) in Engineering Education and Research, 7) Engineering Design, 8) Energy and Environmental Sustainability, 9) Fluid Mechanics, 10) Heat Transfer, 11) Machines and Mechanisms, 12) Materials Engineering, 13) Mechatronics, Robotics, and Control, 14) Microtechnology and Nanotechnology, 15) Solid Mechanics, and 16) Transportation Systems. We have received more than 300 abstracts, full papers and workshop proposals submitted to CSME 2022 Congress, and all accepted contributions can be included in the program as oral presentations.

The Congress will open on Sunday, June 5, 2022 with workshops offered during the day and a welcoming social event planned in the evening. From June 6 to 8, we have organized 6 plenary lectures, 14 keynote lectures and 68 technical sessions (www.csmecongress.org/program). We are delighted to host the award reception ceremonies for the 2020, 2021, and 2022 CSME awards, which will take place during the plenary lectures, the reception ceremony (on June 6, at University of Alberta) and the banquet ceremony (on June 7, at Fairmont Hotel Macdonald).

We are proud to promote EDID in the CSME 2022 Congress through the following highlighted activities: 1) four sessions of EDID in Engineering Education and Research Symposium with invited multi-disciplinary speakers from across Canada discussing various aspects of EDID toward the creation of equitable, diverse, inclusive and decolonized environments at engineering schools and in engineering communities across Canada, and 2) a Power Hour panel event on June 6 afternoon discussing breaking barriers in job searches, networking, recruitment, mentorship and career planning.

The CSME 2022 Congress is an in-person event and will take place in the Faculty of Engineering's facilities, i.e., the Engineering Teaching and Learning Complex (ETLC), and the Electrical and Computer Engineering Research Facility (ECERF). The congress venue is accessible (please visit www.csmecongress.org/venue). The attendees with dietary restrictions or those who require special assistance are encouraged to contact us in advance for proper accommodation.

The CSME Board of Directors meeting, CSME Assembly General Meeting, CSME Technical Committee meetings, and the Mechanical Engineering chairs and directors meeting will also take place during the CSME 2022 Congress.

Finally, we thank our sponsors and supporters (www.csmecongress.org/sponsorship) for their generous support.

For further information, please contact us at csme2022@ualberta.ca.

The Organizing Committee of CSME 2022 Congress (www.csmecongress.org/congress-organizers):

John Doucette, Arman Hemmati, James Hogan, André McDonald, Dan Romanyk, Hossein Rouhani, Lindsey Westover

A glimpse of the Mechanical and Manufacturing Engineering Department at Ontario Tech University

DR. ATEF MOHANY, PhD
Professor and Chair of the Mechanical and Manufacturing Engineering Department
His research interests are in the areas of aeroacoustics, fluid-structure interaction, noise and vibration control.

DR. IBRAHIM DINCER, PhD
Professor and the inaugural University Research Excellence Chair in energy

DR. MARC ROSEN, PhD
Professor and the founding Dean of the Faculty of Engineering and Applied Science

DR. MARTIN AGELIN-CHAAB, PhD
Associate Professor and graduate program director

DR. SEAMA KOOHI, PhD
Associate Teaching Professor

PHOTO BY ATEF MOHANY

GREETINGS FROM THE DEPARTMENT of Mechanical and Manufacturing Engineering at Ontario Tech University (formerly known as University of Ontario Institute of Technology). In 2002, We started our Mechanical Engineering program with two streams in mechatronics and energy engineering. Over the years the Department has grown in terms of the number of undergraduate students, graduate students, staff, and faculty members. In particular, the mechatronics stream had a rapid increase in the number of undergraduate students and thus it was decided in 2016 to offer mechatronics as a standalone program. The mechatronics engineering program continued to grow and it graduated its first cohort in the Winter of 2020. The program has also received its accreditation from the Canadian Engineering Accreditation Board (CEAB). To accommodate the growth in the number of faculty members, undergraduate students, graduate students, research activities, and to better serve our students, the Department was restructured in July 2020 leading to the creation of the Department of Automotive and Mechatronics Engineering and renaming of our former Automotive, Mechanical and Manufacturing Engineering Department as the Department of Mechanical and Manufacturing Engineering. We continue to offer a Mechanical Engineering program with strong steam in Energy Engineering and a standalone Manufacturing Engineering program. In addition, an Industrial Engineering program will be launched in the next academic year with focus on the rapid industrial evolution and the use of artificial intelligence to solve real world industrial problems. These programs are designed to provide students with the best project-based learning experience through innovative curricula. The Department also has a strong graduate studies programs offering PhD, MASc, and MEng degrees in Mechanical Engineering. Currently the Department has over 540 undergraduate students and 115 graduate students.

The Department serves as a hub for innovative research conducted by world renowned researchers in strategic areas including; Renewable and Sustainable Energy, Climatic Engineering, Advanced Manufacturing, Smart Materials, and the general area of Design and Applied Mechanics. We are proud to have 25% female faculty members in the Department and we continue to implement strong Equity, Diversity and Inclusion (EDI) strategies to promote an equitable, diverse, and inclusive working environment. Moreover, several of the faculty members in the Department have had industrial R&D experience before joining Ontario Tech University and they continue leading state-of-the-art research projects in collaboration with industry. This provides our students with exceptional experiential learning opportunities dealing with real life engineering problems using unique research capabilities. These capabilities include a state of the art climatic wind tunnel, small-scale subsonic wind tunnels, an anechoic chamber with a 680 kg multi-axis shaker table, the largest geothermal well fields in the world, state of the art material fabrication and characterization facilities, and the clean energy research center with several unique facilities for hydrogen and green energy research. Thanks to the hard work of our faculty members, the Department has quickly gained national and international recognition since its inception in 2002.

Our Department has significant strength in the areas of sustainable energy research and climatic engineering. We are proud of our highly cited researchers like Dr. Ibrahim Dincer and Dr. Marc Rosen who are among the top 1% of the world's most cited researchers, both of whom lead major research programs at Ontario Tech's Clean Energy Research Laboratory (CERL). CERL is a cutting-edge laboratory for clean energy research (e.g., hydrogen energy production via thermochemical water splitting from nuclear and solar energy) and addressing environmental concerns like climate change. Over the past two decades, the Clean Energy Research Laboratory has been playing a key role in developing hydrogen production technologies, Ammonia fuel cells, integrated and polygeneration energy systems, renewable energy technologies, energy storage technologies, clean transportation technologies, Carbon capturing technologies, and exergy analysis and efficiency improvement. We are also proud to have Dr. Horia Hangan who is a Tier 1 Canada Research Chair in adaptive aerodynamics. His research includes the simulation and impact of high intensity winds (downbursts and tornados), wind energy (sitting in complex terrain, wind turbine blade aerodynamics) and wind environmental impacts (atmospheric pollution dispersion, particulate transport). Having the climatic wind tunnel in our backyard makes the impossible, possible. The Department is also proud to have rising stars like Dr. Martin Agelin-Chaab who is working with the APMA on Project Arrow in which Ontario Tech University and the Department will play a leading role in the development of a fully functional Canadian-made zero-emissions vehicle. Certainly, this cannot be realized without the innovative research that is conducted in the Department in the areas of Advanced Manufacturing, Smart Materials, Design and Applied Mechanics. Due to its geographic location and industrial demographics, Ontario Tech University has always considered these areas as some of its main strategic research areas. In these areas, we are proud of our internationally renowned researchers like Dr. Hossam Kishawy and Dr. Ebrahim Esmailzadeh whose publications are highly cited.

Innovation in teaching is also another pillar of strength in our Department. We are proud of our faculty members who are actively contributing to the development of engineering education and have received the university innovation award in teaching like Dr. Remon Pop-Iliev, Dr. Sayyed Ali Hossieni, Dr. Brendan MacDonald, and Dr. Seama Koohi. Dr. Koohi is actively contributing in the area of engineering education with special interest on pedagogical impact of flipped classroom on mechanical engineering courses.

In summary, I am truly proud of our Department and it is a privilege to lead this great team of professors and researchers who are determined to serve our students and provide them with the best learning experience to prepare them for their future careers.

Call for Nominations – 2023 EIC Awards

The Engineering Institute of Canada (EIC) is pleased to announce that it is currently accepting nominations for its 2023 senior awards and EIC fellowship inductees. The deadline for nominations is midnight, 15 November 2022 for awards to be remitted at the EIC Gala in April 2023.

The senior awards of the EIC are the highest distinctions made by the Institute and are awarded to deserving members of its technical societies:

SIR JOHN KENNEDY MEDAL for outstanding services rendered to the engineering profession, or of noteworthy contributions to the science of engineering, or to the benefit of the Institute.

JULIAN C. SMITH MEDAL for achievement in the development of Canada.

K.Y. LO MEDAL for significant engineering contributions at the international level.

JOHN B. STIRLING MEDAL for leadership and distinguished service at the national level within the Institute and/or its Constituent Societies.

CANADIAN PACIFIC RAILWAY ENGINEERING MEDAL for many years of leadership and service by members of the Societies within the Institute at the regional, branch and section levels.

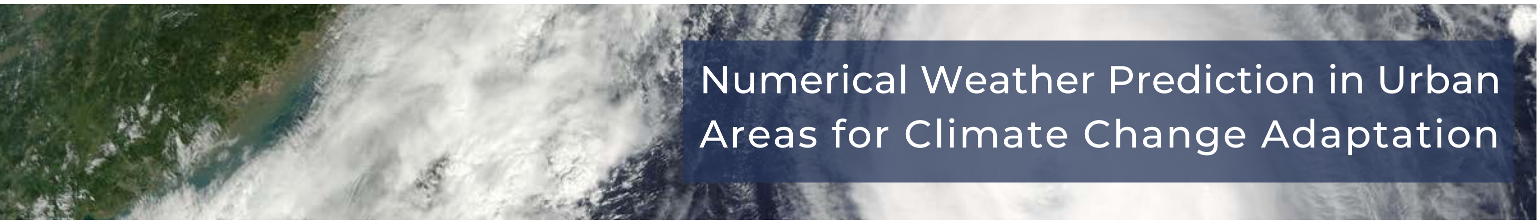
EIC FELLOWS are inducted for excellence in engineering and services to the profession and to society.

Nomination rules and form can be found on EIC's website: eic-ici.ca/honours_awards/nomination

About the EIC

Founded by Royal Charter in Montreal in 1887 as the Canadian Society of Civil Engineers with the mandate to disseminate technical information and experience, the society was renamed by Parliament in April 1918 as the Engineering Institute of Canada. In its first century, the EIC functioned as a learned society with members from various engineering disciplines. It is now a federation of fourteen technical societies representing the main engineering disciplines and whose mandates remain the dissemination of technical knowledge and experience and the maintenance of high standards for engineering practice in Canada.

Contact: Guy Gosselin, EIC Executive Director / ggosselin.eic@gmail.com / www.eic-ici.ca



Numerical Weather Prediction in Urban Areas for Climate Change Adaptation

HOSTING ALMOST 82% OF CANADIANS, CITIES are complex systems particularly vulnerable to climate change while being an important source of its intensification. In combination with the increased heat in cities as compared to their rural counterparts (e.g., the urban heat island phenomenon), global warming has and will continue to have more impacts on population lives through the occurrence of more extreme and more frequent weather hazards. This article highlights how numerical weather prediction (NWP) can be used for adaptation preparedness.

NWP is an important component of weather and climate forecasts. It includes atmospheric models, physical parametrizations, Earth observations to provide model initial state and corrections (data assimilation), and other ancillary data needed by the models. Atmospheric models apply classical laws of physics and resolve the Navier-Stokes and mass continuity equations, the first law of thermodynamics and the ideal gas law to determine the time and space evolution of temperature, pressure, density and wind, complemented by the contribution of radiative, convective and diffusive physical processes. After decades of continuous improvement to NWP[1], more emphasis was brought to the near-surface processes in NWP and their impact on living systems' environmental conditions. Advanced land surface models appeared in the 1980's with continuous further developments that include parametrizations of soil and vegetation physical processes and their interaction with the atmosphere. As cities are specific environments, urban schemes have been developed since the 2000's with different levels of complexity and by considering the 3-D street canyon morphology with artificial materials for which the surface energy budget terms are computed (*Figure 1*).

SYLVIE LEROYER, PhD

Sylvie Leroyer, PhD, is a research scientist at the Meteorological Research Division of Environment and Climate Change Canada (ECCC), in the section of Numerical Environmental Prediction. She completed her PhD at the Ecole Centrale de Nantes, France, where she started to study urban modelling. She continued her research in Canada at McGill University before joining ECCC. With her team and her collaborations with the Canadian Center for Meteorological and Environmental Prediction and universities, she contributes to the design, development, analysis and evaluation of ECCC's urban modelling systems and their applications to propose data and products relevant to urban population needs.

IMAGES COURTESY OF THE RESEARCHER

Figure 1

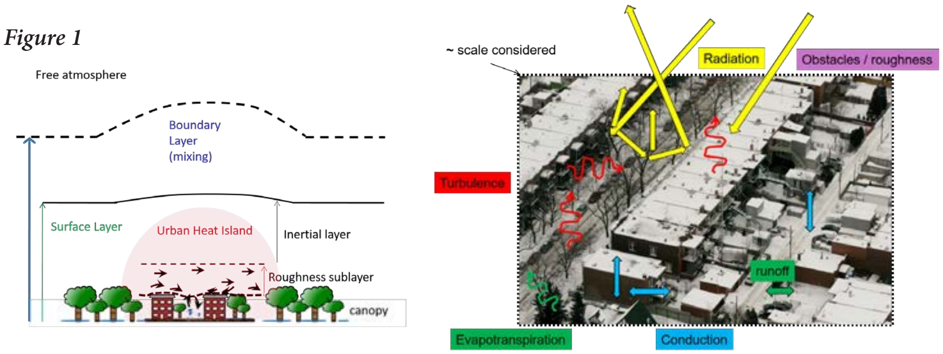


FIG 1: REPRESENTATION OF URBAN MICRO-METEOROLOGY IIN NWP MODELS. LEFT: OVERVIEW OF THE LOWER TROPOSPHERE. RIGHT: SKETCH OF THE MAIN PHYSICAL PROCESSES REPRESENTED IN URBAN AND LAND SURFACE MODELS (SUPERIMPOSED ON A PHOTOGRAPH OF MONTREAL DURING AN OBSERVATIONAL EXPERIMENTAL CAMPAIGN, COURTESY OF PR J. VOOGT).

TOWARDS INTEGRATED URBAN SERVICES (IUS)

Recent advancements in urban NWP have focused on the development of tailored products to respond to societal needs. Emergence of the concept of integrated urban hydro-meteorological, climate and environmental services (IUS)[2], according to which decision-making is ideally the consequence of the integration of a large amount of knowledge and data from different scientific expertise and governance sectors, is supported by the World Meteorological Organization under the United Nations umbrella. These developments are articulated around tools and practices for sustainable development and multi-hazard early-warning systems for cities. Early prototypes, more or less mature, have been settled in the world[3]. Some of them resulted from actions following a major high-impact disaster, and others have been initiated with the opportunity of a special event. That was the case in Canada for the city of Toronto, when the Pan-American and Parapan-American games in 2015 (TO15) offered the opportunity for intensive collaborations, scientific and technical developments[4]. Modelling and prediction steps towards IUS have been achieved at Environment and Climate Change Canada (ECCC) while bringing together several state-of-the-art components as illustrated on *Figure 2* for the provision of urban-scale weather forecasts[5] down to a resolution of 250 m. In addition to the atmospheric model and the large-scale weather conditions, the system integrated refined description of the urban fabric (land use, street morphology and building properties) and related physical processes, the assimilation of soil moisture and temperature, and of the lake surface temperature to compute small-scale meteorological conditions and other derived outputs, and further fed a wave model.

Progress in biometeorology has been part of the journey. Arising from collaborations with health organizations in Ontario, measurement sensors for thermal stress assessment were added to the TO15 observational network in urban areas to provide the Wet-Bulb Globe Temperature (WBGT) thermal comfort index that takes into account multiple factors including the radiation load on the human body. This index is still the reference in occupational health heat stress regulations and for various users, usually obtained with local point measurements. With that opportunity, our team carried out research to be able to model WBGT in the urban system, and results were in good agreement with measurements[6]. With this important step, we are able to provide large-scale forecasting maps of integrated indices to anticipate and locate upcoming stressful conditions, for example for outdoor workers or homeless people.. A novel integrated index, the Universal Thermal and Climate Index (UTCI) has also been implemented in the model[6]. Although its use is less known by end-users in Canada, this index has been developed with the intent to homogenize scientific knowledge in biometeorology and is now widely used worldwide.

Such thermal stress indices are now disseminated daily in one of ECCC's operational systems that includes an urban surface parameterisation and provides short-range weather forecasts with 2.5 km grid spacing. However, the

Figure 2

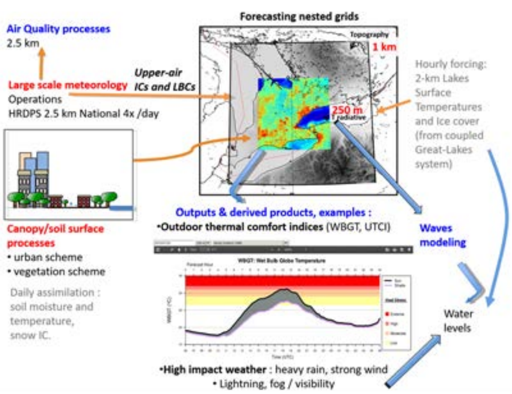


FIG. 2: PART OF THE ECCC STRATEGY FOR PREDICTION DURING THE PAN-AM AND PARA-PANAMERICAN GAMES IN TORONTO IN 2015 AND RE-USED IN 2017 DURING A SPRINGTIME FLOODING EVENT (ADAPTED FROM [3]).

Figure 3

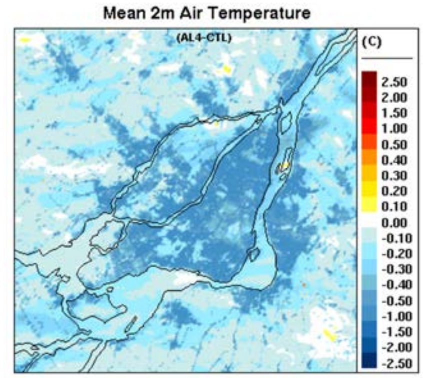


FIG. 3. MEAN FORECASTED TEMPERATURE DIFFERENCE (IN °C) WITH 250 M GRID SPACING DURING JULY 2010 HEATWAVE (4-9 JULY) WHEN CONSIDERING A SCENARIO WITH AUGMENTED REFLECTIVITY OF BUILT-UP SURFACES FOR 95% OF THE MONTREAL METROPOLITAN REGION (INCREASE OF ALBEDO OF ROOF: 0.15 TO 0.65; OF ROADS: 0.2 TO 0.45; OF WALLS: 0.25 TO 0.60)[7] .

resolution is not as high as the 250 m resolution reached during TO15 due to comprehensive delays between up-to-date research and development and operational implementations. One of the complex but critical requirements for this system, was to prepare cities' characteristics for a huge domain covering Canada. As seen with this system, the unprecedented heatwave in British Columbia in June 2021 exhibited heat stress indices that easily overpassed the threshold values assigned for extreme heat stress, even in the coastal urbanized areas of Vancouver, and this situation led to a tragic heat-related morbidity.

Recent advancements stretch beyond the scope of future weather forecasting. The use of urban modeling tools for urban planning assessment is promising, as these have reached a sufficient level of detail and maturity to represent physical processes related to buildings, artificial surfaces, urban vegetation and water runoff, and their interaction with the atmosphere. We have developed a numerical platform for evaluation of urban planning strategies. Our first project considered a comprehensive set of 17 heat mitigation scenarios with various reflectivity and vegetation cover modifications designed for the cities of Montreal and Toronto. Results from corresponding NWP numerical experiments during two overheating periods in 2010 highlighted significant sensitivity of outdoor environmental conditions to the urban infrastructure. Temperature reduction was effective in most cases[7] (*Figure 3*), with values lowered sometimes by up to 3°C locally during the day and by up to 1°C on average for an overheating period. Our team will continue to develop numerical experiments with wider consideration of past heat waves in order to understand the long term impact of urban planning measures on urban climate.

We have recently taken the path towards more integration of the links between outdoor environmental conditions and indoor microclimate and building energy consumption with our research partners. Heat exchange through a building's envelope is currently represented in our NWP systems with simplifications. Research to improve the two-way interactions between urban microclimate and environmental conditions inside buildings is conducted by taking into account detailed building energy models with an inventory of building archetypes at the city-scale, including population habits[8]. It is of primary importance to be able to locate the most vulnerable people during a heat wave. Use of air-conditioning units can be heterogeneous through the city and in addition, limitation of its use can occur during power outages related to a high peak energy demand which could have dramatic impacts that need to be anticipated.

IMPORTANT CHALLENGES

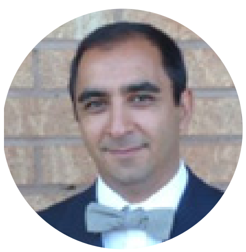
Further considerations are needed to allow accurate and efficient use of urban NWP for sustainability outcomes. Some strategies to decrease outdoor temperature can lead to an improvement of indoor conditions but also to a degradation of outdoor thermal stress conditions due to a change in the radiation budget. The challenge is to explain all nuances of heat mitigation strategies to decision-makers and urban planners to be able to find problem-adapted solutions. Continuous end-user feedback is needed for meteorological early warning systems in order to inform in a useful manner on the direction of future research and development. Complete knowledge of the current urban surface characteristics, including their past and predicted modifications, is necessary and requires the gathering of multiple databases. Inclusion of hydrology infrastructure and modelling in urban areas is at its early stage and will be beneficial for forecasting water hazards such as flood and vegetation dryness. Finally, the goal of integrating most of the Earth system components into one modeling system is daunting to some, as it requires important scientific, technological and human resources, but it will ensure a more global understanding of our environment and how we can mitigate climate change impacts.

References

1. Bauer, P., A. Thorpe, G. Brunet, 2015: The quiet revolution of numerical weather prediction, *Nature*, 525, 7567, pp. 47-55.
2. Grimmond S, Bouchet V, Molina LT, Baklanov A, Tan J, Schlünzen KH, Mills G, Golding B, Masson V, Ren C, Voogt J, Miao S, Lean H, Heusinkveld B, Hovespyan A, Teruggi G, Parrish P, Joe P. 2020. Integrated urban hydrometeorological, climate and environmental services: concept, methodology and key messages. *Urban Climate* 33: 2212–0955.
3. Baklanov A, Cárdenas B, Lee T-C, Leroyer S, Masson V, et al. 2020. Integrated urban services: experience from four cities on different continents, *Urban Climate*. 32:100610
4. Joe, P., and Coauthors, 2018: The Environment Canada Pan and ParaPan American Science Showcase project. *Bull. Amer. Meteor. Soc.*, 99, 921–953.
5. Leroyer, S., S. Bélair, V. Souvanlasy, M. Vallée, S. Pellerin, D. Sills, 2022: An Urban-Scale Numerical Weather Prediction System for the Toronto 2015 Pan and Parapan American Games, *Atmosphere*, *in revision.*
6. Leroyer, S., S. Bélair, L. Spacek, and I. Gultepe, 2018: Modelling of radiation-based thermal stress indicators for urban numerical weather prediction. *Urban Climate*, 25, 64-81.
7. Leroyer, S., Bélair, S., Alavi, N., Munoz-Alpizar, R., Nikiema, O., Popadic, I., 2019. Impact of Urban Planning Strategies on the Microclimate and Thermal Comfort, report for the Quebec Institute for the Public Health, 143 pp. (in French).
8. Schoetter, R., Masson, V., Bourgeois, A., Pellegrino, M., & Lévy, J. P. (2017). Parametrisation of the variety of human behaviour related to building energy consumption in the Town Energy Balance (SURFEX-TEB v. 8.2). *Geoscientific Model Development*, 10(7), 2801-2831.

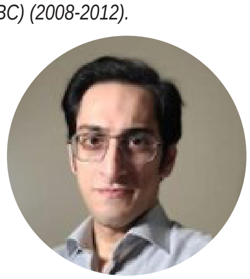
IMAGES COURTESY OF THE RESEARCHER

The Characteristics of an Advanced Building Energy Model



Prof. AMIR A. ALIABADI, PhD

Dr. Aliabadi is an associate professor in the Environmental Engineering program at the School of Engineering, University of Guelph (UofG). His research interest is in environmental thermo-fluid dynamics. He is particularly focused on atmospheric chemistry and physics in indoor and outdoor environments. He has devoted his research endeavor to analytical, numerical, and experimental investigations of thermo-fluid systems. Prior to joining UofG in 2016, he was a Research Associate at the Department of Architecture, Massachusetts Institute of Technology (MIT) (2015-2016) and a Visiting Post Doctoral Fellow at the Air Quality Research Division, Environment and Climate Change Canada (ECCC) (2013-2015). He obtained his PhD in Mechanical Engineering from the University of British Columbia (UBC) (2008-2012).



Dr. MOHSEN MORADI, PhD

Dr. Moradi is a Postdoctoral Fellow at the School of Engineering, University of Guelph (UofG). He is specialized in climate modeling, climate change risk assessment, and big data analysis. He values wide-reaching knowledge dissemination, which has led him to develop numerous open-source software and online tools with application in urban climate modeling and climate change impacts on infrastructure systems. He received his PhD in Environmental Engineering from UofG in (2017-2021).

IMAGES COURTESY OF THE RESEARCHER

BUILDINGS ARE KNOWN TO CONSUME CLOSE TO 40% of the world's energy, and as such they are a major contributor to the greenhouse gas (GHG) emissions globally (Aliabadi et al. 2021). One of the key missions of building energy modelling is to develop computer simulation tools to help design and operate buildings that are environmentally friendly and economical at the same time (Connolly et al. 2010). In this regard, building energy models (BEMs) help investigate many scenarios for building design and operation and thus narrow down the choices. Every BEM developer faces many key questions: What is a good building energy model? How much accuracy and resolution are enough when developing such a model? Should a model be simple or complex? How computationally fast should it be? How many processes should be included when developing such a model?

The short answer would be that BEM components should be designed and integrated in efficient and ingenious ways to strike the balance in achieving the BEM goal. Ideally, when developing BEMs, the modeller would prefer to have as much accuracy and resolution as possible, i.e., to include all known physical/chemical processes and economics related to building design and operation, while reducing computational requirements. The ambitious modeller wants to simulate physical/chemical processes down to temporal and spatial resolutions of milliseconds and millimetres. The modeller also wishes to include all weather and climate processes, all forms of building energy systems, all forms of renewable and alternative energy sources, and all economic models available. However, the modeller soon realizes that the wish list is prohibitively long, perhaps with conflicting items, and it is very complex to achieve such high ideals. This is because of the multi-faceted nature of buildings and how they work. Just to name a few challenges: buildings have a two-way feedback interaction with the background climate and weather conditions; building performance is governed by multi-scale and multi-physics processes; there are countless ways to integrate renewable and alternative energy systems into buildings; buildings are used in unpredictable ways, as opposed to how other engineered devices such as automobiles and aircraft are used. So, sacrifices should be made when developing BEMs. For instance, high accuracy, resolution, simplicity, and computational speed may not be achieved simultaneously. In the end, it is all about the balance and goals of the BEM.

BEM developments have come a long way to rise to the challenges. Among many, physics-based BEMs include tools such as TRNSYS, EnergyPlus, eQuest, IES, Can-Quest, RETScreen, and EE4. In the general sense, given a building design and operational specifications, these tools allow for building load calculations (cooling, heating, electricity, and water) and means of meeting the demands using standard energy systems. Such tools also allow decision support to evaluate energy performance of buildings, cost, GHG emissions, financial viability, and possibly opportunities for inclusion of various types of renewable and alternative energy systems. These tools are either used stand-alone (e.g. IES) or meant to be integrated in larger third-party software (e.g. EnergyPlus) (Connolly et al. 2010, Harish and Kumar 2016, Gao et al. 2019). Recently, BEMs based on Machine Learning (ML) and data-driven approaches have also emerged, which compete with physics-based BEMs. Although this approach is more successful when models are trained with datasets describing predictable scenarios, seri-

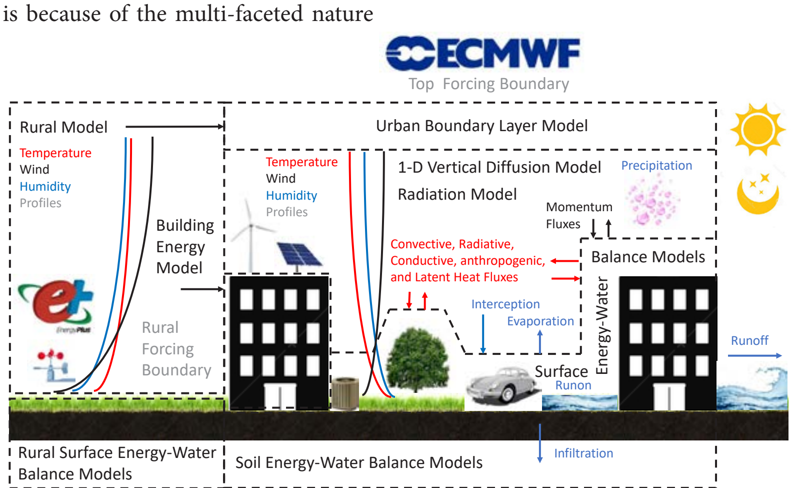


FIG. 1: SCHEMATIC OF THE VERTICAL CITY WEATHER GENERATOR (VCWG) URBAN CLIMATE AND BUILDING PERFORMANCE MODEL .

ous limitations remain for situations not foreseen in the training datasets, where the model has to extrapolate new results (Seyedzadeh et al. 2018, Bourdeau et al. 2019).

Noteworthy gaps in BEMs still exist. BEM developments require a deeper understanding and implementation of the two-way interaction between climate and weather processes and buildings. This is true because while the building energy performance depends on environmental conditions, the building also influences the environmental conditions. For instance, consider a building under cooling mode. Warm outdoor temperatures and the cooling load require operation of air conditioning equipment to lower indoor temperatures. However, air conditioning equipment rejects heat into the outdoor environment and causes further warming of outdoor temperature, and the feedback cycle continues. Also, more flexibility is needed to permit customized renewable and alternative energy integration. More physical processes need to be considered, such as hydrological and vegetation processes. For instance, precipitation and flooding changes the energy balance at the urban surfaces by causing enhanced surface cooling and water evaporation. Further, trees provide shading and undergo evapotranspiration, which could modify water consumption and result in the cooling of the outdoor environment. In addition, BEMs should be designed to allow for long term building energy projections for climate scenarios over many decades into the future. These needs have resulted in the development of a new urban climate and building energy model titled the vertical city weather generator (VCWG) at the University of Guelph.

VCWG is a multi-physics and micro-scale model. Its philosophy is to parameterize numerous physical processes and integrate them to make predictions on urban climate and building performance variables. The paradigm is model integration at the system level, without the temptation to over-complicate model design beyond what is necessary. As shown in *Figure 1*, VCWG integrates various sub-modules including the rural, rural surface energy-water balance, building energy, surface energy-water balance, soil energy-water balance, vertical diffusion, and urban boundary layer models. VCWG is forced either by 1) EnergyPlus Weather (EPW) climate forcing data in a rural area, or 2) meso-scale weather model data products on top of its domain (e.g. Weather Research and Forecasting (WRF), Global Environmental Multi-scale (GEM) model, or European Centre for Medium-Range Weather Forecasts (ECMWF) model). It then simulates urban climate variables in air (wind, temperature, humidity), on surface (temperature, sensible and latent heat fluxes, evaporation, precipitation, run-on, runoff), in soil (temperature, moisture, leakage), and building (indoor temperature, humidity, heating/cooling/hot water loads, natural gas/electricity consumption). The sub-modules are fully integrated and account for two-way feedback interaction between the building and the environment (Moradi et al. 2021, 2022).

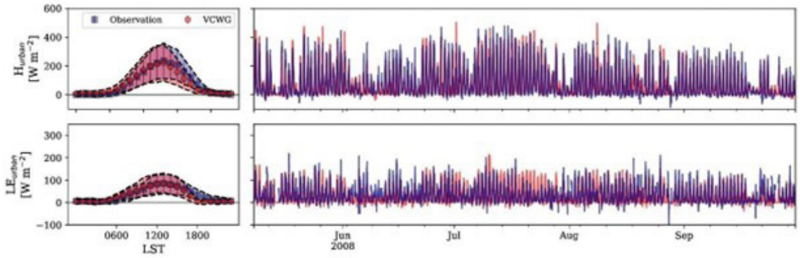


FIGURE 2 COMPARISON BETWEEN THE VANCOUVER SUNSET DATASET (BLUE/SQUARES) VERSUS SIMULATED (RED/CIRCLES) VALUES OF SENSIBLE H AND LATENT LE HEAT FLUXES [W M-2] ABOVE THE URBAN AREA USING VCWG; THE HOURLY MEANS ARE SHOWN; TIMES IN LOCAL STANDARD TIME (LST); SIMULATION FOR A 5-MONTH PERIOD IN 2008. THE SHADED AREA IS SENSIBLE/LATENT HEAT FLUX ± 1 STANDARD DEVIATION.

The building energy model in VCWG descended from EnergyPlus (Bueno et al. 2012a, 2012b), but it has been continually refined. Given that it is part of a large modelling system, currently the energy model is a single zone model, but it is furnished with all the standard parameters (energy load calculation, glazing, ventilation, infiltration, resistance values of building envelop, building stock materials, coefficient of performance, and thermal efficiency of energy equipment). Most recently it was enabled with a configuration for renewable/alternative energy systems, and it can simulate roof-top photovoltaics, roof-top wind energy, roof-top solar thermal collection, thermal energy storage (both sensible and phase-change) via building mass, heat pump, energy recovery, and more. VCWG also offers an economic analysis for multi-objective optimization of renewable and alternative energy to reduce cost, gas consumption, and electricity consumption simultaneously (Aliabadi et al. 2021). VCWG is designed to be forced using downscaled weather data from regional climate models, such as CanRCM4, to simulate building energy performance many decades into the future.

VCWG originated at Massachusetts Institute of Technology (MIT) by the name Urban Weather Generator (UWG) (Bueno et al. 2012a, 2012b). It was then inherited by the University of Guelph for further refinement with the help of Spain's Center for Energy, Environment and Technology (CIEMAT), University of British Columbia (UBC), and ETH Zürich. Validation data were provided by Western University and University of Freiburg. Compared to urban climate observations in Basel, Switzerland (2002), VCWG has achieved a bias (RMSE) of -0.53 (0.56) [K], -0.46 (0.44) [$m\ s^{-1}$], and 0.0000 (0.0003) [$kg\ kg^{-1}$] for potential temperature, wind speed, and specific humidity at pedestrian level air, respectively. *Figure 2* shows the performance of VCWG in predicting the sensible and latent heat fluxes above the urban canopy layer compared to observations in Vancouver, BC, Canada (2008). VCWG achieved a bias (RMSE) of 0.65 (18.1) [$W\ m^{-2}$] and 1.35 (27.7) [$W\ m^{-2}$] for sensible and latent heat fluxes, respectively (Moradi et al. 2022). These error statistics indicate equal or superior performance by VCWG in comparison to other models. VCWG is continuously being refined and developed by many collaborators internationally.

VCWG is written in the Python programming language with an open-source code[1]. It is computationally fast, able to simulate a latitude-longitude for an entire year in just about 20 minutes on a single CPU, producing hourly outputs of all variables. It is a research tool that can be configured for any type of exploration easily, such as environmental impact analysis, optimization of building energy systems, urban neighborhood planning/development, micro-climate and thermal comfort predictions, and more. All data is manipulated in text and NetCFD formats. For more reading and to download different versions of VCWG, please refer to the references (Aliabadi et al, 2021, Moradi et al, 2021, 2022).

Future advancements for VCWG are possible. Although sufficient to meet the goals of the model, almost all parameterizations in VCWG can be refined and improved to represent more details and increase spatial or temporal resolutions if required. Some examples include the vegetation, building energy, vertical diffusion, and radiation models.

VCWG offers a flexible, computationally fast, and multi-physics approach to urban physics modeling at micro-scale. It can fuel a lot of research projects forward, particularly those that focus on well-balanced building energy modeling.

References continued on page 14

Prof. AMANDA GIANG, PhD
Dr. Giang is an Assistant Professor in the Department of Mechanical Engineering and Institute for Resources, Environment, and Sustainability at the University of British Columbia. Her research focuses on improving environmental impact assessment and policy analysis methods, to inform technology and policy interventions for pollution, climate, and energy issues. She received her PhD in Engineering Systems and SM in Technology Policy from MIT, and BASc in Engineering Science from the University of Toronto. She serves as an Editorial Board member for the Environmental Research Communications *journal and as an Early Career Editorial Advisory Board Member for Environmental Science & Technology.*

DR. NAOMI ZIMMERMAN, PhD, P.Eng.
Canada Research Chair of Sustainability, Department of Mechanical Engineering, UBC

DR. ADAM RYSANEK, PhD
School for Architecture and Landscape Architecture, Department of Mechanical Engineering, UBC

DR. PATRICK KIRCHEN, PhD, P.Eng.
Patrick Kirchen, PhD, PEng, Department of Mechanical Engineering, UBC

DR. VLADAN PRODANOVIC, PhD, P.Eng.
Department of Mechanical Engineering, Department of Chemical and Biological Engineering, UBC

THE MOST RECENT REPORTS OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC) have made it clear: "climate change is a threat to human wellbeing and the health of the planet"[1]. The impacts of climate change—from sea-level rise to wildfires—are already being experienced around the world, and the worst of these impacts are often borne by those least responsible for contributing to climate change[1,2]. If we are to avoid the most catastrophic climate futures, we must collectively embark on systems transformation of unprecedented scale, scope, and speed. Rapid and large-scale reductions of greenhouse gas emissions are needed from all sectors to limit warming to 1.5°C above pre-industrial levels[3]. Our infrastructure and ways of life need to be resilient to a changing and unpredictable climate[1]. And, at the same time, we must tackle drivers of the climate crisis and linked societal challenges, from overconsumption of resources to widespread inequality[3]. Mechanical engineers have important roles to play in all of these transitions[4,5]. Mechanical engineering innovation has been central to how we produce energy, move people and goods, design and operate buildings, and undertake industrial activities. Now, how can mechanical engineering help us reimagine these sectors to be low carbon, climate resilient, sustainable, and just?

As mechanical engineering researchers and educators, the outputs of our work are not only technologies and processes, but people: training the next generation of engineering professionals. So what are the transformations we need in engineering education to better prepare mechanical engineers to address the challenges of the climate crisis? As summarized in *Figure 1*, we argue that three things are needed: (1) climate change content needs to be a core, and not peripheral, part of the technical curriculum; (2) mechanical engineering education needs to be enriched to also emphasize competencies around systems-thinking, interdisciplinarity, complexity, uncertainty, ethical dimensions, and communication; and (3) institutional incentives need to be aligned to support the curricular innovations described above.

MAKING CLIMATE CHANGE CORE

Climate change content is sometimes treated as a complementary part of the curriculum, which means missed opportunities for showcasing how mechanical engineering fundamentals are core to climate solutions. For instance, applications of thermofluids, solid mechanics, and control systems are needed to decarbonize some of the sectors that contribute most to Canadian greenhouse gas emissions, including energy production (34%), transportation (25%), buildings (12%), and heavy industry (11%)[6]. When we teach thermodynamics and heat engines, we can introduce how transitioning to heat pumps is a means to electrify and decarbonize space heating[7]. Fluid mechanics is critical to the improved design of turbines for harnessing renewable sources of energy, such as wind and

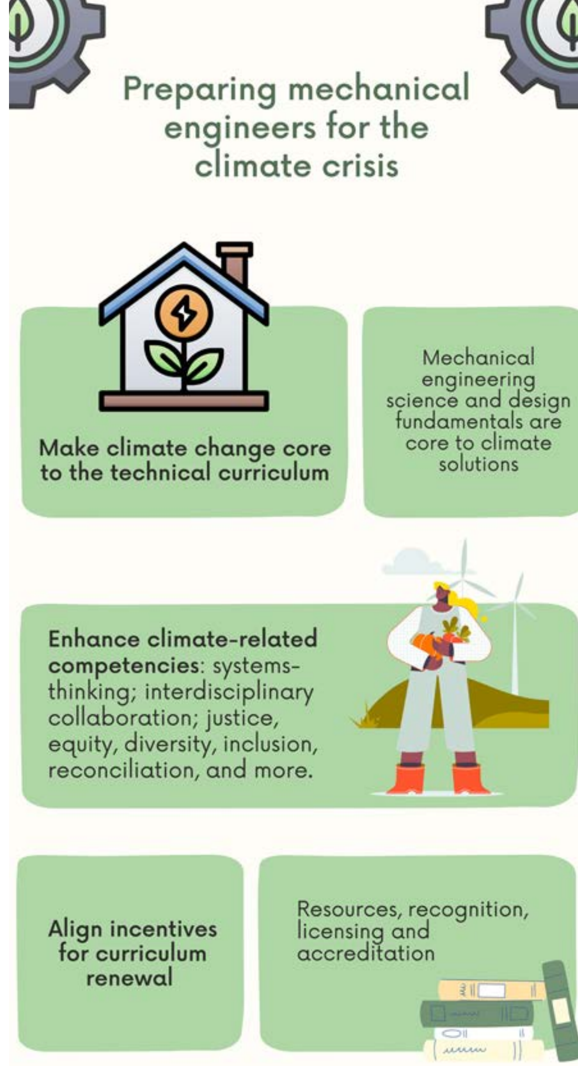


Figure 1

tidal[8]. Control systems and optimization can improve energy efficiency and carbon intensity of HVAC and propulsion systems[9]. Applications of solid mechanics can improve structures and the fuel efficiency of aviation and shipping, and materials and manufacturing innovations can reduce reliance on fossil-fuel plastics and enhance opportunities for a circular economy[10]. In all of these examples, the fundamental engineering science concepts have not changed, but the application contexts that are highlighted emphasize the role that mechanical engineering can play in decarbonization. Further, these examples also highlight how consideration of a wider range of performance indicators can be incorporated into the engineering design process. In our teaching, there is opportunity to weave in new canonical examples into existing courses, to equip students to be leaders in the transitions that will be unfolding over the next thirty years, not those of the past three hundred. When mention of climate change only happens in select courses (e.g., impact of engineering on society and environment), or when climate literacy focuses only on the nature of the problem and not on opportunities for innovation, it sends the message to students that climate and sustainability considerations are not core to the mechanical engineering identity.

ENHANCING CLIMATE-RELATED COMPETENCIES

To prepare mechanical engineers to effectively address the climate crisis, we also need to enhance training in areas that have not been traditionally emphasized in engineering education. The systems transformations needed bring together interlocking technical, social, and environmental dimensions. Engineering science and design is an important piece of the puzzle, but not the whole picture. Engineering professionals will need to be prepared to work in diverse, multi-sectoral and interdisciplinary teams, in a spirit of collaboration and intellectual humility; this includes appreciation for diverse forms of expertise and knowledge, recognizing that climate solutions must weave knowledge from engineering, natural and social sciences, Indigenous knowledge, local knowledge, and experiential knowledge if they are to be effective, scalable, and socially and environmentally robust. It also includes the ability to communicate, in plain language, to a wide range of stakeholders and rightsholders, including policy-makers, industry, and communities. Engineering practice during a time of rapid technological, environmental, and social change means graduates must be equipped with frameworks for anticipatory and preventive thinking, and decision-making under uncertainty and values diversity. In many cases, the design constraints of the past will not be a good predictor for the future, and the meaning of good system performance must evolve to include a wider range of factors. Finally, there is increasing recognition that advancing justice, equity, diversity, inclusion, and reconciliation are very much part of the professional responsibilities of engineers, and that failure to honour these responsibilities has resulted in historical and ongoing harms[11]. Understanding social and ethical context is critical to how engineers engage with the climate crisis. Engineering graduates must be trained to think critically about how environmental risks and benefits of engineered systems are distributed (between generations, between geographic regions, and between different social groups), who participates in technical decision-making, and who is and is not represented in engineering communities currently, why, and what that means for the design of climate solutions. Exposure to, and practice with, these competencies—for instance, through applied, capstone experiences—will support graduates in becoming tomorrow's engineering and climate leaders.

INCENTIVES FOR CHANGE

There is demand for these changes in mechanical engineering training—from students, and from industry, government, and society-at-large. Many educators are already participating in bottom-up efforts to reimagine engineering training, but to accelerate curriculum renewal, we need to align incentives for change at the department, university, and professional level. Possible pathways include more explicit emphasis on climate mitigation and adaptation in accreditation and licensure, funding for curriculum development efforts, and recognition of these efforts in tenure and promotion. For instance, at the University of British Columbia, new programs such as the Climate Education Grant and Climate Teaching Connector programs provide support for incorporating climate change content in existing courses, in the form of financial resources and facilitated access to climate experts across campus. These programs are promising first steps to mainstreaming climate content, and could be further supported by program-level curriculum mapping efforts. Climate change is one of the defining challenges of our time, and we have a duty as educators to empower students with the knowledge, skills, and attitudes they need to help build the future that they would like to live in. There is much work to be done, and the reality is we don't have time to wait.

References

1. IPCC. Climate Change 2022: Impacts, Adaptation, and Vulnerability. In: Pörtner HO, Roberts DC, Tignor M, Poloczanska ES, Mintenbeck K, Alegría A, et al., editors. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press; 2022.
2. Emmerling J, Tavoni M. Representing inequalities in integrated assessment modeling of climate change. *One Earth*. 2021 Feb 19;4(2):177–80.
3. IPCC. Climate Change 2022: Mitigation of Climate Change. In: Shukla PR, Skea J, Slade R, Al Khourdajie A, van Diemen R, McCollum D, et al., editors. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press; 2022.
4. Webber ME. New Engineering Thinking for a New Climate. *Mech Eng*. 2016 Jun 1;138(06):28–33.
5. Linow S. Integrating Climate Change Competencies into Mechanical Engineering Education. In: Leal Filho W, Hemstock SL, editors. Climate Change and the Role of Education [Internet]. Cham: Springer International Publishing; 2019 [cited 2022 Mar 21]. p. 33–51. (Climate Change Management). Available from http://doi.org/10.1007/978-3-030-32898-6_3
6. Environment and Climate Change Canada. Canadian environmental sustainability indicators: greenhouse gas emissions. [Internet]. 2020 [cited 2021 Mar 14]. Available from: https://epe.lac-bac.gc.ca/100/201/301/weekly_acquisitions_list-ef/2021/21-06/publications.gc.ca/collections/collection_2021/eccc/en4-144/En4-144-18-2020-eng.pdf
7. Knobloch F, Hanssen SV, Lam A, Pollitt H, Salas P, Chewpreecha U, et al. Net emission reductions from electric cars and heat pumps in 59 world regions over time. Nat Sustain. 2020 Jun;3(6):437–47.
8. Hsu M-C, Bazilevs Y. Fluid–structure interaction modeling of wind turbines: simulating the full machine. *Comput Mech*. 2012 Dec 1;50(6):821–33.
9. Serale G, Fiorentini M, Capozzoli A, Bernardini D, Bemporad A. Model Predictive Control (MPC) for Enhancing Building and HVAC System Energy Efficiency: Problem Formulation, Applications and Opportunities. Energies. 2018 Mar;11(3):631.
10. Sharmina M, Edelenbosch OY, Wilson C, Freeman R, Gernaat DEHJ, Gilbert P, et al. Decarbonising the critical sectors of aviation, shipping, road freight and industry to limit warming to 1.5–2°C. *Clim Policy*. 2021 Apr 21;21(4):455–74.
11. Baillie C. Engineering and Social Justice. In: *The Routledge Handbook of the Philosophy of Engineering. Routledge; 2020.*

References: "The Characteristics of an Advanced Building Energy Model", page 11

1. https://github.com/AmirAAliabadi, https://zenodo.org/record/4255225

Aliabadi, A. A., Moradi, M., McLeod, R. M., Calder, D., & Dernovsek, R. (2021), How Much Building Renewable Energy Is Enough? The Vertical City Weather Generator (VCWG v1.4.4), *Atmosphere*, 12(7), 882, doi:10.3390/atmos12070882.

Bourdeau, M., Zhai, X.-Q., Nefzaoui, E., Guo, X., & Chatellier, P. (2019), Modeling and Forecasting Building Energy Consumption: A Review of Data-driven Techniques, *Sustainable Cities and Society*, 48, 101533, doi:10.1016/j.scs.2019.101533.

Bueno, B., Norford, L., Hidalgo, J., & Pigeon, G. (2012a), The Urban Weather Generator. *Journal of Building Performance Simulation*, 6, 269-281, doi:10.1080/19401493.2012.718797.

Bueno, B., Pigeon, G., Norford, L.K., Zibouche, K., & Marchadier, C. (2012b), Development and Evaluation of a Building Energy Model Integrated in the TEB Scheme. *Geoscientific Model Development*, 5, 433–448, doi:10.5194/gmd-5-433-2012.

Connolly, D., Lund, H., Mathiesen, B., & Leahy, M. (2010), A Review of Computer Tools for Analysing the Integration of Renewable Energy into Various Energy Systems. *Applied Energy*, 87, 1059-1082, doi:10.1016/j.apenergy.2009.09.026.

Gao, H., Koch, C., & Wu, Y. (2019), Building Information Modelling Based Building Energy Modelling: A Review. *Applied Energy*, 238, 320-343, doi:10.1016/j.apenergy.2019.01.032.

Harish, V. S. K. V. & Kumar, A. (2016), A Review on Modeling and Simulation of Building Energy Systems. *Renewable and Sustainable Energy Reviews*, 56, 1272-1292, doi:10.1016/j.rser.2015.12.040.

Moradi, M., Dyer, B., Nazem, A., Nambiar, M. K., Nahian, M. R., Bueno, B., Mackey, C., Vasanthakumar, S., Nazarian, N., Krayenhoff, E. S., Norford, L. K., & Aliabadi, A. A. (2021), The Vertical City Weather Generator (VCWG v1.3.2), *Geoscientific Model Development*, 14(2), 961-984, doi:10.5194/gmd-14-961-2021.

Moradi, M., Krayenhoff E. S., & Aliabadi, A. A. (2022), A comprehensive indoor-outdoor urban climate model with hydrology: The Vertical City Weather Generator (VCWG v2.0.0), *Building and Environment*, 207(B), 108406, doi:10.1016/j.buildenv.2021.108406.

Seyedzadeh, S., Pour Rahimian, F., Glesk, I., & Roper, M. (2018), Machine Learning for Estimation of Building Energy Consumption and Performance: A Review, *Visualization in Engineering*, 6, 5, doi: 10.1186/s40327-018-0064-7.

Cultured Meat: A Process Engineering Prospective

CAITLIN KNAPIK, P.Eng.

Caitlin Knapik, P.Eng., is a process engineer at BFC Technologies Inc. Caitlin holds a BASc in Chemical Engineering from the University of Waterloo. Leading BFC's west coast office located in Vancouver, BC, she specializes in designing modular process equipment for the clean technology and pharmaceutical industries.

IMAGES COURTESY OF THE RESEARCHER / TITLE IMAGE CREATED VIA CANVA

INTRODUCTION TO CULTURED MEAT

Cultured meat, cultivated meat, and lab grown meat are all vocabulary used to describe a meat source grown from a small amount of starting animal cells in a controlled environment. Significant technological advancements have been made within the emerging cultured meat industry promising a sustainable alternative protein source. Current life cycle assessments predict a reduction of GHG emissions of up to 92% as well as reduction in water consumption compared to traditional beef production[1]. The first commercial product is predicted to enter the U.S. market in 2022 demonstrating the achievements in engineering and food safety regulations over the last several years. Although culturing animal cells for human consumption is a relatively new industry, the processes of proliferating animal cells are applied in the well-established therapeutic and virus vaccine industries. Scale-up of engineering principles from these fields will become the fundamental building blocks for lab grown meats.

ENTERING THE MARKET

There are seven major steps for developing cultured meat depicted in *Figure 1*. A successful product starts with selecting and harvesting a robust, rapid replicate-able cell. Continuing in the process, cells from the cell bank are introduced to bioreactors for proliferation of cells. Once the desired cell count within the bioreactor is obtained, scaffolding material is added to achieve the desired meat structure. The cell structures are then harvested from the reactor, sent for final processing, then packaged. Proliferation of cells is the rate limiting step for cultivated meat production emphasizing the importance of bioreactor design and optimization.

Stirred tank bioreactors are industry standard for animal cell cultures in the biotechnology industry. Key considerations for bioreactor design are agitation, aeration, growth media, pH, and temperature. Dissimilar to plant cells, animal cells lack a cell wall and are especially sensitive to shear forces that can rupture the cell. Shear sensitivity limits agitation and sparging capabilities making homogeneity in the reactor difficult to obtain, constricting oxygen delivery to the cells. Typically for animal cells, paddle impellers such as an axial hydrofoil impeller, are implemented with their proven agitation capabilities and low shear stress. Gas sparging is also critical to ensure adequate oxygen delivery to all cells within the reactor as well as the removal of carbon dioxide. A detailed sparger design is needed to ensure homogeneity of the reactor and prevent gas bubble coalesces that would disrupt the animal cells. Another research focus for the scale up of cultured meat is the growth media used. Optimizing nutrient delivery is key to making cultured meat an economically viable solution for consumers.

Upon completion of proliferation, scaffolding material is added to the reactor to differentiate cells and obtain the final desired structure. Scaffolding material consists of either edible or biodegradable material that will provide a framework for the cells in the bioreactor. Existing scaffolding technology limits the current product offerings to less structured forms, but technology such as electro spun nanofibers are starting to overcome these obstacles. With the desired meat structure any non-edible scaffolding material will be removed, cells are harvested from the bioreactor and sent for final processing, such as adding season and formation of patties, then packaging. This aseptic operation requires equipment to be cleaned and sterilized between production runs to limit contaminates. Models suggest a range of water consumption for these cleaning steps leaving a broad window for optimization and creating a more sustainable process.

A review of the current process scalability highlights the need for engineering improvements to facilitate the availability of cultured meat. The average Canadian consumes approximately 83 kg of meat per year[2] which equates to 3.5 million tons of meat consumed annually in the country. To replace a fraction of this industry with cultured meat we will need significant process capacity. Typical cell densities obtained with animal cells for other industries such as vaccines range from 0.1 to 1 g/L[3] but values as high as 200 g/L have been published for air-lift bioreactors[4]. Assuming a 14-day residence time and a cell density of 200 g/L, we would need more reactor capacity than the entire Canadian brewing industry[5] to feed even 10% of Canadians. *Figure 2* depicts the bioreactor demand based on cell density and residence time.

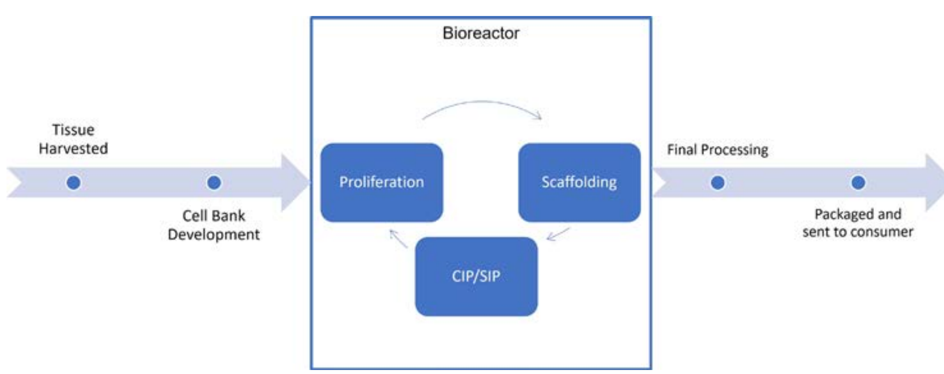


FIG. 1: CULTIVATED MEAT PROCESS FLOW

The scalability issues require an increase in allowable cell density and a decrease in residence time to achieve substantial production output. Mass and energy transfer coefficients are not well known for these large-scale animal cell reactors and require more research to understand. New regulations required for emerging industry

FUTURE OF CULTIVATED MEAT

With climate change and sustainable living becoming a major consumer concern there is a momentum to find more sustainable and environmentally friendly food sources. Meat is at the forefront of this given its relatively large contribution to GHG within the food industry.

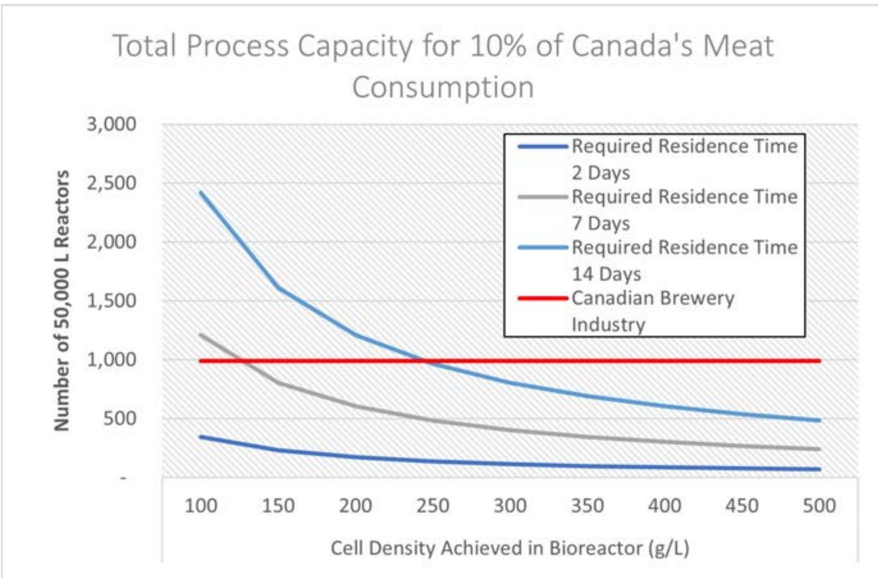


FIG. 2: CULTIVATED MEAT SCALE-UP PRODUCTION REQUIREMENTS

Cultured meat manufacturing blends food and biotechnology practices requiring developed guidelines that balances these to existing industries. The Food and Drug Administration (FDA) and U.S. Department of Agriculture (USDA) have been working closely together with cultivated meat companies to establish regulations for this industry. In 2019, the responsibility divisions were agreed upon between the two organizations, but collaboration will be critical for appropriate and systematic oversight. The USDS will oversee inspection of facilities handling livestock and cell harvesting while the FDA will oversee the cell collection, cell line generation, and cell culturing. Guidelines have been established by the FDA leveraging existing policies for genetically engineered food, but this may lead to gaps[6] in the regulations. Labelling requirements are heavily debated to ensure the products are adequately disclosed and clearly understandable by consumers. Development of standard operating procedures (SOPs) for compliance with cGMP will also be critical to ensure a safe product. These SOPs can then be used to develop hazard analysis critical control point (HACCP) plans for the cultured meat industries, allowing identified hazards to be controlled and mitigated. While post-manufactured products can be adequately managed under the existing FDA framework, better guidelines and regulations in the cell harvest and manufacturing process will help standardize the industry and build consumer trust.

Although cultivated meat looks promising in current models, greater technological advancements are required for wide-spread adoption. Mechanical engineers will play a crucial role in the upcoming years in overcoming obstacles such as identifying viable scale-up solutions. As more companies look to introduce products into the North American market, the rules and regulations will need to be further developed to ensure safety and quality. A careful balance of biotechnology and food industry standards are needed to provide a sustainable, economical, and safe alternative protein source.

References

1. Swartz, Elliot. "New Studies Show Cultivated Meat Can Benefit Climate and Be Cost-Competitive by 2030." *The Good Food Institute*, 9 Mar. 2021, https://gfi.org/blog/cultivated-meat-lca-tea/.
2. Hannah Ritchie and Max Roser (2017) - "Meat and Dairy Production". Published online at OurWorldInData.org. Retrieved from: 'https://ourworldindata.org/meat-production'
3. Shuler, Michael L., and Fikret Kargı. "Chapter 12 Bioprocess Considerations in Using Animal Cell Cultures." *Bioprocess Engineering: Basic Concepts, Prentice Hall,* Englewood Cliffs, NJ, 2002, pp. 385–402.
4. "Cultivated Meat Bioprocess Design: Deep Dive." *The Good Food Institute*, 6 Aug. 2021, https://gfi.org/science/the-science-of-cultivated-meat/deep-dive-cultivated-meat-bioprocess-design/.
5. Conway, Jan. "Domestic Beer Production Volume Canada 2020." Statista, 18 Feb. 2022, https://www.statista.com/statistics/951755/beer-domestic-production-volume-canada/.
6. Thomas, Natalia. "FDA Public Meeting: Foods Produced Using Animal Cell Culture Technology Docket No. FDA-2018-N-2155." *Food Produced Using Animal Cell Culture Technology*, 12 July 2018, https://www.fda.gov/media/115122/download.

Welcome new CSME members

1 Oct 2021 - 30 April 2022

Prof. Rafiq Ahmad, *University of Alberta*
Mr. Mawafag Alhasadi, *University of Calgary*
Mr. John Ambrose, *Ambrose Investment Counsel Ltd.*
Mr. Premkumar Asokkumar, *Commissionaires Manager*
Mr. Adeyinka Atoyebi, *Osun State Polytechnic, Iree (Nigeria)*
Mr. Nirmal Kumar Balaguru, *Black & McDonald*
Dr. Mahdis Bisheban, *University of Calgary*
Dr. Fereydoon Diba, *Lead Research Scientist*
Dr. Patricia Dolez, *University of Alberta*
Prof. Philip Egberts, *University of Calgary*
Prof. Salvatore Federico, *University of Calgary*
Dr. Amin Ghobeity, *Sheridan College*
Dr. Ken Harris, *Nanotechnology Research Centre*
Ms. Anna Henley, *McGill University*
Mr. Kshitiz Khanna, *CertaSIM CANADA ULC*
Prof. Bob Koch, *University of Alberta*
Mr. Ryan Lancaster
Prof. Carlos Lange, *University of Alberta*
Prof. Rob Langlois, *Carleton University*
Dr. Subhamoy Mahajan, *University of Alberta*
Dr. Gordon McTaggart-Cowan, *Simon Fraser University*
Mr. Abdelsalam Metwalli
Mr. Matthew Mills, *Motioneering*
Prof. Ryan Orszulik, *York University*
Dr. Srikantha Phani, *University of British Columbia*
Prof. Sayyad Zahid Qamar, *Sultan Qaboos University (Oman)*
Mr. Naveen Kumar Rejeti, *Asian Development Bank, Republic of Palau*
Dr. Morten Rikard Jensen, *CertaSIM, LLC*
Dr. Shakirudeen Salaudeen, *University of Prince Edward Island*
Dr. Mahdi Shahbakhti, *University of Alberta*
Prof. Yves St-Amant, *Université Laval*
Prof. Wylie Stroberg, *University of Alberta*
Prof. Tian Tang, *University of Alberta*
Dr. Jaime Wong, *University of Alberta*
Prof. Behrooz Yousefzadeh, *Concordia University*
Prof. Hesheng Yu, *China University of Mining and Technology*

ME NEWS & RESEARCH

HIGHLIGHTS

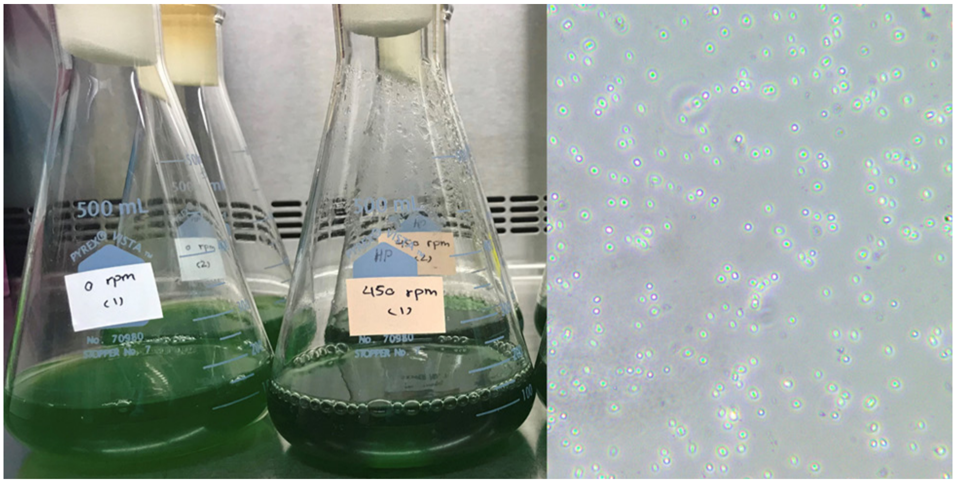


FIG. 1: SYNECHOCYSTIS SP. CPCC 534 SAMPLES SUSPENDED IN FLUID WHICH UNDERWENT MIXING AT 0, 450, 900 AND 1500 RPM (LEFT). THE VISCOSITY INCREASES LINEARLY AS A FUNCTION OF CELL VOLUME FRACTION, BUT THE INCREASE IS SMALLER THAN IT WOULD BE FOR SPHERICAL RIGID PARTICLES BECAUSE THESE MICRO-ORGANISMS ARE SOFT, DEFORMABLE AND NON-SPHERICAL (RIGHT).

In the search for sustainable alternatives to fossil-sourced fuels, the production of energy from biomass has gained increased attention. Generations of biofuels have emerged, where first-generation biofuels are those based on edible plant parts and, and second-generation biofuels are those based on non-edible plant parts or non-edible plants. Third-generation biofuels are those which use micro-algae or cyanobacteria as a feedstock, and therefore don't require the use of food crops or arable land for their production. Photo-synthetic micro-organisms use solar energy support their metabolism which can convert inorganic carbon, such as CO_2, to biomass. These micro-organisms can grow and survive in various climates, and also produce pigments with substantial roles in the food, cosmetics and pharmaceutical industries. Photosynthetic micro-organisms can be cultivated in photobioreactors, where the efficiency of micro-organism cultivation is influenced by mixing. While helps ensure sufficient nutrient distributions, better exposure to light and helps avoid the development of thermal gradients and cell settling, too much shear stress can damage or kill the micro-organisms. Therefore, its essential to study the effects of shear on micro-organism behavior and productivity to optimize mixing in photobioreactors. A team at Western University lead by Professors **John de Bruyn**, **Christopher DeGroot** and **Hassan Peerhossaini** recently completed a studied the effects of mixing on one such micro-organism, *Synechocystis* sp. CPCC 534[1]. Their experiments investigated the effects of shear during *Synechocystis* cell growth on biomass production, growth rate and cell count, which all increased when shear conditions were present but were relatively insensitive to the amount of shear (within the ranges studied). Production of some useful pigments (chlorophyll and carotenoid) also increased under shear conditions, whereas lipid content decreased. Examining the rheology of *Synechocystis* suspensions, Netwonion behavior was observed at different cell concentrations and viscosity increased with increased cell concentrations. Overall, their results can guide improvements in bioreactor design to yield better productivity. — *Technical Editor, Prof. Ryan Willing*

Article references

1. Allaf M, Malihe, Habib Z, de Bruyn JR, DeGroot CT, and Peerhossaini H. Rheological and Biophysical Properties of Living Fluids Under Shear: Active Suspensions of Synechocystis sp. CPCC 534. *Journal of Fluids Engineering* 144(2) (2022). doi.org/10.1115/1.4052053
2. https://sdgs.un.org/goals

Canadian Universities Leading for Global Sustainability

Canadian Universities have been recognized for their contributions to building a better world by Times Higher Education (THE), who released their 2022 Impact Rankings in April. THE rated more than 1500 post-secondary institutions from 110 counties with respect to the goals set within the UN's 2030 Agenda for Sustainable Development[2]. This sets out 17 Sustainable Development Goals (SDGs), which include not just actions to tackle climate change and for the preservation of life and habitats on land and in the sea; however, also recognizes that ending poverty and other deprivations must happen concurrently with strategies that improve health and education, reduce inequality and stimulate economic growth. THE Impact Rankings are based on metrics and indicators across four key areas – research, teaching, outreach, and stewardship, assessing hundreds of data points and qualitative evidence to measure the impact of higher education institutions in addressing urgent global challenges. Two Canadian Universities ranked within the global top 10 (Western – 3rd, and Queen's – 7th) and five more within the top 50 (Alberta – 11th, UBC – 13th, Laval – 36th, McMaster – 37th, and Calgary – 42nd). This strong showing for Canadian Universities reflects their commitment to practicing and promoting sustainability for the good of society, and sets the bar high for our global neighbors.

IMAGE COURTESY OF THE RESEARCHER / CANADA FLAG VIA CANVA

Caitlin Knapik, P.Eng., is a process engineer at BFC Technologies Inc. Caitlin holds a BASc in Chemical Engineering from the University of Waterloo. Leading BFC's west coast office located in Vancouver, BC, she specializes in designing modular process equipment for the clean technology and pharmaceutical industries.

At BFC, you work on a large range of technologies, from biotech to nuclear technology. Is there a common denominator among these technologies? Which one?

Engineering within regulated industries and applying fluid mechanics are two common denominators among the projects BFC Technologies works in. Designing compliant processes and equipment requires a comprehensive knowledge of applicable codes and guidelines. Each field has their own set of regulations to adhere to, but all possess the shared priorities of safety. The other commonality is the importance of applied fluid mechanics principles. The ability to predict fluid behavior in a complex, interacting system is essential to a successful project. These translate into real world decisions regarding equipment sizing, pipe geometries, and heat transfer properties. BFC applies engineering principles across all disciplines and leverages technological developments from one to another.

How can your current work, as a process design engineer, contribute to the reduction of anthropogenic impacts on climate change?

Aiding in the development of clean technologies and improving existing processes are the primary roles engineers will play in the reduction of anthropogenic impacts on climate change. Canada has a rapidly growing clean technology market. Process engineers will be critical in the commercialization of these technologies. However, this commercialization will take time. Continuous improvement is a philosophy engrained in process engineers limiting climate change impact by increasing production efficiencies, reducing waste, and decreasing power consumption. Process improvements for these existing technologies is an immediate action that can be implemented to realize increased sustainability.

What link do you see between sustainability and climate change mitigation? Do they always go in the same direction, or can they also be opposite?

Climate change and sustainability are closely linked with only minor differences. Climate change is often discussed as actions needed to immediately mitigate GHG emissions while sustainability relates to a broader reaching 'circular' economy. Sustainability activities may not have a direct correlation to GHG reduction but can have indirect impacts. For example, developing a more sustainable food source can decrease deforestation, positively impacting climate change. A debated divergence of climate change and sustainability is discussed in the subject of lithium-ion batteries. Electric cars are a widely publicized climate change action requiring an abundance of lithium materials for battery components. Current standard practices for mining lithium are criticized by some for being unsustainable. This illustrates where these two efforts can differ. The final technology, electric cars, will help with the immediate mitigation of climate change but parts of the manufacturing process are not currently considered sustainable.

We often hear about "clean technology" in the industry; how do you define clean technology from the lens of your activities?

I would define clean technology as a process or equipment that facilitates the reduction of GHG emissions, either directly or indirectly. It is a broad term that is often used to describe processes that remove or utilize atmospheric CO_2, such as carbon bio-fixation, or technologies that reduce emission sources from conventional methods, such as electric vehicles.

Among the current or future activities of BFC we see carbon bio-fixation, cultured meat, and hydrogen production from biogas. These technologies rely on the foundation of biotechnology. Please explain the technology behind each and their impact on climate change and sustainability.

Carbon bio-fixation utilizes living organisms to convert CO_2 into biodiesel and other commodities. BFC is in collaboration with Western University to develop bio-solar facades to capture CO_2 in the atmosphere and convert it to a useful product. These facades would be installed on the sides of buildings with the added benefit of building temperature control. BFC sees this as a scalable and commercially viable clean technology that we are excited to be a part of.

Cultured meat uses a small sample of animal cells to grow meat in a controlled environment. The animal cells are proliferated in a bioreactor with nutrients and oxygen which then can be harvested for human consumption. Meat grown in this manner requires less animals, land, and water, potentially reducing the GHG emissions compared to traditionally farmed meat.

Hydrogen production has a substantial energy demand and is primarily synthesized with fossil fuels. There is a large push for clean hydrogen generation and using biogas is one alternative. An anaerobic digester is used to create biogas from organic waste which then can be used to produce hydrogen.

In your experience, how concerned are governments and companies about the impacts of climate change?

Companies are demonstrating an increased concern for the impacts of climate change. This is evident with many businesses now reporting on climate change risks and mitigation strategies. Executives are seeing the need for climate change initiatives as consumer choices are increasingly swayed by a company's sustainability effort. Increased concern by the Canadian government is also evident in their recently released 2030 Emissions Reductions Plan. This document targets an emissions reduction of 40% compared to the 2005 levels by 2030. One of the strategies to obtain this goal is the Net Zero Accelerator initiative that will provide up to \$8 billion to support projects reducing greenhouse gasses.

How can mechanical engineers help adapt to the new changing environment?

Disruptive technology will be required to solve the climate change issue. Engineers will need to reevaluate current practices with a critical eye and leverage existing principles in new applications to help tackle climate change. As a company, BFC thrives on transferring technology across industries. The company's staff have voiced a desire to apply our talents to clean technology and we are going in that direction through the opening of an office hub for this work.

How does sustainability/climate change mitigation rank in the list of BFC's priorities and how much of a challenge is it to address?

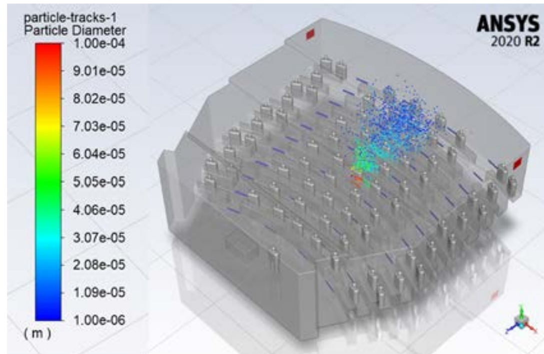
Sustainability and climate change mitigation are top priorities for BFC. Factory acceptance testing (FAT) demands high water usage at our Toronto facility. To improve our sustainability, we have built specific testing equipment that recycles and reuses water. In the future, BFC is looking to use clean energy, such as solar panels, to power our facility. Covid has also facilitated virtual communication such as meetings, factory acceptance tests (FATs), sales presentations, and working from home, decreasing our commuting footprint. We have proven that a successful project can be delivered with these virtual communications, and so we plan to continue this methodology going forward.

York University
Dr. Marina Freire-Gormaly

Better mechanical engineering design with new collaborative tools

COVID-19 AEROSOL TRANSMISSION AND HVAC DESIGN

Dr. Marina Freire-Gormaly and her team are conducting research on how aerosols move within indoor environments to understand the risk of transmission of airborne diseases, such as COVID-19, and how we can improve the HVAC design to improve the indoor air quality. Masters students, Arma Khan (OGS recipient), Kishon Webb (NSERC CGS-M recipient), and Abu Raihan Ali are working on Computational Fluid Dynamic modeling using ANSYS FLUENT. On-going research shown in the figure from Arma Khan's modeling of an infected person inside a classroom, shows how the aerosol moves towards the back of the classroom. You can listen to Kishon Webb's conference presentation at the CSME Congress 2022 in Edmonton on modeling the molecular dynamics of the COVID-19 virus in humid outdoor environments. The work is funded in-part by the NSERC Emerging Infectious Disease Modeling grant with the Canadian Centre for Disease Modeling, York University's COVID-19 Funding, and a new NSERC Missions Alliance Grant with industry collaborators De Havilland Inc., Downsview Aerospace Innovation and Research (DAIR) and TMBN Extrados Inc. The research was also featured in the National and International media (Radio Canada International, CTV, City News, and others) throughout the pandemic, and a CSME *Bulletin* article[1].



AEROSOL PARTICLES SPREAD FROM AN INFECTED PERSON IN THE MIDDLE OF THE CLASSROOM IN THE BERGERON BUILDING TOWARDS THE BACK OF THE CLASSROOM WHERE THE HVAC OUTLETS ARE LOCATED. RESEARCH CONDUCTED BY MASTER'S STUDENT, ARMA KHAN UNDER DR. MARINA FREIRE-GORMALY'S SOLE SUPERVISION.

Dr. MARINA FREIRE-GORMALY, PhD, P.Eng., EIT, LEED GA, MCSME

Dr. Freire-Gormaly is an Assistant Professor at York University in the Department of Mechanical Engineering since July 1, 2019. She completed her PhD in Mechanical Engineering at the University of Toronto in April 2018. Earlier, she conducted her Masters of Applied Science in Mechanical Engineering and BASc in Engineering Science at U of T. She has published to date, 20 peer-reviewed international journal papers and conference proceedings including in Renewable Energy, Desalination, Desalination for Water Treatment, *Journal of Membrane Science, and* Microporous and Mesoporous Materials.

Dr. Freire-Gormaly's research team focuses on the development of sustainable energy and resilient drinking water systems for communities. Her team works in the field of micro-nano technologies for membrane-based separation processes, novel methods for understanding how improved HVAC can improve indoor air quality using Computational Fluid Dynamics (CFD) and Machine Learning and developing novel aerogel materials for clean water and clean air.

IMAGES COURTESY OF THE RESEARCHER

MATERIALS DEVELOPMENT USING METAL 3D PRINTING

In a collaborative project, Dr. Freire-Gormaly is working on metal 3D printed materials for developing novel high entropy alloys. With collaborators, Dr. Solomon Boakye-Yiadom and Dr. Ruth Urner, they are developing new metal mixtures to tune for material properties that are useful for the aerospace, electric vehicles, and energy industries. The research builds on Dr. Freire-Gormaly's expertise on material characterization of microporous materials[2-4] and applied optimization approaches[5]. The work is funded in part by the Canada Foundation for Innovation (CFI-JELF).

AEROGEL MATERIALS

In a collaborative project, Dr. Freire-Gormaly is co-supervising graduate students working on Aerogel materials for clean water and filter materials. With collaborators, Dr. Thomas Cooper and Dr. Paul O'Brien, and master's students Amanda Capacchione and Mubariz Nagi they are developing new aerogel materials for water purification and enhanced window technologies. The image shows one of the Silica aerogel materials made in the laboratory facilities by Mubariz Nagi, and computational models made by Amanda Capacchione. The work is funded in part by the Lassonde Innovation Fund, NSERC Discovery Grant, Canada Foundation for Innovation (CFI-JELF), and a new project led by Dr. Kulbir Ghuman (INRS) and Dr. Paul O'Brien from the SSHRC New Frontiers in Research Foundation-Exploration (NFRF-E) for novel carbon capture materials.

RESILIENT RENEWABLE POWERED WATER TREATMENT

Dr. Freire-Gormaly's research on water treatment involves several researchers, including master's students, Brandon Truong, Liam Horrigan (NSERC CGS-M recipient), and PhD student, Thipphathong (Dorothy) Piluk. The research is currently focused on developing novel material coatings for membranes and anti-fouling approaches for renewable powered water treatment systems that are commonly implemented in off-grid and remote communities. Using newly built experimental systems similar to those in earlier work[6, 7], mathematical modeling[8], and eventually pilot-scale systems in remote communities, the team is developing more robust and resilient systems to provide affordable clean drinking water for communities. Simulation-based design optimization methods are also used in the research to select the lowest cost and most reliable system configuration of the renewable-powered water treatment systems considering the community's geographic location and daily water needs[5]. The research is funded in part from the NSERC Discovery Grant with an Early Career Researcher Supplement, York University Start-up Fund and the Department of National Defence Canada for the Pop up City Contest.

ACCESSIBLE HEALTHCARE

Chronic Kidney Disease is a major challenge facing about 700 Million people globally, with millions dying each year because of lack of affordable treatment, according to the National Kidney foundation[9]. Estimates are that about 58 million people died worldwide in 2005 due to kidney disease, with 35 million directly caused by chronic disease, according to the World Health Organization[10]. Kidney Dialysis is typically performed with expensive dialysis machines that require treatment by nephrologists, dialysis nurses, and frequent technician intervention. Dr. Freire-Gormaly's team of undergraduate researchers developed a low-cost portable kidney dialysis system, SimplysisTM. The team competed as finalists in the ASME iShow - USA 2021. SimplysisTM is a new design for an adaptable, user-friendly and cost-effective hemodialysis machine for use in low and middle-income countries (LIC, MIC) based on locally available resources for sustainable design. The design focuses on minimizing cost to create a compact and portable machine weighing under 25 lbs. This project focused on sub-Saharan Africa, with aspects of the final design having potential to reduce health care inequalities around the world. Two additional teams of undergraduate researchers have contributed to the project, one team developed a conceptual solar powered charging station for the portable dialysis machines, and the second team developed an educational and community resource to raise awareness, provide educational resources, and encourage preventative care and diagnosis to reduce the occurrence of Chronic Kidney Disease at GoKidney.org. This research is funded, in part, by the York University Lassonde School of Engineering Competitive Research Grant.

ACADEMICS WITHOUT BORDERS

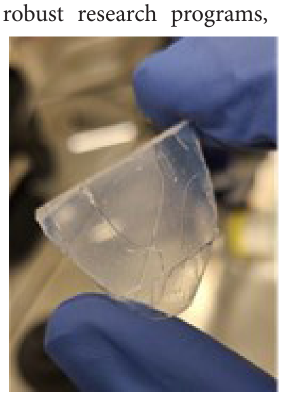
Dr. Freire-Gormaly is the Co-Chair of Strengthening Engineering Research with Academics Without Borders. The Strengthening Engineering Research (SER) initiative aims to support Faculty at emerging institutions to develop robust research programs, including the Mbarara University of Science and Technology in Uganda and the Bahir Dar Institute of Technology in Ethiopia. Through a series of lectures, experiential learning, mentorship from academic volunteers, participants develop and hone their proposal development writing skills, research skills, and graduate student mentorship skills. Projects that previous teams have tackled include developing low-cost animal health monitoring systems, evaluating the safety of drinking water from household-level water cisterns, and assessment of solar-powered street lighting programs.

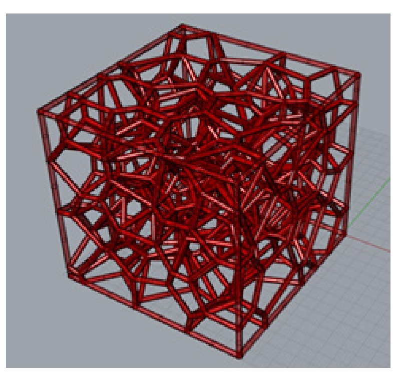
OUTREACH

Dr. Freire-Gormaly believes in motivating a diverse engineering community to pursue research. She serves as a Faculty mentor York University's 'K2I academy for Black, Indigenous and Women' high-school students. The most recent project explored mask effectivity through hands-on learning experiences including an experiment using a 3D-printed mannikin to test masks, and microscopy of mask materials using microscopes that attach to cellphone cameras. High school students in the 'K2I Academy' program worked as research assistants, were paid as interns, and gained a high-school co-op credit. Dr. Freire-Gormaly is the faculty advisor of York's Women in Renewable Energy (WiRE) chapter and the Women and Inclusivity in Sustainable Energy Research (WISER) York Chapter based in the Robarts Institute. She also currently serves on NSERC's Scholarships and Fellowship Committee – 202 for Mechanical Engineering.

FUTURE COLLABORATIONS

Dr. Freire-Gormaly is very interested in solving challenging research problems that can have an impact on communities and help move society towards more sustainable energy sources. Working with communities, municipalities and industry partners to mobilize the research is also a very exciting approach for collaborative research that she enjoys leading. You are invited to connect on LinkedIn, Twitter, at her lab website, or by email (marina.freire-gormaly@lassonde.yorku.ca).





A PHYSICAL SAMPLE OF THE (LEFT) SILICA AEROGEL MATERIAL AND (RIGHT) COMPUTATIONAL MODEL OF THE AEROGEL MATERIALS.

References

1. Khan, A., Mohee, F. M., Freire-Gormaly, M., (2020) Modeling droplet and aerosol spread for minimizing airborne transmission of COVID-19 & other diseases in public spaces, CSME *Bulletin* - Fall 2020, p.11-12.
2. Freire-Gormaly, M., Ellis, J. S., MacLean, H., Bazylak, A., (2016) Pore Structure Characterization of Indiana Limestone and Pink Dolomite from Pore Network Reconstructions. *Oil & Gas Science and Technology–Revue d'IFP Energies nouvelles*, vol. 71 (3), p.33-46.
3. Freire-Gormaly, M., Ellis, J. S., Bazylak, A., MacLean, H., (2015) Comparing Thresholding Techniques for Quantifying the Dual Porosity of Indiana Limestone and Pink Dolomite. *Microporous and Mesoporous Materials*, vol. 207, p.84-89.
4. Freire-Gormaly, M., Bilton, A., (2019) Impact of Intermittent Operation on Reverse osmosis membrane fouling for brackish groundwater desalination systems, *Journal of Membrane Science*, vol. 583, p. 220-230.
5. Freire-Gormaly, M., Bilton, A., (2019) Design of Solar Powered Reverse Osmosis Desalination Systems Considering Membrane Fouling caused by Intermittent Operation, *Renewable Energy*, vol. 135, p. 108-121.
6. Freire-Gormaly, M., Bilton, A., (2018) Experimental quantification of the effect of intermittent operation on membrane performance of solar powered reverse osmosis desalination systems, *Desalination*, vol. 435, p. 188-197.
7. Freire-Gormaly, M., Bilton, A., (2017) An Experimental System for Characterization of Membrane Fouling of Solar Photovoltaic Reverse Osmosis Systems under Intermittent Operation, *Desalination and Water Treatment*, vol. 73, p. 54-63.
8. Horrigan, L., Freire-Gormaly, M., (2022) Mathematical Modelling of Ultrasonic Cavitation Onset in Spiral-Wound Reverse Osmosis Desalination Modules, *Desalination*, vol. 521, 115332.
9. "Global Facts: About Kidney Disease," National Kidney Foundation, 11-Mar-2015. [Online]. Available: https://www.kidney.org/kidney-disease/global-facts-about-kidney-disease. [Accessed: 29-Sep-2020].
10. Levey AS, Atkins R, Coresh J, et al. Chronic kidney disease as a global public health problem: approaches and initiatives - a position statement from Kidney Disease Improving Global Outcomes. Kidney Int. Aug 2007;72(3):247-259.

University of Waterloo
XiaoYu Wu

Capture and reuse carbon dioxide using mixed ionic-electronic conducting membranes

The emission and accumulation of carbon dioxide (CO_2) in the Earth's atmosphere impacts the mean global temperature. It is critical to develop efficient and sustainable technologies to capture and reuse CO_2 to achieve a net-zero emissions economy. Dr. Wu and his team are using mixed ionic-electronic conducting (MIEC) membranes for this purpose. A MIEC oxygen-permeable membrane conducts ions (e.g., oxygen ions) and electrons (or electron holes) simultaneously at elevated temperatures, i.e., 500 – 1000°C, as shown in *Figure 1*. In the carbon capture mode (a), oxygen dissociates and incorporates on the feed side as ions, which then diffuse to the permeate side for oxy-combustion to produce heat, water and CO_2. Once water condenses, CO_2 is easily separated and captured. In the carbon reuse mode (b), CO_2 is the oxygen source and is reduced into carbon monoxide as a fuel or chemical feedstock, and oxygen ions that diffuse to the permeate side. The chemical potential gradient across the membrane is the driving force for species diffusion. The MIEC membranes can be integrated with various industry processes for higher efficiency, such as hydrogen production and biomass gasification. There is an urgent need to develop MIEC membranes for higher permeability and stability.

During his PhD at MIT, Dr. Wu experimentally investigated the rate-limiting steps for two processes in MIEC membranes, i.e., water splitting for hydrogen production and CO_2 thermochemical reduction. A button cell reactor with a $La_{0.9}Ca_{0.1}FeO_{3-\delta}$ membrane is shown in *Figure 2* as an example. The overall processes were broken down into multiple surface reaction and bulk diffusion steps as shown in *Figure 1*. A resistance-network model was developed to determine the rate-limiting steps, where each step is modelled as a resistance. Depending on the operating conditions and membrane configurations, the rate-limiting steps can change from different surface reactions to bulk diffusion. These results guided the development of new catalysts and membrane configurations to enhance the hydrogen production and CO_2 reduction rates. Later, Dr. Wu worked closely with industrial partners to evaluate the techno-economics and energy efficiency of these membrane reactors for hydrogen production with CO_2 capture.

Currently, Dr. Wu and his team are working on novel membrane configurations and catalysts to improve permeability and stability. For example, Janus membranes are being developed with the two sides of a membrane favoring different reactions to accelerate the overall process. Another example is using exsolved nano-metal catalysts on the MIEC material backbones to overcome the critical challenges such as coking and catalyst degradation. These novel membranes can combine different processes in one reactor to achieve better thermal and chemical integration and higher efficiency. For instance, CO_2 reduction on the feed side can be integrated with partial oxidation or oxidative coupling of methane on the sweep side in a dual-purpose membrane reactor. Both experimental and numerical methods are used in the group to obtain detailed information about the permeation processes in these membranes.

Ultimately, the team aims to facilitate the use of MIEC membranes in various industrial applications, such as fuel cells, electrolysis and energy storage to improve the sustainability of the society. For more information, please visit Dr. Wu's group website:
uwaterloo.ca/greener-production-group

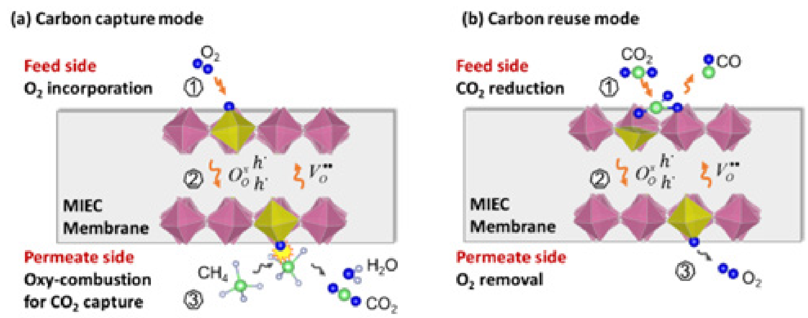


FIG. 1: (A) CARBON CAPTURE AND (B) REUSE MODES OF MIEC OXYGEN-PERMEABLE MEMBRANES AT ELEVATED TEMPERATURES (SCHEMATICS ARE NOT-TO-SCALE AND NON-STOICHIOMETRIC. OCTAHEDRONS REPRESENT MIEC PEROVSKITE LATTICES). 1 AND 3 ARE SURFACE REACTION STEPS, WHILE 2 IS A BULK DIFFUSION STEP.

Dr. XiaoYU WU, PhD, MCSME

Dr. Wu joined the Department of Mechanical and Mechatronics Engineering at the University of Waterloo as an Assistant Professor in 2020. He obtained his PhD degree in the Department of Mechanical Engineering at MIT in 2017, and master and bachelor's degrees in Energy Engineering at Zhejiang University. Dr. Wu leads the Greener Production Group, and his research interests include inorganic membranes, oxide catalysts, hydrogen and ammonia conversion, carbon capture, as well as understanding the transport phenomena and techno-economics of these processes.

IMAGES COURTESY OF THE RESEARCHER

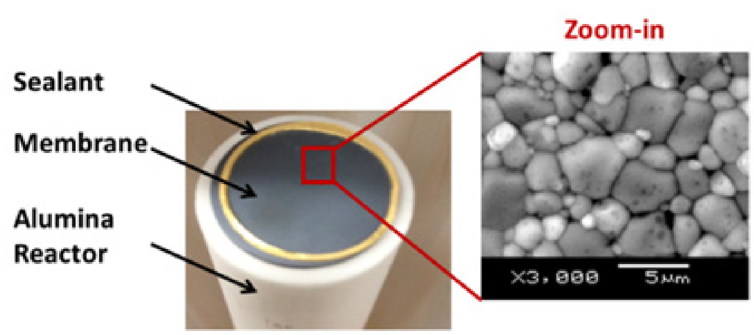


FIG. 2: A BUTTON-CELL $La_{0.9}Ca_{0.1}FeO_{3-\delta}$ MIEC MEMBRANE REACTOR

Professor Michael Yovanovich:

Celebrating 50 Years of Canadian Pioneering Research on Thermal Contact Resistance and Heat Transfer

DR. M. MICHAEL YOVANOVICH OBTAINED A BASc from Queen's University in 1957 and a Doctorate from the Massachusetts Institute of Technology (MIT), 1967, in Mechanical Engineering. Michael held academic positions at the University of Poitiers, France (1967 – 1969) and the University of Waterloo (1970 – 1999), where he retired as a Distinguished Professor. Michael made significant and lasting contributions to heat transfer, electronic cooling, and thermofluidic sciences during his academic career. His unique approach to analytical modelling has been recognized throughout the microelectronic industry as setting the standard for elegant, easy-to-use, and accurate analysis and design of thermal management systems. Perhaps, his most important contribution is on "thermal contact resistance," a topic that is as relevant today as when Michael did his PhD dissertation in 1967 at MIT. Because of his work, he has often been aptly named "the father of thermal contact resistance." Furthermore, his pioneering work on introducing characteristic length scales, asymptotic solutions, and unifying theories for fluid flow and heat transfer analyses is internationally recognized and unique because of its modeling aspect. His models on heat transfer are taught extensively in textbooks to date.

Michael trained more than 50 graduate and post-graduate students who have become leaders in industry and academia and are building a considerable legacy of his contribution to the engineering community across Canada and worldwide. In addition, he served on numerous conference committees, gave countless keynote lectures, and held workshops worldwide. Michael lives in Waterloo, where he still writes papers and book chapters 22 years after retirement. Some of his honours and awards include the CSME Jules Stachiewicz Gold Medal for Heat Transfer (2007), ITherm Achievement Award (2004), ASME Heat Transfer Memorial Award (2003), IEEE Thermi Award (2003), ASME Life Fellow (2000), Distinguished Professor Emeritus (2000), Fellow of the American Institute of Aeronautics and Astronautics (1992), Fellow of the American Association for the Advancement of Science (1989), and the AIAA Thermophysics Award (1984). — *Dr. Majid Bahrami, Professor and Tier 1 Canada Research Chair in Alternative Energy Conversion Systems, Simon Fraser University, British Columbia.*

In memory of Martha Eva Salcudean

February 26, 1934 - July 17, 2019

PHOTO OF M. SALCUDEAN COURTESY OF PROF. TIM SALCUDEAN

Professor **Martha Salcudean**, a survivor of the Bergen-Belsen concentration camp during the Second World War, was born in 1934 in Cluj, Romania. She received her bachelor's degree from the Cluj Polytechnic Institute, Romania, in Mechanical Engineering (1955). She also completed her post-graduate degrees in Romania and worked in the Research Centre for Metallurgy. After moving to Canada, she joined McGill University in 1976 and the University of Ottawa as a faculty member at the Department of Mechanical Engineering in 1977. Later, in 1985, Martha moved to the University of British Columbia (UBC) as the first female head of the Department of Mechanical Engineering at UBC. In 1993, she became UBC's associate vice-president of research.

Dr. Salcudean was a leading expert in fluid dynamics and heat transfer and has published widely in these areas. She was also very active in industrial collaborations, including Atomic Energy of Canada Ltd., Cominco, and Weyerhaeuser Paper Company. In addition, Dr. Salcudean served on the Defense Science Advisory Board for the Department of National Defense, Chair of the Science Council of BC's Board, Chair of the Leading Edge Endowment Fund (LEEF), and was a member of the National Research Council's governing body. In 1996, Dr. Salcudean was awarded a position as Weyerhaeuser Industrial Research Chair in Computational Fluid Dynamics in the Department of Mechanical Engineering at UBC (1996). In 2019, Dr. Salcudean published her memoir, I*n Search of Light (*Second Story Press 2019), describing her remarkable life during and after the Holocaust was published shortly before her death.

Some of her honours and awards include:

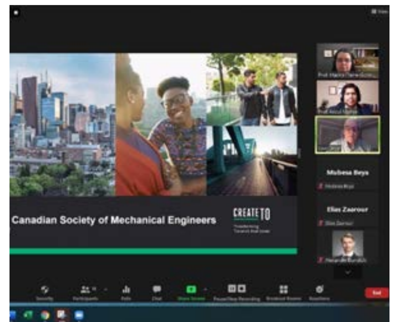
- Fellow, The Canadian Academy of Engineering
- Fellow, Royal Society of Canada
- Fellow, Canadian Society for Mechanical Engineering
- Julian C. Smith Medal, The Engineering Institute of Canada
- Honorary Doctorates from the University of Ottawa, Waterloo, and the University of British Columbia
- Izaak Walton Killam Memorial Award for Engineering
- Order of British Columbia
- Officer, Order of Canada
- Queen Elizabeth II Golden Jubilee Medal
- Queen Elizabeth II Diamond Jubilee Medal

Martha was genuinely interested in people, remembering and caring about what was important in their lives. She had many friends and was a hugely dedicated mother and grandmother. She deeply cared about education at all levels and was involved in outreach activities where she talked about her past experience as a concentration camp and communist regime survivor. — *Mr. George Salcudean and Dr. Tim Salcudean, Professor, Canada Research Chair in Intelligent Computer Interface Design, Department of Electrical and Computer Engineering, University of British Columbia; and Dr. Farid Golnaraghi, Chair, CSME History Committee.*

References

- Salcudean, Martha. *In Search of Light* (The Azrieli Series of Holocaust Survivor Memoirs, 59). The Azrieli Foundation, 2019.
- blogs.ubc.ca/holocaustliterature/articles/the-life-of-martha-salcudean-a-reminder-of-the-human-capacity-for-resilience-and-healing
- hwww.science.ca/scientists/scientistprofile.php?pID=415
- give.ubc.ca/memorial/martha-salcudean
- www.thecanadianencyclopedia.ca/en/article/martha-salcudean
- www.sfu.ca/sfuwest/cc-2015/keynotes/martha-salcudean.html

CSME STUDENT & PROFESSIONAL AFFAIRS REPORT



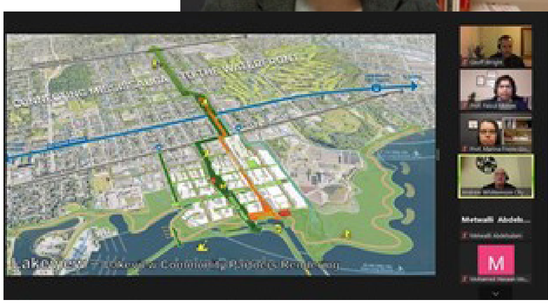
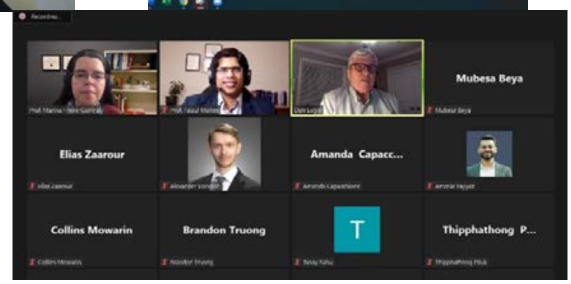


PHOTO TOP: GEOFF WRIGHT, FAIZUL MOHEE, MARINA FREIRE-GORMALY, AND ANDREW WHITTEMORE AND ATTENDEES AT THE CSME WEBINAR ON JANUARY 25, 2022.

PHOTOS RIGHT: MARINA FREIRE-GORMALY, FAIZUL MOHEE, AND DON LOGIE AND ATTENDEES AT THE CSME WEBINAR ON FEBRUARY 8, 2022.



THE CSME STUDENT & PROFESSIONAL AFFAIRS committees facilitate the CSME Student Chapters and Professional Affairs Chapters to organize events, conduct networking and host outreach activities. During the past few months, the committees ran several webinars open to all CSME members. We are looking forward to future events that the CSME chapters will host over the next few months, especially as the pandemic wanes, and in person events return!

Dr. Faizul Mohee, led the organization and moderation of a joint CSME Professional Affairs and CSME Student Affairs webinar on January 25, 2022. The webinar session featured two guest speakers from the City of Mississauga: Commissioner Geoff Wright, P.Eng., MBA and Commissioner Andrew Whittemore, MURP. A total of 24 CSME members participated from across Canada, including Toronto, Waterloo, Windsor, Mississauga, PEI, and international attendees from the USA.

Attendees learned from Commissioner Geoff Wright, and Commissioner Andrew Whittemore, about the City of Mississauga's new transit expansion and the new developments that are being implemented in the City of Mississauga to promote sustainability and improve the quality of life for residents. The attendees were very engaged and there was a lively discussion and Q&A session after the talks.

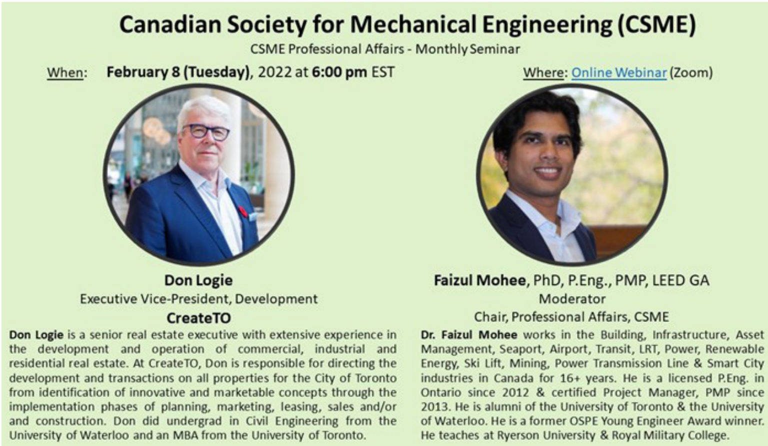
Dr. Faizul Mohee led the organization and moderation of a joint CSME Professional Affairs and CSME Student Affairs webinar on February 8, 2022. The webinar session featured a keynote lecture from Don Logie, Executive Vice-President, Development of CreateTO. A total of 18 CSME members participated from across Canada, including Toronto, Brampton, Kingston, Ottawa, Mississauga and international attendees from the Philippines.

Attendees learned from Don Logie about CreateTO's mandate and projects to revitalize the waterfront in Toronto and the new developments within the City of Toronto. Don Logie shared details of the Port Lands Flood Protection (PLFP) project which is transforming the brownfields and industrial areas near the waterfront into a flood protection zone with wetlands, new developments, and new affordable housing projects to make Toronto a more livable city filled with wildlife. There were a lot of questions from the audience and an interesting discussion continued after his presentation.

Dr. Marina Freire-Gormaly led the organization and moderation of a joint CSME Professional Affairs and CSME Student Affairs webinar on March 7, 2022. The webinar session featured a keynote lecture from John Hepburn, PhD, FRSC/MSRC, CEO & Scientific Director of Mitacs. Attendees learned from John Hepburn about all the internship opportunities and funding that are available through Mitacs. Dr. Hepburn gave a very interesting talk about the work Mitacs does to facilitate University and Industry research projects to foster growth and innovation in Canada. It was a particularly insightful reminder of the role PhD's play in spurring innovation in industry. Dr. Hepburn

POSTER FOR THE CSME WEBINAR ON JANUARY, 25 2022.

IMAGES PUBLISHED WITH PERMISSION OF THE EVENT ORGANIZERS



POSTER FOR THE CSME WEBINAR ON FEBRUARY 8, 2022.

JOHN HEPBURN, MARINA FREIRE-GORMALY, FAIZUL MOHEE, AND ATTENDEES AT THE CSME WEBINAR ON MARCH 7, 2022.

highlighted research showing that economies with strong innovation, such as European countries, have higher percentages of PhD's compared to Canada. Attendees were present from Toronto, Egypt, and Bangladesh. Several audience members asked questions and there was palpable excitement about the opportunities Mitacs offers through its programs.

The CSME Student & Professional Affairs committee is looking forward to hosting monthly webinars over the next year to facilitate member learning, collaboration and networking.

Please join as a CSME member, it is FREE for students (csme-scgm.ca/application). The Engineering Careers site (www.engineeringcareers.ca) also provides an opportunity for you to plan for your career. We are also looking forward to facilitating CSME students to learn about the Mechanical Engineering industry in Canada and network with industry professionals.

Thank you to all the professional chapter executives, student chapter executives, volunteers and faculty mentors for your hard work! We are looking forward to featuring your upcoming events at your CSME chapters.

If you are interested in leading and founding a CSME student chapter at your campus or a Professional chapter in your community, let us know. Contact us at the CSME, we will walk you through the process. We are also looking to expand the CSME Student Affairs Committee and the CSME Professional Affairs Committee. If you are interested in helping lead activities locally or at the national level, please reach out!

Do you have a great idea, story or proposal? Feel free to share your ideas with us!

DR. MARINA FREIRE-GORMALY, PhD, EIT, LEED GA

Chair of CSME Student Affairs

Marina is an Assistant Professor at York University in the Department of Mechanical Engineering. She completed her PhD at the University of Toronto in the Department of Mechanical and Industrial Engineering. Marina's research team is investigating how COVID-19 transmits in air, and how to make energy and water systems more reliable and sustainable. Her research and teaching spans energy systems, nuclear, computational modelling, materials, biomedical devices and sustainability.

DR. FAIZUL M. MOHEE, PhD, P.Eng., PMP, MCSME

Chair of CSME Professional Affairs

Faizul is the Director of Research at TMBN Extrados Inc. in Toronto. Faizul teaches at the Royal Military College (RMC) as an Assistant Professor. He completed his PhD at the University of Waterloo on mechanical anchors for composite materials. He also did a Masters at the University of Toronto. He has taught a Machine Learning, Artificial Intelligence and Big Data for Manufacturing course at York University. He also taught the Materials Science course at the University of Toronto in the Department of Mechanical and Industrial Engineering. He previously worked at Hatch, WSP and projects for OPG, Bruce Power, Terrestrial Energy, Baffinland, Stornoway, SaskPower and Emera. Faizul works in research and development for the energy, mining and nuclear industries. Faizul is currently conducting research on how COVID-19 transmits in air and HVAC systems. Faizul is passionate about research, teaching and student engagement to build smart and sustainable infrastructure that is resilient and adaptive to climate change.

The Canadian Society for Mechanical Engineering
A constituent society of the Engineering Institute of Canada

La Société Canadienne de génie mécanique
Une société constituante de l'Institut canadien des ingénieurs

NEWS COMMUNIQUÉ

Office of the President February 2022

The Canadian Society for Mechanical Engineering (CSME), founded in 1970, is pleased to announce the winning recipients of its regular 2022 awards. CSME awards may be bestowed to members of the society for their outstanding contributions to mechanical engineering in Canada.

The following exceptional engineers will be presented with their awards or inducted as FCSME on 7 June 2022 at the 2022 CSME International Congress to be held from 5-8 June at the Faculty of Engineering, University of Alberta, Edmonton, AB. Please consider attending the 2022 Congress to present a lecture, network with colleagues and congratulate the 2022 award winners.

www.csmecongress.org.

I.W. Smith Award

For "outstanding achievement in creative mechanical engineering within 10 years of PhD degree"

Tsz-Ho Kwok, PhD, MCSME
Associate Professor, MIAE Department, Concordia University, QC

New Fellows of the CSME

For "excellence in mechanical engineering and significant contributions to the progress of the profession"

Xili Duan, PhD, MCSME
Associate Professor, ME Department, Memorial University, NL

Atef Mohany, PhD, MCSME
Professor and Chair, MME Department, Ontario Tech University, ON

Pouya Rezai, PhD, MCSME
Associate Professor, ME Department, York University, ON

Zhongchao (Chao) Tan, PhD, MCSME
Professor, MME Department, University of Waterloo, ON

Call for Nominations – 2023 CSME Technical Award

Nominations of CSME peers are currently solicited for three of the society's six technical awards, specifically CSME medals for outstanding contributions to the fields of Heat Transfer, Mechatronics and Emerging Technologies. Note that members cannot nominate themselves – worthy candidates from the diverse CSME community must be nominated by CSME Fellows. The nomination deadline is 30 September 2022 and the nomination form is available on the CSME website: csme-scgm.ca/awards

---

PO Box 40140, Ottawa ON K1V 0W8
+1 (613) 400-1786 / admin.officer@csme-scgm.ca / www.csme-scgm.ca

Mechatronics, Robotics and Controls

– Prof. Farrokh Janabi-Sharifi

During the past six months, the website of the committee was organized and calls for additional membership was distributed amongst potentially interested parties across the Canadian universities. Also several new activities were planned for the committee. The first annual virtual connector symposium of TC-MRC was also planned for April 13, 2022.The 2022 symposium will include presenters from the University of Victoria, Ryerson University and University of Waterloo. Moreover, the committee was involved in the organization of Mechatronics, Robotics, and Control Symposium for CSME 2022 Congress to be held at the University of Alberta.

Advanced Energy Systems

– Dr. Xili Duan

The main activities of the CSME Advanced Energy Systems (AES) Technical Committee over the past six months include:

- Supported the CSME International Congress 2022 to be held at the University of Alberta, by promoting the conference and organizing the Symposium on Advanced and Future Energy Systems, and reviewing submissions to the symposium.
- Supported the CSME Transactions published through the Canadian Science Publishing (CSP) by handling the review of submissions in the field of energy systems.
- Organized three online seminars (in November 2021, February and April 2022) of the CSME Heat Transfer and Energy Systems Seminar Series jointly with the Heat Transfer Technical Committee.

Engineering Design and Analysis

– Dr. Kamran Behdinan

Main activities include:

1. Associate Editor of the CSME *Transactions* (assessed several submitted papers and submitted my recommendations to the editor)
2. Symposium Chair/member of the organizing team (representing the TC): Integrated Engineering Design for Industry 4.0- the CSME Congress 2022 (University of Alberta)
3. Recruited a few new members to the TC
4. Member of CNC-IUTAM and IUTAM General Assembly in 2021, proposed a symposium for its Congress in 2024.
5. Presented the TC at the CSME board in 2021.

Microtechnology and Nanotechnology *–Dr. Mohsen Akbari*

Current activities:

1. The TC reviewed 10 abstracts for the Microtechnology and Nanotechnology Symposium at 2022 CSME Congress at the University of Alberta.
2. Dr. Akbari, the TC chair has organized the first ever monthly e-Seminar series on Micro- and Nanotechnologies. These series will be virtual and will be occur on the last Monday of each month. Thus far, the event has 9 confirmed speakers including Dr. Woo Soo Kim (Simon Fraser University), Dr. Dan Sameoto (University of Alberta), Dr. Mohammed Quesaimeh (New York University), Dr. Carlos Escobedo (Queen's University), Dr. Mina Hoorfar (University of Victoria), Dr. Ting Zou (Memorial University), Dr. Pouya Rezaei (York University), Dr. Ali Ahmadi (École de technologie supérieure), and Dr. Houman Savoji (University of Montreal). The first talk was well received and had ~90 registered participants from all over the globe. This event is also (www.cmc.ca) sponsored by CMC Microsystems. Those who are interested can register at: bit.ly/3PN72WS

Future activities:

1. Organize the Microtechnology and Nanotechnology Symposium at 2022 CSME Congress at the University of Alberta.
2. Continue the monthly research e-seminars with speakers from the TC.

Transportation Systems

– Dr. Yuping He

CSME 2022 Congress

- Discussed with the local organizing committee regarding the organizers for the Symposium of Transportation Systems.
- Distributed the information about the call for papers for the upcoming symposium.
- Reviewing 7 papers and 16 abstracts.

ii. *TCSME*

- An associate editor

iii. Plans for Next 6 Months

- Organizing and guest editing a special issue of *TCSME* on Active Safety Technologies of Road Vehicles.

Dr. Tsz-Ho Kwok

Dr. Tsz-Ho Kwok is an Associate Professor in the Department of Mechanical, Industrial and Aerospace Engineering at Concordia University, Montreal, QC. His research interests include additive manufacturing, functional design and fabrication, cyber-manufacturing system, and mass customization. Dr. Kwok has received several awards including the ASME CIE Young Engineer Award (2021), the SME Outstanding Young Manufacturing Engineer Award (2021), the University Research Award (2020), the Petro-Canada Young Innovator Award (2019), and a Silver Medal Award at the international exhibition of inventions of Geneva (2019). He was selected as the 20 Most Influential Academics in Smart Manufacturing (2021) by the Smart Manufacturing magazine. Dr. Kwok serves as an Associate Editor for the *Transactions* of the Canadian Society for Mechanical Engineering (TCSME) and the ASME *Journal of Computing and Information Science in Engineering* (JCISE). He is an Executive committee Member of the ASME ComputerAided Product and Process Development (CAPPD) technical committee.

Dr. Xili Duan

Professor Xili Duan is an Associate Professor in the Department of Mechanical Engineering at Memorial University of Newfoundland. He has made significant contributions to Mechanical Engineering in the fields of phase change heat transfer, interfacial phenomena, drag reduction and energy systems, including over 60 journal articles in these areas.

Dr. Duan's contributions have been recognized, nationally and internationally, through several technical awards and keynote presentations at conferences, including the Terra Nova Young Innovator Award in 2018. Dr. Duan's research outcomes have led to technology transfer to industry and other partners, including three patents. Dr. Duan is an Associate Editor of the Transactions of the CSME and Chair of the CSME Technical Committee on Advanced Energy Systems.

Dr. Atef Mohany

Dr. Mohany obtained his BSc and MASc from Cairo university in 1998 and 2001, and PhD from McMaster University in 2006. His research contributions address a wide range of practical engineering problems related to aeroacoustics, noise and flow induced vibration. Prior to moving to the academia, Dr. Mohany was a Nuclear R&D Scientist at Atomic Energy of Canada Limited (AECL) where he was involved in several strategic projects related to the design and operation of nuclear power plants. He is a professional engineer of Ontario and currently serving as chair of the department of mechanical and manufacturing engineering at Ontario Tech University. He is a member of different National Standard Committee and a leader of research activities sponsored by industry and government agencies.

Dr. Pouya Rezai

Dr. Pouya Rezai is an Associate Professor in mechanical engineering at the Lassonde School of Engineering at York University, a professional engineer in Ontario and the founding mechanical engineering graduate program director at the school. Dr. Rezai's research interest is in multi-phase flows within microfluidic and Labon-Chip (LoC) devices. It aims to understand interactions between biological nano- and micro-particles and fluids in biomimetic microsystems for health-and-safety applications (point-of-care and point-of-need biodetection). Dr. Rezai has published over 100 refereed journal and conference papers, 7 book chapters, and filed 5 patents. He is a recipient of the I.W. Smith Award from the CSME, the President's Emerging Research Leadership Award from York University, and the Early Researcher Award from the Ontario provincial government. He is the editor of the Canadian Society of Mechanical Engineering *Bulletin*, a topic editor for *Biosensors and Fluids*, and an editorial board member for *Nanotechnology for Environmental Engineering*.

Dr. Zhongchao (Chao) Tan

Dr. Zhongchao Tan is a professor of Mechanical Engineering at the University of Waterloo. He received his BSc and MSc degrees from Tsinghua University, and PhD degree from UIUC. He was the Associate Dean (International) of Waterloo Engineering and the Executive Director of Tsinghua-Waterloo Joint Research Centre for Energy and Environmental Technologies. Dr. Tan's contribution to scholarship has been recognized by international peers. For example, his single-authored book, Air Pollution and Greenhouse Gases, reached 1.7+ million downloads globally. His impact on his peer groups and the wider society is also evidenced by numerous domestic and international awards, including PhD Thesis Award, Early Research Excellence Award, Outstanding Performance Award, Highly Cited Researcher (top 1%) from Clarivate Analytics, and Distinguished Visiting Professorship at Tsinghua University. Dr. Tan has mentored 100+ HQPs; many of them have taken leadership roles in their chosen fields, winning various awards including chair professorship and best paper awards.

Canada Research Chair (Tier 2) in Science or Engineering
Lassonde School of Engineering, York University

The Lassonde School of Engineering, York University invites highly qualified candidates to apply for a professorial stream tenure-track appointment in any field that is a current or developing area of strength of the Lassonde School of Engineering (described in the numbered list below) at the Assistant or Associate Professor level, to commence **July 1, 2022**. The successful candidate will be nominated for a NSERC Tier 2 Canada Research Chair in Science or Engineering. The successful candidate will be appointed to a department best suited to their research and teaching. Salary will be commensurate with qualifications and experience. All York University positions are subject to budgetary approval.

Lassonde School of Engineering is committed to providing a welcoming and supportive environment for all who wish to study, teach and conduct research. For this search, only candidates who self-identify as a member of an underrepresented group may apply. This includes women, Aboriginal (Indigenous), Black peoples of African Descent (for example Africans and African heritage people from the Caribbean, Americas, Europe) and persons with disabilities.

This appointment is contingent upon a successful nomination to the Canada Research Chairs program (www.chairs-chaires.gc.ca) at the Tier 2 level.

A PhD in a relevant field of Science or Engineering is required, with a demonstrated record of excellence in research and in teaching. Applicants should have a clearly articulated program of research and specialize in one or more of the following areas:

(1) Earth or Space Sciences
(2) Vision Research
(3) Computing Research
(4) Technology Entrepreneurship or Knowledge Mobilization
(5) AI, Society or Mobility
(6) Water Security or Environmental Engineering
(7) Materials, Energy or Sustainability
(8) Automation in Health Systems and Technology
(9) Critical Infrastructure

The successful candidate will be expected to engage in outstanding, innovative, and as appropriate, externally funded research at the highest level. If the successful candidate is in an Engineering field, commitment to the engineering profession shall be demonstrated by being licenced as a Professional Engineer in the province of Ontario or by becoming licenced soon after appointment.

Candidates must provide evidence of research excellence of a recognized international calibre as demonstrated in: the research statement; a record of publications (or forthcoming publications) with significant journals in the field; presentations at major conferences; awards and accolades; success in acquiring and administering research grant funding; research supervision of students and other highly qualified personnel (HQP); and strong recommendations from referees of high standing.

The position will involve graduate teaching and supervision, as well as undergraduate teaching and the successful candidate must be suitable for prompt appointment to the Faculty of Graduate Studies.

Evidence of excellence in teaching will be provided through: the teaching statement; teaching accomplishments and pedagogical innovations including in high priority areas such as experiential education and technology enhanced learning; teaching evaluations; and strong letters of reference.

The Canada Research Chairs (CRC) program seeks to attract outstanding researchers for careers at Canadian universities. Tier 2 Chairs are intended for exceptional emerging scholars (i.e., who, at the time of nomination, are within 10 years of attaining their highest degree, with consideration for career breaks) who have the acknowledged potential to lead their field of research. Appointment to a Tier 2 Chair is for five years, is renewable once, and comes with enhanced research support, access to infrastructure funding and other support from the program directly and from the university. Applicants who are more than 10 years from their highest degree (and where career breaks exist, including maternity leave, extended sick leave, clinical training, etc.) may have their eligibility for a Tier 2 Canada Research Chair assessed through the program's Tier 2 justification process. Please see the CRC website (www.chairs-chaires.gc.ca) for further eligibility details.

York acknowledges the potential impact that career interruptions (e.g., maternity leave, leave due to illness, etc.) can have on a candidate's record of research achievement. Applicants are encouraged to explain in their application the impact that career interruptions may have had on their record of research achievement; this will be taken into careful consideration during the assessment process.

Established in 2012, the Lassonde School of Engineering, York University offers a broad range of undergraduate and graduate programs to educate multidisciplinary problem solvers, critical thinkers, and entrepreneurs who understand creativity, communications, social responsibility, and cultural diversity. Further information is available at lassonde.yorku.ca.

York is a leading international teaching and research university, and a driving force for positive change. Empowered by a welcoming and diverse community with a uniquely global perspective, we are preparing our students for their long-term careers and personal success. Together, we can make things right for our communities, our planet and our future.

York University has a policy on Accommodation in Employment for Persons with Disabilities and is committed to working towards a barrier-free workplace and to expanding the accessibility of the workplace to persons with disabilities. Candidates who require accommodation during the selection process are invited to contact Prof. John E. Moores, Chair of the Search Committee at ad.research@lassonde.yorku.ca.

York University is an Affirmative Action (AA) employer and strongly values diversity, including gender and sexual diversity, within its community. The AA Program, which applies to women, members of visible minorities (racialized groups), Aboriginal (Indigenous) people and persons with disabilities, can be found at www.yorku.ca/acadjobs or by calling the AA line at 416-736- 5713. Applicants wishing to self-identify as part of York University's Affirmative Action program can do so as part of the online application process. For this search, only candidates who self- identify as women, Aboriginal (Indigenous), Black peoples of African Descent (for example Africans and African heritage people from the Caribbean, Americas, Europe) and persons with disabilities may apply.

All qualified candidates are encouraged to apply; however, Canadian citizens, permanent residents and Indigenous peoples in Canada will be given priority. No application will be considered without a completed mandatory Work Status Declaration form which is included as part of the online application process.

The deadline for receipt of completed applications is **January 31st, 2022**. You should complete the online application process at apply.lassonde.yorku.ca. A letter of application (indicating the rank you wish to be considered for), an up-to-date curriculum vitae, statements of contribution to research, teaching and curriculum development, teaching evaluations, three sample research publications and the names and contact information for three people who have agreed to provide reference letters.

CSME BOARD DIRECTORS & STAFF / DIRECTEURS ET PERSONNEL SCGM

EXECUTIVE COMMITTEE / COMITÉ EXÉCUTIF

President / Président	Mina Hoorfar, FCSME	mina.hoorfar@ubc.ca
Sr. Vice President / Premier vice-président	Alex Czekanski, FCSME	alex.czekanski@lassonde.yorku.ca
Immediate Past President / Président sortant	Maciej Floryan, FCSME	floryan@uwo.ca
Honorary Treasurer / Trésorier honoraire	Eric Lanteigne, MCSME	eric.lanteigne@uottawa.ca
Honorary Secretary / Secrétaire honoraire	David Weaver, FCSME	weaverds@mcmaster.ca
Vice-President, Technical Programs / Vice-président, programmes techniques	Xianguo Li, FCSME	x6li@uwaterloo.ca
Executive Director / Directeur exécutif	Guy Gosselin, FEIC	ggosselin.eic@gmail.com

STANDING COMMITTEES / COMITÉS PERMANENTS

Congresses / Congrès	Ali Ahmadi, MCSME	aahmadi@upei.ca
History / Histoire	Farid Golnaraghi, FCSME	mfgolnar@sfu.ca
Membership / Adhésions	Alex Czekanski, FCSME	alex.czekanski@lassonde.yorku.ca
Professional Affairs / Affaires professionnelles	Faizul Mohee, MCSME	fmm_p@yahoo.com
Student Affairs / Affaires étudiantes	Marina Freire-Gormaly, MCSME	marina.freire-gormaly@lassonde.yorku.ca
Student Paper Competiton/ Concours de publication des étudiants	Mina Hoorfar, MCSME	mina.hoorfar@ubc.ca

TECHNICAL COMMITTEES / COMITÉS TECHNIQUES

Advanced Energy Systems / Systèmes avancés d'énergie	Xili Duan, MCSME	x6li@uwaterloo.ca
Biomechanics / Biomécanique	Hossein Rouhani, MCSME	aahmadi@upei.ca
Computational Mechanics / Mécanique numérique	Maciej Floryan, FCSME	floryan@uwo.ca
Engineering Analysis & Design / Conception et analyse en ingénierie	Kamran Behdinan, FCSME	behdinan@mie.utoronto.ca
Environmental Engineering / Génie de l'environnement	Horia Hangan, FCSME	hmh@blwtl.uwo.ca
Fluid Mechanics Engineering / Génie de la mécanique des fluides	Martin Agelin-Chaab, MCSME	martin.agelin-chaab@ontariotechu.ca
Heat Transfer / Transfert de la chaleur	Sunny Li, MCSME	sunny.li@ubc.ca
Machines and Mechanisms / Machines et mécanismes	Eric Lanteigne, MCSME	eric.lanteigne@uottawa.ca
Manufacturing / Fabrication	Alex Czekanski, FCSME	alex.czekanski@lassonde.yorku.ca
Materials Technology / Technologie des matériaux	Frank Cheng, MCSME	fcheng@ucalgary.ca
Mechatronics, Robotics and Controls / Mécatronique, robotique et contrôles	Farrokh Janabi-Sharifi, FCSME	fsharifi@ryerson.ca
Microtechnology and Nanotechnology / Microtechnologies et nanotechnologies	Mohsen Akbari, MCSME	makbari@uvic.ca
Transportation Systems / Systèmes de transport	Yuping He, FCSME	yuping.he@ontariotechu.ca

PUBLICATIONS

Editor, ***Bulletin*** / Rédacteur, ***Bulletin***	Pouya Rezai, MCSE	pouya.rezai@lassonde.yorku.ca
Associate Editor, ***Bulletin*** / Rédacteur associé, ***Bulletin***	Marc Secanell, MCSME	secanell@ualberta.ca
Art Director, ***Bulletin*** / Directrice artistique, ***Bulletin***	Nina Haikara	bulletin@csme-scgm.ca
Technical Editor, ***Bulletin*** / Rédactrice technique, ***Bulletin***	Ryan Willing, MCSME	rwilling@uwo.ca
Chief Editor, ***CSME Transactions*** / Rédacteur en chef, ***Transactions SCGM***	Marius Paraschivoiu, FCSME	marius.paraschivoiu@concordia.ca
CSME Webmaster	Amr Nagaty	a.k.nagaty@gmail.com

SPECIAL COMMITTEES / COMITÉS SPÉCIAUX

Canadian National Committee - IUTAM / Comité national canadien - UIMTA	Marco Amabili, MCSME	marco.amabili@mcgill.ca
Honours and Awards / Prix honorifiques	Maciej Floryan, FCSME	floryan@uwo.ca

CSME OFFICE / BUREAU SCGM

Administrative Officer / Agent administratif	Mohammud Emamally	admin.officer@csme-scgm.ca

CSME Address / Adresse de la SCGM
P.O. Box 40140, Ottawa, ON, K1V 0W8
Phone / Téléphone 613.400.1786 Email: admin.officer@csme-scgm.ca www.csme-scgm.ca

The CSME would like to acknowledge the support from the following ME Departments

La SCGM tient à remercier les départements de génie mécanique suivants pour leur aide

University of Alberta

BCIT

Schulich School of Engineering – University of Calgary

Carleton University

Université Concordia University

Dalhousie University

ÉTS – Engineering for Industry

Lakehead University

Laurentian University / Université Laurentienne – Bharti School of Engineering / École de génie

Université Laval

University of Manitoba

McGill

McMaster University Engineering

Memorial University

Université de Moncton – Campus de Moncton – Faculté d'ingénierie – Génie mécanique

Polytechnique Montréal

UNB Faculty of Engineering – Department of Mechanical Engineering

uOttawa

University of Prince Edward Island

Queen's University

RMC CMR

University of Saskatchewan

SFU Simon Fraser University

Université de Sherbrooke

Mechanical & Industrial Engineering – University of Toronto

The University of British Columbia – Faculty of Applied Science

The University of British Columbia – School of Engineering – Okanagan Campus

Toronto Metropolitan University

Ontario Tech University

University of Victoria – Mechanical Engineering

University of Waterloo

Western Engineering

University of Windsor – Faculty of Engineering

Lassonde School of Engineering – York Université University

Return undeliverable Canadian addresses to:
P.O. Box 40140
Ottawa, ON K1V 0W8