Carbon Solutions – Strategic Priority Fund Project

Summary Report

May, 2026

Project Description

The Government of Canada is committed to achieving net-zero greenhouse gas (GHG) emissions by 2050. Canada's leading research universities are at the foundation of the research, development and innovation ecosystem that will enable an economy which embraces a net-zero future. As Canada develops programs, strategies, research and education of next generation of talent to exceed its carbon reduction targets, an expert centre focused on all areas of carbon reduction and benefits will be crucial in supporting federal, provincial and municipal requirements. We are proposing strategic investments in a national center housed at Western University, Carbon Solutions, that will allow Canada to leverage existing investments and further integrate the role of universities and strategic assets at leading research institutions across Canada in collaboration with key industry and community partners.

Carbon Solutions will support Canada's efforts by:

1. Bringing together the best of research and national partners to develop leading solutions for addressing identified carbon reduction strategies for Canada.
2. Enhancing products and developing new technologies that would raise Canada's renewable energy technology capability. This would support stronger sector expansion and create made in Canada solutions for the global market.
3. Focusing on the circular economy and encouraging Canadian manufacturers and producers to develop sustainable and enhanced life cycle development strategies to products, energy usage and recycling.

These three strategies are complemented and supported by initiatives in education, social acceptance, law, policy, and entrepreneurship in successfully implementing solutions that will meaningfully decrease GHG.

Carbon Solutions @ Western University is based on academic and partner collaboration to address carbon reduction and replacement. The sectors of focus for carbon reduction will have strong ties to the Southwestern Ontario and Ontario economies for opportunities that will have significant national impact either directly or through validation for deployment across Canada and internationally.

Western University has substantial assets in place to support carbon reduction strategies and is already engaged with business and government. Carbon Solutions @ Western would focus existing assets and required additional resources on the reduction and elimination of greenhouse gas emissions to meet the national GHG reduction commitments, while building an economy that provides jobs in the future.

Outcomes

- Viable potential solutions including demonstration projects, prototypes, system testing, designs and intellectual property.

- Identify opportunities for research and translation required in areas where there are knowledge gaps including policy development, education, legal and regulatory, economic assessment.
- Develop a national network of universities, industry and government partners to develop new products and processes related to a carbon transition economy

Key Performance Indicators

- Number of project partnerships initiated
- Number of projects that move to development and pilot implementation stage
- Number of external partners, faculty, students
- Potential/real GHG reduction by end of Year 2.
- Policy changes influence by Carbon Solutions (municipal, provincial, federal)

Networking events

- Symposia for principal investigators, trainees and guests were held each May 2023, 2024 (joint with WAFAR) and 2025. Participants presented updates on projects and trainees presented posters during networking sessions.
- Cleantech Symposia were held November 2023 and 2024 which partnered Carbon Solutions researchers with the Morrisette Institute of Entrepreneurship to foster discussion on cleantech startups and the ecosystem support available.
- Wrap-up symposium was held December 2025.

Project duration

- Requests for proposals and adjudication by the steering committee (Oana Branzei, Caroline Calmettes, Miriam Capretz, Janis Cardy, David Muir, Bryan Neff, James Voogt) were accomplished in four rounds for project funding.

Project leader(s)	Start date	End date
Gualandris	8/1/2022	1/31/2024
Arjalies	7/1/2022	6/30/2025
Klinghofer	9/1/2022	4/31/2025
Bassi	9/1/2022	2/28/2025
Straatman/Siddiqui/Pearce/Hunsberger	9/1/2022	12/31/2024
Berrutti/Henry	9/1/2022	2/28/2025
Boutilier/Briens	9/1/2022	2/28/2025
Zheng	1/1/2023	12/31/2024
Santoro/Rehman	5/1/2023	10/31/2024
Pearce	5/1/2023	4/30/2025
Zhao	7/1/2023	6/30/2025
Grolinger	9/1/2023	8/31/2025
Sabarinathan/Haque	9/1/2023	8/31/2024
Lindo	9/1/2023	2/28/2025
Mensink	1/1/2024	9/30/2025

Project Investigators

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Dr. Diane-Laure Arjaliès, Ivey Business School and Centre for Building Sustainable Value

Scaling up nature-based climate solutions for carbon emissions though an Indigenous- and community-led Conservation Impact Bond

External Partner(s): Carolinian Canada –Conservation Impact Bond (CIB)

This project advances the Deshkan Ziibi Conservation Impact Bond (DZCIB), the first pilot of a Conservation Impact Bond (CIB) an innovative financial model co-created with Indigenous nations, local communities, and private investors to scale up and deep nature-based climate solutions. It aims at protecting biodiversity and restoring ecosystems. The DZCIB pilot phase targets 1,000 hectares of ecosystem restoration to optimize the sequestration of 750 tonnes of CO_2 annually. Once matured, these ecosystems will store up to 200,000 tonnes. By rethinking traditional conservation funding, the model unlocks new pathways for private and public investment in ecological restoration while centering Indigenous leadership and community governance.

This research focuses on how the CIB can be replicated, scaled, and adapted across diverse landscapes, stakeholders, rightsholders and conservation priorities. Through community-based participatory research, the team is developing a scalable national framework for CIB that maximizes biodiversity gains, carbon sequestration, and long-term financing for conservation. This work supports Canada's 2030 Emissions Reduction Plan and demonstrates a powerful model for funding climate action at scale.

Impact:

- Provided training and experience for a postdoctoral fellow and 11 undergraduate research assistants through through programs such as Heads and Hearts and the Western Undergraduate Summer Research Internship (USRI).
- Produced and delivered a comprehensive practitioners' report examining the role of accounting mechanisms in Conservation Impact Bonds, using the Carolinian Canada Coalition as a case study.
- Produced and delivered a comprehensive practitioners' report, in collaboration with EY, examining culturally sensitive auditing practices, using the CIB as an example.
- Presentation at the European Group for Organizational Studies (EGOS) and at the Administrative Sciences Association of Canada Conference in 2025.
- Publication of "Creating Third Epistemological Spaces with Indigenous Communities: A Two-Eyed Seeing/Etuaptmumk Methodology" (2026) drawing on the learnings of the CIB.
- Book chapter in *Indigenous Management: Knowledges and Frameworks* (Sage, 2025). This chapter, "The Deshkan Ziibi Conservation Impact Bond: A Two-Eyed Seeing Financial Model for Addressing the Biodiversity Loss and Climate Crises," directly addresses our outcome of capacity building within educational institutions.

Dr. Amarjeet Bassi, Chemical and Biochemical Engineering

Microalgae-based Eco-plastic

External Partner(s): Ontario Greenhouse Vegetable Growers; Aspire Foods; IESO

Dr. Amarjeet Bassi and his team are developing sustainable bio-based plastics by leveraging microalgae grown on waste resources. Supported through Western's Carbon Solutions initiative, the project demonstrates pilot-scale cultivation using a 500-litre bioreactor, where microalgae convert wastewater streams into valuable biomass. This process not only produces clean, recycled water but also generates algal-derived material with potential for bioplastic composite development, offering a circular alternative to petroleum-based plastics. The research aims to reduce carbon emissions across the plastic value chain by integrating waste remediation with low-carbon biomaterial production.

A second project, conducted in collaboration with Western colleagues, explores innovative pathways for generating pale blue hydrogen. This work focuses on producing low-emission hydrogen through improved efficiency and carbon-mitigation strategies, aligning with Canada's clean energy goals. Together, these projects highlight Western's commitment to advancing scalable climate-positive technologies across sustainable materials, waste reduction, and clean energy.

Impact:

- Training and experience for three PhD students, three NSERC USRA undergraduate students and a postdoctoral fellow.
- Publications
    - "Comparative techno-environmental analysis of grey, blue, green/yellow and pale-blue hydrogen production", *International Journal of Hydrogen Energy* (2025)
    - "Investigation of microalgal tolerance and growth in simulated tailings pond water containing naphthenic acids", *Canadian Journal of Chemical Engineering* (2025)
    - "Investigation of physical properties of microalgae-pectin-based bio-composite with addition of pine needle for environmental application", *Environmental Progress & Sustainable Energy* (2024)

Dr. Franco Berruti, Chemical and Biochemical Engineering and ICFAR

Dr. Hugh Henry, Biology

Development of a farm-size biomass carbonizer for biocarbon production and carbon sequestration

External Partner(s): BioIndustrial Innovation Canada; Gudgeon Thermfire International; WESSUC; JCT Calderas; ITER Technologies; Whitecrest Mushrooms

The project began with a detailed techno-economic analysis and business model. This initial phase focused on evaluating a novel, energy-efficient pyrolysis technology designed to convert agricultural residues into high-quality biochar—an organic material that can improve soil health and capture carbon from the atmosphere. Using data based on agricultural waste available in Ontario and Canadian manufacturing costs, the analysis revealed that the technology would not be economically viable under current conditions. Profitability would require reducing capital costs and ensuring a steady, year-round supply of agricultural feedstock. Following this assessment, the team partnered with a manufacturing company in Colombia to design a large-scale (25 tonnes/day) biochar production unit integrated with a drying system. To support demonstrations and testing, a smaller (2.5 tonnes/day) version was also built for in-house operation. The testing has demonstrated the outstanding performance of this technology and we proved that we could design and build high quality units at much lower capital costs than originally projected. In addition, extensive trials were conducted to evaluate the effects of biochar on plant growth, both in soil and soilless environments. The results were promising, with many crops showing a consistent 20–30% increase in growth when biochar was applied at a rate of 2 metric tonnes per hectare. Overall, the project has been a resounding success. It met its original goals and significantly expanded its network of industrial collaborators, paving the way for broader adoption of this sustainable technology. Future work will be focusing on further enhancing the quality of the biochar products by adding functional features for specific applications and by activating it to achieve performance characteristics even superior to commercially available fossil-based activated carbon products.

Impact:

- Created a spin-off company ITER Technologies Ltd to commercialize the pyrolysis technology for biomass feedstocks to biocarbon. Partnered with JCT Calderas based in Medellin, Colombia which has over 40 years of experience in the design and manufacturing of thermal processing equipment.
- Training and experience for eight (8) graduate students and postdoctoral fellows.
- Publications
    - “Self-energized Pyrolysis Process for Sustainable Biochar Production”, *Energy & Fuels* (2024).
    - “Biochar is a long-lived form of carbon removal, making evidence-based CDR projects possible”, *Biochar* (2024).

Dr. Michael Boutilier, Chemical and Biochemical Engineering

Dr. Cedric Briens, Chemical and Biochemical Engineering

Converting coker unit off-gas into hydrogen and carbon nanomaterials

External Partner: Syncrude Canada Ltd.

Eliminating sources of greenhouse gas emissions in oil production is essential to meeting Canada's climate targets. Coking and steam reforming in hydrogen production, prevalent processes used in Canadian oil production, are major contributors to these emissions. In addition to the desired oil produced by coking, carbon-containing gases are generated and burned to supply heat required by the process, releasing an estimated 50,000 tonnes of carbon dioxide daily in Canada. At the same time, Canada's future sustainability plans depend on low emission sources of hydrogen gas for renewable energy storage and shipping, applications where batteries are impractical. We develop a process whereby, instead of burning gases produced through coking, they are instead converted into a hydrogen-rich gas and carbon nanotubes, without producing carbon dioxide. The process can be designed so that the hydrogen gas can be burned to supply the same heat required in the process or purified to supply low emission hydrogen. The carbon nanotubes store carbon, preventing its release into the atmosphere, while having value as a high strength material used in wind turbines and/or as battery electrodes for electric vehicles. The main outcome of the project was that byproduct gases from oil sands bitumen processing were successfully converted into hydrogen and commercial-quality carbon nanotubes without generating the carbon dioxide usually produced when these gases are burned.

Impact:

- Developed a process whereby a diverse range of hydrocarbon mixtures can be converted into a hydrogen-rich gas, and insensitive to hydrocarbon feed gas composition. Successfully applied to industrially relevant byproduct gas streams produced from bitumen and waste plastic pyrolysis gases.
- Characterized the carbon nanotubes produced from industrially relevant byproduct gases and confirmed that they are of commercial quality.
- Publication
    - “Conversion of bitumen and waste plastics pyrolysis gases into hydrogen and carbon nanotubes” *International Journal of Hydrogen Energy* (2026)

Dr. Katarina Grolinger, Electrical and Computer Engineering

Dr. Miram Capretz, Electrical and Computer Engineering

Dr. Girma Bitsuamlak, Civil and Environmental Engineering, WindEEE Research Institute

Digital Twins with Machine Learning for a Sustainable Future

External Partner: London Hydro

Buildings account for roughly 40% of total energy consumption, making them critical targets in achieving Canada's net-zero emissions goals. This project integrates digital twins, Internet-of-Things (IoT) sensors, and advanced machine learning (ML) to improve building energy performance, forecasting, and carbon reduction opportunities.

Digital Twin is a digital representation of the building that continually evolves and reflects the real-world building based on real-time data from sensing/IoT systems. In collaboration with London Hydro, the research team will develop digital twins of selected buildings and combine them with ML/AI models trained on historical and real-time datasets. These models will enable more accurate prediction of energy consumption, identification of inefficiencies, and optimization of occupant-building interactions.

By uniting building analytics, IoT monitoring, and AI-driven forecasting, the project offers a powerful tool for reducing energy use and emissions. The outcomes will inform utility planning, enhance grid resilience, and support the transition to net-zero building operations.

Impact:

- Training and experience for three (3) PhD students and a postdoctoral fellow.
- Publications
    - "Toward smart-building digital twins: BIM and IoT data integration." *IEEE Access* (2023)
    - "Continuous model calibration framework for smart-building digital twin: A generative model-based approach, *Applied Energy* (2024)
    - "Data-driven and Physics-based Modeling Approaches and Their Integration in Building Digital Twins: A Systematic Review" *Journal of Building Engineering* (2025).

Dr. Jury Gualandris, Ivey Business School, Centre for Building Sustainable Value

Towards Net-Zero: Assessing and Improving the Carbon Reduction Potential of Circular Clusters

External Partner(s): City of Guelph (including Our Food Future & the Circular Opportunity Innovation Launchpad (COIL))

This study explores and assesses a network of businesses in Montreal that both collaborate and compete to upcycle food waste. This network efficiently repurposes discarded items like spent grains, fruit, and vegetable residues into products such as juice, cookies, powders, cosmetics, mushrooms, insect-based proteins, soil amendments, and green energy. This urban system functions similarly to nature by recycling nutrients and energy. It diverts significant amounts of food waste from landfills, cutting greenhouse gas emissions and water use, while reducing the strain on rural agricultural systems. By documenting the structure and operation of this circular economy, the study provides a model of an emerging urban circular economy that can be replicated in other cities. The network follows the US EPA food recovery hierarchy, prioritizing human-directed uses (like juices, cookies, and cosmetics) over applications like animal feed or returning nutrients to the soil. This approach is driven by public policies and widespread beliefs that human consumption is the best use for food discards. However, the study warns that this structure might become inefficient as the network grows. A balanced approach is needed to ensure all upcycling pathways develop proportionally, so as not to miss opportunities for greater GHG emissions and water savings. Public policies should support this balanced growth.

Impact:

New funding and projects:

- Genome Canada: Omics for Closing the Loop. “Omics to close the loop: optimized amendment from local agrifood waste for carbon footprint reduction”. The project involves identifying optimal ways of transforming urban food waste collected from local companies (e.g., bakeries, breweries, juice producers etc.) into productive uses such insect protein, mushrooms, compost, and green bio-mass based energy. The project is based in Montreal and is a joint effort of several international teams of researchers.
- CSA: Standards development for climate-smart circularity. CSA was interested to apply the methodology we developed through Carbon Solutions project to two other sectors, namely construction and textile. In this study, we are interested in studying the relationship between a) the embedded carbon of materials and products that circular solutions substitute for, and b) the maximum thresholds of geographical scale and total energy consumption that circular processes need operate within.
- The Conference of Great Lakes St. Lawrence Governors and Premiers (GSGP): 100% Great Lakes Fish. The Great Lakes are home to a sizeable commercial fishery for Lake Whitefish, Yellow Perch, Walleye and Lake Trout. People eat the fillet of the fish, and the other 60% of the fish is used for low-value animal feed or discarded. Using the entire fish (e.g. for pharmaceuticals, clothing/textiles, food supplements) can create significant economic returns for the Great Lakes region, creating more jobs, and helping rural economies develop. GSGP is

leading a collaborative effort to encourage full utilization of each commercially caught fish from the Great Lakes, utilizing a model successfully deployed in Iceland. Build directly on the @Carbon Solutions investigation of circular clusters and networks, the BSV Centre's has been engaged by GSGP to support key supply chain mapping and development activities to inform the development of the 100% Great Lakes Fish model (initial funding $35k USD).

- Environment & Climate Change Canada (ECCC): business data needs for the circular economy. Ivey was commissioned by ECCC to identify and clarify the key data needs of Canadian business to accelerate the adoption of circular models and practices, as well as the potential data infrastructure that may be required to provide this data (and the role of government in providing this infrastructure). The project research is primarily focused on the agri-food and construction sectors, as two key sectors with major waste issues and high potential for improved levels of circularity, enabling the wider shift towards the circular economy in Canada.

Publications

- Jain, S., and Gualandris, J., (2023). "When does upcycling mitigate climate change? The case of wet spent gains and fruit and vegetable residues in Canada." *Journal of Industrial Ecology*, doi.org/10.1111/jiec.13373. o RRBM Honor Roll – The paper has been selected as an example of research that is both rigorous and relevant by an important academic association, Responsible Research in Business and Management (RRBM)
- Gualandris, J., Jain, S., "Beliefs and networks: how firms collectively organize to give resources new life." This working paper has been presented at the 2023 Decision Science Conference in Atlanta (USA) and the 2024 Production and Operations Management Society conference in Minneapolis (USA). The working paper is currently in the latest stage of preparation for submission to the *Journal of Operations Management*, a top-tier journal in the business and management discipline.
- Jain, S. and Gualandris, J., Climate-smart circularity: Guiding decision-making through data-informed standard protocols. Scientific Reports [In preparation]

Dr. Naomi Klinghoffer

Production of renewable jet fuel from waste

External Partner(s): Greenfield Global

This project explored new pathways to improve the feasibility of producing sustainable aviation fuel (SAF) from Canadian waste streams. One challenge with utilizing low value feedstocks such as mixed waste or biomass is that these waste streams are typically decentralized, have low energy density, and have high moisture content. It can be difficult to run chemical plants with complex conversion processes on small scales in remote locations. However, transporting these waste streams can be expensive and may result in high CO_2 emissions from transportation. These challenges can be addressed by pre-processing waste at the collection site in order to remove moisture and volatile matter while increasing energy density. The densified intermediate is then transported to a centralized facility for gasification and subsequent Fischer-Tropsch synthesis. We explored a range of conditions for thermochemical conversion of waste, including low temperature torrefaction and high temperature pyrolysis. Our worked included an investigation of mixed municipal solid waste as well as Canadian forestry residues. Experiments were conducted in a pilot-scale horizontal pyrolysis reactor equipped with mechanical mixing, as well as a batch reactor for processing smaller quantities of feedstocks under slower heating rates. Products such as bio-oil and biochar were recovered from the process and were characterized. These products were evaluated as part of a process design that aims to optimize energy recovery and volumetric energy density, while also considering critical properties such as viscosity. The work demonstrated that thermochemical conversion has the potential to significantly increase the energy density of the waste in order to make it suitable for transportation to a centralized facility for SAF production. This will significantly expand the potential for waste utilization and renewable fuel production in Canada.

Impact:

- Awarded a Mitacs Elevate fellowship ($120,000), funding a post doctoral fellow for two years who worked on pyrolysis of forestry residues as a pathway for energy densification. Research continues with Greenfield Global and a second Mitacs grant has been awarded.
- Publications:
    - F. Salami, N. B. Klinghoffer, Enhancing Energy Recovery from Waste through Torrefaction: A Study on Municipal Solid Waste (MSW) Fractions under N2 and CO_2 Atmospheres, Canadian Journal of Chemical Engineering, 2026, 104, 1100-1120; selected by the Editor in Chief as a feature article in Issue Highlights, 2026
    - F. Salami, N. B. Klinghoffer , Torrefaction of Municipal Solid Waste Mixture: Assessing the Potential of CO_2 and Flue Gas as Cost-Effective Alternatives to Nitrogen, in preparation.

Dr. Zoe Lindo

Soil Biodiversity as Nature-based Solutions to Promote Boreal Forest and Peatland Carbon Storage

External Partner(s): Ontario Ministry of Natural Resources and Forestry

Soils play a vital role in fighting climate change because they store more carbon than all the world's vegetation and atmosphere combined. But as the climate warms and land use changes, soils may release more greenhouse gases—like carbon dioxide and methane—into the air, making climate change worse. Our research, supported by the Ontario Ministry of Natural Resources and Forestry, focused on understanding how soil organisms, plants, and microbes interact to store or release carbon in Ontario's boreal forests and peatlands. We combined long-term data and field experiments to uncover how warming and silviculture treatments influence soil carbon. In forests, we analyzed a 20-year soil carbon dataset and conducted new sampling to understand how soil properties, microbial activity, and biodiversity affect long-term soil carbon storage. In peatlands, we tracked vegetation shifts, greenhouse gas emissions, and soil biodiversity under experimental warming. This work revealed how warming reshapes plant communities, alters microbial function, and increases carbon vulnerability. Through data on soil biodiversity, greenhouse gas emissions, and soil carbon storage, our research is helping improve models that predict how much carbon Ontario's ecosystems can hold. This knowledge supports better land-use decisions, including how forests are managed and how wetlands are protected. Our findings directly support Ontario's Nature-based Carbon Solutions strategy by improving carbon models and informing land-use planning. The project also trained a diverse group of early-career researchers in climate science and ecology, strengthening Ontario's capacity to lead on climate action and carbon market participation.

Impact:

- This project generated significant environmental, academic, and policy-relevant outcomes that directly benefit our external partner, the Ontario Ministry of Natural Resources and Forestry (OMNRF). By producing empirical data and modeling outputs related to soil biodiversity and carbon cycling, the project supports the province's strategic goals for using Nature-based Carbon Solutions (NbCS) to mitigate climate change, particularly through peatland protection and forest management.
- Our research provides a mechanistic understanding of how climate change and forest management affect soil carbon dynamics and greenhouse gas emissions. Data collected from our field experiments in boreal peatlands and forests will inform ecosystem-specific recommendations to enhance soil carbon storage and reduce emissions, specifically the work contributes to refining carbon models used in land-use planning, forest carbon offset programs, and conservation strategies under Ontario's Made-in-Ontario Environmental Plan. By improving the predictability and credibility of NbCS strategies, the project enhances Ontario's potential to participate in carbon markets, both through emissions reductions and carbon credit generation.

- Training of HQP (PhD, 2 MSc, UG) with interdisciplinary skills builds capacity for the green economy, strengthening future workforce readiness in sectors including climate science, environmental consulting, and government policy.
- Publications
    - Ferguson, P. and Lindo, Z. 2025. Disentangling the effect of temperature and moisture on boreal peatland microbial activity and function. *Pedobiologia – Journal of Soil Ecology*.
    - Barreto, C., Buchkowski, R.W., Lindo, Z. 2024. Restructuring of soil food webs reduces carbon storage potential in boreal peatlands. *Soil Biology and Biochemistry* 193:109413, https://doi.org/10.1016/j.soilbio.2024.109413
    - Deighton, H.D., Bell. F.W. and Lindo, Z. Long-term effects of forest management on boreal forest soil carbon. Submitted to *Canadian Journal of Forest Research*.
    - Lindo, Z., Hopkins, S. McLaughlin, J., Barreto, C., and Branfireun, B. Biotic reorganization and carbon vulnerability: Seven years of warming in fast and slow boreal peatlands. In preparation for *Global Change Biology*.
    - Hopkins, S. and Lindo, Z. Traits explain changes in *Sphagnum* moss composition under experimental warming in a boreal peatland. In preparation for *Journal of Ecology*.
    - Obi, E. and Lindo, Z. Experimental climate warming in boreal peatlands alters oribatid mite communities through peat drying. In preparation for *Applied Soil Ecology*.
    - Barreto, C., McLaughlin, J., Branfireun, B. and Lindo, Z. 2024. Understanding the effects of climate change on peatlands in Northern Ontario: The BRACE experiment. Ministry of Natural Resources, Science and Research Branch, Peterborough, ON. Climate Change Research Note CCRN-15. 15 p. + appendix. http://dx.doi.org/10.13140/RG.2.2.20004.18560

Dr. Paul Mensink

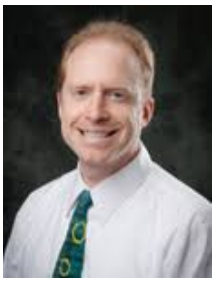
Nature-based carbon solutions: Carbon sequestration through land conservancies

External Partner(s): Thames Talbot Land Trust (TTLT)

The team developed an innovative software tool to help prioritize land conservation efforts across southern Ontario. The toolkit evaluated over 250,000 land parcels using ecological criteria such as habitat type, parcel size, and carbon storage potential, enabling land trusts to focus resources on areas that deliver the greatest environmental benefit. This transparent, data-driven approach streamlines decision-making for TTLT, supporting the identification and protection of high-value habitats. In addition, the project established a baseline inventory of carbon stored on TTLT properties and assessed the impacts of restoration activities on soil carbon. Together, these outcomes support climate action, strengthen community engagement, and advance community-led conservation, contributing to the protection of natural heritage and long-term ecological health in the region.

Impact:

- We are pursuing new partnerships to support the next phase of the project and broaden its application. This includes working with additional carbon solutions partners on land valuation and assessment, as well as engaging CIRT partners interested in our toolkit. The objective of these partnerships is to strengthen multi-criteria assessment of land parcels against environmental and policy goals, including identifying marginal land suitable for conservation easements, nature-based solutions, or carbon sequestration.
- In parallel, we are continuing collaborative work on soil sampling and carbon stock verification with Dr Liz Webb, comparing field data with modelled variables to strengthen the project's scientific foundation. There is also potential for collaboration with the City of London to integrate verified datasets into the City of London Climate Emergency Dashboard, supporting evidence-based planning and climate action.
- Publications
    - Vey, R., Koscinski, D., Webb, E., Henry, HAL$_4$, Mensink, P (in prep) *Soil Carbon Storage Post Restoration in a Restored Meadow*.



Dr. Joshua Pearce

Dr. Soodeh Nikan

Dr. Raymond Thomas

Agrotunnel Agrivoltaics Hybrid for Sustainable Food

External Partner(s): Food Security Structures Canada (FSSC), Green Magic Homes, Adragone Aeroponics, Vertical Green, SolarCities

This groundbreaking project developed and demonstrated the world's first agrivoltaic-agrotunnel hybrid system. It is an integrated, solar-powered approach to year-round food production in cold climates. Deployed successfully in mid-winter conditions, the system combines renewable energy generation with controlled-environment agriculture to enable zero-carbon, zero-waste, and sustainable food production anywhere in Canada.
The research team designed a semi-mobile agrotunnel in partnership with Food for deployment in other regions. To support rapid and affordable adoption, the team also developed several low-cost, open-source solar photovoltaic racking systems, including ballast-mounted designs that eliminate ground-digging restrictions.

In controlled trials, the agrotunnel achieved accelerated growth from seed to ripe strawberry in just three months, producing sweet, high-quality berries through the winter. A low-cost growing bin system reduced the expense of commercial vertical farming by 90%, while detailed economic analyses identified the most viable crops for both indoor and outdoor cultivation. Field experiments achieved the first-ever documented agrivoltaic yield increase in Canada, with strawberries showing an 18% yield boost under 69% transparent solar panels. Complementary studies at Western's Biotron research facility validated these findings and optimized system design for Canadian current and future climates. To enable net-zero operations, the team created a validated energy model for agrivoltaic agrotunnels, allowing precise photovoltaic sizing for different regions. The project also set a world record in computer vision accuracy for strawberries (98.4%), distinguishing ripeness and diagnosing seven key plant diseases with advanced AI.

Impact:

- Additional funding *Outdoor Solar Energy from Agrivoltaics Powering Indoor Growing* MITACS $530k and *Agrotunnel Agrivoltaics Hybrid for Sustainable Food*, Weston Family Foundation $1M. Total support for the project more than $1.4M.
- Publications

- Asgari, N.; Jamil, U.; Pearce, J.M. Net Zero Agrivoltaic Arrays for Agrotunnel Vertical Growing Systems: Energy Analysis and System Sizing. *Sustainability* 2024, 16, 6120. https://doi.org/10.3390/su16146120
- Aghamohammadesmaeilketabforoosh, K.; Nikan, S.; Antonini, G.; Pearce, J.M. Optimizing Strawberry Disease and Quality Detection with Vision Transformers and Attention-Based Convolutional Neural Networks. *Foods* 2024, 13, 1869. https://doi.org/10.3390/foods13121869
- Qian, J.-Y.; Pearce, J.M. Open-Source Indoor Horizontal Grow Structure Designs. *Designs* 2024, 8, 95. https://doi.org/10.3390/designs8050095
- Uzair Jamil, Joshua M. Pearce, Experimental impacts of transparency on strawberry agrivoltaics using thin film photovoltaic modules under low light conditions, *Solar Energy*, 290, 2025, 113375. https://doi.org/10.1016/j.solener.2025.113375
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- Over 35 mainstream media stories about the agrivoltaics agrotunnel and accomplishments on this project including coverage in: *CBC News, Toronto Star, London Free Press, CTV*, and technical press such as Vertical *Farm Daily, Horti Daily,* and *AI News*.
- Nominated to be of two projects going forward to the global MacArthur 100&Change competition and have passed the first two rounds of cuts of thousands of applicants down to 500 as our application advanced to the *Wise Head Panel* for the $100 million prize.

Dr. Jayshri Sabarinathan

Dr. Anwar Haque

Drone based Multispectral Imager for Monitoring Methane emissions from Landfills

External Partner(s): City of London

The primary objective of this research project is to validate an innovative drone-based multispectral imager (MSI) designed to provide quantitative measurements of methane emissions from landfills. This technology offers a comprehensive and accurate method for assessing methane emissions over large areas, presenting a potential alternative to existing UAV-based methane detection technologies, which are often constrained by point-based measurements or qualitative imaging techniques. The project utilizes a Dual Band Short Wave Infrared Imager (DBSI), specifically customized to capture methane absorption spectra. This technology is well-suited not only for monitoring diffuse methane release sites, such as landfills, but also for addressing more concentrated methane emissions found in industries like oil and gas. Ultimately, the project aims to generate valuable scientific data on methane flux dynamics, deepen understanding of emission patterns, and contribute to the advancement of environmental monitoring methodologies. The City of London, along with other stakeholders involved in landfill management, is actively seeking enhanced tools for assessing methane emissions at landfill sites, particularly at the W12A Landfill. This research aligns with the City's commitment to improving landfill methane management, ensuring that emission control measures are both effective and compliant with environmental regulations. The development of this novel drone-based imaging system will provide more precise data for evaluating the performance of methane capture systems, identifying methane hotspots, and ultimately supporting the City's sustainability objectives. Furthermore, the project contributes to broader regulatory goals, such as Canada's commitment to reducing methane emissions by 35% by 2030.

Impact:

- Methane Emission Reduction: The City of London, as an external partner, will benefit from this improved methane emissions monitoring system. The new UAV-based methane imager will allow for better and faster surveys of the field. This will make it easier to assess the performance of methane extraction systems in landfills, detect leaks easier and fix them faster. This will directly contribute to the municipality's efforts in managing and reducing methane emissions, which is crucial for meeting Canada's 2030 reduction goals for greenhouse gases (GHGs).
- Enhanced Landfill Management: By accurately mapping methane emissions over landfills, the City of London can quickly identify problem areas in their methane extraction systems, leading to more efficient and sustainable waste management practices.
- Broader Environmental Impact: The technology developed has the potential for broader applications, including monitoring methane emissions in boggy areas, methane gas pipelines, and other industrial sites. This capability will benefit not only the City of London but also other municipalities and industries across Canada, contributing to the country's overall greenhouse gas (GHG) reduction targets.
- Cost-Effective Monitoring: The proposed drone-based imager offers a cost-effective and efficient alternative to traditional methane monitoring methods, such as ground-based inspections or

satellite imagery. By reducing operational costs and increasing the frequency and precision of monitoring, municipalities and industries can achieve more accurate and timely assessments of methane emissions, which can lead to savings in mitigation efforts and improved regulatory compliance.

- $200k in funding from Environment and Climate Change Canada for the project “Multi-scale Monitoring of Methane Emission from the City of London W12A Landfill” led by Sarah Gallagher. This project involves the collection of data from the landfill site at different scales (ground-based measurement, drone-based TDLAS measurements, and satellite-based measurements from GHGSat) and at different times of year. The data sets were collected to create useful data products for the city to guide their decisions regarding methane extraction and management at their landfill site.
- Training for Research Associate, four PhD students, summer undergraduate research students
- Publications:
    - J. Sabarinathan, "Remote Sensing Instrumentation and Spectral Imagers for Monitoring Methane Emissions.," (INVITED) in *Optica Sensing Congress 2024 (AIS, LACSEA, Sensors, QSM)*, Technical Digest Series (Optica Publishing Group, 2024), paper AW1A.4. https://doi.org/10.1364/AIS.2024.AW1A.4
    - A. Bakhtazad, S. Amey, and J. Sabarinathan, "Dual Band SWIR Imager for Methane Emission Mapping," in *Optica Sensing Congress 2025 (AIS, Sensors, QSM)*, Technical Digest Series (Optica Publishing Group, 2025), paper AM2E.1. https://doi.org/10.1364/AIS.2025.AM2E.1
- Public Press Articles
    - Western Space: Interdisciplinary space science to tackle major societal challenges, https://www.innovationnewsnetwork.com/the-innovation-platform/
    - Researchers measuring city landfill-emissions, climate impacts of waste, https://www.theweathernetwork.com/en/news/climate/solutions/researchers-measuring-city-landfill-emissions-climate-impacts-of-waste
    - Western researchers to probe greenhouse gases at city landfill https://news.westernu.ca/2023/09/western-researchers-measure-methane-landfill/
    - Canada funds methane monitoring pilot programs https://www.wastetodaymagazine.com/news/canada-methane-reduction-pilot-funding/

Dr. Domenico Santoro

Dr. Lars Rehmann

Circularizing carbon solutions in the municipal sector: replacing methanol with biodegradable (compostable) plastics as carbon source for biological nutrient removal from wastewater

External Partner(s): NEWHub Corporation and Municipality of Middlesex Centre

This project explored how compostable plastics—the same kind used in some food packaging—can be used to make wastewater treatment more sustainable. Typically, wastewater plants rely on methanol, a fossil fuel, to help remove harmful nutrients like nitrogen and phosphorus from water. While effective, methanol is flammable, expensive, and contributes to greenhouse gas emissions. Instead, the research team tested biodegradable plastics such as polycaprolactone (PCL) as an alternative. These plastics slowly dissolve in wastewater, releasing organic material that "feeds" helpful bacteria responsible for cleaning the water. The team found that warmer temperatures and higher surface areas made the plastics dissolve more effectively, and that real wastewater helped speed up the process even more. The plastics performed well over time, offering a safer, greener substitute for methanol.

This work also helped connect two major environmental goals: reducing plastic waste and lowering emissions from water treatment. The project trained new researchers, led to a scientific publication, and laid the groundwork for a pilot demonstration with the Municipality of Middlesex Centre. In the future, these biodegradable materials could be used in rural and small-town treatment systems across Canada—turning waste into a solution for cleaner water and a healthier planet.

Impact:

- The Carbon Solutions project delivered several impactful outcomes aligned with both academic goals and partner-driven objectives. For the external partners - NEWHub Corp and the Municipality of Middlesex Centre—the project provided actionable evidence to support the transition from fossil-derived methanol to safer, biodegradable polymers for nutrient removal, aligning with both operational and sustainability mandates.
- The project demonstrated the feasibility of replacing methanol—an energy-intensive, GHG-intensive external carbon source—with polycaprolactone (PCL), a biodegradable alternative. The substitution is estimated to reduce greenhouse gas emissions by up to 2.2 kg CO_2e per kg of methanol displaced, representing a significant opportunity for decarbonization across wastewater treatment operations. Additionally, using biodegradable plastics that would otherwise be landfilled or incinerated supports solid waste diversion and contributes to a circular economy by valorizing waste-based polymers as functional treatment media.
- For small and medium municipalities, external carbon dosing can represent up to 10–15% of annual operating costs in wastewater treatment. By deploying a passive carbon source like PCL, the need for methanol storage, dosing pumps, and regulatory safety infrastructure is eliminated or significantly reduced. The use of solid-phase carbon further stabilizes costs by

reducing exposure to volatile methanol market prices, while also minimizing labor and compliance burdens.

- The project provides a safer and more resilient treatment option that is particularly relevant to municipalities with limited technical capacity. The avoidance of hazardous chemicals improves worker safety and lowers the risk profile for water utilities. The research also aligns with public interest in sustainable infrastructure and climate adaptation strategies and demonstrates the integration of food-grade and packaging plastics into a positive reuse cycle.
- Training for a research associate, Master student

Dr. Anthony Straatman

Dr. Joshua Pearce

Dr. Kamran Siddqui

Dr. Carol Hunsberger

An integrated solar-powered heat pump and modular thermal storage system to offset natural gas usage for heating applications

External Partner(s): Magnus Homes, Eden Energy Equipment

Space and water heating accounts for 45% of energy demand worldwide and 80% of direct carbon dioxide emissions. Buildings accounted for 12% of Canada's greenhouse gas emissions in 2019, only surpassed by oil and gas and transportation. Over 85% of the building sector emissions in Canada come from space and water heating due to the use of fossil fuel equipment and Canada's cold climate.

Green homes are typically electrified, with most of the power coming from clean sources. Although, during on-peak hours, the grid electricity in Ontario is supplemented with natural gas. Most of the heat is needed at night, which is off-peak hours and thus mostly clean. It is preferable to use grid electricity generated by non-emitting sources whenever possible rather than residential gas-driven appliances due to the reduced GHG emissions; however, this is not always possible.

Rooftop solar PV has become more affordable over the last decade and when coupled with heat pumps it is both practical and economic to heat a home using solar PV. Although PV is an economical solution, particularly in Ontario with highly subsidized nuclear power the electric rates are low enough that the ROI for PV+HP is low and relatively unappealing. Most residences have enough rooftop area for a total-offset solar PV system, meaning the home could be net-metered to zero annually. Most of the solar PV energy is generated during the day, but heating is mostly required at night and during low flux times of the year. On small and medium scales, in an urban environment, this can be alleviated with a net-metering-based rate structure, but recently, rate structures have changed so that solar homeowners are not given the full value of the electricity they generate unless they use it themselves in real time. This, along with policy issues, a mismatch in the sale value of electricity compared to the cost to buy (i.e., the value of solar), and the inability of the grid to support a net-metering scheme on a large scale, leaves room for improvement.

One solution to the mismatch between solar electricity generation and use would be to store the energy until it is needed. Space and water heating uses a large amount of electricity and would be expensive and impractical to store with chemical batteries. Another storage method is to store the energy directly as heat until it's needed, otherwise known as thermal energy storage. Particularly, using a "thermal battery" that has storage material that takes advantage of the large amount of energy involved with freezing and melting, called a phase change material (PCM), allows a lot of heat to be stored in a small volume. These PCM batteries have high cyclic efficiencies and lifetimes

as high as 50 years. The use of PCM thermal batteries is more common in Europe but has hardly been used in the Canadian climate.

The goal of this project was to develop and demonstrate an affordable, net-zero carbon, prototype residential heating system integrating rooftop solar PV, a heat pump, and a thermal battery. The solar PV generates enough electricity to offset 100% of the home's energy needs. The heat pump is a very efficient method of space heating, and the thermal battery helps alleviate the mismatch between the generation and use of solar energy.

Impact:

- In partnership with Magnus Homes and Eden Energy Equipment, a heating system of this kind was installed and is currently being monitored in a home in Kilworth, Ontario. The results from this testing will prove its efficacy and affordability in the Canadian climate.
- Generated two research proposals for continuing research OCI Collaborate to Commercialize with Magnus Homes, $50k awarded to field test a novel HVAC system incorporating Thermal Storage in a Magnus Home. OCI-NSERC Collaborate to Commercialize with Eden Energy Equipment (and Enbridge), to oversee field testing of a novel HVAC system incorporating Thermal Storage in a Magnus Home.
- Trained two research associates, two PhD students, two Master students and two undergraduates.

Dr. Yang Zhao

High-performance Na-S Batteries for Large-scale Grid Energy Storage and Electric Vehicles

External Partner(s): General Motors

Climate change has highlighted the urgent need to reduce greenhouse gas emissions and move toward sustainable energy solutions. Canada has pledged to cut carbon emissions by 2030 and reach net-zero by 2050. One of the biggest challenges is finding better ways to store clean energy so it can be used when needed. Batteries are the most practical technology for this purpose. Today's most common batteries are lithium-ion (Li-ion) batteries. They power everything from smartphones to electric vehicles (EVs), but lithium is expensive and in limited supply, making it less ideal for large-scale energy storage. Sodium (Na) batteries are a promising alternative because sodium is abundant and inexpensive. In particular, room-temperature sodium–sulphur (Na-S) batteries have two major advantages: i) High energy density – They can store more than twice the energy of Li-ion batteries. ii) Low cost – Sodium and sulfur are common materials, making these batteries much cheaper to produce. This project aims to develop high-performance, low-cost Na-S batteries for both EVs and large-scale grid energy storage. This project could lead to safer, cheaper, and more sustainable batteries for electric vehicles and renewable energy storage, helping reduce carbon emissions and support a cleaner future.

Impact:

- Trained four PhD students
- Publications
    - E. Jin, J. Su, H. Hou, P. Pirayesh, Y. Wang, Y. Yuan, H. Yan, G. Popov, L. Goncharova, S. Ketabi, F. Dai, C. Cao*, L. Chen*, Y. Zhao*, Electro-chemo-mechanically Stable and Sodiophilic Interface for Na Metal Anode in Liquid-based and Solid-State Batteries, Advanced Materials, 2024, 36, 2406837
    - E. Jin, H. Hou, Y. Zhao, Y. Wang, C. Zhang, P. Pirayesh, Y. Yuan, Y. Gan, G. Popov, L. Goncharova, S. Ketabi, F. Dai, J. Song, C. Cao, Y. Zhao, Dual-Metal-Site Hybrid Interfaces Coupling Ionic Transport and Mechanical Reinforcement for Stable Sodium Metal Batteries, submitted.

Dr. Ying Zheng

Plasma-assisted CO2 to methanol at ambient conditions

External Partner(s): CanmetMaterials, NRCan

This project has developed a groundbreaking technology to turn carbon dioxide (CO2) and methane—two major greenhouse gases—into valuable fuel and chemical feedstock, using a novel solar-powered plasma reactor. By operating at room temperature and atmospheric pressure, this system is energy-efficient, cost-effective, and avoids the high temperatures and pressures typically required for such processes. The team also designed a highly efficient catalyst to enhance the conversion process, which has been shared openly with the scientific community to accelerate further innovation. Through collaborations with leading institutions and industry partners, the project has advanced sustainable energy solutions, trained the next generation of scientists, and promoted equity and inclusion in research. This technology offers a practical way to reduce emissions, support clean energy transitions, and contribute to a greener future.

Impact:

- The following projects have been secured as PI due to the seed funding provided by the Carbon Solution program:
    - Developing CO2 hydrogenation catalysts for ethanol production and identifying the effect of plasma on CO2 activation (2024-2026, $75,000) awarded by the Natural Resources Canada (NRCan)
    - Catalytic CO2 hydrogenation to alcohols via non-thermal plasma, awarded by NSERC Alliance Advantage (2024-2026, $120,000).
    - CO2 Electrochemical Conversion (2025-2026, $70,000) awarded by Natural Resources Canada (NRCan)
    - NET- PBH2: Negative emissions technology for Pale Blue Hydrogen, (2024, $996,000) awarded by Hydrogen Innovation Fund.
- Trained two postdoctoral associates, two PhD students and a research assistant.
- Publications
    - Rasoul Salami, Yimin Zeng, Xue Han, Sohrab Rohani, Ying Zheng, Exploring catalyst developments in heterogeneous CO2 hydrogenation to methanol and ethanol: A journey through reaction pathways, Journal of Energy Chemistry, 101, 2025, 345-384.
    - Vahid Shahed Gharahshiran, Ying Zheng, Synergistic plasma and platinum catalysts interactions in CO2 reforming of propane at room temperature: The role of supports. Chemical Engineering Journal. 499 (2024) 156492.
    - Chun Li, Qiuji Zhu, Chaojie Song, Yimin Zeng, Ying Zheng, Electrocatalysts for Urea Synthesis from CO_2 and Nitrogenous Species: From CO_2 and N_2/NOx Reduction to urea synthesis, ChemSusChem 2024, e202401333.
    - Joshua O. Olowoyo, Vahid Shahed Gharahshiran, Yimin Zeng, Yang Zhao and Ying Zheng, Atomic/molecular layer deposition strategies for enhanced CO_2 capture, utilisation and storage materials. Chem. Soc. Rev. 53, 2024, 5428-5488.

- Ying Zheng, “Plasma-Induced Catalyst Modification for CO2 hydrogenation”, 27th Canadian Symposium on Catalysis, Sherbrooke, May 12-15, 2024 (Invited).
- Chun Li and Ying Zheng, Copper Single-Atom Catalysts generated from Atomic Layer Deposition for Electrosynthesis of Urea from CO2 and Nitrate, Canadian Chemical Engineering Conference, Toronto, Ontario, October 6-9, 2024
- Vahid Shahed Gharahshiran and Ying Zheng, “Non-thermal plasma-assisted CO_2 reforming of propane over Pt catalysts” 27th Canadian Symposium on Catalysis, Sherbrooke, Quebec, May 15- 18, 2024.