
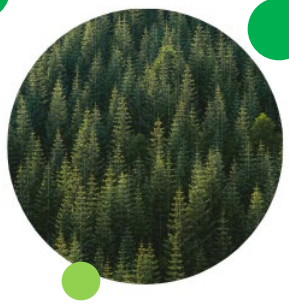
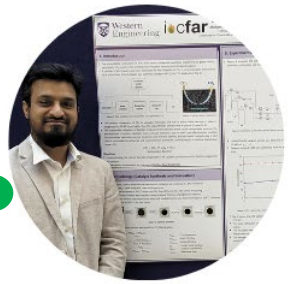


Nature-inspired solutions for carbon transformation

September 2023—August 2024

Theme-end outcomes report for the *Nature-inspired solutions for carbon transformation* research theme capturing the period of September 2023—August 2024

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Western Academy for Advanced Research

Contents

Transforming Waste into Climate Solutions:
Nature-inspired Solutions for Carbon Transformation (September 2023—August 2024)

Key Highlights:

- New breakthroughs in renewable energy & biochar
- An international research community
- Carbon Solutions Consortium
- Emerging connections with industry, academic, and government partners

Climate change poses a threat to all living systems on Earth. Despite this reality, human-driven greenhouse gas emissions continue to rise at a staggering scale. How can climate technologies help us address this daunting challenge?

The Nature-inspired solutions for carbon transformation research theme aims to address this problem by finding answers in nature. Carbon capture occurs naturally through processes like photosynthesis (in plants) and mineralization (in geological systems). The theme seeks to harness this knowledge to promote a circular model of resource production and consumption in which waste is transformed into valuable products. Their goals are two-fold: to develop breakthrough solutions that mimic processes that already exist in nature, *and* to build connections with industry and government leaders who can transform their research into real-world applications.

The Western Academy for Advanced Research (WAFAR) provided the theme with dedicated time, space, and administrative support to produce original research with real-world impacts. Under the leadership of wastewater expert and lead investigator for Ontario's SARS-CoV-2 Wastewater Surveillance Initiative, Chris DeGroot (Western Engineering), and Western Fellows Naomi Klinghoffer (Western Engineering)

and Elizabeth Webb (Earth Science), the theme built a diverse interdisciplinary community comprised of WAFAR-funded Visiting Fellows Paola Giudicianni (Consiglio Nazionale delle Richerche; Naples, Italy) and Mojtaba Jarrahi (Universite Paris-Saclay; Gif-sur-Yvette, France), WAFAR postdoctoral associates Muhammad Waqas Iqbal and Seyed "Zia" Miry, and contributing researchers Mahsa Asgari (Western University), Seong-heon Cho (Pusan University), and Alexandra Frainetti (Western University).

In addition to their core team, the group drew upon knowledge and resources from their campus partners, the Institute for Chemicals and Fuels from Alternative Resources (ICFAR), Carbon Solutions @ Western, and Western Engineering. WAFAR provided the venue for these partnerships to converge into a dynamic research community. Theme Leader Chris DeGroot recognizes WAFAR's role in making this community possible:

Theme Leader Chris DeGroot

"I have found that multidisciplinary collaborations are some of the most rewarding experiences that can be had in a research environment, but [are] also the most difficult to get off the ground. A lot of time is required to have discussions, understand each other's perspectives, and plan for new projects. It was a unique and rewarding experience to be given such an opportunity through WAFAR."

During their year-long tenure with WAFAR (September 2023—August 2024) the Nature-inspired solutions theme produced

- New breakthroughs in renewable energy and *biochar*, an emerging carbon-sequestration technology that could also pave the way for sustainable fuel production, among many other applications.
- An international team with vital contributions from Visiting Fellows Paola Giudicianni (Consiglio Nazionale delle Richerche) and Mojtaba Jarrahi (Université Paris-Saclay)
- A key partnership with Carbon Solutions @ Western, with plans for a consortium that will lay the foundation for further industry and academic connections
- Emerging connections with stakeholders in government (e.g. City of London) and industry that could create new pathways for commercialization

With these successes in place, the Nature-inspired solutions team is well-positioned to advance sustainable solutions that could lead to a cleaner atmosphere.

New discoveries in renewable energy and sustainable technologies

Biofuels are a renewable alternative to fossil fuels. If manufactured in a sustainable way, biofuels can promote a circular economy, however renewable fuel production is not yet at the point where it can meet global demand. The Nature-inspired solutions theme discovered a new technique that could improve how biofuels are manufactured (Frainetti & Klinghoffer, 2024). This discovery harnesses the potential of ***biochar*,** a carbon-rich material made from plant and animal matter that is often derived from agricultural or forestry waste. This is one example of a promising breakthrough that could have lasting benefits to society.

Biochar is a key area of focus for the Nature-inspired solutions theme. An emerging climate solution, biochar is produced when organic waste products are treated using a thermochemical process (pyrolysis). During pyrolysis, carbon that would otherwise be released into the atmosphere is captured and stored in the resulting product, making biochar a viable tool for carbon capture and sequestration. With contributions from renewable energy expert, and WAFAR Visiting Fellow, Paola Giudicianni (Consiglio Nazionale delle Richerche), the team has advanced better, more sustainable ways of producing biochar[1]. A highly versatile product, the theme has uncovered new insights into the following biochar applications:

Biochar
Image source:
Wikimedia Commons

- carbon capture and sequestration
- catalysts for biofuel production[2]
- soil remediation and enhancement
- carbon reduction in wastewater treatment

Wastewater treatment technologies are another important area of development. Under the direction of Theme Leader Chris DeGroot, the theme is investigating methods for transforming sewage sludge and

[1] Also see postdoctoral associate Zia Miry's investigation into smouldering systems, published (Miry, Zazoni, Rashwan, Kinsman, Torero, & Gerhard, 2024) and in-progress (Miry, Klinghoffer, & DeGroot, n.d.).
[2] See Frainetti and Klinghoffer (2024) and research led by postdoctoral associate Muhammad Waqas Iqbal, still in progress (Iqbal, Giudicianni, Webb, DeGroot, Klinghoffer, n.d.).

biosolids into useful products, like biochar and biogas. "Sludge biochar," as it is known, has gained attention as a promising tool for removing contaminants from wastewater. Additionally, the theme has worked closely with Visiting Fellow Mojtaba Jarrahi (Université Paris-Saclay) to better understand the role of microalgae in supporting these applications. Continued research in this area will be funded by an NSERC Discovery grant (CAD $160,000), which will be dispersed over the course of five years.

The concept of a circular economy is a key guiding principle for the Nature-inspired solutions theme. By developing applications that could eliminate all or most waste products, the theme is well on its way to advancing a truly sustainable approach that could lead to long-lasting change. *For a current list of research developments, please refer to "New Advances," pg. 11.*

An international research community

The climate crisis demands close examination from multiple angles. The Nature-inspired solutions theme brought together a diverse, international community that represents many varied perspectives. It is through this spectrum of disciplines, backgrounds, and experiences that the theme can approach this most urgent challenge from different points of view. Western Fellow Naomi Klinghoffer describes a moment when Western Fellow Elizabeth Webb helped her to see her research in a new light:

Western Fellow
Naomi Klinghoffer

Western Fellow
Elizabeth Webb

"[Liz] showed me that you can use isotopes to understand the history of forest fires. Forest fires produce biochar, and its properties can give you information about the fire such as its temperature. We're using that concept in our reactor work, in a process where we use biochar catalysts to make sustainable fuels out of carbon dioxide. Isotope tracing helps us measure the stability of the biochar […]

I think this discovery is starting to open a door for me in terms of how we can use these tools to better understand what's happening in our systems. It's exciting to work with collaborators with different expertise and learn about new

ways to better understand and improve the systems that I am working with."

International visiting scholars continue to play a crucial part in the success of WAFAR's research themes. Visiting Fellow Paola Giudicianni (Consiglio Nazionale delle Richerche) was in residence at Western University for a combined total of six months.[3] A fully integrated member of the Nature-inspired solutions theme, Giudicianni enriched the team's understanding of sustainable technologies by sharing knowledge and resources from her home institution; for example, the theme has benefited from the use of biochar samples produced at Consiglio Nazionale delle Richerche, and, in turn, Giudicianni has used techniques developed by the research theme in her work with biochar samples from the archeological site at Pompeii. Through Giudicianni, the theme has established a connection with Hamed Sanei (Aarhus University), a globally recognized biochar researcher. Visiting Fellow Mojtaba Jarrahi (Université Paris-Saclay) has served as another important contributor. A positive and supportive team member, Jarrahi—who was in residence at Western University for a combined total of five weeks[4]—elevated the theme's knowledge about microalgae and wastewater technologies. The theme's association with Jarrahi could open doors for further connections with sustainability researchers in France and beyond.

WAFAR made these visits possible through funding, in the form of a living allowance, access to dedicated office space, housing (Malhotra House), and administrative support. This key aspect of WAFAR's programming fulfills the goals expressed in Western's *Global Engagement Plan* not only by attracting global contributors to Western's campus, but by fully integrating them into the university's research community. Furthermore, Western's international profile is bolstered by the theme's connection to the Italian National Research Council (Consiglio Nazionale delle Richerche), which shows promise of opening new doors to further international connections.

[3] Giudicianni was on-site for three separate visits (September—November 2023, April—May 2024, July—August 2024). She was housed at Malhotra House.
[4] Jarrahi was on site in May 2024 and August 2024. He resided at Malhotra House.

“The [“Nature-inspired solutions”] team brought an interdisciplinary approach to carbon sequestration, which led to innovative solutions that address all aspects of the topic. My experience at the Western Academy for Advanced Research was very productive for my research work, and it has paved the way for a strong collaboration between Western University and Consiglio Nazionale delle Richerche.”

Paola Giudicianni, Visiting Fellow
Consiglio Nazionale delle Ricerche; Naples, Italy

“Joining the dynamic team has opened up a new international collaboration that will certainly endure over time. I brought my expertise in the hydrodynamics of phototactic microalgae to the Western University, and thanks to the team's dynamism, we were able to conduct interesting experiments that are still ongoing even after my departure. We plan to strengthen this collaboration by responding to calls for projects that will maintain this momentum in 2025 and beyond.”

Mojtaba Jarrahi, Visiting Fellow
Université Paris-Saclay; Gif-sur-Yvette, France

Carbon Solutions Consortium

Real world solutions are not possible without buy-in from stakeholders in industry and government. The Nature-inspired solutions theme is pursuing opportunities with stakeholders in industry and local government (City of London), who could help translate breakthroughs into tangible results (*see Emerging connections, pg. 9*). Additionally, the theme has also worked with collaborators throughout Western, most notably Carbon Solutions @ Western. In spring and summer 2024, the teams collaborated on two events that increased their visibility to the local research community and to potential industry partners:

- **Exploring Solutions for Carbon Transformation, Western University, May 23, 2024**: A conference and workshop with participant-driven round table discussions. ~65 attendees, including representatives from academia, local government (City of London), and industry (Mitacs, Ontario Greenhouse Vegetable Growers, Ontario Forest Research Institute). Jointly organized by Carbon Solutions @ Western and the Nature-inspired solutions theme.
- **Nature-inspired Solutions for Carbon Transformation, Western University, July 29, 2024**: A highly interactive, "design-thinking" based workshop with ~40 attendees. Attendance included interdisciplinary academic partners from across campus (Earth Sciences, Geography, Engineering). Featured keynote speeches by Visiting Fellows Giudicianni and Jarrahi. Organized by Nature-inspired solutions with strong involvement from Carbon Solutions @ Western.

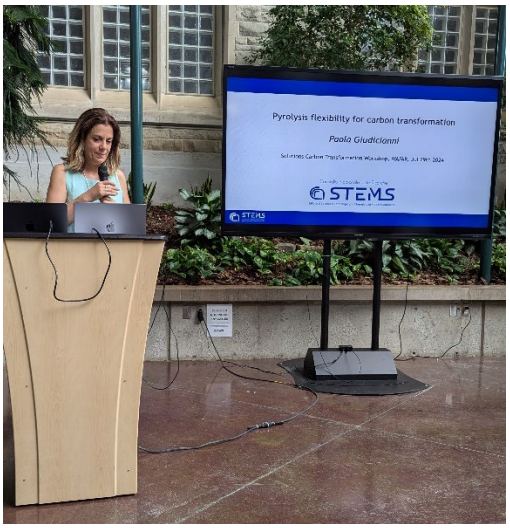
The theme aims to join Carbon Solutions @ Western in a consortium that will grow their relationships with academic and industry stakeholders even further. The Carbon Solutions Consortium aspires to establish Western as a leader in carbon reduction strategies by

- leveraging existing relations and funding from the Strategic Priorities Fund[5]
- bringing together sustainability experts from within the Western community and beyond it
- responding to calls for larger funding opportunities (e.g., New Frontiers in Research)

[5] The Strategic Priorities Fund supports the goals set out by *Towards Western at 150: Western University Strategic Plan*.

- identifying new opportunities for collaboration (e.g., Mitacs) and seed funding for carbon reduction technologies

The proposed consortium will be led by Andy Hrymak, Director of Carbon Solutions @ Western, and Chris DeGroot, with scientific leads Naomi Klinghoffer and Elizabeth Webb. The Carbon Solutions Consortium will seek seed funding for projects that will advance new developments in areas that overlap with the goals of the theme, including nature-inspired solutions, carbon sequestration, and carbon reduction. Currently, members are seeking support from internal and external stakeholders so that their proposed model can become a reality.



Top-left: Naomi Klinghoffer and Chris DeGroot present at Exploring solutions for carbon transformation (May 2024); Top-right: Workshop participants brainstorm sustainable technologies at the Nature-inspired solutions workshop (July 2024); Bottom-centre: Paola Giudicianni delivers a keynote address at the July 2024 workshop

Emerging connections

The Nature-inspired solutions theme has engaged with prospective partners at the City of London and with industry partners specializing in sustainable technologies. Key areas of engagement include:

- **Greenhouse gas monitoring project, Greenway Wastewater Treatment plant** *(Confirmed partner: City of London; Potential partners GHD Group, Aquafy Water Technologies)*: This project will involve collaboration with the City of London and potential industry partners Australian Engineering firm, GHD Group, and environmental equipment distributor, Aquafy Water Technologies. This initiative will be supported using funding from an NSERC Discovery grant (CAD $160,000).

- **Caldwell First Nation soil carbon inventory initiative** *(Confirmed partner: Caldwell First Nation):* The Caldwell First Nation is working in collaboration with Western Fellow Elizabeth Webb to measure levels of carbon stored in agricultural soils on reclaimed lands. This initiative, which begins in Fall 2024, draws upon Indigenous practices as well as knowledge gained from the Nature-inspired solutions theme.

- **Biochar applications in parks and urban agriculture** *(Potential partners: City of London, Terra Optima Labs)*: Biochar can improve the health of soil. Theme members are seeking opportunities to incorporate biochar into parks and urban agricultural sites. The theme has discussed this possibility with contacts at the City of London and Terra Optima Labs, a London-based company that produces compost for soil enhancement and other agricultural products.

- **Sustainable solutions for biochar production** *(Potential partner: Ferme Agricola of Opasatika Farm, Inc.)*: Western Fellow Naomi Klinghoffer has connected with a potential supplier of feedstock for biochar production. The supplier is seeking sustainable solutions for processing waste products from the forestry industry.

Future directions

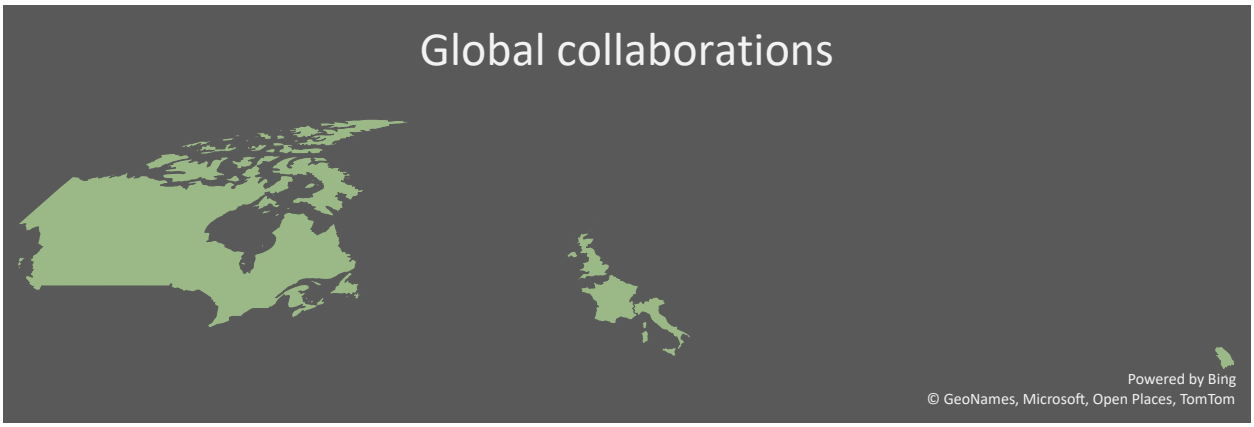
In the next year (September 2024 to August 2025), the Nature-inspired solutions theme aims to grow their existing connections, while also forming new ones. In the words of Theme Leader Chris DeGroot, “starting new collaborations is not a single event but a process that occurs over an extended period of time.” As the theme deepens its engagement with partners in research, industry, and research, over the course of the next year, it will be well positioned to create sustainable strategies with direct benefits to the local community and beyond.

"It feels like we have so many ways of developing new solutions, and now is the time to do it."

Dr. Naomi Klinghoffer
Western Fellow

Western Academy for Advanced Research

Appendix One: New Advances



The Nature-inspired solutions theme brings together researchers from Canada, France, Italy, South Korea, & the United Kingdom

Publications

Chen, L., DeGroot, C.T., & Bassi, A. (2024). Biofilm growth enhancement in microalgae biofilm reactors: Parameters, configurations, and modeling. *Journal of Water Process Engineering, 65,* 105780. https://doi.org/10.1016/J.JWPE.2024.105780

Frainetti, A. J., & Klinghoffer, N. B. (2024). Engineering biochar-supported nickel catalysts for efficient CO2 methanation. *Biomass and Bioenergy, 184,* 107179. https://doi.org/10.1016/J.BIOMBIOE.2024.107179

Miry, S. Z., Zanoni, M. A., Rashwan, T. L., Kinsman, L., Torero, J. L., & Gerhard, J. I. (2024.) Fuel mobility dynamics and their influence on applied smouldering systems. *Combustion and Flame, 270,* 113789. https://doi.org/10.1016/j.combustflame.2024.113789

Works in progress, as of November 2024

Cho, S., & Klinghoffer, N. Production and characterization of graphitic biochar from agricultural wastes via high temperature catalytic pyrolysis.

Hadizade, A., Jarrahi, M., Peerhossaini, H, & DeGroot, C. Investigating chlamydomonas reinhardtii behaviour in structurally confined environments.

Iqbal, M.W., Giudicianni, P., Webb, E., DeGroot, C., & Klinghoffer, N. Biochar supported catalysts from biochar produced from biomass containing immobilized heavy metals.

Frainetti, A., Webb, E., Giudicianni, P., & Klinghoffer, N. Understanding stability of biochar-supported catalysts using stable carbon isotope tracing.

Miry, S. Z., Klinghoffer, N., & DeGroot, C. Continuous smouldering-driven pyrolysis reactors for thermo-chemical conversion of waste to active bio-char.

Appendix Two: Funding Applications[6]

Lead PI	Co-PIs	Collaborators	Proposal Title	Funding Body	Value (CAD)	Status	Comments
Chris DeGroot			The role of wastewater in community health and climate change mitigation	NSERC (Discovery)	$160,000	Successful	Program of research includes study of greenhouse gas emissions in wastewater treatment.
Chris DeGroot	Joshua Pearce		Low-Carbon Grain Drying Using Modular Heat Pump System with Energy Storage	Ontario Grain Farmers	$175,000	LOI approved for full application	Proposal responds to urgent need for innovative, energy-efficient grain drying solutions.

[6] Additional funding opportunities pursued by this theme included proposals submitted to the Ontario Agri-food Research Initiative, Ontario Grain Farmers, and the Western Interdisciplinary Development Initiatives. While applications submitted in 2024 were not successful, the theme might apply for future competitions.