Carbon Management Canada

New pathways to reduce greenhouse gas emissions.

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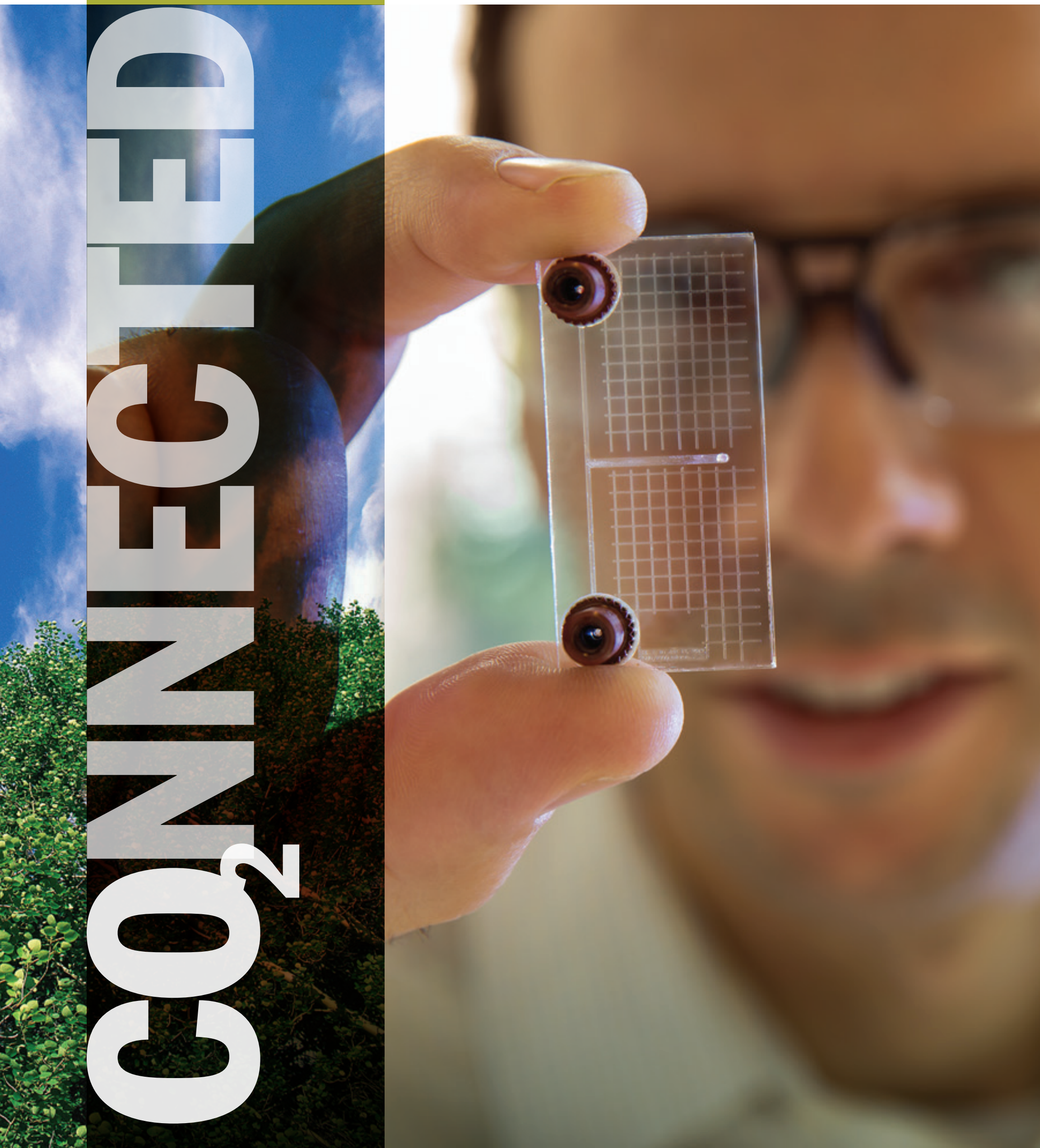
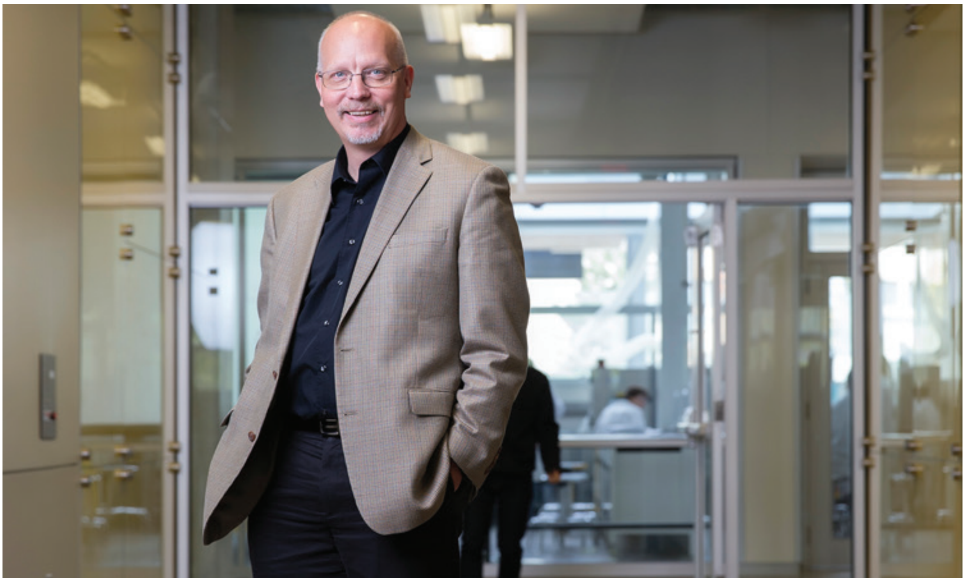


Greg Dipple
University of British Columbia

"Nature holds fascinating and different ways of doing things.
This year we are studying weathering processes in landslides for insights into our carbon mineralization work."



Innovation occurs when people with deep knowledge of current practice *have an eye* for what is possible.

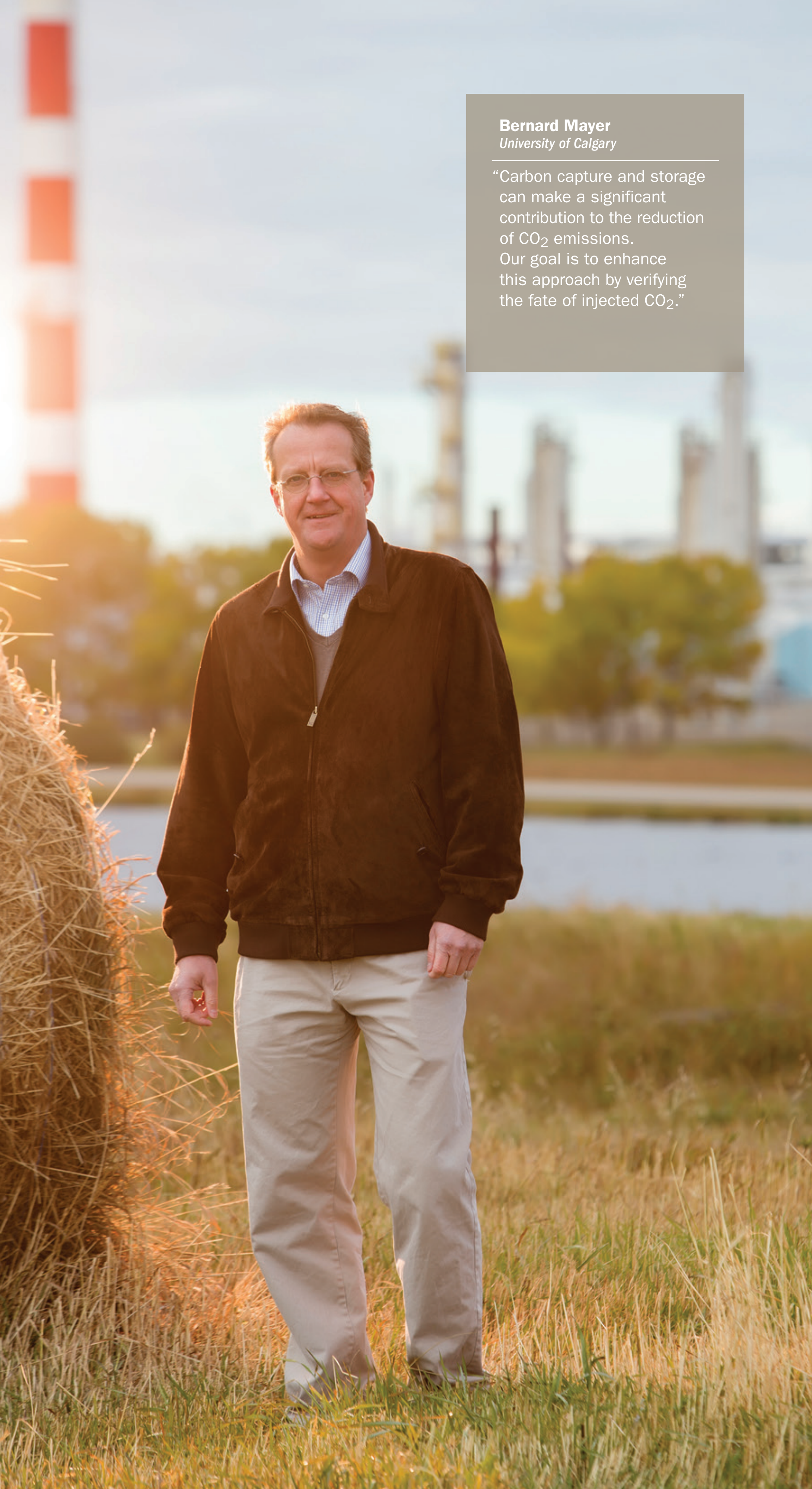
Carbon Management Canada has built an impressive network of 155 researchers focused on finding new pathways to reduce greenhouse gas emissions.

We are now developing research institutes across Canada staffed with experts who will work with industry to find commercially feasible ways to address carbon management challenges in the fossil and renewable fuels, chemical, cement, mining and metallurgical processing industries. Through these institutes, CMC will provide a wide range of services including technology identification, translation, integration, performance validation, scale-up, application development, and project management. The first of these, the Containment and Monitoring Institute (CaMI), will be focused on detecting and remediating containment issues for fluids in the sub-surface.

This booklet outlines the services that will be offered through CaMI as well as some of the 44 innovative projects currently funded by CMC. The technologies and protocols being developed by our researchers are diverse and range from carbon capture to instrument development, lab methods, carbon conversion, and risk and technology assessment.

In a growing global economy, the demand for energy from fossil fuels will continue to increase. At the same time, the transition to a low carbon future is inevitable. At CMC, we are working to find commercially viable ways to reduce greenhouse gas emissions that will be critical to the ongoing operations of many industries.

Richard Adamson
Managing Director,
Carbon Management Canada



Bernard Mayer
University of Calgary

"Carbon capture and storage can make a significant contribution to the reduction of CO_2 emissions. Our goal is to enhance this approach by verifying the fate of injected CO_2."

Containment and early identification of fluid and gas migration out of zone is critical to exploration, production and storage projects.

CMC's Containment and Monitoring Institute (CaMI) will offer research, development and demonstration capabilities to monitor the safe, reliable and efficient storage of fluids underground, and to determine fluid detection threshold capabilities for various monitoring technologies.

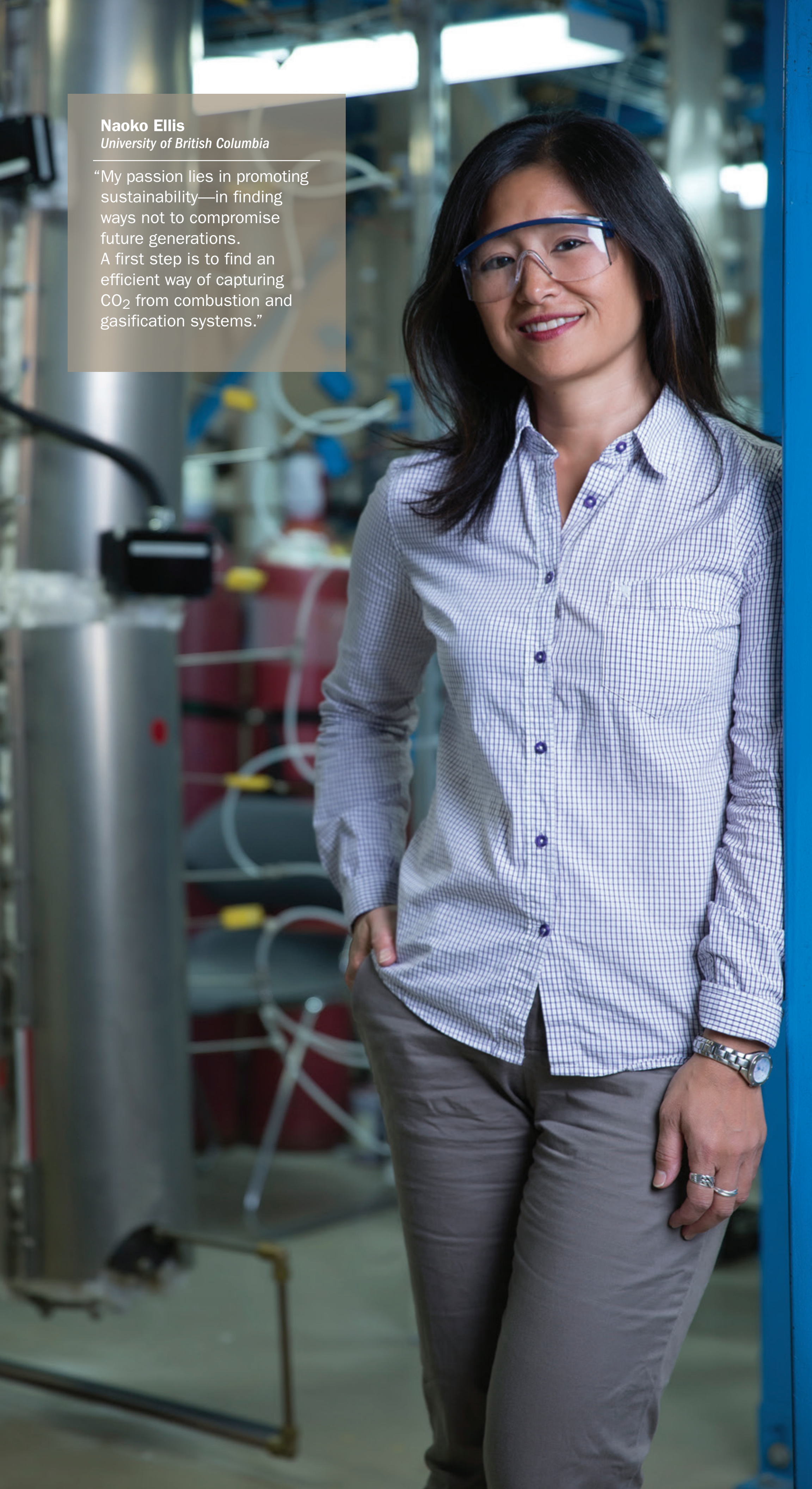
CaMI will focus on performance validation and field-testing of sensors, instruments and technologies associated with the detection of loss of containment or conformance. Key to CaMI will be its field research stations where customers from industry and academia can work to improve product performance, and also research and develop new technologies needed for monitoring conventional and unconventional hydrocarbon production, including acid gas disposal, fracking, and steam chamber growth, as well as containment of CO_2 and methane.

The first of these stations is under development and will focus on technologies including innovative, data-linked geophysical and geochemical surface and subsurface surveillance systems and novel cap rock assessment procedures. Some of the methods which will be available at this site include seismic, geochemical tracer tools, geoelectric and electromagnetic tools and novel sensors.

With completion scheduled for summer 2014, the field research station will initially comprise the following infrastructure:

- *two shallow injections wells (300 and 700 meters depth);*
- *two observation wells;*
- *four fresh water aquifer monitoring wells;*
- *3D seismic array;*
- *broadband seismometers;*
- *down-hole electrical resistivity tomography systems;*
- *permanent GPS monuments and a near-surface tiltmeter array;*
- *interferometric synthetic aperture radar (InSAR) reflectors; and*
- *monuments for time-lapse microgravity surveys.*

For more information contact CaMI Director Dr. Don Lawton at 403-210-9784 or Don.Lawton@cmcghg.com.



Naoko Ellis
University of British Columbia

"My passion lies in promoting sustainability—in finding ways not to compromise future generations.
A first step is to find an efficient way of capturing CO_2 from combustion and gasification systems."

A critical need in carbon management is to find better, cheaper ways to capture CO_2.

The most costly part of most carbon mitigation projects is capturing CO_2 from dilute streams.

CMC's researchers are working on next-generation capture methods for use in pre- and post-combustion approaches that will cut costs and lower energy requirements in a wide variety of industrial processes.

Traditional CO_2 capture technology is energy-intensive because liquid amine capture solutions need to be cooled and then heated to release trapped CO_2. Solid sorbent materials can be used for the pre-combustion capture of CO_2, operating at more suitable temperatures. CMC-funded researchers are currently testing different solid sorbent compounds to find forms that are: 1) stable in thermochemical processes like combustion and gasification, and 2) capable of being reused hundreds or even thousands of times in chemical looping processes without loss of activity or physical degradation.

We also have researchers working to more efficiently capture CO_2 at the post-combustion stage.

For example, George Shimizu of the University of Calgary is developing a class of porous solids, Metal Organic Frameworks (MOFs), that work like sponges with pores engineered to hold CO_2 molecules. A huge benefit of the process is that the gas can be easily released from the MOF without huge inputs of energy—saving up to 50% in capture expense. Another team is using pelletization and coating to improve calcium-based solid sorbents for integrating CO_2 capture with gasification.

Investigators on another of our projects are integrating proprietary nanoporous sorbents into an electricity generation system based on solid oxide fuel cells (SOFCs). Nanoporous sorbents are being developed for the removal of both CO_2 and SO_2 in the SOFC process, but would be equally useful in any low-temperature (70°C) CO_2 or SO_2 removal process including flue gas, natural gas, biogas and air.

David Sinton
University of Toronto

"I'm excited to leverage small-scale tools to impact large-scale challenges. The pore-scale transport and reactions at the heart of massive sub-surface operations present a tremendous opportunity."

We're developing measurement and monitoring solutions that will revolutionize testing and analysis in the lab and field.

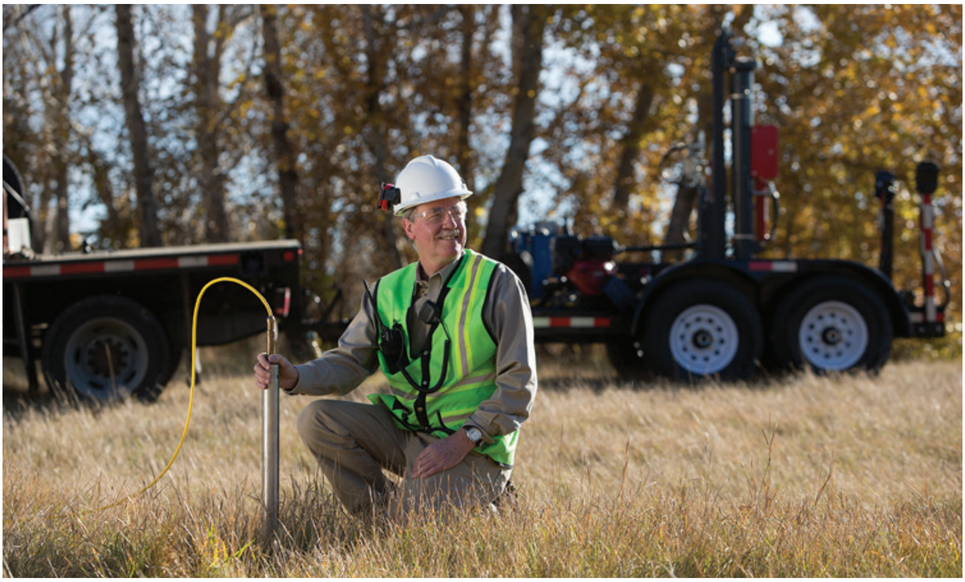
From the development of small-scale testing systems using microfluidic chips to improvements in 3-D geophysical monitoring, our work is pushing beyond the boundaries of current technical capabilities.

Microchip techniques to analyze bitumen-gas interactions at the pore scale in seconds instead of days using a tiny sample have been developed by a research team at the University of Toronto. These revolutionary devices model the behavior of gas and fluids in pores in oil and gas reservoirs and in saline formations under different pressures and in different rock formations. The same technology has been adapted to assess dew point effects on transport of CO_2. The streamlined process, which saves time and money, is more relevant to actual operating conditions than other technologies currently available.

Another novel monitoring system under development is a fibre-optic sensor system that will make distributed measurements of CO_2 concentrations at deep, large storage sites and over long time periods. This unique technology can be used for carbon capture and storage, enhanced oil recovery and also for monitoring in natural and marine environments.

A technology with applications wider than carbon storage is the development of a comprehensive monitoring protocol that combines next generation semiconducting gravity meters with advanced satellite radar remote sensing and geodetic technologies. The result is an ultra-sensitive system capable of detecting extremely small changes in the Earth's gravity field and millimeter scale surface deformation as the result of fluid injection.

Understanding the seismic response of rock during methane exploration, in geothermal recovery and at carbon sequestration sites is critical to safe development and operations. At a laboratory in Edmonton, investigators are studying the impact CO_2 in its various phases has on the seismic characteristics of porous sandstone and caprock. This work will provide fundamental measurements of the effects of CO_2 phase changes on seismic properties and the results will improve the interpretation of time-lapse seismic surveys.



Improved data interpretation can help solve the challenges associated with fluid injection and storage.

We're working to refine monitoring techniques to detect very small changes in rock as a result of CO_2 sequestration.

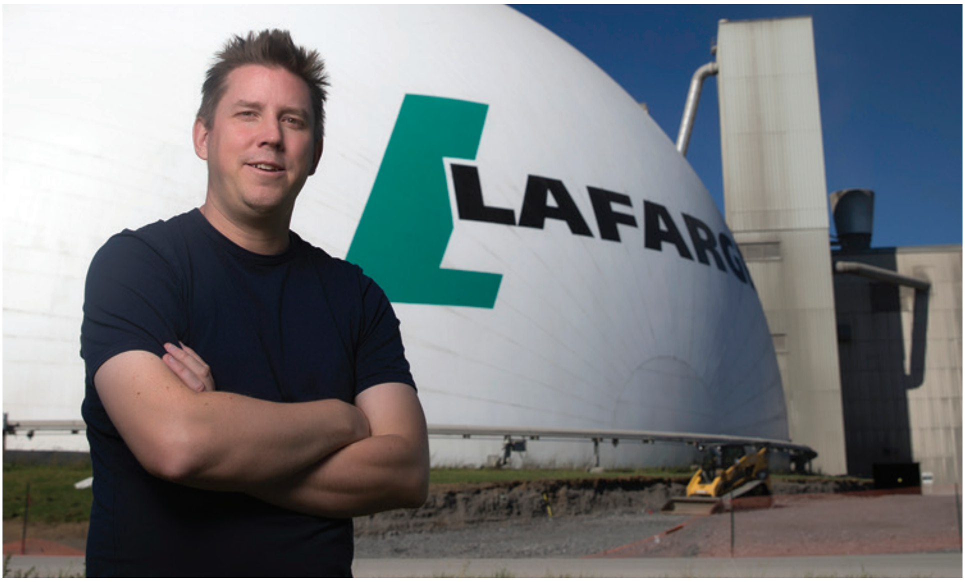
Don Lawton, Director of CMC's Containment and Monitoring Institute (CaMI), is undertaking research to refine seismic methods to map CO_2 plume growth and to identify natural potential leakage pathways. At other labs, researchers are studying the interaction of CO_2 with the rock matrix and native pore fluids to better predict the geochemical changes due to CO_2 storage over long periods of time.

> **Don Lawton**
> *Director, Containment and Monitoring Institute*
>
> "I've been working on plans for a field research station for years. It's exciting to watch that dream become a reality."

Hydrogeological and geochemical techniques are being used to trace the movement of CO_2 in storage reservoirs to identify and quantify transport and trapping mechanisms. The novel monitoring approaches will enable a more accurate and precise tracing of injected CO_2 at carbon capture and storage (CCS) and enhanced oil recovery sites.

It's critical to know what impact an earthquake will have on geologic storage formations. Probabilistic Seismic Hazard Assessment (PSHA) is a well-known method for determining earthquake hazards and ground motion on the surface. David Eaton, at the University of Calgary, is customizing PSHA methodology for use deep underground to better understand the long-term risks for geological storage of CCS from earthquakes.

Very small microseismic events can't be felt by humans but they may have a negative impact on containment sites. Microseismic events can be caused by the injection of fluids, such as CO_2, into the rock mass and researchers are developing ways to monitor the rock deformation that may begin to occur before the microseismic release.



Reducing emissions by converting CO_2 into carbonate rock could create a valuable commodity and new markets for carbon.

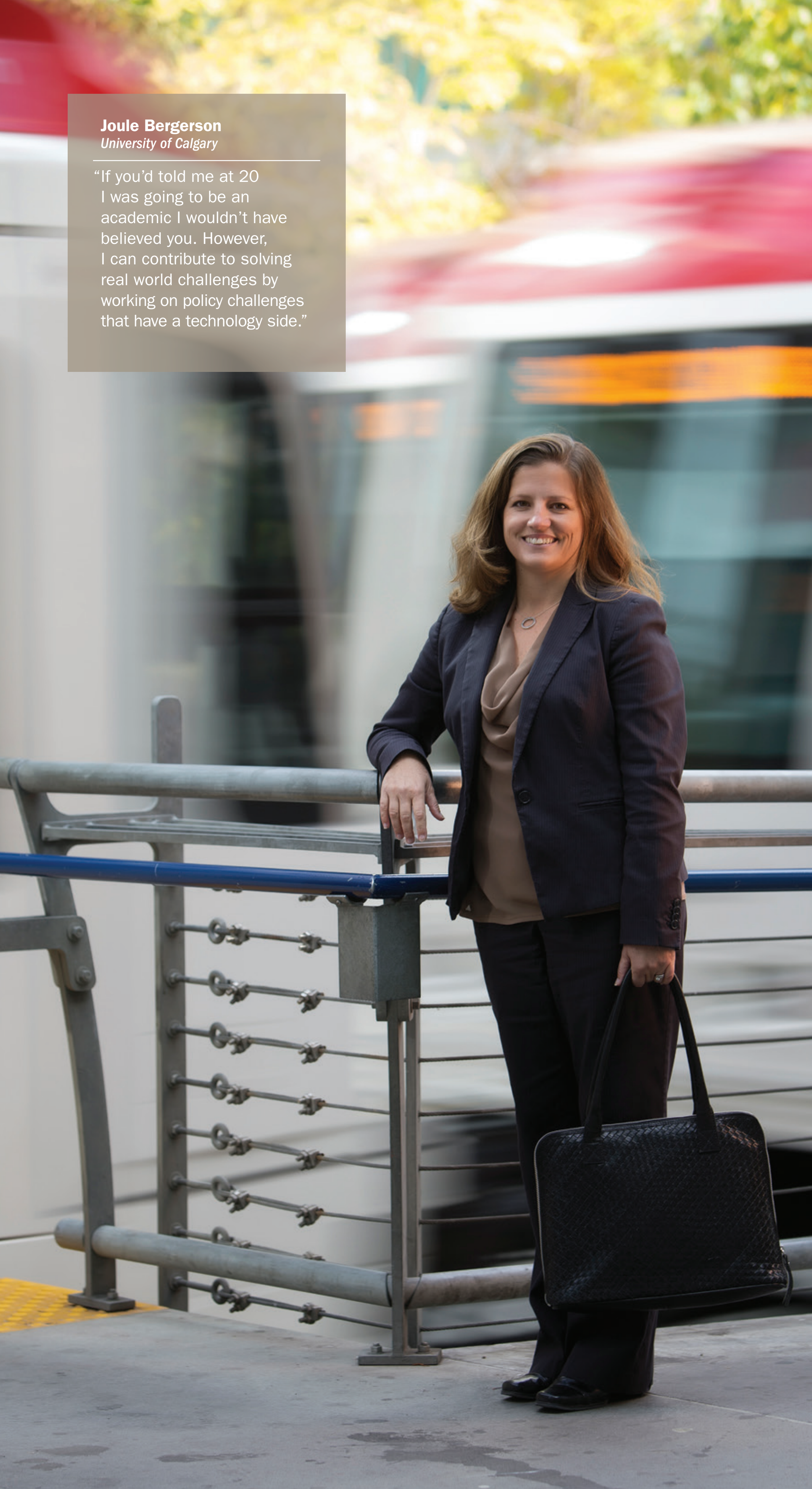
Carbon mineralization can trap CO_2 in rock for thousands of years. CMC researchers are working to harness and enhance that process.

In Quebec, a team of researchers is developing an economically attractive process that would allow steel, coal, cement, and oil and gas facilities to directly react CO_2 present in flue gas streams with crushed rock. The process is being designed so that it can be easily integrated into existing plant facilities using simple and readily available materials such as waste concrete. The chemical reaction will remove 80% of the CO_2 from flue gas, leaving behind carbonate rock which can be sold for use as a refractory material or as an alkaline agent in waste water treatment.

Across the country at the University of British Columbia, another researcher is making use of the mineralization process, albeit in slightly different fashion. Greg Dipple's research group is accelerating the mineralization process in mine tailings by bubbling a CO_2 solution through a slurry rich in magnesium silicate materials.

> **Warren Mabee**
> *Queen's University*
>
> "The cement industry is a great example of a sector where we can do a lot to reduce carbon emissions through the application of renewable energy sources."

This process will be combined with a second approach in which an enzyme, carbonic anhydrase, is used to catalyze the hydration of aqueous CO_2 to a form which can be more easily mineralized, leading to even better results. The project team is evaluating how large-scale sequestration activities can be optimally developed within mine operations, so mines could reduce their carbon emissions and even process CO_2 streams from other sources, turning their operations into net carbon sinks.



Joule Bergerson
University of Calgary

"If you'd told me at 20 I was going to be an academic I wouldn't have believed you. However, I can contribute to solving real world challenges by working on policy challenges that have a technology side."

Technology evaluation can help decision-makers evaluate and invest in strategies that will improve environmental performance in ways that make economic sense.

One reason for not implementing carbon management procedures or technologies is a lack of information about the impacts of adoption.

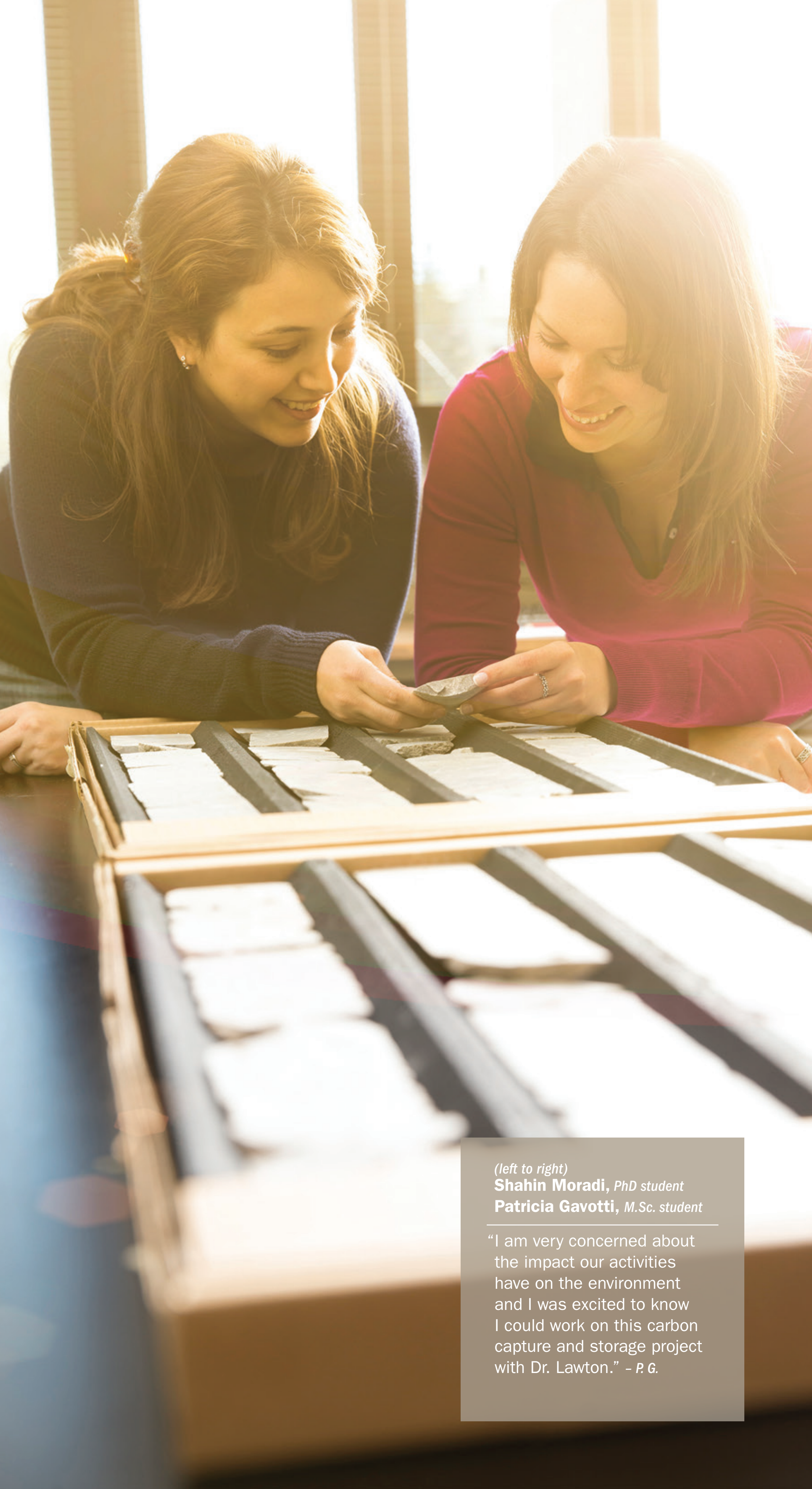
Combining life cycle assessment (LCA) and life cycle costing (LCC) of a resource or product can help determine trade offs and provide a more complete picture of the technical feasibility of carbon management scenarios from cost and environmental standpoints.

Carbon Management Canada researchers are working on projects in the energy and cement industries that will inform research and development decisions, operating strategies and policy making.

Joule Bergerson, at the University of Calgary, and Heather MacLean, at the University of Toronto, are working to assess existing and emerging innovative energy technologies in the oil sands. The investigators are looking at the techno-economic and environmental implications of mitigating greenhouse gas emissions in the oil sands using a broad range of strategies. The goal is to develop the tools and methods to assess energy innovations to ensure goals are achieved and unintended consequences are minimized.

The cement industry in Canada is responsible for up to 2% of the country's CO_2 emissions, much of it due to burning coal. While carbon emissions could be reduced by introducing biomass and other low carbon fuels into the system, there is limited science to demonstrate its effectiveness.

Queen's University Professor Warren Mabee and his team are working with Lafarge and Natural Resources Canada to test six different bio and waste fuels at pilot plant facilities. This is the first science to include comparative life cycle assessments, full emissions comparisons, evaluation of water use and burner optimization. The goal is to show that alternative fuels can safely and effectively displace coal in existing industrial processes.



(left to right)
Shahin Moradi, *PhD student*
Patricia Gavotti, *M.Sc. student*

"I am very concerned about the impact our activities have on the environment and I was excited to know I could work on this carbon capture and storage project with Dr. Lawton." – *P. G.*

Investing in the talent that will deliver industry success is just one of the ways we're keeping our eye on the future.

As the global economy moves into a carbon constrained era, we are going to require a skilled pool of people capable of working in the carbon management and clean energy fields.

In fact, a recent study commissioned by CMC shows just how many more positions Canadian industry will require. Our forecast shows that for Canada to achieve its long-term GHG emission reduction targets by 2050, the labor force will require as many as 27,000 additional, full-time equivalent positions in 2030. High demand areas will include engineers, geologists, geophysicists and hydrogeologists as well as construction trades, project managers and process operators.

At Carbon Management Canada, we have over 250 trainees collaborating on carbon management projects in disciplines including engineering, geosciences, geography, chemistry, nanotechnology, biology, law and business. CMC research projects are interdisciplinary and run across national and international universities giving our trainees the benefit of learning from people in other fields and in other parts of the world.

We also provide opportunities for training outside of the lab and the classroom so these highly qualified people are better prepared to step into professional positions in industry. Students can take advantage of summer schools, workshops, webinars and exchange programs.

This value-added experience will continue at our institutes where junior researchers will gain experiential learning by working to solve industry-identified challenges. We will also partner with select companies to offer junior researchers opportunities to make connections and learn about industry first-hand.

Our connection to this new generation of young professionals infuses CMC with energy and excitement. Their passion is inspiring and contagious. It is with them and for them that we push toward solving carbon management challenges in Canada and around the world.

Carbon Management Canada

To learn more about how CMC can help you manage your carbon challenges contact Richard Adamson.

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