Green process engineering

By Cedric Briens, P.Eng., Paul Charpentier, P.Eng., and Ajay Ray, P. Eng.

EXECUTIVE SUMMARY

The University of Western Ontario's engineering school has introduced a groundbreaking program designed to meet the needs of both contemporary society and its students. Called green process engineering, it is a three-year course of study that will produce engineers skilled to meet today's and tomorrow's environmental and sustainability challenges.

Students accepted into the green process engineering program will have taken the same first-year program as other engineering students. Their three years of specialized courses range from ethics and business to green power, green design and solar power. The goal is to equip graduates with a unique skill set to develop and help policy-makers determine which alternative technologies are most likely to meet conservation and sustainability goals.

It is common knowledge that the world faces critical environmental and sustainability challenges. What is not widely appreciated is that engineers can play a leading role in confronting these challenges. At the University of Western Ontario, we have established a new academic engineering program tailored to help solve these problems, which threaten us all. Called green process engineering, it will prepare students to play a leading role in emerging biofuel and other green power industries as well as in the design of green chemical products and green manufacturing processes.

Green process engineering responds as well to the demands of today's students, who display a keen interest in the emerging alternative energy and clean-tech revolution. The roots of this revolution are complex, although contributing factors include dwindling fossil fuels, exponential population growth with resultant exponential energy demand, growing economies in the Middle East and the Far East and concerns over carbon dioxide release and climate change.

Many of us recall the energy crisis of the mid-1970s, when then-president Jimmy Carter urged people to "turn down the thermostat and put on a sweater." Today, we can do better. Although enhanced conservation is crucial for sustainability, there is also tremendous opportunity in the new Green Tech Revolution, perhaps analogous to the Information Technology Revolution of 25 years ago, which has been and will continue to be a tremendous creator of jobs and wealth. However, while the public is pressuring governments to address carbon emissions and climate change, policy-makers lack the expertise to determine which technologies are likely to succeed.

The U.S. Pollution Prevention Act of 1990 is one of the earliest attempts to address the green challenge. It shifted the focus from cleaning up environmental damage to "source reduction," or designing processes and products that minimize or prevent pollution. This piece of legislation is widely touted as leading to the rise of green chemistry and engineering. Green engineering is defined by the U.S. Environmental Protection Agency (EPA) as "the design, commercialization and use of processes and products that are feasible and economical while reducing the generation of pollution at the source." Within this context, there is a tremendous need for developing clean processes that are based on renewable feedstocks, clean solvents and a small carbon footprint. These are fundamentally different objectives from those traditionally pursued by environmental chemistry or other engineering studies, which largely focus on the effects of pollution.

Meanwhile, the study of alternative energy has been integrated into the field of green chemistry and engineering as a result of a growing realization that every available energy source will be required to secure North American energy independence from fossil fuels. These alternative sources include biomass, geothermal, solar, wind and even the controversial nuclear energy.

Together, this situation has made it abundantly clear that a new skill set is required to deal with these topics, which are not currently incorporated in any engineering curriculum.

THE WESTERN APPROACH

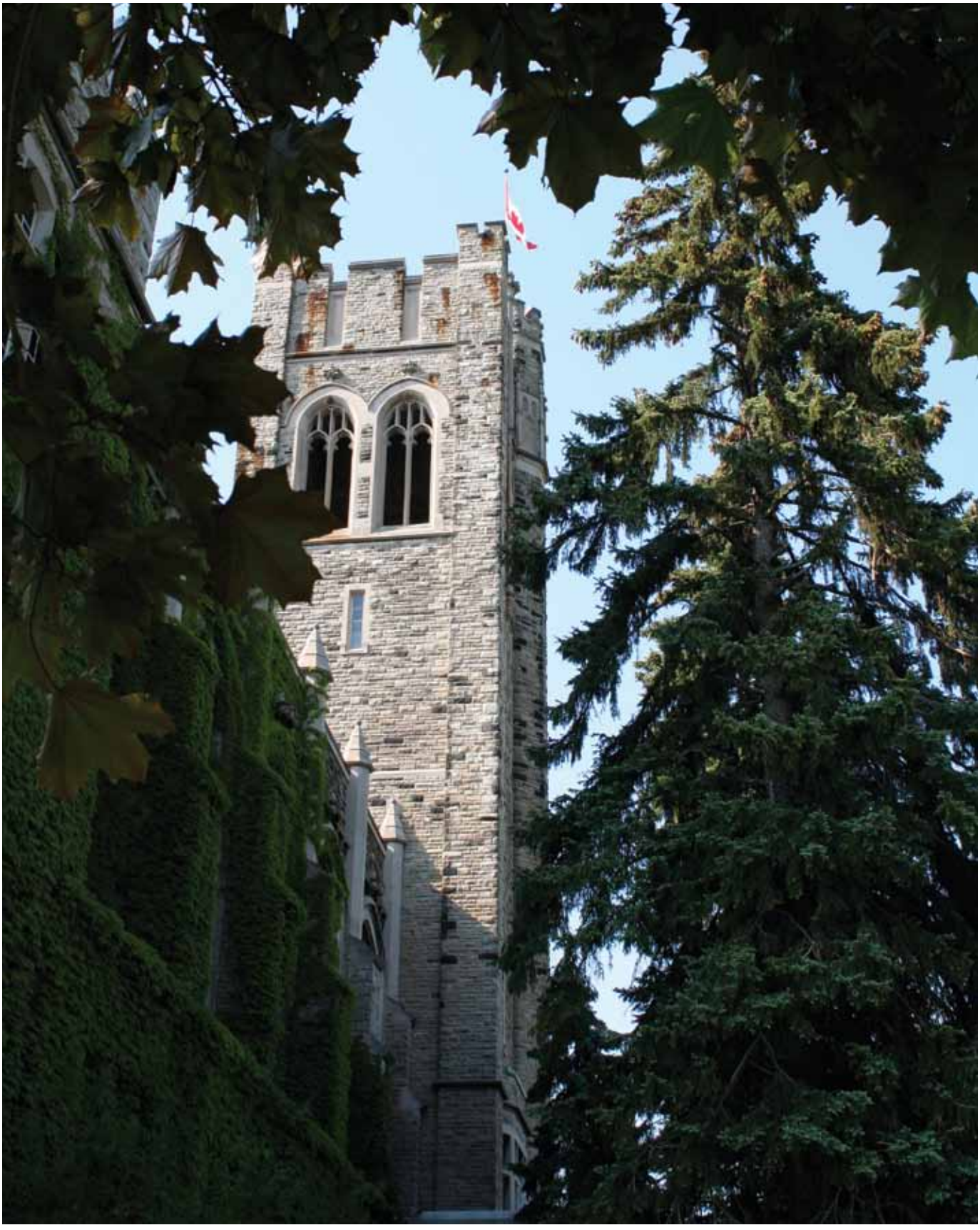
Located in London, Ontario, the University of Western Ontario is at the centre of a region rich in agricultural resources as well as home to a wide variety of manufacturing industries. Oil was discovered 150 years ago a mere 70 kilometres away in Petrolia; Western engineering professor Maurice Bergougnou discovered "green oil," which is biodegradable and toxicologically user safe, some 35 years ago by pyrolyzing a variety of natural biomass products.

Within this context, green technology and alternative energy research have flourished at Western, with major initiatives in solar, wind and biomass processing. However, as individual researchers, we can only do so much in our labs. To truly create a difference, we must educate the next generation of students who will manage the new economy while filling key roles in academia, government and the private sector.

To do so, we established the green process engineering program in 2009. This undergraduate program is the first of its kind in Canada. Its objective is to combine and integrate the fundamental principles of engineering with the design of commercial products and processes that are safe, economical and environmentally friendly. Among the distinguishing features of our program is the emphasis on green chemistry, green power, solar and bio-fuel cells and conversion of waste (such as agricultural byproducts) to value-added products.

In short, Western's green process engineering program will produce engineers specialized in the creation and implementation of "green" approaches to the design and development of processes and products that meet society's needs.

While this three-year program is housed in the chemical and biochemical engineering department, it has key input from other engineering departments, including civil and environmental, mechanical and



The University of Western Ontario, with a rich history of green technology and alternative energy research, established its green process engineering program last year. It is the first undergraduate program of its kind in Canada

Students accepted into the green process engineering program acquire hands-on experience in a variety of disciplines in the laboratories of Western's new $22-million, LEED-certified facility

materials, and electrical. All engineering students will continue to take a common first year that provides the basic engineering principles of design, statics, materials, etc.

In their first year in green process engineering, students learn the basics of green chemistry, thermodynamics, physical chemistry, applied math and fluid flow. In the following year, students take applied courses in the fundamentals of green engineering, green power, solar and fuel cells and several basic chemical engineering courses in heat transfer, staged operations and process control. In their final year, students take a capstone design process course, focusing on green measures. Green fuels and chemicals, business organization, engineering ethics and several electives from subjects such as air pollution and wastewater treatment make up the remainder of the curriculum.

We are also using labs in our new $22-million, 45,000-square-foot facility, which is the university's first LEED-certified structure, to provide hands-on experience that students can use when they enter the marketplace. Entrepreneurship is another key skill that will be integrated into the student's learning kit through specific courses.

We have made our program flexible to allow specialization in a variety of disciplines. At present, the curriculum is based in chemical engineering, although in the future, students will be able to take a wide variety of paths, including nanomaterials, electrical energy and policies required for sustainability.

We expect that our graduating students will have a wide variety of job prospects. In the private sector, power and energy companies require people with excellent communication abilities combined with strong technical skills. Our students will understand how energy sources can be converted to electrical and transportation energy, instruction lacking in most traditional programs. As well, our students are taught key entrepreneurial skills, required by emerging alternative energy companies.

Our program will attempt to provide skill sets that focus on the needs of Ontario, but that can also address emerging worldwide markets. The curriculum will evolve to meet the needs of both the students and the workplace as the program matures.

GREEN PROCESS ENGINEERING IN DETAIL

This section compares the existing academic green-related disciplines of environmental science, environmental engineering, green chemistry and chemical engineering with the new green process engineering program to highlight its unique features.

Environmental science emerged in the 1960s, buoyed by increasing awareness of pollution and its noxious impact on the environment and the human population. It spans fields from physical sciences such as biology, chemistry and geology to social sciences such as demography, economics, ethics and politics. Environmental science focuses on understanding the physical and sociological impacts of pollution.

For example, environmental science tackles the issue of nitrogen-oxide and sulphur oxide emissions by first studying the chemical processes that produce them in car engines and the biochemical processes that produce them in fertilizers. It then investigates how the processes are affected by fuel composition and combustion conditions.

Computer models have been developed to predict how nitrogen oxide and sulphur oxide are conveyed and dispersed by atmospheric currents and then dissolved in rain droplets that contaminate lakes. Chemical and biochemical interactions in typical lake environments have been modelled and their impact on various fish species and their predators have been investigated. Finally, various strategies for the reduction of nitrogen oxide and sulphur oxide emissions have been evaluated, using economic and sociological models.

For its part, environmental engineering involves the application of science and engineering to improve the environment through pollution control and safe waste disposal. Environmental engineering followed the development of environmental science and became popular in the 1970s and 1980s. Environmental engineers focus on the development of physical, chemical and biochemical processes to treat gas, liquid and solid streams to remove or destroy pollutants for safe release into the environment. They typically do not change the basic chemical or refining processes, but instead add new units either to treat emissions just before their release to the environment or to remove toxic chemicals just before products are shipped to customers.

In the specific case of nitrogen oxide and sulphur oxide emissions from cars, environmental engineers focus on developing effective catalysts for their removal from car exhausts. They have also developed processes for the removal of sulphur from gasoline and diesel fuels before they are shipped from oil refineries.

Meanwhile, green chemistry, or sustainable chemistry, is a relatively new discipline that emerged in the mid-1990s. Green chemists focus on the development of chemical synthesis schemes that are inherently sustainable and have a small environmental footprint. This is usually achieved by preventing waste generation or pollutants at the source instead of cleaning up afterward.

In the case of nitrogen oxide and sulphur oxide emissions, green chemists, for example, might use advanced nanochemistry to develop more efficient car batteries that would make hybrid cars more popular. They would develop batteries that would not require toxic chemicals for their manufacture and would not release toxic materials after their disposal.

Chemical engineering is a much older discipline, dating back to the late 1800s as the chemical industry blossomed. Chemical engineering concentrates on the design and improvement of processes for the manufacture of chemicals and fuels. Because of its emphasis on process design, it is sometimes called process engineering. Although chemical engineers are still involved in the design and operation of large refineries and chemical plants, they are as likely, nowadays, to be involved in the manufacture of pharmaceuticals or advanced materials such as carbon nanotubes or artificial skin.

To refer again to the example of nitrogen oxide and sulphur oxide emissions from cars, chemical engineers would produce models of the operation of catalytic converters to determine the ideal chemical and physical characteristics of the catalyst pellets that can convert nitrogen oxide and sulphur oxide economically and in environmentally safe ways. The chemical engineers design and operate processes to manufacture the catalyst pellets, from the chemical reactors that produce the catalyst to the dryers, granulators and pelletizers that produce pellets with the most desirable characteristics. Chemical engineers also adjust fuel-refining processes to produce fuels that will emit less pollutants when combusted.

For their part, tomorrow's green process engineers will combine chemical engineering tools with the findings of green chemists, biologists and environmental scientists to design new processes for the manufacture of chemicals, fuels and products with a much reduced environmental footprint. This will be achieved through the development of processes that use renewable resources, non-toxic solvents and chemical intermediates. Green process engineers will focus on the development of green processes and products that are effective, efficient and economical.

In the case of nitrogen oxide and sulphur oxide emissions, green process engineers would work with green chemists, agricultural scientists and combustion engineers to develop new green fuels from renewable resources such as agricultural residues that would produce less nitrogen oxide and sulphur oxide. They would also work with plant scientists to develop and formulate new, more effective fertilizers produced from the same renewable resources to cut net nitrogen oxide emissions.

CONCLUSION

In the last decade, the scientific community has witnessed a growing interest in environmental issues and the value of environmentally friendly energy generation and chemical processes. Several professors at Western's chemical and biochemical engineering department have distinguished themselves by developing environmentally friendly (green) chemical processes. Moving forward, we will ensure that our chemical engineering program on both the graduate and undergraduate levels takes advantage of the new available resources and opportunities and is based on solid fundamentals so that future graduates will be well equipped to face responsibly and skilfully the challenges of society in the years to come.

Cedric Briens, P. Eng., is a professor in the department of chemical and biochemical engineering at the University of Western Ontario where he founded Western's fluidization group. His areas of expertise are fluidization and particulate operations, and his current research projects include an industrial process to convert biomass and fossil fuels into valuable fuels and chemicals. Briens holds a PhD from Western.

Paul Charpentier, P.Eng., an associate professor in Western's department of chemical and biochemical engineering, is developing new green technologies for environmentally friendly and alternative energy applications. Charpentier received a Petro-Canada Young Innovators Award from Research Western in 2007 and a Premier's Research Excellence Award in 2002. He holds an M.Sc. from the University of Waterloo and a PhD from McMaster University.

Ajay Ray, P.Eng., a professor in Western's chemical and biochemical engineering department, is also cross-appointed to the department of applied mathematics. Earlier, he was an assistant then associate professor at the National University of Singapore. Since 2004, he has been on the editorial boards of the Euro-Asian Journal of Applied Sciences *and the* Euro-Asian Journal of Scientific Research. *Ray holds an M.Tech. from the Indian Institute of Technology in Kanpur, India, and a PhD from the University of Minnesota.*