ENERGY issue beckons P.Engs in NEW DIRECTIONS

By Michael Mastromatteo

Does the search for new, sustainable energy present a new challenge for P.Engs, or is it simply a matter of directing a time-honoured skill set to particularly vexing problems?

Ottawa-based engineer David Gerwing, P.Eng., should know a little something about squeezing new efficiencies from non-traditional energy sources.

As principal of Menova Engineering Inc., Gerwing recently generated a lot of media buzz with an innovative and energy-saving project in the design of a new 220,000-square-foot roof on a Wal-Mart store in Markham, ON.

In addition to the above-normal load factor, the roof construction project is noteworthy for its use of solar hybrid cells that allow for the heating, cooling and electrical powering of the sprawling retail facility.

Menova Engineering's Power-Spar system makes use of solar cells to provide both heat and electricity to schools, industrial facilities and other large buildings. Light concentrators focus the sun on photovoltaic solar cells to produce electricity, and fluid-filled chambers retain the sun's heat. The system also redirects energy through the use of fibre-optic cables.

The "smart roof" project is the kind of innovation that has earned Gerwing and Menova numerous awards for conservation and energy efficiency, but it's all in a day's work for such an energy-conscious engineer.

"Finding energy efficiencies has been a 28-year effort for me," Gerwing told *Engineering Dimensions*. "In addition to work in automotives and railway switch heating, I was involved with a consulting company that specialized in electronics packaging. As a result, we knew a lot about heat transfer in high-end simulations. The power density we now have on the solar cells is exactly the same as what we were packaging up for the long-haul optical networking, so we came to understand that world."

Gerwing believes energy efficiencies can come about by engineers "repackaging" things in different ways. Yet despite his understated emphasis, Gerwing's work illustrates one response of the engineering profession to the enormous challenges involved in providing for a reliable and environmentally sustainable energy future.

TRANSFORMATIVE TECHNOLOGIES

For many observers, energy is the pre-eminent issue for the first half of the 21st century. Concerns about depletion of traditional fossil fuels, the degradation of the environment and climate change are signs of an energy marketplace in the throes of a very real transformation. Just as fossil fuel burning, the internal combustion engine and electricity generation using alternating current changed society in the early years of the 20th century, today's engineers are looking for similar "transformative" technologies to respond to energy, environmental and societal concerns for the 21st.

Much of their struggle means overcoming what might be called energy supply lethargy. Traditional power technologies had their roots in the late 19th and early 20th centuries, and while they have enabled progress and an improved standard of living, they have now become deficient when measured against the new constraints of sustainability, climate change and steadily increasing demand. As well, the wide availability of traditional energy sources, coupled with their (until recently) low cost, has forestalled the search for alternative sources.

With economics and the environment as key drivers, the engineering profession is also being challenged to develop and extol conservation measures as a form of extending existing supplies. This is made even more complex against the commercial imperative to do more with less.

A key response to the energy situation clearly involves innovation. As such, engineers are actively involved in such transformative technologies as "water splitting" for large-scale hydrogen production, harnessing the sun's light for heating, light and electricity, and electrification of the entire transportation sector. Meanwhile, engineers are engaged in determining an approximate energy supply mix for today, including making better use of existing fossil fuels, charting a course for nuclear power, and abetting renewable sources, such as wind power and bioenergy.

OUTLOOK FOR CANADA

In November 2007, the National Energy Board released its *Canada's Energy Future* report, outlining energy demand scenarios for the period 2002 to 2030. The report suggests that while conventional energy will continue to be the number one fuel source for Canadians, emerging and alternative sources will make an impact on the overall fuel balance. The report suggests energy decisions made over the next five to 10 years will have lasting repercussions over the coming half century. This, in turn, suggests a stronger role for engineers–to ensure these decisions are fully informed ones.

The report offers an optimistic prediction that, despite increasing demand, Canadians are not likely to fall short on energy supply. "Canadian markets are working well and will continue to ensure that there is enough supply to meet the demand," the energy board says. "Canadian consumers are adjusting to higher energy prices. As for the range of options for fuel resources, what is available will also be determined by price and consumer preferences."

Likewise, in the spring of 2007, the Canadian Academy of Engineering (CAE) released its *Energy Pathways Task Force* report, which made recommendations for Canada's role as a "sustainable energy superpower."

The task force report zeroed in on some specific challenges for engineers.

"Engineers build to a design specification for the benefit of all Canadians," the CAE report says. "But what are the design specifications for a Canada that is a sustainable energy superpower? Regardless of the precise definition, as engineers, it is our role to ensure that we have the technological capacity to make contributions to a new and expanded domestic and international energy role for Canada."

For the CAE, these contributions include enabling a shift to economic, renewable energy resources, reductions in the environmental impacts of energy recovery, processing and use, meeting the current and future energy demands of all Canadians on a sustainable basis, and exporting value-added energy products.

ENERGY EDUCATION

Engineering regulators have also started addressing aspects of the energy challenge to the profession at large. In 2006, PEO published its *Sorting Through the Noise* paper, which cited "value analysis" as a way to effectively evaluate competing interests to reach sound and broadly acceptable conclusions. Although PEO's energy paper didn't have lasting impact within the Ontario government, it was further evidence of the interconnectedness between a reliable and secure energy supply and the engineering profession.

It's a link that's clearly having an impact on the education of future engineers. The University of Ontario Institute of Technology (UOIT) in Oshawa includes a number of energy-related courses in its undergraduate program, while the University of Toronto's (U of T) civil engineering school is adding a new course for fourth-year civil engineering students on sustainable energy systems.

The course will provide students an overview of the energy "landscape," energy demands throughout the economy, major energy technologies, how these technologies are evaluated quantitatively, and their impacts on the environment. Systems approaches, including life cycle assessment (LCA), will be used to help students evaluate the total impact of energy systems. Additional focus will be placed on analysis of energy alternatives within a "carbon-constrained" economy.

Heather MacLean, PhD, P.Eng., who will be teaching the new U of T course, is an authority on using LCA on matters relating to energy and the environment.

Although not a new tool, LCA is becoming more important for engineers in researching more efficient means of energy extraction and use, whether from traditional or alternative sources. LCA is essentially an approach to assess environmental impact, in conjunction with economic impacts under consideration. The scope of the assessment is the whole life cycle of a product, comprising production, the phase of use and end of life.

MacLean, a professor of civil engineering, says it's critical that all engineers be aware of energy's importance to practically all facets of social and economic activity.

"With increasing energy demands, calls for conservation, volatile energy prices, the impacts of all types of energy production on sustainability and associated climate change, and other drivers, it is becoming even more critical that practising engineers are familiar with energy fundamentals," MacLean told *Engineering Dimensions*.

MacLean says energy issues traditionally were the domain of electrical, mechanical, chemical, mining and petroleum engineering programs. Less emphasis was placed on energy issues in civil engineering curricula. "For civil engineers, energy requirements for buildings are large and must be well understood [because] energy is also required to produce all materials used in our infrastructure from mining [and] extraction through processing and transportation," she adds. "Knowing energy fundamentals, where this energy comes from, how resources/feedstocks are converted to various types of energy, how energy efficiency can be improved, and the implications of energy production and use on the environment, economy and society are not trivial issues," MacLean says. "Ensuring that all graduates are aware of these issues will be a first step in improving the situation and moving toward more progressive, more sustainable energy systems in the 21st century."

LIFE CYCLE KEY

Jennifer McKellar, P.Eng., a U of T PhD student who studied under MacLean, is bringing LCA to a study of greenhouse gas emissions in Alberta oil sands exploration. The objective of the study is to identify the most promising replacements for natural gas among different fuel sources, with special emphasis on greenhouse gas emissions, energy consumption and overall cost.

McKellar says that although LCA's ability to make precise estimates depends on the quality of data being used at the time of assessment, engineers should still consider life cycle approaches in their energy-related work.

"I think LCA is a valuable tool for professional engineers to employ in analyses of energy supply options and their potential impacts on the environment," McKellar says. "Before decisions are made regarding the implementation of some new technology or process, the potential impacts over its entire life cycle must be taken into account."

FINDING ALTERNATIVES

If life cycle analysis challenges engineers to bring a wider perspective to energy-related work, there remain more specific areas to develop. Among these are biofuels or biomass, seen as a possible remedy to the greenhouse gas problems associated with the use of coal and other fossil fuels.

Biomass is considered carbon dioxide neutral because the CO_2 released by burning wood and similar materials has been stored in trees and plants over the last 40 to 80 years, while burning coal releases CO_2 that has been stored for millions of years. By this yardstick, burning coal releases *new* CO_2 into the ecosystem.

Such ubiquitous material as wood is being studied for its potential to fire electricity generating stations, especially as these stations shift away from burning coal.

Ontario Power Generation (OPG) is now studying the use of biomass (in particular, wood pellets) as fuel in all of its coal-fired generators. OPG recently completed a successful firing of its Atikokan Generating Station, 150 kilometres east of Fort Frances, ON, with wood fuel. OPG is now conducting tests of longer duration at Atikokan and other coal-burning stations to determine the feasibility of using biomass fuel over an extended period.

Rob Lyng, P.Eng., director, environmental policies and programs, sustainable development, OPG, says such research is natural to a profession charged with uncovering fuel alternatives that meet the test of sustainability. He says with continued testing and evaluation of biomass energy properties, OPG could conceivably convert all of its coal-fired generating stations to biomass by 2014.

Lyng outlined some of the current challenges involved in biomass fuel. Among these are a higher cost relative to coal, an underdeveloped biomass fuel supply infrastructure, and limitations in the handling and storage of large volumes of biofuels. These challenges are over and above the problems associated with the performance of a new fuel source in OPG's existing generators.

Nonetheless, Lyng says developing biomass as a carbon-neutral fuel source is just one avenue for the engineering profession to realize a transformative technology in the energy sector. As a possible bonus, harnessing wood and other biofuels could provide new commercial opportunities for Ontario's vulnerable forestry industry.

EFFICIENT ELECTRICITY

But with potential new fuels providing additional generating capacity, engineers are also hard pressed to consider electricity transmission and distribution enhancements. Some are exploring the benefits of distributed generation that would see limited-capacity stations providing electricity to smaller residential communities or industrial parks.

When it comes to efficiencies with wider electricity transmission, however, engineer Richard Marceau, PhD, P.Eng., has some relatively novel ideas.

Marceau, provost and acting dean of engineering, UOIT, and long-term employee of Hydro-Quebec, has developed an argument for "asymmetric" operation of AC power transmission that he believes would deliver power to homes and businesses more reliably and with fewer disruptions.

In their new book, *Asymmetric Operation of AC Power Transmission Systems*, Marceau and co-authors Don McGillis and Abdou-R. Sana argue that the traditional symmetric or three-phase transmission system is less efficient and prone to disruption. With the three-phase system, a fault or short-circuit on any one line takes the entire system out of operation. In effect, a flaw in one-third of the entire line automatically deprives the network of 100 per cent transmission on the same line.

"Asymmetric operation, as a concept, defines the operation of a three-phase transmission line as three independently operated entities," the book states. "In this approach, a three-phase line can be operated with one or two phases out of service for single-line transmission corridors, or with one, two or three phases out of service in the case of multiple-line corridors, while preserving three-phase symmetrical operation at the corridor extremities. When faults on individual phases occur, undesirable voltages and currents are 'contained' within the affected corridor, the latter therefore appearing essentially unaffected from outside."

Marceau also believes asymmetrical transmission would prove more economical in the middle and long terms. "In asymmetric operation," he says, "the generator keeps generating, the customer keeps getting electricity. Everybody thinks the power is being delivered symmetrically, but [if] you've lost only one conductor, you're still using the two remaining conductors. So you've contained the contingency within the corridor [and] you've lost one phase. You're really using those three conductors for all the value they can deliver. If there's only one that's faulty, you can still use the two remaining conductors that are perfectly capable of transmitting power."

Although there is some resistance within the industry to Marceau's asymmetrical model, he believes it's a novel kind of approach that engineers ought to consider in looking for efficiencies and innovations in the overall energy marketplace.

"This idea comes simply from questioning the way we have been doing things for over a century and how we would do things knowing what we know today," Marceau told *Engineering Dimensions*. "I see this as a natural, long-needed evolution of our existing power transmission systems. It is essentially based on looking at the 'sacred cows' of our engineering discipline and challenging them with the benefit of what we've learned over the past century."

SUSTAINABLE TRANSPORTATION

Whatever improvements to electricity distribution might accrue with line enhancements, engineers must also deal with challenges associated with "smarter" use of electricity, especially with demand expected to continually increase.

In fact, some observers believe the anticipated electrification of the automotive sector will put engineering innovation to the ultimate test. It's a challenge taken on by people like Matthew Stevens, EIT, of CrossChasm Technologies in Cambridge, ON.

A PhD graduate in chemical engineering from the University of Waterloo, Stevens and his partners have developed expertise in the development of longer-term batteries and plug-in/extended-range all-electric vehicles. Much of that expertise was derived through their participation in the Challenge X competitions, in which student engineering teams strive for improvements to hybrid and battery-powered cars.

CrossChasm Technologies specializes in modelling and commercialization of advanced hybrid powertrains and is developing products related to plug-in hybrid vehicles.

In an interview with *Engineering Dimensions*, Stevens reflected on the special problems facing engineers in responding to electricity as the dominant power source in the transportation sector.

"For the long term, it's hard to find a sustainable energy vector for transportation that doesn't include electrification, whether the energy be used to charge batteries, generate hydrogen, or a combination thereof," Stevens says. "We like electrification for two reasons: diversity and efficiency."

Stevens agrees that any breakthroughs in the development and roll-out of plug-in vehicles must be coordinated with corresponding enhancements and management of the power grid loads. "It appears as though a well-coordinated vehicle charging system would allow for a significant number of electric vehicles to enter the North American market with negligible impact on generation and transmission equipment," says Stevens. "Having said that, there still need to be studies performed on distribution-level impacts to evaluate factors such as reduced nighttime cooling, and the effects in grid-congested areas such as Toronto. Given that our power sector is already in need of investment, it will be important that the new planning reports consider the long-term integration of vehicle charging loads."

HYDROGEN HOPE

Discussion of electrification of the transportation sector also invites consideration of the impact of hydrogen as an energy carrier. Hydrogen is considered a form of clean energy because its oxidation does not emit greenhouse gases that contribute to global warming and climate change.

Greg Naterer, PhD, P.Eng., professor of engineering and applied science, UOIT, is principal investigator in a research project to develop large-scale hydrogen production by way of thermochemical water splitting using a copper-chlorine cycle.

"UOIT is leading a large consortium of university partners across Ontario and internationally, developing revolutionary technology for splitting water into hydrogen and oxygen using the thermochemical copper chlorine cycle," Naterer said in an interview. "We're very optimistic about the potential of this project. One result could be nuclear-based hydrogen production as a very low-cost energy carrier to supply industry and residential needs and at the same time drawing waste heat from nuclear reactors to a useful purpose, rather than emitting to the environment."

Naterer says quality of life, security and environmental concerns have provided the necessary impetus to get professional engineers moving on a wide range of energy issues.

"We [engineers] can be conservative as a group and, with respect to the energy issue, many times solutions are presented that are really band-aid type of solutions that might work temporarily, but they don't really address the large-scale magnitude of the problem," he says. "That requires some major leadership for us to take some bold ventures. For example, hydrogen is one of those examples that has the potential to really transform the global economy and to preserve our planet, but it takes some bold leadership to really step forward and make it come true."

MARKET REALITY

Engineers are no doubt aware that market realities and the often high failure rate in the commercialization of new products and systems have some bearing on energy innovation. Engineer Gerwing of Menova believes Canadian companies and investors are so risk averse as to hinder adequate funding of research that could result in important energy innovations.

"There are two sides to the question," Gerwing says, "one is anything new is dangerous, so as an engineer, I'm protecting the public by being very focused on the inertial things that I've done and always doing things the same because there's low risk in that. Then there's the view that the new innovative stuff is scary because there is only a 10 per cent chance it will be any good. Ninety per cent of all new innovations fail. That's the new reality. You've got to do it 10 times before you get it right."

Robert Stasko, P.Eng., director of business development, Ontario Centres of Excellence (OCE), energy division, says there is a fine balance between the need to invest in transformational energy technologies while preserving and enhancing the best elements of traditional sources.

The OCE energy office was created by the provincial government in response to the challenges and opportunities posed by the energy situation in Ontario. The centre promotes research collaborations between industry and colleges, universities and research hospitals. It also works with industry to solve problems by engaging researchers at Ontario's universities and colleges in the challenges faced by businesses. Finally, the centre co-invests in research and development of competitive, industrially relevant technologies, with the goal of bringing these ideas to the market.

"We are well aware of the high failure rate of new technologies as they are moved from bench-top to the commercial realm," Stasko says. "In fact, it's important to keep in mind that a 10 per cent success rate applies to ideas that have already proven to be scientific or technical successes, but which for one reason or another never become successful business propositions. If we looked at ideas in general, maybe one in a thousand makes it to commercial success. Issues such as market barriers, manufacturing costs, undercapitalization, a bad management team and governing regulations can turn a successful experiment into a business failure."

Stasko says that despite OCE expertise in guiding new products through to successful commercialization, there is always some risk involved. "I wish we could say that engineering skills and scientific discipline are sufficient in making the right choices. In fact, that helps us narrow the field to technologies that have merit, but it does not ensure success. We do that by using 'soft skills' to guide fledgling enterprises, and by not betting on a few horses, but having a huge stable."

THINK LONG-TERM, ACT NOW

Whatever the commercial risks inherent with most innovations, engineers appear to be saddled with a major responsibility in helping transition society to the new realities in the energy marketplace. Some have suggested the challenge is a new and unique one, while others believe it's nothing different for a profession ultimately dedicated to the greater public good.

Amir Shalaby, P.Eng., vice president, power system planning, Ontario Power Authority, says that whatever technical challenges lie before the profession in the energy sector, engineers must also pay heed to active communication about energy solutions with community leaders and other stakeholders affected by the debate.

"There's no doubt engineers make a major contribution to all aspects of the energy supply and distribution network in Ontario, but so do a lot of other groups," Shalaby says. "But because the engineering profession is respected and is striving for a heightened public awareness, it can really help itself by partnering with other groups and helping to explain all the impacts of decisions being made about energy."

The communication theme, abstract as it may be to technologically inclined engineers, also rings true to Marc Rosen, PhD, P.Eng., professor of engineering, UOIT, and president, Engineering Institute of Canada.

Much of Rosen's work centres on thermodynamics, heat transfer and the environmental impact of energy and industrial systems. As with other issues affecting engineers and the profession's responsibilities, Rosen believes it's time to take an expansive view.

"To me the bigger issue is that engineers tend to have tasks assigned either by their companies or their employer, and these tend to be very near term," Rosen says. "The other role, which is engineers linking up with government and taking longer-term thinking, is why don't we look 10, 20 and 50 years ahead, because now, while [energy] prices are down a little bit, it's probably the time to do something, and not worry about it in a panic mode when prices skyrocket. Let's get the solutions in place while we're not under severe stress and pressure to get it done yesterday." Σ