it that way.… We need to get over this obsession with comparing ourselves to these other professions." Letter from Joseph Grubb to *Engineering Dimensions*, January/February 2008: 8.

13. One plausible explanation for this distinction is that law and medicine have enjoyed "guild power," especially a monopoly over the skills they provided, and engineering has not. See Elliott A. Krause, *Death of Guilds: Professions, States, and the Advance of Capitalism, 1930 to the Present* (New Haven: Yale University Press, 1996): 60-67.
14. Beverley M. McLachlin, et al., *The Canadian Law of Architecture and Engineering*, second edition (Toronto: Butterworths, 1994).
15. www.legermarketing.com/documents/spclm/070522ENG.pdf. Accessed Dec. 28, 2008.
16. *Engineering and Technology Labour Market Study*: 38.
17. Internal Trade Secretariat, *Agreement on Internal Trade: Consolidated Version*, May 2007 www.ait-aci.ca/index_en/ait.htm. Accessed Dec. 28, 2008. Provincial governments have set April 1, 2009 as the deadline for achieving compliance with the provisions of the labour mobility section of the agreement and to achieve full labour mobility for professions in Canada. See also Directive 89/48/EEC of the European Union that covers the mutual recognition of qualifications in recognized professions that require a university degree or equivalent. eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31989L0048:EN:HTML. Accessed Dec. 31, 2008.

Appendix 4

Illustrative licence categories

Licences are instruments created by legislation to enable the professional engineering body to govern an individual in the public interest. The licence sets standards and ensures public accountability. All licence holders are members of the professional engineering body. To regulate all engineering activities, products and services, it is necessary to license individuals while they are gaining the requisite experience. The intern and collaborator licences provide these needed instruments.

Professional licence

A professional licence holder is entitled to practise professional engineering independently and to offer services directly to the public in the holder's self-determined areas of competence through a Certificate of Authorization.

Specific scope licence

The specific scope licence permits individuals to practise professional engineering independently in a defined scope of practice. The holder can offer services within the specified scope directly to the public by virtue of a Certificate of Authorization. The professional engineering body assesses the competencies of the applicant to determine the specific scope. This instrument is a useful tool for allied professions, qualified technologists, applied science graduates and international engineering graduates who have not had the required breadth of education needed for a professional licence. Specific-scope licence holders would be able to upgrade their academic qualifications to become professional licence holders. An associate member would normally be a specific scope licence holder.

Intern licence

An intern licence is granted to a member who is in the process of acquiring the work experience necessary for licensure under the direction of a licence holder. A graduate member would normally operate under the intern licence.

Collaborator licence

The collaborator licence is designed for international engineers with at least three years of experience so that they may practise professional engineering in the holder's areas of competence while working with a licence holder competent in the areas of practice. After the collaborator licence holder has become familiar with Canadian codes, standards, engineering business practices and ethics (typically after one year), he/she would qualify for a professional licence or specific scope licence.

Why engineers need public policy training and practice

Andrew Colombo, PhD[i], and Bryan Karney, PhD, P.Eng.[ii]

Members of our profession have for decades been involved in public policy-making. Yet our participation in debates about public policy, and engagement in its formulation, are often misunderstood and undervalued by the public and not as effective as they should be. As engineers, our collective approaches tend to be ad hoc, random and subject to the whims of a process we barely understand and rarely appreciate.

Indeed, frustration among engineers is often high. How often do we get asked to serve in some form of advisory role only to find our sound advice has been distorted, ignored or watered down? In some cases, seemingly wise counsel may even provoke heated debate and consternation. What transforms well-intentioned and competent advice into something quite different, or perhaps something barely recognizable? Why isn't an engineer's technical advice in the public policy process more respected and more effective?

To some extent, at least, the answers, if they are to be found at all, lie in a greater understanding of public policy, a fascinating yet complex interplay of diverse interests and power relationships that brings together various actors with multiple perspectives in a quest to achieve something resembling a common objective. Thus, the time has come to revisit something once thought familiar and replace our often tacit assumptions with a more informed and critical perspective.

The nature of public policy

Isolated elements of the policy-making process are familiar to many engineers. Some have served on technical advisory committees or have provided expert testimony in legal matters. Others have participated in public inquiries or worked with community organizations at a range of levels, such as local homeowners' associations and municipal government committees. Various interest or advocacy groups have retained yet others for their unique academic and professional insight and experience.

Whether paid or voluntary, the service rendered by engineers in public policy-making is not always fully appreciated, or utilized, by those who seek it or would appear to benefit from it. But is that the whole story? Can it be that many engineers involved in policy-making fail to appreciate neither the myriad interests surrounding policy matters nor how to perceive the special dynamics of the unfolding process? Yes and no.

Although engineers generally lack a sophisticated fluency with the intricacies of public policy-making, most of us are more aware of its dynamics than we realize, thanks to a seemingly mundane acquaintance with many of policy-making's common instruments. For example, we all recognize anti-smoking ads, new road tolls and green energy-saver logos as policy instruments related to health care, transportation and environmental policy.

Subsidies are another example. Those of us who "ride the rocket" to work in Toronto are familiar with the apparently ever-escalating fares for the bus and subway. Still, despite high TTC prices, we riders understand that we do not pay the full price of service since the municipality covers part of the cost from its general revenues. In other jurisdictions, public transit is even more generously subsidized in an effort to reduce congestion and pollution; that is, the subsidies are instruments of both transportation and environmental policy.

On a more sophisticated level, engineers will be familiar with less quotidian manifestations of policy. Two examples are effluent charges on emissions from industrial facilities and energy efficiency standards, common tools of environmental policy. A more sophisticated measure would be the relatively new idea of carbon-trading markets to facilitate CO_2 reductions, an instrument of energy, environmental and foreign policy.

Many of us, as members of Professional Engineers Ontario, don't realize how much policy we make and guide through the creation and publication of guidelines, standards and best practices. Since provincial law grants the profession self-regulation, we can and do exert a decisive influence on policy in certain domains, especially those related to infrastructure, which are fundamental to the smooth functioning of society in general. Despite an unacknowledged and intuitive understanding of certain policy elements, extrapolation of this familiarity does not automatically bring us to a point where we can appreciate the dynamics of the broader process and how this is so important for determining the objectives, instruments and delivery of public policy.

An updated curriculum

Recognizing the need for more than just elegant technical solutions to demanding problems, undergraduate engineering curricula have traditionally included at least one course in engineering economics so that prospective engineers may be acquainted with the financial and monetary dimensions of their trade. In a similar vein, mandatory and optional technical writing courses are offered in most programs to ensure graduates are able to communicate effectively, as well as possess a minimum aptitude for cross-disciplinary dialogue. More recent additions to many programs involve courses (or at least class modules) pertaining to environmental sustainability, a response to the attention being paid to such pressing global challenges as climate change concerns, the possibility of peak oil or the widely acknowledged issues of resource depletion.

What is certainly less appreciated, but perhaps no less important, is the role that public policy training could play in both graduate and undergraduate engineering programs. It is well known that professional engineers are sought for their technical expertise as consultants in both the public and private spheres. Frequently, they serve as expert witnesses in legal proceedings or on scientific advisory panels that aim to inform policy-making. Clearly, some fluency with the public policy concepts and mechanisms introduced above would be helpful.

Sophisticated new policy dynamics

Classic issues defining the relationship between science professionals and broader society are taken up in the sociology of scientific knowledge (SSK). Common themes in this body of work include, among other things, bias in scientific advising, conflict of interest, effective communication of technical knowledge to lay audiences, public trust and confidence in expert opinion and divergent perceptions of risk. For example, McComas et al. (2005) describe the challenge in bias assessment posed by drawing from a limited group of experts to serve on regulatory agency panels when the same experts may simultaneously collaborate with the regulated industries; the "shared pool" dilemma.

Ross and Karis (1991) address the need for engineers engaged in public policy issues to acquire communication skills more versatile than those typically required within their discipline so they can enter into discourse in "non-congruent sites" or in cross-disciplinary dialogue that includes both technical and non-technical components. Closer to the point of this article, Young and Matthews (2007) examine deficiencies in reciprocal understanding between technical experts and the public in the context of the controversial Canadian aquaculture industry. In their survey of numerous experts familiar with aquaculture, they noted reluctance on the part of technical experts when it came to embracing "local" or "lay" knowledge of particular issues and observed that "what is generally lacking is research into experts' understanding of the public." This is a vital observation and it can easily be expanded to read "experts' familiarity with basic public policy."

While these SSK issues are certainly important and relevant to engineering knowledge of public policy, they address only limited aspects of the issue and provide no sense of the scope or dynamics of the policy-making environment. The organization and intermediation of societal interests seems just as complex as the issues that mobilize them. This is especially apparent nowadays, given what many have perceived as a paradigm shift in the nature of governance from a traditional state-centred, top-down approach to a "horizontal" framework in which government steers policy communities, advocacy coalitions and an intricate arrangement of entities comprising regulatory agencies, Crown corporations, interest groups, community associations, experts, academics, public-private partnerships and various other stakeholders/actors (Skelcher, 2000; Castells, 2000).

Several authors address and describe public policy networks (Dowding, 1995; Thatcher, 1998; Marsh and Smith, 2000; Evans, 2000). The corresponding literature is becoming rich with different approaches to conceptualizing these networks by classifying them according to their structure and/or seeking to explain how they operate in terms of power relationships and differing levels of influence of policy actors. Introductory textbooks, such as those by Pal (2005) and Hudson & Lowe (2004), outline and summarize key developments in policy network theory.

Perhaps nowhere in recent experience have engineering insights and public policy development interacted more strongly than in the intersection of energy, environmental and economic issues. Take, for example, the seemingly straightforward question of what light bulb to choose. Significant attention related to environmental/energy policy has been focused on the question of which is better: the fluorescent or the incandescent light bulb?

The question seems at first glance clear, yet the answer, which is critical to good policy, is not. Conventional wisdom suggests fluorescent bulbs are preferred because they consume less energy in the form of "wasted" heat. Yet, in a cold Canadian home during winter, is the heat emitted by such a bulb really wasted?

If lights do indeed provide a kind of electrical subsidy to fossil fuel heating, should the policy choice take into account the electrical and heating technology mix? And when does the symbolic power of a simple action get lost in the complexity of real world evaluation? These are not easy questions.

Rendezvous in the corn belt

Another example of the sometimes tricky rapport between engineering and public policy-making can be found in the promotion (or resistance) of corn-based ethanol as a renewable biofuel. Almost anyone who followed the recent US presidential election is likely to have heard mention of ethanol as a key part of an energy policy strategically aimed at reducing American dependence on imported petroleum and bolstering energy security. While corn-based ethanol was a pillar of the Bush administration's energy vision, the Obama-Biden campaign's energy plan also includes biofuel development among its several proposals, claiming "advances in biofuels, including cellulosic ethanol, biobutanol and other new technologies that produce synthetic petroleum from sustainable feedstocks offer tremendous potential to break our addiction to oil" (Obama and Biden, 2008).

The history of corn-based ethanol in the US offers an intriguing example of the often awkward fit between engineering and public policy. Keeney (2009) recently reviewed and critiqued the adoption of corn-based ethanol as a key instrument of US energy policy. He points out that the enthusiastic espousal of corn-based ethanol has as much, or even more, to do with the intricacies of policy-making than with straightforward engineering, illustrating how various commercial and political interests have shaped policy-making over the last few decades. Examples include early lobbying by the Archers Daniels Midland company, a major corn fructose manufacturer, which helped usher in such ethanol-friendly legislation as the 1978 *Energy Tax Act* that exempted a portion of the federal fuel excise tax on gasoline that favoured the company's interests, or the 2004 tax credit to blenders of ethanol with gasoline as part of the *American Jobs Creation Act*.

The domestic ethanol industry has also enjoyed the protection offered by other policy instruments, such as a tariff levied against Brazilian ethanol and binding mandates associated with renewable fuel standards. That many of these initiatives amount to a de facto subsidy for farmers in corn belt states has not been lost on most observers. Curiously, one of the early policy network models is the so-called "iron triangle," a decision-making subgovernment comprising the relevant executive agency, its associated congressional subcommittee (or bureaucracy) and its associated economic interest group. While simple and static relative to more advanced policy network models, the idea continues to remain useful and is perhaps applicable to understanding the early ethanol lobby.

Motivated by reasonable goals of energy conservation and employment security, does energy policy favouring corn-based ethanol ensure consistency with other vital policy domains? According to Keeney, no. Of course, there is ongoing research into this question, but recent and substantial increases in corn and food prices, as well as questions about the true energy benefits from corn-based fuel, suggest this is still an open question. Life cycle analyses of corn-based ethanol suggest the agricultural energy demand (pumping of irrigation water, processing, transport to market) consumes much of the energy produced from the biofuel.

Additionally, increased fertilizer in runoff and other pollution related to farming further offsets some of the advantages sought by policy-makers. This demonstrates the energy policy conflict with environmental policy. Competition with food uses of corn, coupled with heightened speculation in commodities markets, also has implications for food security and can undermine various aspects of health policy.

Recent research into the use of cellulosic residual material marks an attempt to address some of the challenges faced by the North American biofuels industry. Engineering insight will continue to be necessary so that public policy in this area remains well-informed of the latest and most promising developments.

Power to the people

An important part of the economic development strategy to assist poor countries involves the establishment of modern energy infrastructure; in particular, the electrification of rural areas. Much policy formulation in this area depends, as with the corn-based ethanol and our light bulb debate, on sound engineering and effective technical communication. Crucially, how well is typical policy in this area conceived?

Several authors address the issue from a developing country's perspective (Wolde-Ghiorgis, 2002; Abdalla, 1994; Haanyika, 2006) and reveal major inconsistencies. For example, Wolde-Ghiorgis (2002) points out how subsidies for rural road development in Ethiopia (part of a general economic development strategy in that country) have robbed funds for investing in local renewable energy schemes and that, lacking adequate energy infrastructure, the roads are largely unused.

Abdalla (1994) notes that since it is women who make many decisions regarding household energy consumption and the use of scarce wood and biomass resources, improved education aimed specifically at women can reduce energy use. The clear indication here is that the education and energy policy domains are closely linked. Haanyika (2006) examines various challenges related to the financing of new energy infrastructure in rural areas, highlighting the policy insights needed to ensure that privatized power companies in a reformed sector contribute to rural electricity access.

Recommendations

Far from being cast in stone, the focus of engineering and engineering curricula do change with the times and have arguably been successful in balancing traditional core material with new courses aimed at covering emerging problem areas, filling gaps and establishing links with other fields of study. Examples of this include the adoption of engineering economics and, later, the evolution of courses pertaining to environmental sustainability into mainstream programs. We believe such courses should be made a compulsory part of degree programs. While the vast majority of engineering students, or current professionals for that matter, do not require thorough exposure to the intricacies of policy network theory, a well-conceived introduction to public policy concepts and how they pertain to engineering research and practice could provide all of us with a better sense of our potential role in policy-making and would begin to answer some of the questions posed at the outset of this article.

Moreover, we recommend three general approaches to the practice of engineering and public policy:

1. All engineering has public implications and thus interacts with, and is largely practised within the context of, public policy. The public policy context of engineering is a reality about which all engineers should be aware;
2. Understanding the significant role of public policy can help to make for better engineering solutions and engineering participation in public policy formulation can result in better informed and designed public policies. The engineering profession needs a small number of specialists and public policy advocates to inform the public debate of important issues and to speak to these issues in the public arena from an engineering perspective; and
3. The skills needed to perform well in public policy development overlap with, but are not identical to, those of engineering. Engineers would be more influential and better participants in the public policy process if they understood policy skills better. To this end, engineering curricula should be modified to encompass a public policy orientation.

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