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A DEAN'S PERSPECTIVE ON THE FUTURE OF AGRICULTURAL ENGINEERING EDUCATION IN CANADA

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ABSTRACT This presentation draws from the author's expertise and 20-year experience in three (3) Canadian universities as a professor and as an academic leader. It first addresses the following contextual issues: recent trends in engineering education in North America; evolving expectations associated to the recent revision of the professional accreditation criteria by the Canadian Engineering Accreditation Board (CEAB); agricultural engineering in Canada. On the basis of the data collected and analyzed, the author estimates that agricultural engineering currently accounts for about 1% of both the engineering education systems and of the engineering profession in Canada. In order to optimize the use of the public and private resources that are required to support the delivery of agricultural engineering education programs, the author proposes to create four regional Canadian Agricultural Engineering Institutes that would be responsible for post-secondary education programs in agricultural engineering (at the college and university levels) as well as for agricultural engineering R&D and for public services activities to various stakeholders. The undergraduate agricultural engineering programs that would be offered by these institutes would include the desirable features that have been identified by various engineering education leaders in recent years: outcome-based assessment of graduates, increased emphasis on 'non-engineering' disciplines, less specialization.

Keywords: Agricultural engineering, Canada, Education.

INTRODUCTION This paper is concerned with the future of agricultural engineering education in Canada. As such, one of its most important starting points must be the elusive answer to the question: What is engineering? In that regard, the author believes that the definition provided by the Canadian Academy of Engineering more than ten years ago remains one of the most accurate and complete: '*Set in a social context, engineering is a profession concerned with the creation of new and improved systems, processes and products, to serve human needs as they are expressed by individuals, communities, governments and corporations. Its central focus is design, an art entailing the exercise of ingenuity, imagination, knowledge, skill, discipline and judgement based on experience. The practice of professional engineering requires sensitivity to the physical potential of materials, to the logic of mathematical analysis, to the operational principles of processes and systems, to the constraints of human resources, physical resources and economics, and to the social and environmental context for society, now* *and into the future*'. The recent 'Montréal Declaration' issued at the conclusion of the 2009 National Engineering Summit has further captured the strategic importance of the engineering profession for any society by coining a most appropriate statement of purpose: '*Engineers: The enablers of dreams - Engineers play a key role in our societal development, contributing to and enabling initiatives that drive economic progress, enhance social and physical infrastructures, and inspire the changes that improve our quality of life*' (CELF 2009). Engineering education in Canada is going through a period of important and rapid changes that result from the evolving needs and expectations voiced by the engineering profession, employers of engineering graduates, and society in general – the Montréal Declaration being one of the most recent manifestations in that regard. Another important driver is the fact that a decreasing proportion of engineering students indicate that they definitively intend to pursue an engineering career; a recent study by Lichtenstein et al. (2009) indicated that this proportion was as low as 42%.

The traditional field of agricultural engineering – which for the purpose of this discussion must also include disciplines such as bioresource, biosystems, and food engineering – is also evolving. In 1988, the Canada Committee on Agricultural Engineering Services stated that '*the purpose of engineering in the agri-food system is to develop and apply the principles and practices of engineering required to maintain and advance agricultural production and food processing*' (CCAES, 1988). In their vision document, Fraser et al. (1995) suggested the label '*bio-agro-environmental engineering*' as a more appropriate descriptor of our profession resulting from all these changes. Their vision has evolved into the current statement of purpose adopted by the Canadian Society for Bioengineering: '*engineering in agricultural, food, environmental and biological systems*'. In their futuristic essay that is already more than 20 years old, Crossley and Curtis (1987) envisioned a 21^{st}-century food production system in which '*there will be no direct human intervention from the time a grain of wheat is planted until it turns up as bread on the family table*'. Such a system will of course require an intimate integration of many engineering as well as non-engineering disciplines well beyond the traditional field of practice of agricultural engineers.

The evolution of the agricultural engineering profession and of its field of practice in Canada is having significant impacts on the engineering education systems that are serving it. In this paper, the author begins by reviewing current trends in engineering education in Canada and in the United States of America (USA). Next, he focuses on the evolving expectations and demands resulting from the recent revisions of the professional accreditation criteria by the Canadian Engineering Accreditation Board (CEAB). In the third section, the author presents and discusses factual information relative to agricultural engineering in Canada (academic programs, student enrolment, demand for graduates, etc.). Finally, the author offers some perspectives related to desired changes to the Canadian agricultural engineering education system in order to address the opportunities that the agricultural – food – environmental – biological sectors will offer in the future as well as the changing general expectations and requirements associated to engineering education.

1. ENGINEERING EDUCATION IN CANADA AND IN THE UNITED STATES OF AMERICA The minimal educational requirements for access to the engineering profession in Canada, as well as in the USA, consist in the successful completion of a 4-year university program of study at the undergraduate level and the awarding of a bachelor degree in applied science (B.A.Sc.) or in engineering (B.Eng.). Students who enrol into engineering programs have typically completed 12 or 13 (in Québec) years of primary, secondary, and college (Québec only) education with a focus on mathematics and natural sciences at the high school / college level.

The prevalent model of engineering education in North America in which engineering schools are part of comprehensive universities that offer programs of study in a broad variety of disciplines is quite different from the one found in many other developed countries (CAE, 1997). In these countries, engineering schools are typically full fledged autonomous technical universities which are considered part of the economic system rather than of the education-science-culture domain. CAE (1997) stated that this second model presents two major advantages in terms of better integrating engineering education and research with the economy and society in general: 1. Engineering research and development (R&D) activities taking place in engineering schools are more thoroughly integrated with industrial, economic, and regional development interests and priorities, and 2. Engineering students gain a better understanding of the natural linkages between engineering R&D and real-world socio-economic implications.

1.1 Enrolment and degrees awarded There are over 40 universities and other post-secondary institutions that offer engineering programs at the undergraduate and/or graduate level in Canada. There were respectively 57,011 and 18,557 full-time equivalent (FTE) students enrolled in undergraduate and graduate engineering programs during the 2008 – 2009 academic year (Engineers Canada 2009). According to the same source, 11,619 undergraduate and 4,620 graduate degrees in engineering were granted in Canada in 2008. Figures 1.1.1 and 1.1.2 respectively present 5-year trends for student enrolment in engineering programs and engineering degrees granted in Canada. During this 5-year period, undergraduate and graduate enrolments in Canadian engineering programs have grown by 3.7 and 11.7% respectively while the number of engineering degrees granted at the undergraduate and graduate levels did increase by 12.7 and 13.4% respectively.

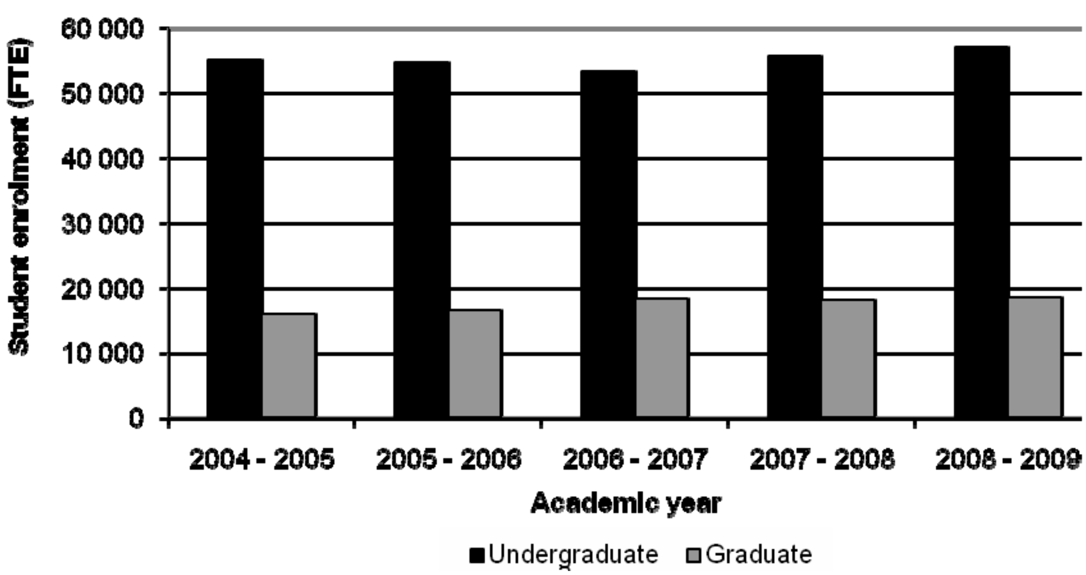

Figure 1.1.1. Undergraduate and graduate enrolment in engineering programs in Canada (2004 – 2005 to 2008 – 2009) (Source: Engineers Canada (2009)).

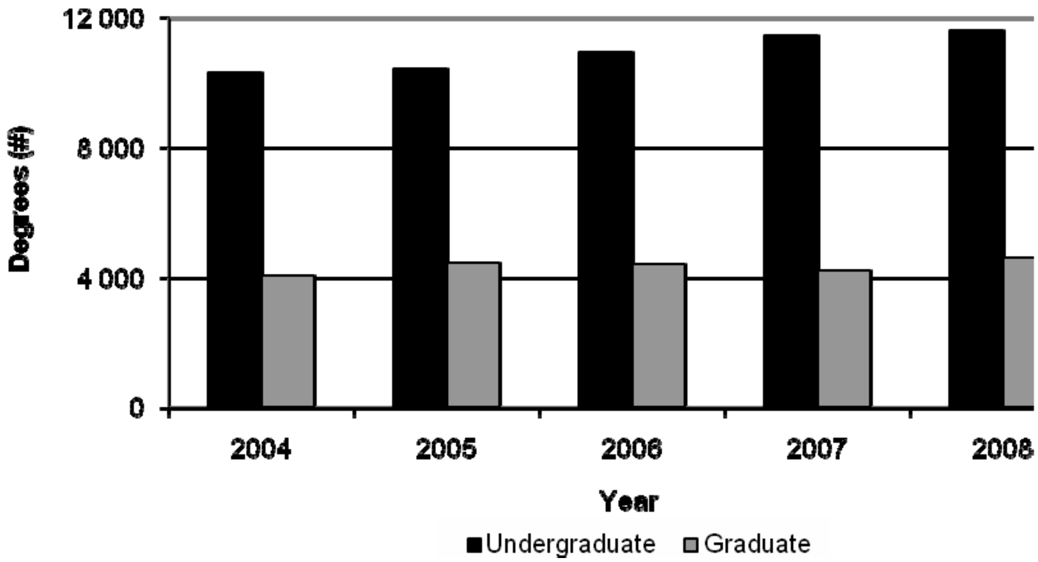

Figure 1.1.2. Undergraduate and graduate engineering degrees granted in Canada (2004 to 2008) (Source: Engineers Canada (2009)).

Figure 1.1.3 presents the evolution of the number of accredited undergraduate programs in engineering as well as of the average student enrolment in these programs of study since 1995 – 1996, as calculated from the information published in the Canadian Engineers for Tomorrow reports of Engineers Canada. It can be seen that the number of accredited programs has increased from 210 in 1995 – 1996 to 256 in 2008 – 2009. During the same period, the average student enrolment per accredited program did increase from 195 to 223 and it did reach a maximum value of 239 in 2003 – 2004.

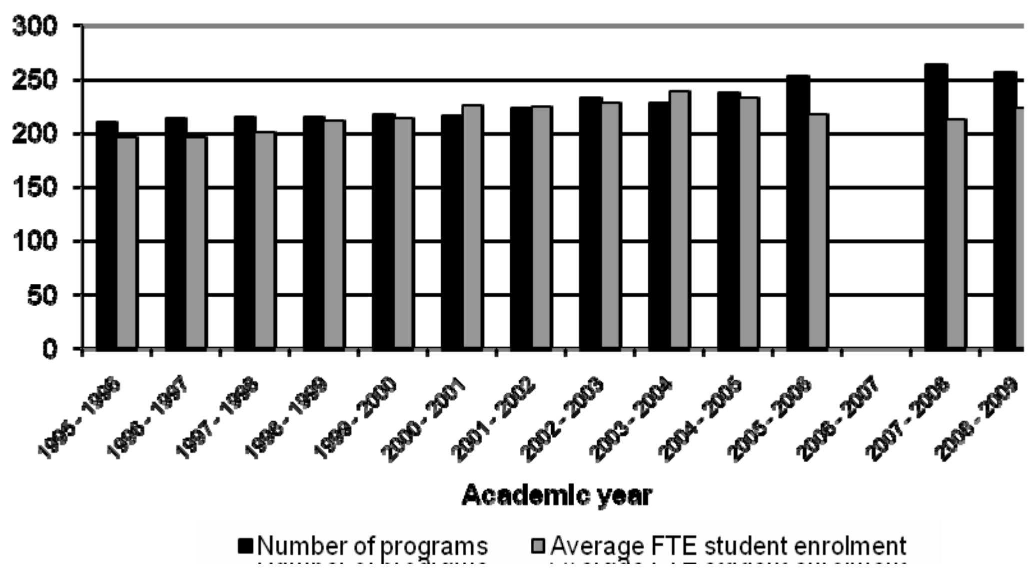

Figure 1.1.3. Number of accredited undergraduate engineering programs in Canada and average student enrolment in these programs (195 – 1996 to 2008 – 2009) (Source: Engineers Canada (Canadian Engineers for Tomorrow annual reports)).

Figures 1.1.4 and 1.1.5 present 5-year trends for student enrolment (headcount data) in engineering programs and engineering degrees granted in the USA similar to those of Figures 1.1.1 and 1.1.2. During this 5-year period, undergraduate and graduate enrolments in American engineering programs have grown by 6.6 and 5.8% respectively while the number of engineering degrees granted at the undergraduate and graduate levels did increase by 1.8 and 3.3% respectively.

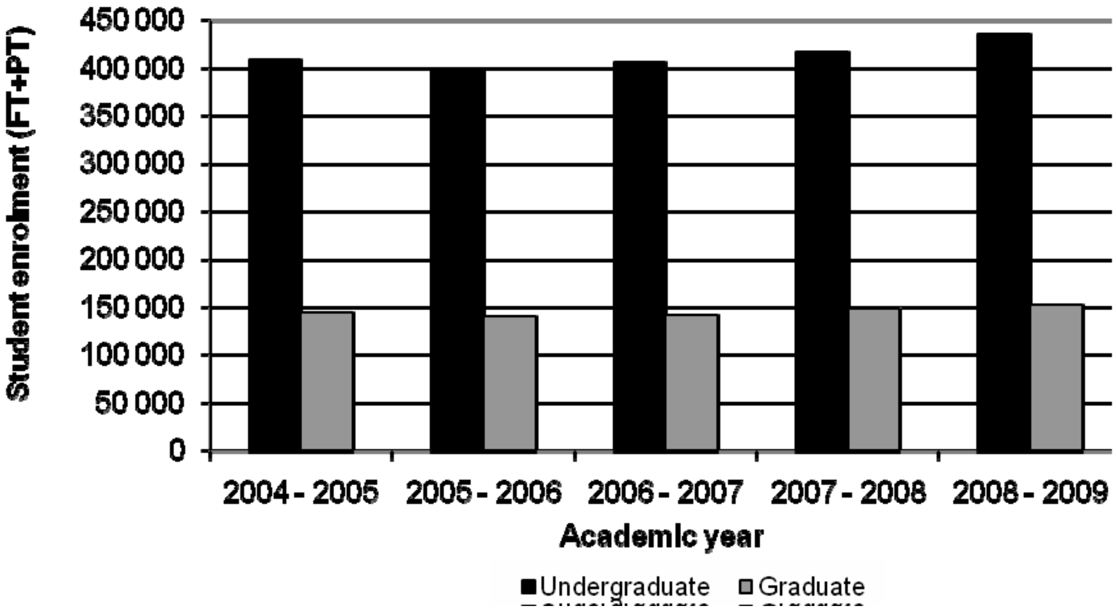

Figure 1.1.4. Undergraduate and graduate enrolment in engineering programs in the USA (2004 – 2005 to 2008 – 2009) (Source: ASEE (2009)).

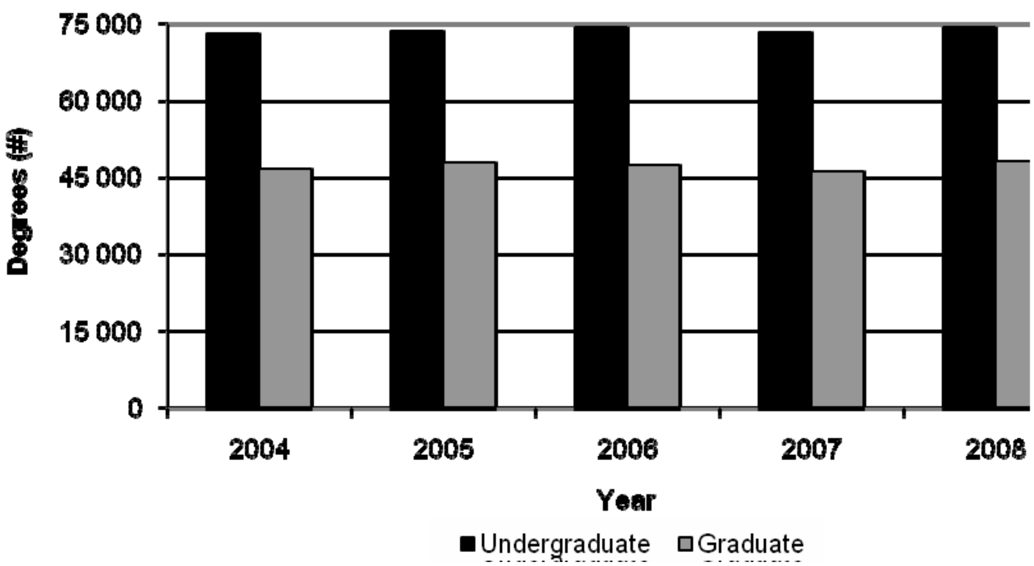

Figure 1.1.5. Undergraduate and graduate engineering degrees granted in the USA (2004 to 2008) (Source: ASEE (2009)).

1.2 Financial support to engineering education As public institutions, Canadian engineering schools rely on five broad categories of revenues to support their activities:

- Operating grant: These revenues are provided by provincial governments (education is a provincial jurisdiction in Canada) on a per-student basis according to formulas that vary from one province to the other. In Ontario for example, the value of the provincial operating grant at the undergraduate level varies between $3,100 per FTE student per year (general arts and science programs) and $24,200 (dentistry, medicine) and has a value of $8,300 in engineering (Clark et al., 2009).
- Student fees: These revenues come from students in the form of tuition and ancillary/service fees that also vary from one province to another as well as between institutions. Tuition fees for domestic (i.e. Canadian citizens and permanent residents) undergraduate students in Ontario in 2009 – 2010 ranged from just under $5,000 to more than $24,000 per FTE student per year across disciplines and institutions. The range for engineering programs was $5,110 to $9,486 (source: University of Ottawa internal data).
- Research grants and contracts: These revenues are provided by private and public organizations that sponsor research and development (R&D) activities and they cover all the direct costs (personnel (including students), equipment, materials, etc.) associated to the completion of R&D projects and programs.
- Indirect costs of research: These revenues also come from the private and public organizations that sponsor R&D activities but they are used to offset the indirect costs that are associated to these activities (e.g. internal management, use of facilities and equipment, utilities, etc.).
- Philanthropic revenues: These revenues are provided by individuals and corporations to support programs and initiatives such as financial aid to students, new infrastructure projects, chairs and professorships, etc.

The delivery of undergraduate and graduate education programs rely almost exclusively on operating grant and student fees revenues. At the University of Ottawa for example, the total unit operating revenues (expressed in dollars per financial full-time equivalent student (FFTE)) in 2009 – 2010 amounted to $13,545 (up from $12,045 in 2005 – 2006), of which $7,352 (54.3%) came from provincial grants and $5,561 (41.1%) from student fees. In 2005 – 2006, these two sources accounted for $6,684 (55.5%) and $4,722 (39.2%) respectively (source: University of Ottawa internal data).

In recent years, the proportion of operating grant revenues has been declining while student fees were increasing as provincial budgets allocated to post-secondary education have not been able to keep pace with the rapid growth of student enrolment in Canadian universities and with increasing program delivery costs (Clark et al., 2009). Between 1993 – 1994 and 2007 – 2008, the average value of the unit operating grant revenues provided to Canadian universities by provincial governments has been reduced by 0.4% (from $12,546 per FTE student to $12,500) despite the increasing delivery costs of post-secondary programs (CAUT, 2009). In addition, the values of unit operating grant vary a lot from one jurisdiction to another. In 2007 – 2008, these values ranged from a low of $9,718 per FTE student in Ontario to a high of $22,469 in Alberta. As a result, most Canadian universities have had to rely more and more on philanthropic revenues to support the offering of their undergraduate and graduate programs. A case in point: At the Faculty of Engineering of McGill University, which is currently ranked 20th among engineering and computer science schools worldwide, philanthropic revenues add about 20% to the faculty's operating revenues (Morazain, 2009).

The National Council of Deans of Engineering and Applied Science (NCDEAS) has been compiling data on the unit operating budgets available to Canadian engineering schools for the delivery of their undergraduate and graduate programs. Figure 1.2.1 illustrates the evolution of the average value of this indicator at the national level since 1995 – 1996. These data indicate that the average unit operating budget in Canadian engineering schools has increased by 57.6% between 1995 – 1996 and 2008 – 2009.

As was indicated in Section 1.1 above, there were a total of 75,569 FTE students enrolled in Canadian engineering schools in 2008 – 2009. Multiplying this value by $11,014, which was the value of the average unit operating budget available to these institutions during that same year, provides the following estimate of the total operating budget of engineering schools in Canada: $832,300,000. It is important to point out that this amount does not include the value of the services that are provided to many Canadian engineering schools by the central administration of their respective universities. This value is very difficult to estimate because of the many differences that exist in the types and scopes of central services that are available to these schools. On the basis of his academic leadership experience in three different Canadian universities, the author believes that the overall value of these central services at the national level should be of the same order of magnitude as the total operating budget for all engineering schools. For example, the distribution of the total unit operating budget (expressed in dollars per FFTE student) of $14,110 between the academic and service units of the University of Ottawa in 2009 – 2010 amounted to $6,691 (49.3%) and $7,149 (50.7%) (source: University of Ottawa internal data). On that basis, it could be reasonably estimated that the total value of the engineering education enterprise in Canada is in excess of $1.6B per year.

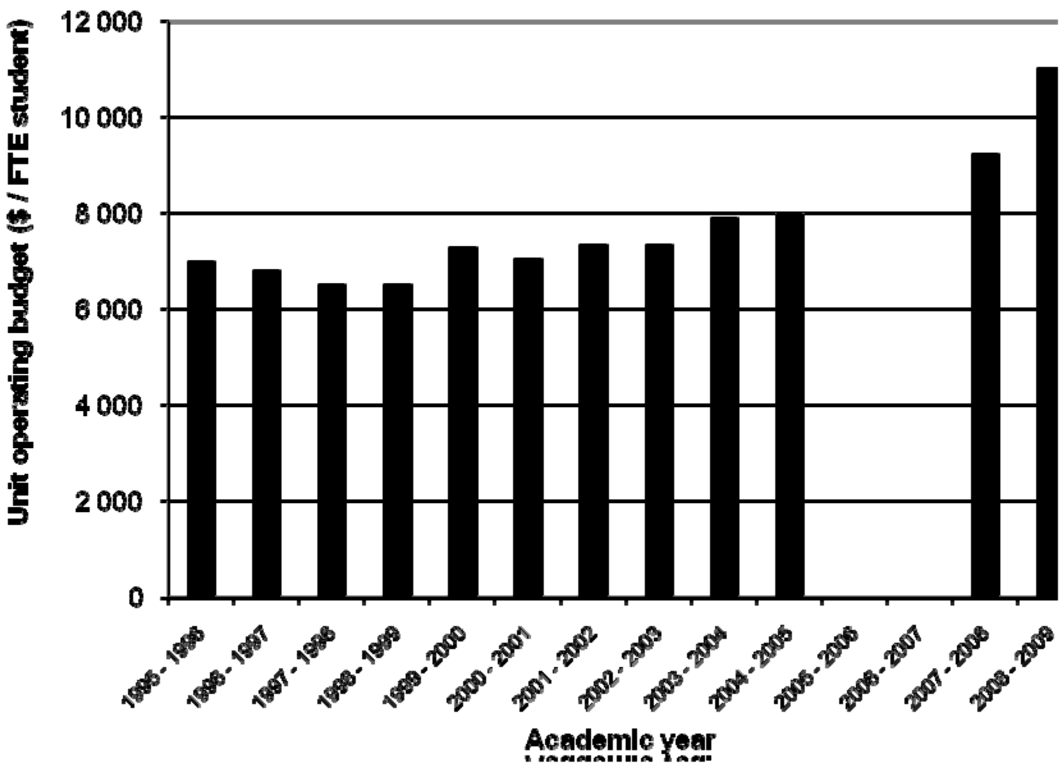

Figure 1.2.1. Average values of the unit operating budget in Canadian engineering schools since 1995 - 1996 (Source: NCDEAS).

1.3 Emerging trends As was indicated in the introduction, engineering schools and engineering education in Canada are subjected to a number of external forces and pressures that are the source of important changes. One such factor is the increasing importance of research and graduate education, especially in research-intensive universities (Boyer, 2008). Because of the fact that engineering schools are uniquely positioned to successfully address both fundamental and applied R&D endeavours, they are increasingly called upon to contribute to innovation and economic development. Brzustowski (2008) provided a very comprehensive summary of this relatively new context: '*excellence in university science and engineering promotes excellence in science and engineering across the economy and that has an impact on wealth creation and national prosperity* (…) *engineering education and research in universities contribute to wealth creation and economic development by: 1. education of students who are then employed by private and public organizations; 2. collaborative university – industry R&D endeavours; 3. successful commercialization of university research outcomes*'. In the USA, Duderstadt (2008) has recommended the establishment of Discovery Innovation Institutes closely linked to engineering schools and tailored on the medical research centres model.

New engineering education models have been proposed in the USA in recent years in the wake of changes that are occurring in the rest of the world, especially in the European Union further to the adoption of the Bologna Accord on post-secondary education. Duderstadt (2008) and Galloway (2008) have both proposed to extend the minimal educational requirements for entry into the engineering profession from four to five years. These two authors and others such as King (2008) in Australia are also calling for the inclusion or strengthening of key complementary studies elements in engineering curricula: communication, ethics and professionalism, diversity, globalization, leadership, life-cycle analysis, multidisciplinarity, project management, public policy, risk management, social – business – legal – economic considerations, sustainability. Beck and Connoly (1995) identified four skills required of engineers to thrive in the new information age technology: 1. computer skills, 2. information and communications, 3. working as a team, and 4. communications skills. Sheppard (2009) argues that engineering education should be articulated around four integrated goals: '*1. Developing a robust base of substantive knowledge of engineering science; 2. Developing robust skills for using knowledge to interactively formulate and solve problems: creativity, engineering intuition, practical ingenuity; 3. Developing the attitudes necessary to interactively formulate and solve problems: persistence and healthy scepticism, dynamism, agility, and flexibility; 4. Developing the skills and attitudes for effective leadership, teamwork, and communication; enabling students to move from being passive viewers of engineering action to taking their place as active participants or creators within the field of engineering*'. This constitutes a complete paradigm shift compared to the views that have prevailed since the beginning of the twentieth century and that were reflected in the views of the Society for the Promotion of Engineering Education (SPEE) in 1896 – '*crowded density of the engineering curriculum resulting in the need to eliminate 'cultural' courses'* – and again in 1905 – '*hope to abandon all requirements in English and foreign languages, as reportedly the humanities and social sciences disciplines were considered to have little merit to the engineer'* (reported in Leydens and Schneider, 2009).

In Canada, the Canadian Academy of Engineering published its Engineering Education and Canada report in 1997 (CAE, 1997). This seminal report contains a number of recommendations that all arise from the acknowledgement that *the primary goal of engineering education must derive from that of the profession of engineering, which is to provide society with engineering services of high quality*. CAE (1997) identified seven key issues that need to be considered in the review of the overall Canadian engineering education system:

- *Broader, less specialized, more integrated undergraduate programs with increased emphasis on design and social context.*
- *Increased interaction between engineering professors and practitioners in the profession.*
- *One-year professional masters programs.*
- *More formal development programs for Engineers-in-Training.*
- *More formal continuing education programs.*
- *Expanded cooperative research and development programs.*
- *Enhanced professional experience for engineering professors.*

Colombo and Karney (2009) have emphasized the importance for engineers to become much more familiar with public policy development and they stated that: *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*. Building on the experience acquired at McMaster University's Dofasco Centre for Engineering and Public Policy, Krantzberg and Hrymak (2009) have further highlighted the importance of the contributions that engineers educated in public policy could make in the specific case of the infrastructure renewal and revitalization projects that governments worldwide are currently undertaking.

Vanasupa et al. (2009) have proposed an innovative, open-ended approach to engineering education making use of the Four-Domain Development Diagram (4DDD) that promotes a more effective learning experience. According to these authors, this allows for a broader and more effective development of the cognitive, social, affective, and psychomotor skills that today's engineering graduates should demonstrate.

2. PROFESSIONAL ACCREDITATION OF ENGINEERING PROGRAMS IN CANADA The Canadian Council of Professional Engineers (CCPE) is the federation of the provincial and territorial regulating bodies that license engineers and oversee the engineering profession in Canada. In 1965, the CCPE (that now operates under the business name of Engineers Canada) established the Canadian Engineering Accreditation Board (CEAB). CEAB's role is to accredit Canadian undergraduate engineering programs that meet or exceed educational standards acceptable for professional engineering registration in Canada (CEAB, 2008).

Until recently, CEAB's accreditation criteria included three broad categories of criteria: student-related processes (admission, promotion and graduation, counselling and guidance); curriculum content; program environment. In 2008, the CEAB introduced a fourth category of outcome-based criteria that address the changing expectations that were discussed in the introduction of this paper as well as in section 1.3 above. This new category – which directly builds upon recommendation 21 of the CAE (1997) report (*The Canadian Engineering Accreditation Board should place its primary emphasis on criteria which depend on measures of the (…) quality of the attributes, skills and knowledge acquired by the undergraduate engineering students*) – includes the following 12 graduate attributes: knowledge base for engineering, problem analysis, investigation, design, use of engineering tools, individual and team work, communication skills, professionalism, impact of engineering on society and the environment, ethics and equity, economics and project management, and life-long learning (CEAB, 2008). This new category of criteria is being introduced in a progressive manner during a phase-in period that will end in 2014. At that time, engineering schools will need to demonstrate: 1. that graduates of their programs of study possess these 12 attributes at the time of graduation and 2. that program outcomes are being assessed in the context of these attributes and that the results of these assessments are applied to the further development of the program (i.e. continuing improvement).

The new CEAB graduate attributes criteria represent a major paradigm shift for engineering education in Canada. However, it is something that is consistent with changes that have been happening and continue to happen with other national accreditation systems for engineering as well as for other professions. The evolution of the CEAB criteria is also aligned with the Ministerial Statement on Quality Assurance of Degree Education in Canada that was released by all the provincial ministers of education of the country in 2007 (CMEC, 2007). These general expectations have been translated into six Undergraduate Degree Level Expectations (UDLE) in the province of Ontario that directly relates to the CEAB graduate attributes (OCAV, 2007):

- Depth and breadth of knowledge
- Knowledge of methodologies
- Application of knowledge
- Communication skills
- Awareness of limits of knowledge
- Autonomy and professional capacity

Before the introduction of the CEAB graduate attributes, Canadian undergraduate engineering programs used to be developed and modified over time according to input-based parameters that were relatively easy to control and modify, especially in the area of curriculum content. From now on, four additional considerations will need to be taken into account (Frank, 2009):

- What are specific and measurable criteria associated to each graduate attribute?
- How to measure each of these criteria?
- Where (i.e. lecture, laboratory, project, work term (co-op, internship), etc.) to measure each of these criteria?
- How to integrate the measurements relative to each criterion in a continuing program improvement process?

3. AGRICULTURAL ENGINEERING IN CANADA

3.1 Education Formal undergraduate education in agricultural engineering in Canada goes back to the early 1900's. A chronological list of Canadian undergraduate agricultural engineering programs was compiled by CCAES (1988):

- University of Saskatchewan (1925)
- University of British Columbia (1949)
- Ontario Agricultural College (under the University of Toronto (1956) and then under the University of Guelph (1967))
- Université Laval (1969)
- University of Manitoba (1971)
- McGill University (1971)
- Technical University of Nova Scotia (1972)
- University of Alberta (1982)

Further to a request to that effect, Engineers Canada graciously provided the author with historical enrolment and degree awarded data for the following engineering disciplines that encompass the bulk of the overall agricultural engineering field:

- Agricultural engineering
- Agricultural and bioresource engineering
- Biological engineering
- Bio-resource engineering
- Biosystems engineering
- Food engineering
- Génie agroenvironnemental
- Génie alimentaire
- Génie rural
- Water resources engineering

Figures 3.1.1 and 3.1.2 respectively present trends for student enrolment and degrees granted in the above engineering disciplines in Canada for the period 1991 – 1992 to 2008 – 2009. Between 1991 – 1992 and 1997 – 1998, undergraduate enrolment did increase by almost 85% but this was followed by a 34% decline from 1997 – 1998 to 2008 – 2009. The 398 FTE students that were enrolled in these programs in 2008 – 2009 correspond to an all-time low since 1992 – 1993. Graduate enrolment reached a maximum value of 233 FTE students in 1994 – 1995 and it had been reduced to 152 in 2008 – 2009. The number of engineering degrees granted in these disciplines did vary from 74 to 153 at the undergraduate level and from 21 to 67 at the graduate level during that 18-year period of time. Values in 2008 had reached 124 and 44 respectively.

A comparison of these agricultural engineering enrolment and degree awarded data with the overall data presented on Figures 1.1.1 and 1.1.2 for the period 2004 – 2005 to 2008 – 2009 indicates the following comparative trends:

- Undergraduate enrolment: Decrease of 15.5% vs. overall growth of 3.7%.
- Graduate enrolment: Increase of 25.6% vs. overall growth of 11.7%.
- Undergraduate degrees: Increase of 13.8% vs. overall growth of 12.7%.
- Graduate degrees: Increase of 110% vs. overall growth of 13.4%.

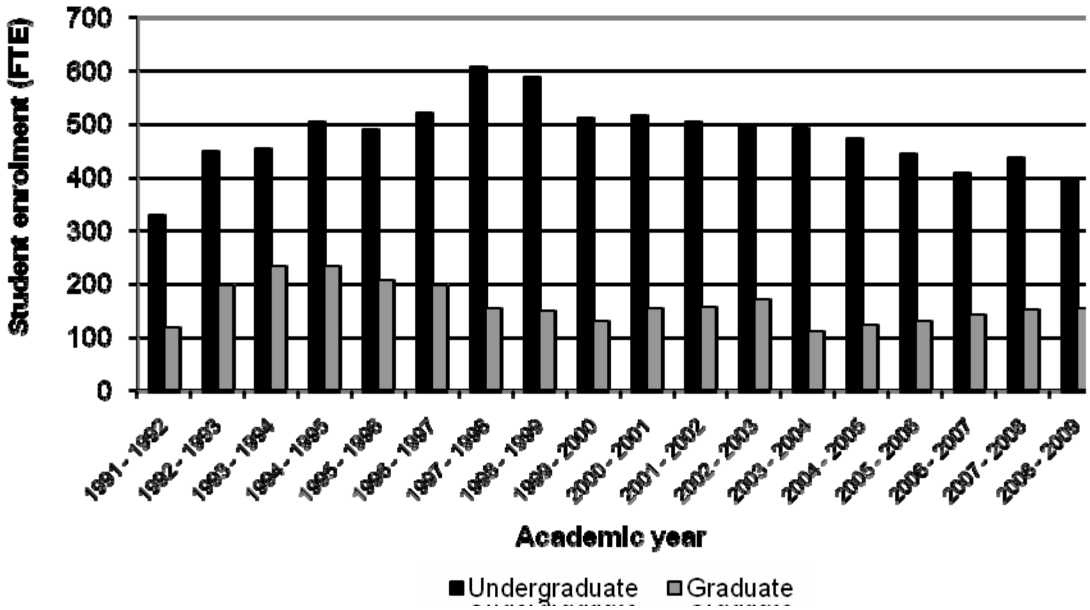

Figure 3.1.1. Undergraduate and graduate enrolment in agricultural engineering programs in Canada (2004 – 2005 to 2008 – 2009) (Source: Engineers Canada (personal communication)).

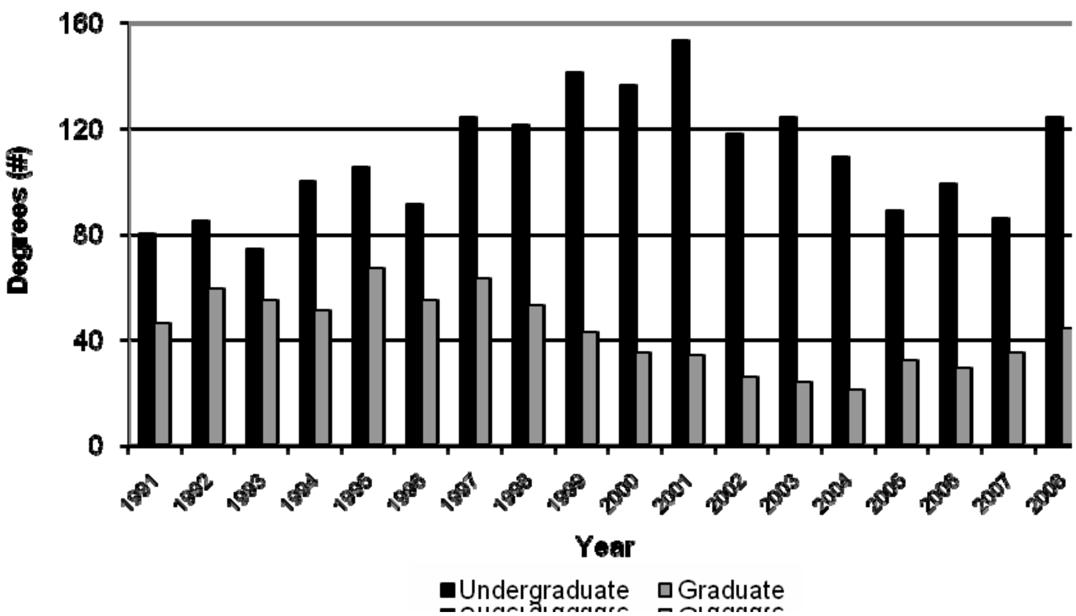

Figure 3.1.2. Undergraduate and graduate agricultural engineering degrees granted in Canada (2004 to 2008) (Source: Engineers Canada (personal communication)).

One can also use these data to assess the relative importance of these agricultural engineering enrolment and degree awarded data with regards to the most recent (2008 – 2009) national numbers:

- Undergraduate enrolment: 0.7%.
- Graduate enrolment: 0.8%.

- Undergraduate degrees: 1.1%.
- Graduate degrees: 1.0%.

At the time that they reached their respective peaks, undergraduate (peak of 606 FTE students reached in 1997 – 1998) and graduate (peak of 233 students reached in 1994 – 1995) enrolment in agricultural engineering programs represented 1.4% and 2.5% of the total FTE student enrolment in Canadian undergraduate and graduate engineering programs of study respectively.

This analysis indicates that the agricultural engineering sector currently accounts for about 1% of the total Canadian engineering education system in terms of both student enrolment in undergraduate and graduate programs of study and degrees awarded. On the basis of the financial data presented in Section 1.2 above, it may thus be estimated that the agricultural engineering education enterprise currently receives annual funding in the order of $16M in the form of provincial operating grants and student fees.

3.2 Professional practice In its 50^{th}-anniversary overview of the Canadian engineering profession covering the period 1936 to 1986, CCPE (1986) identified three (3) agricultural engineering-related milestones out of a total of 29: self-propelled combine (1938), mechanized seeder (1952), and the vacuum transport of maple sap (1969). When the National Academy of Engineering identified the twenty greatest engineering achievements of the 20th century in the USA, it ranked agricultural mechanization in seventh position, ahead of better known engineering milestones such as computers, spacecrafts, and even the telephone (Goering et al., 2003).

Despite these significant contributions, agricultural engineering as a profession suffers from a similar lack of popularity as the one for education programs described in Section 3.1 above. In its 1997 survey of the Canadian engineering profession, CCPE (1998) reported a total of 1,486 Canadian engineers active in the general field of biosystems engineering out of a total of more than 120,000 registered engineers at the time. Data on the number of engineers by field of occupation from this survey are presented on Figure 3.2.1 and the distribution of biosystems engineers across the different provinces and territories of the country is presented on Figure 3.2.2. The proportion of biosystems engineers in the total engineering population in 1997 varied from a low of 0% in Yukon and in the Nothwest Territories to a high of 11% in Prince Edward Island for a national average of 1.25%.

In 2009, Engineers Canada, the Canadian Council of Technicians and Technologists (CCTT), and Human Resources and Skills Development Canada (HRSDC) jointly published the results of a national Engineering and Technology Labour Market Study (Engineers Canada et al., 2009). The survey of practising engineers and of engineering technicians and technologists that was completed as part of this study indicated that less than 1% of the sampled engineers did hold a bachelor degree in the general field of agricultural engineering (Engineers Canada and CCTT, 2009).

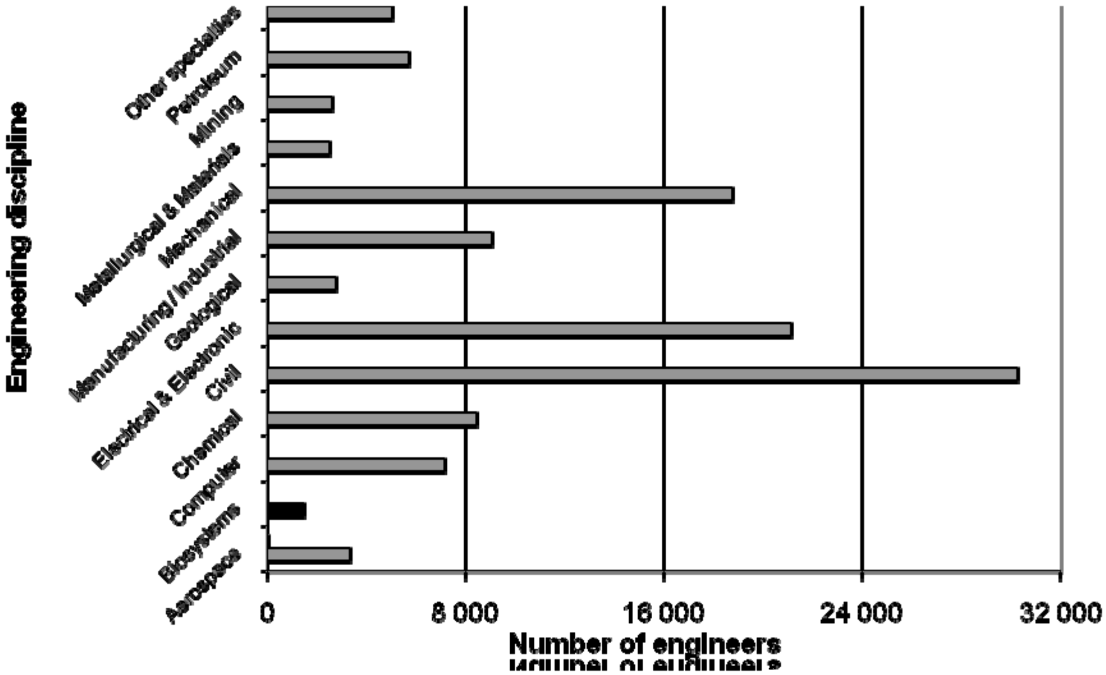

Figure 3.2.1. Number of engineers by field of occupation in Canada in 1997 (Source: CCPE (1998)).

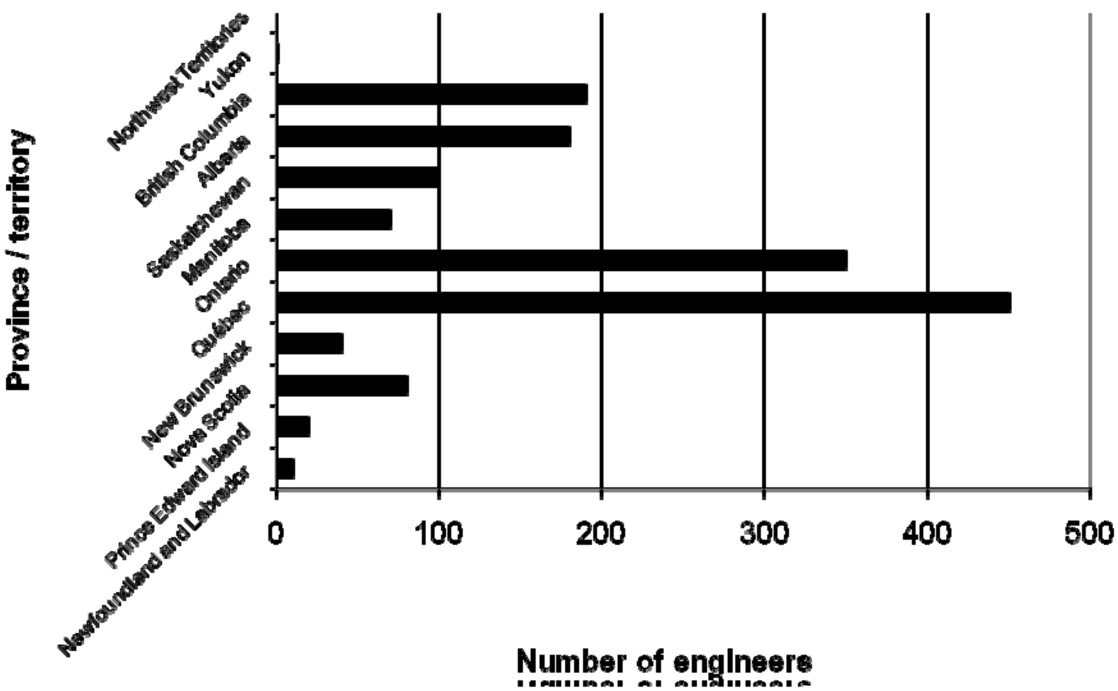

Figure 3.2.2. Number of biosystems engineers by province / territory in Canada in 1997 (Source: CCPE (1998)).

The author has analyzed the offers of employment for engineering positions in the province of Québec published in the weekly electronic newsletter 'Info-Réseau' during the period July 1, 2008 to December 31, 2009 (RIQ, 2008 – 2009). A total of 1,549 engineering positions were announced during that 18-month period, including only nine (9) related to agricultural engineering and six (6) to food engineering. Together, these 15 positions accounted for less than 1% of the total number of positions offered.

Huffman (2009) expressed serious concerns about this very low representation in terms of the recognition of the agricultural engineering discipline for professional registration (i.e. PE status) in the USA. In that country, agricultural engineering is part of Group II, a group that includes the smaller disciplines that are 'subsidized' by the core Group I disciplines (i.e. chemical, civil, electrical, and mechanical engineering) with regards to the professional registration examinations. The professional registration regulations in place in the USA require a minimum of 50 first-time takers of the examinations in any given discipline over any two-year period of time. The data presented by Huffman (2009) indicate that the agricultural engineering PE examination has not met these requirements since 2003: 22 (2003), 20 (2004), 18 (2005), 24 (2006), 18 (2007), and 24 (2008). Even if the current probationary status of the agricultural engineering PE examination has been extended to 2011, it is at a serious risk of being discontinued after that. This would have major negative implications on the professional recognition of the agricultural engineering profession in the USA.

4. PROPOSED CHANGES TO THE CANADIAN AGRICULTURAL ENGINEERING EDUCATION SYSTEM

4.1 Context The historical program accreditation data compiled by CEAB (2008) and presented in Table 4.1.1 provide a good indication of the many changes to which the Canadian agricultural engineering education system has been confronted over the years. It is worthwhile to note that all eight original programs (re. Section 3.1) as identified by CCAES (1988) had all changed their names as of 2008. Only Université Laval (génie agroenvironnemental, génie alimentaire) and the University of Saskatchewan (agricultural and bioresource engineering) currently offer undergraduate programs whose names directly refer to either agriculture or food. The situation is somewhat different in the USA where more than half (25 of 47) of the undergraduate programs included in the 2009 list published by ASABE still include the words 'agricultural' or 'food' in their names (ASABE, 2009a).

Engineering challenges and opportunities continue to exist in the Canadian agri-food sector regardless of the names that are used to qualify agricultural engineering as a discipline and a field of practice. ASABE (2009b) for example has identified ten different areas in which the expertise of agricultural engineers continues to be in demand: aquaculture, bioprocess engineering, energy, environmental quality, food and process engineering, information and electrical technologies, power and machinery, soil and water, standards and safety, structures and environment. While this comprehensive list does not imply that agricultural engineers are the only ones who can effectively solve engineering problems in these ten very broad areas, it does however signal that the expertise of agricultural engineers is required, albeit at different levels, in each of them

(Laguë et al., 1994). Engineering in the agri-food sector is a field of practice that is directly connected to fundamental human needs such as clothing, energy, food, and water. Because of that, agricultural engineering, if appropriately celebrated and promoted, could contribute to attract more women into the engineering profession given that women are especially attracted to engineering disciplines that are closely related to life sciences (Frize, 2009).

Table 4.1.1. Periods of accreditation of undergraduate programs of study in the agricultural engineering field in Canada.

Name of discipline	Institution	Accreditation period	
		Beginning	End
Agricultural engineering	University of British Columbia	1965	1978
	University of Saskatchewan	1965	1992
	University of Manitoba	1971	1998
	McGill University	1971	2006
	University of Guelph	1973	1995
	Dalhousie University	1974	2000
	University of Alberta	1983	1995
Agricultural and bioresource engineering	**University of Saskatchewan**	**1992**	**n/a**
Biological engineering	**University of Guelph**	**1973**	**n/a**
	Dalhousie University	**1997**	**n/a**
Bioresource engineering	**McGill University**	**2005**	**n/a**
Bio-resource engineering	University of British Columbia	1979	2001
Biosystems engineering	**University of Manitoba**	**1996**	**n/a**
Chemical and biological engineering	**University of British Columbia**	**2003**	**n/a**
Environmental engineering	**University of Windsor**	**1991**	**n/a**
	University of Waterloo	**1999**	**n/a**
	Carleton University	**1996**	**n/a**
	Dalhousie University	**2006**	**n/a**
	University of British Columbia and University of Northern British Columbia	**2007**	**n/a**
Food engineering	University of Guelph	1993	2000
Génie agroenvironnemental	**Université Laval**	**2002**	**n/a**
Génie alimentaire	**Université Laval**	**1997**	**n/a**
Génie rural	Université Laval	1973	2002
Water resources engineering	University of Guelph	1973	n/a

Note: Entries in **bold characters** correspond to programs that were still accredited as of 2008.

4.2 Vision In 2000, the author did propose a vision for agricultural engineering education and R&D in the province of Québec (Laguë, 2000). His proposal called for the creation of the Institut de génie agroalimentaire du Québec (IGAQ) that would assume the postsecondary education responsibilities in agricultural engineering currently carried by three different institutions (one college and two universities) as well as fundamental and applied R&D activities in that discipline. Given the difficulties that have confronted the Canadian agricultural engineering education system during the last decade (e.g. drop in student enrolment and degrees granted (re. Figures 3.1.1 and 3.1.2); program changes (re. Table 4.1.1)) and the challenges and opportunities that currently lie ahead of the engineering profession and of the engineering education system, the author is of the opinion that a consolidation of agricultural engineering education (at the college and university levels) and of agricultural engineering R&D and public service activities on the model of the proposed IGAQ is necessary. These institutes would move the Canadian agricultural engineering education system closer to the technical university model that is found in many other developed countries and that offers advantages compared to our current engineering education system (CAE, 1997).

Below is a preliminary list of key characteristics of these Canadian *Agricultural* (or other more appropriate qualifier) Engineering Centres/Institutes:

- **Number and geographic distribution**: 4 (one for the four Atlantic Canada provinces, one in Québec, one in Ontario, and one for the four Western Canada provinces); this would be similar to the structure that currently exists for veterinary medicine education and research in Canada. The Atlantic provinces and Ontario have already consolidated their university-level programs in agricultural engineering at two universities (Dalhousie University, University of Guelph) and these institutions would constitute obvious choices for the establishment of the Atlantic and Ontario institutes respectively. The institute for the Western provinces could be built around the existing Prairie Agricultural Machinery Institute (PAMI) that currently operates applied R&D centres in Manitoba and in Saskatchewan. The author continues to believe that the Québec Institute (IGAQ) should be established in Saint-Hyacinthe where it could take advantage of existing forces in the agri-food sector (e.g. Institut de technologie agroalimentaire, Faculté de médecine vétérinaire of the Université de Montréal, etc.).

- **Program offering**: 2- and/or 3-year technical programs, undergraduate programs, graduate programs at the master's (professional and research) and doctoral levels. Provisions would exist to streamline the transfer of qualified technical students to the university-level undergraduate programs as well as the transfer of engineering students having completed one or two years of general undergraduate engineering education in other engineering schools. The undergraduate engineering curricula would be designed around the general concept of outcome-based assessment and more specifically the 12 graduate attributes criteria of the CEAB (re. Section 2). On the basis of the data presented in Figure 3.1.1, total student enrolment in university-level undergraduate and graduate programs of study across the four institutes could amount to 500 and 200 FTE students respectively.

- **Faculty and professional complement**: Faculty members would include professional engineers as well as specialists from other disciplines to provide the comprehensive educational experience that will be required for future engineers (re. Section 1). The faculty complement of the institutes would include both professional practitioners and academics that would contribute to the different types of programs according to their individual expertise and interests. In addition to this diverse teaching staff, other professionals (practitioners and academics) would also contribute to the R&D and public service missions of the institutes.

- **Capital and operating funding**: The creation of the four proposed institutes will obviously require significant amounts of one-time capital funding in terms of infrastructure and equipment. The specific amounts will depend on a number of elements: types and number of college- and university-level programs to be offered, expected student enrolment, possibility of using existing physical resources, etc. Appropriate operating funding from diverse sources (i.e. provincial grants, student fees, multi-year contributions from stakeholders in the agri-food sector, etc.) will also be needed to ensure the long-term sustainability of these institutes. The $16M in annual operating funding that the author has estimated as the current share of agricultural engineering education in Canadian universities would translate in unit operating funding to support the offering of university-level programs of just under $23,000 per FTE student per year.

This new integrated model would positively address at least five of the seven key issues identified by CAE (1997) for the review of the overall Canadian engineering education system and that were presented in section 1.3:

- *Broader, less specialized, more integrated undergraduate programs with increased emphasis on design and social context.*
- *Increased interaction between engineering professors and practitioners in the profession.*
- *More formal continuing education programs.*
- *Expanded cooperative research and development programs.*
- *Enhanced professional experience for engineering professors.*

Further more, the author believes that the establishment of these proposed institutes could revitalize the education and R&D activities in the area of agricultural engineering as well as the profession itself. It would also allow for a more effective and efficient use of the private and public resources that are invested in agricultural engineering education. These institutes would constitute unique testing grounds for new approaches and delivery methods in engineering education and could make agricultural engineering a leading discipline in the ongoing quest to educate well-rounded engineers. These integrated engineering schools / research / public service centres would be in a unique position to educate the global engineers of the future as described by Chan and Fishbein (2009):

- *Engineers who understand the broad, bigger-picture context of engineering work.*
- *Engineers having excellent expertise in one discipline yet comfortable in many disciplines and able to work in an interdisciplinary way.*
- *Engineers who are creative problem solvers.*
- *Adaptive engineers who can deal with complexity and are skilled at systems thinking.*
- *Engineers who can collaborate on a global basis and possess an understanding of people, cultures, and languages and are aware of current world issues and emerging trends.*
- *Engineers who understand and apply sustainability.*

- *Engineers who have a well-developed sense of social responsibility and ethics for their own professional and personal activities as well as for the world and society in general.*
- *Entrepreneurial engineers who are prepared to work in various types of organizations and in many different roles.*

At the undergraduate level, the agricultural engineering programs offered by these institutes would be very general with no options or streams into any particular disciplinary field (e.g. buildings, environment, food, machinery, soil and water, etc.) as it is currently the case in many existing programs. Specialization would only occur at the graduate level.

In light of the new graduate attributes accreditation criteria of the CEAB, these undergraduate agricultural engineering programs could likely evolve from the traditional course-based model to the project-based learning model that is becoming increasingly popular in other professional disciplines (e.g. medicine). Table 4.2.1 presents a high-level description of the materials that should be included, either in the form of courses or project-related modules, in such programs.

SUMMARY On the basis of the data collected and analyzed, the author estimates that agricultural engineering currently accounts for about 1% of both the engineering education systems and of the engineering profession in Canada. In order to optimize the use of the public and private resources that are required to support the delivery of agricultural engineering education programs, the author proposes to create four regional Canadian Agricultural Engineering Institutes that would be responsible for post-secondary education programs in agricultural engineering (at the college and university levels) as well as for agricultural engineering R&D and for public services activities to various stakeholders. The undergraduate agricultural engineering programs that would be offered by these institutes would include the desirable features that have been identified by various engineering education leaders: outcome-based assessment of graduates, increased emphasis on 'non-engineering' disciplines, less specialization.

Table 4.2.1. Proposed content of undergraduate agricultural engineering programs.

Component	Examples	Approximate program content (%)
Mathematics	Calculus, differential equations, discrete mathematics, linear algebra, probability and statistics, numerical analysis	10
Natural sciences	Animal and plant sciences, biology, chemistry, geology, physics	10
Fundamentals of engineering	Computer science, controls, electrical and electronic circuits, fluid and solid mechanics, history of engineering, strength of materials, transport phenomena	10
Fundamentals of agricultural engineering	History of engineering in the agri-food sector, interactions between biological systems and engineered systems	10
Management	Business administration, engineering economics, entrepreneurship, project management	10
Professional communication	Effective communications (reading, writing, speaking, listening) to experts and to the general public	10
Professional behaviour and practice	Accountability, equity, professional ethics, roles and responsibilities of engineers, social and environmental aspects of engineering, sustainability	10
Problem analysis and engineering design	Definition of agricultural engineering problems (identification, formulation, analysis, resolution), inclusion of all relevant aspects (e.g. economical, environmental, social, political, etc.), integration of increasingly complex agricultural engineering problems from the beginning to the end of the curriculum	30

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Academic leadership experience of the author. Dr. Laguë has been the Dean of the Faculty of Engineering at the University of Ottawa since 2006. He has served on the Executive Committee of the National Council of Deans of Engineering and Applied Science (NCDEAS/CCDISA) as Chair (2008 – 2010) and Past-Chair (since 2010) and he is the current Vice-Chair of the Council of Ontario Deans of Engineering (CODE). Previous academic leadership positions include: Dean of the College of Engineering at the University of Saskatchewan (2002 – 2006), vice-doyen à la recherche (1995 – 1996) and directeur du département des sols et de génie agroalimentaire (1996 – 1999) at Université Laval.

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