



Strategic Plan

of the Department of Chemistry
Queen's University
2018-2023

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Queen's Chemistry Mission Statement

Q*The Department of Chemistry has a long tradition of teaching and research excellence in a supportive community fostering fairness, diversity, and respect for individual creativity. Our mission is to discover and disseminate new knowledge and, through education and research, address challenges of relevance to industry and global society.*

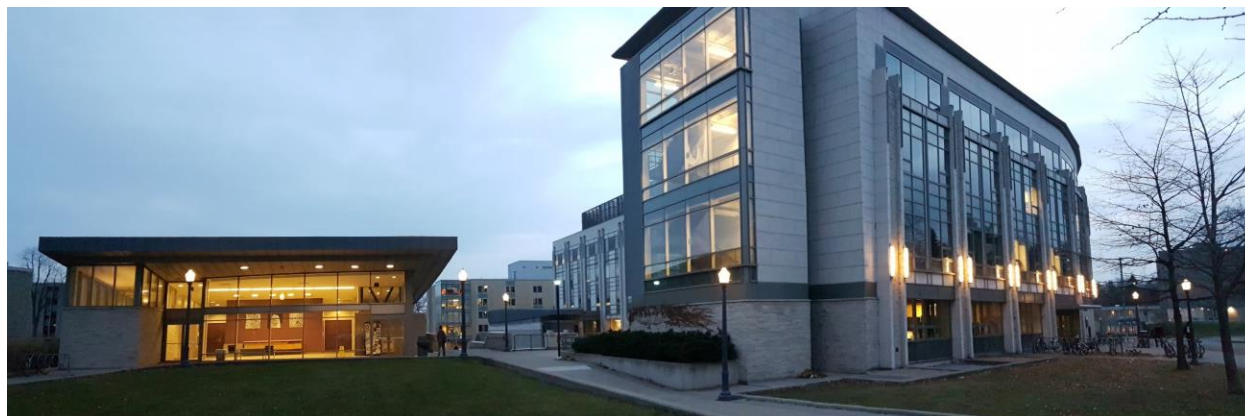
1 Executive Summary

In 2018 the Department of Chemistry at Queen's University is in the enviable position to be able to invest in the education and research of its members. We have several opportunities to substantially improve the delivery of our educational programs and to further increase our research activity. This plan describes several initiatives that will be launched with the aim to sustainably grow and improve our departmental activities. All are fully aligned with our mission *"to discover and disseminate new knowledge and, through education and research, address challenges of relevance to industry and global society"*.

The undergraduate program delivery will be both improved and expanded. The revised curriculum will include a new course for non-science students, tentatively titled "Chemistry for Decision Makers". We will also improve labs and lecture components in CHEM112, rebalance the workload in the second-year courses and update the 3rd-year lab course. With these initiatives we intend to make the chemistry program more attractive to our own students and to those in other programs. These revisions in combination with enhanced promotion of our program to first-year students are aimed at increasing the number of chemistry majors to about 50 per year. All these initiatives will be implemented in consultation and collaboration with the Queen's Chemistry Undergraduate Student Council and their representatives.

We will also increase our graduate enrollment to about 150 Ph.D. and M.Sc. candidates. Several recruitment initiatives will help us increase the number of domestic and international applicants, including some that are targeting our own undergraduates. We will increase the breadth of the graduate program offerings through the introduction of new programs such as certificates, professional programs and joint international programs. Finally, in collaboration with the Queen's Graduate Chemistry Society, we will aim to improve the graduate experience by strengthening the ties between faculty, staff, and graduate students through, both, formal interactions and social events.

Currently, departmental infrastructure is replaced on an *ad hoc* basis, which sometimes leads to research delays when an instrument ages poorly or fails entirely. A proactive infrastructure review and replacement strategy will help us predict the remaining life of departmental instrumentation used for teaching and research and replace these instruments before they fail catastrophically. We plan to use all departmental infrastructure much more frequently for service contracts and other external work, thereby increasing the departmental revenue and our reputation for research excellence.



Examination of our department's impact on chemistry research and education in Canada indicates a strong correlation to the number of full-time faculty. To further increase our international reputation, we must increase our complement of research-active faculty. Departmental growth is ultimately limited by the availability of research space; the capacity of Chernoff Hall is estimated at 27-30 research groups. Currently, we house 22 research groups. New hires will be selected based on their ability to address global research needs and to educate undergraduate and graduate students. In both regards, we acknowledge that "growth happens at the interface", i.e. we expect that future faculty hires have chemistry expertise that is complementary to those already in the department and that they are interested in collaborative and interdisciplinary research. Diversification of the department through the hire of under-represented groups such as women and members of visible minorities is expected to not only increase our educational and research impact but also set an example nationally. Several other initiatives described in the plan will help further increase our capacity for collaborative and diverse research. This is consistent with our vision to become the most collaborative and diverse department in Canada.

The Department of Chemistry at Queen's University is at a crossroads in 2018. While our reputation for teaching and research excellence remains outstanding, we also need to acknowledge that trends in the last decade have not been in our favour and, consequently, we have become an aging and shrinking department with a small undergraduate program compared to other STEM departments at Queen's. This strategic plan provides for a route to reverse many of these trends. Most initiatives involve sustainable growth of our existing programs and of the associated faculty and staff complement. While growth also entails considerable risk – and requires sacrifices from most of us - it is required to give students a better choice of more attractive courses, to permit research on a grander scale, and to (re)establish Queen's Chemistry among the top chemistry departments in Canada.

Only through a renewed investment of funding and a commitment by all departmental members, will we be able to fully realize the core of our mission *"to discover and disseminate new knowledge and, through education and research, address challenges of relevance to industry and global society"*.



2 Preamble

The Department of Chemistry at Queen's University is one of the oldest chemistry departments in Canada. Queen's University offered instruction in chemistry as early as 1854 and has been granting degrees in Chemistry for over 100 years. To remain not only relevant but also at the forefront of chemistry education and research, our department must remain innovative in its research endeavours, and imaginative in its educational program delivery. Only by looking forward and adapting quickly to a rapidly evolving society, changing student expectations, and ever-changing financial constraints, are we able to maintain and grow our reputation for excellence in research and education.



Our departmental staff consists currently (March 2018) of 23 research-active faculty (professors, associate professors and assistant professors), 3 continuing adjunct professors, 7 emeritus professors, 3 instrumentation managers, 6 technical staff, 7 administrative staff, and 3 research administrators. We direct 115 graduate students in M.Sc. and Ph.D. degree programs and approximately 100 students (2nd - 4th year) in Chemistry Major degree programs. We also co-instruct nearly the same number of students in the Engineering Chemistry program.

The 2018-2023 Strategic Plan builds on what has been accomplished in the past and follows the 1995-2000 Strategic Plan, the 2001-2006 Strategic Plan, and the May 2006 Strategic Planning Exercise¹. The current plan describes short- and long-term goals and includes several concrete recommendations that will form the basis for future reviews of our undergraduate and graduate curricula, allocation of financial resources and staffing/hiring priorities.

This Strategic Plan is based on a working document that was the outcome of a day-long strategic planning session on December 5th, 2017. All full-time faculty, as well as the Departmental Manager and Advancement Coordinator were invited to the retreat and contributed to the working document. A first draft of the Strategic Plan was written by the Department Head (H.-P. Loock). It was in turn reviewed and revised by

- Queen's Chemistry Innovation Council (QCIC) members: Rui Resendes, Adi Treasurywala, and Hugh Helferty.
- Richard Oleschuk, Associate Head, and Heather Drouillard, Dept. Manager.
- The Advancement and Planning Committee (Evans, Crudden, Brown, Armstrong, Sequeira, Mainguy, Logan).
- All chemistry faculty and representatives of the graduate and undergraduate students.

At the Faculty Meeting of April 11th, 2018, the plan was discussed and one minor amendment was made. The plan was then ratified unanimously.

¹ to the best of our knowledge, this exercise did not produce a strategic plan.

The photo shows the Honours Science Class of 1888

3 Trends

While it is difficult to guess at the future of fields as broad as chemistry education and research, several trends are apparent from historical data. One may assume that they will continue over the 5-year term of the current Strategic Plan.

3.1 Undergraduate education and enrollment

- At Queen's enrollment numbers in the chemistry major program are strongly tied to the first-year enrollment. The enrollment in first-year natural science is currently capped at about 1200 students² and it is about 700 students in the faculty of Engineering and Applied Science (FEAS). Any enrollment increase in the chemistry programs would have to be at the expense of the enrollment of other programs in the natural sciences.
- The enrollment in the Engineering Chemistry Program appears to be decreasing. Also, the participation of the Department of Chemistry in the delivery and administration of the Engineering Chemistry program has decreased with the retirement of Whitney and the transfer of several courses from the Department of Chemistry to the Department of Chemical Engineering.
- The fraction of female undergraduate students in chemistry and engineering chemistry programs has increased within a generation from well below one-half to about 2/3 in chemistry and 1/2 in engineering chemistry.
- Tuition fees are likely to keep increasing at a moderate pace.
- Anecdotally, it appears as if students and their parents view university studies in the natural sciences as an investment into a career as opposed to an open-ended education. Students will continue to have high expectations from their degree and are willing to switch programs to improve their career opportunities.
- Student mental health is an increasing concern. In a 2013 survey of Queen's students, 15% of the students polled reported suffering from depression, 14% from anxiety, 5% from eating disorders, and 4% had considered suicide in the last term. Of those surveyed, 6% said that they had a disability related to mental illness but 40% of this group stated that they did not need accommodation.
- The number of students who require accommodation in the FAS has increased from 3.5% in the 2011-12 academic year to 6% in 2016-17. This may be due to a worsening mental health situation or to an increasing fraction of affected students who ask for accommodation.
- Approximately one-half of all B.Sc. graduates continue their education and pursue graduate studies in chemistry. Of those who join the job market with a B.Sc. degree, approximately 30% work in the chemical or related industry. The remaining B.Sc. graduates either obtain a teaching degree, continue their education in professional school (law school, medical school, business school), or are employed in a variety of fields such as engineering, the health industry, business and finance. A chemistry degree is therefore a gateway to a large variety of careers. It is likely that an even larger fraction of B.Sc. graduates will consider graduate studies in the future.



² These are students requiring CHEM 112 for their studies

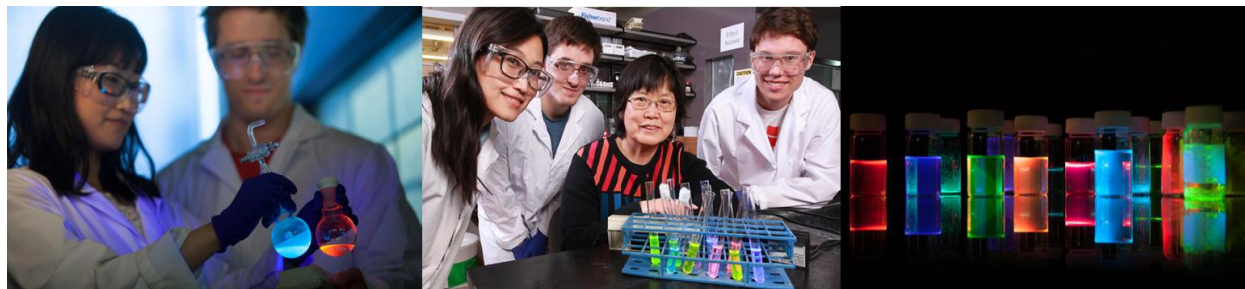
3.2 Graduate education and enrollment

- In the last 10 years the enrollment in graduate studies has been nearly constant at about 110 students. The graduate student body is split approximately 50:50 into male:female, into M.Sc.:Ph.D. candidates and into domestic:international students. In recent years, these ratios have not changed much.
- The Department of Chemistry has one of the largest average research group sizes in the FAS at about 4 graduate students per faculty member. The average group size has increased by 10-20% in the last 10 years – likely commensurate with an increase of funding for graduate research.
- The number of graduate modules listed in the academic calendar has slowly increased due to the addition of new modules and not removing “dormant” modules. Together with decreased graduate course requirements, especially in the Ph.D. program, the enrollment in several graduate modules has decreased substantially.
- The minimum graduate stipend has increased only moderately in the past. The current minimum stipend of \$23,000 p.a. is no longer competitive with that of most chemistry departments in Ontario but is higher than the average graduate student stipend in the Faculty of Arts and Sciences at Queen’s.
- Financial support for graduate students is also available through additional stipends, entrance awards and teaching awards. The department distributes four teaching awards every year, five internal academic awards, two entrance scholarships and at least a dozen Ontario Graduate Scholarships and NSERC Scholarships. Recent advancement initiatives are targeting graduate student support to further increase the number of rewards for outstanding students.
- Graduate students are assuming greater responsibility for their education and the departmental welfare: they participate on committees, are involved in hiring decisions, and advise the Department Head. Their deep concern for their education has prompted several initiatives that have improved graduate education and the student morale. For example, in 2017, the graduate representatives together with the Department Head undertook an initiative to establish an ombudsman, within the department, to provide a confidential mechanism for students to receive and address graduate student concerns.
- The School of Graduate Studies has transferred much responsibility for graduate program administration to the department and has a decreasing role in guiding the graduate programs in the Department of Chemistry. The faculty office has assumed an increasing responsibility for graduate recruitment – especially of domestic students. There are several new incentives that permit departments to grow their graduate enrollment.
- We compete with other Canadian and international universities for the best graduate students. In recent years, several universities in the UK and US may have become less attractive to non-resident students.
- Surveys of recently graduated M.Sc. and Ph.D. students indicate that about one-third enter the private sector in their first position, about one-third continue in teaching or the academic sector and the remaining third continue their education and training.
- Of those undergraduate and graduate students who start careers in the private sector, less than 50% are employed in the chemical industry and the remainder are employed as chemists in other economic sectors – from scientific writing and patent law, to agriculture, health sciences, forensics and finance.



3.3 Research trends

- Since 2010, retiring faculty (Baird, Brown, Buncel, Newstead, Snieckus, Tilk, Whitney) and departing faculty (Pratt, Lemieux) were no longer automatically replaced. During this time there were only two hires of assistant professors (Stamplecoskie and Ross), one continuing adjunct hire (Carran), and one senior hire (Evans as Bader Chair in Organic Chemistry). It appears as if this trend has been reversed in the last years, and the Dean of the FAS intends to permit hiring of several new faculty (off-cycle positions) and to promptly replace retiring faculty (budget-cycle positions).
- Likely as a consequence of the decreasing number of research groups of senior (retiring) researchers, our research productivity has somewhat declined – at least by some measures such as the number of journal publications. It is expected that the trend will be reversed as more and younger faculty join the department and become prolific.
- In Canada and internationally, scientific research has become more collaborative and frequently involves research teams from several universities, disciplines and countries. This trend is expected to continue, and funding is likely to become increasingly available for collaborative research projects. By contrast, funding for individual NSERC Discovery Grants has declined considerably over the past two decades in inflation-adjusted dollars.
- Members of the Department of Chemistry collaborate intensely. For example 10 out of 115 graduate students are co-supervised. Also, 1105 out of 3950 publications that were published in the last 20 years by faculty in our department have at least one more faculty member from Queen's Chemistry as a co-author. Many more articles are published with collaborators in other departments at Queen's and at other institutes. Countless research initiatives (and many research grants) are supported by teams of Queen's Chemistry members.
- Research that is driven (and partly financed) by the private sector has gained a large role in the last 15-20 years. The influence of the private sector on university research appears to be steady or may be even waning, though, as there are increased demands for government support of curiosity-driven research, e.g. by the Naylor report, and 2018 federal budget increases to the tricouncil agencies.
- It is likely that interdisciplinary research by individual principal investigators or by research teams will be increasingly funded. This is especially the case when the research area pertains to perceived areas of strength and assets in Canada such as NSERC's Strategic Partnership Grants Target Areas.
- It is likely that graduate and undergraduate student education will continue to be important in the allocation of research support by funding agencies and university administration alike.
- Several universities, especially small and/or underfunded universities, prefer to bundle their resources in "research clusters" which allow an otherwise small player to have international impact - albeit at the expense of other research fields. This exercise may be beneficial in the short term but can be problematic, if that field evolves over the residence time of a typical faculty member (about 30 years). There are indications that Queen's considers clustering research activities in the future.
- At the time of writing of this strategic plan the research direction of the university is hard to predict, as the Vice-Principal Research position is filled temporarily (until June 2018), and Queen's University has had no Strategic Research Plan from July 2017 to the time of writing (April 2018).



3.4 Infrastructure and governance

- Our ability to forecast our departmental budget depends on (1) our ability to predict the impact of any departmental initiative on our budget and (2) the impact of the initiatives of the FAS office on our finances. Within the activity-based budget model, it has become the departments' responsibilities to invest into, e.g., new courses, research initiation grants, advancement initiatives, lab renovations and student recruitment. In the FAS, each department has therefore considerable financial autonomy. Currently, this model has been only partially implemented and our department has not been able to fully benefit from efficiency increases of the past years. With the 2018 budget, some of the efficiency gains are passed on to the Department of Chemistry and it is expected that the budget model will eventually be phased in. A delay in fully implementing the activity-based budget model remains as a major obstacle in our ability to improve departmental operations.
- If the activity-based budget model were fully implemented, the size of our departmental budget would be largely determined by the number of students and courses that are taught by department members (~60%). About 11% of the budget is based on the number of graduate students that are educated and 20% depend on the number of faculty and staff under contract. About 11% of the departmental budget is linked directly or indirectly to our research activity. It is not likely that this allocation scheme is going to change much in the next five years.
- After Chernoff Hall was completed and occupied in 2002, the university practically stopped maintaining the building on a regular basis. As of 2018 several upgrades and renovations have become necessary. Starting in 2017, funding was made available and was spent on building upkeep, renovations and repair. It is expected that the FAS office and Physical Plant Services will allocate financial resources for building maintenance.
- The capacity of Chernoff Hall is estimated to be about 27-30 research groups, assuming that at least some groups (such as those of theoretical chemists) have low demands on e.g. instrumentation space.
- Safety and environmental concerns, such as energy conservation and lab safety, have rightly taken a more prominent role in the last five years. Workplace safety (pertaining to chemical safety but also harassment and bullying) has been increasingly addressed by provincial and university policies. Within the university, the Department of Chemistry has frequently played a leadership role and is usually among the first to implement Health and Safety regulations. It is assumed that this trend will continue.
- The diversity of the undergraduate and graduate chemistry contingent is very much comparable to that of Canadian society as a whole. On the other hand, the diversity profile among faculty members and staff leaves room for improvement. Women represent 24% of faculty members in Chemistry. When compared to the Canadian Workforce Population (48.2%), Chemistry would need to hire 6 women faculty to fill the gap. Currently, there are no Aboriginal faculty members in Chemistry, therefore when compared to the Canadian population, Aboriginal Peoples are the most under-represented designated group in chemistry. To fill the gap, we would need to hire one Aboriginal faculty member. Visible minority faculty members are the second most under-represented group.
- Departmental Administration and Leadership has been quite variable in the past 8 years. From 2010-2018, the Department of Chemistry has had 5 Department Heads: Lemieux (Head, 2007-2011), Baird (Acting Head, 2011-2012), Cann (2012- 2014), Oleschuk (Acting Head, 2014-2015), Cann (2015-2016), and Looock (interim Head, 2016-2017, Head since 2017). In the same period the department also had two department managers and two finance administrators. While the day-to-day operation of the department was not affected by the frequent change at the helm, it is likely that long-term planning had been affected. It is expected that the departmental administration will remain fairly stable for the period of this strategic plan.

4 Strategic Plan

4.1 Introduction and Vision

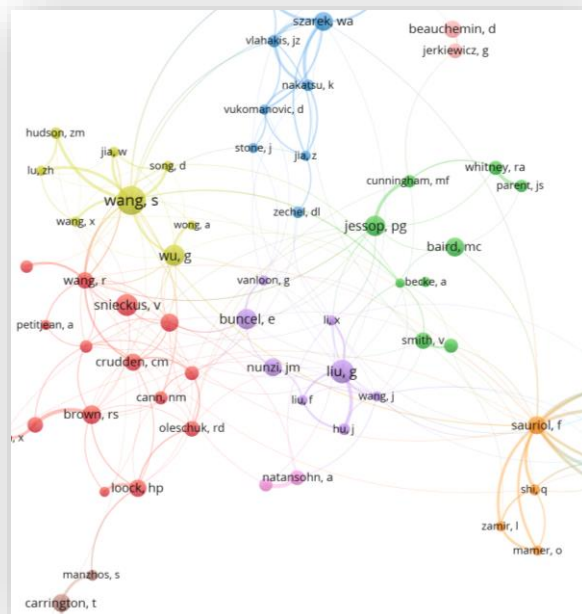
This strategic plan is meant to guide the members of the Department of Chemistry and those administering its operation. The strategic plan sets several objectives to maintain and enhance the effectiveness of the two main departmental functions – chemistry education and research.

A strategic plan for an academic unit differs necessarily from a plan for a profit-oriented enterprise. The directive of our mission is “to discover and disseminate new knowledge and, through education and research, address challenges of relevance to industry and global society”. Our “output” is knowledge and (hopefully) well-educated people. “Becoming the best”, is a common phrase in most strategic plans, but it is ill-defined in an academic context.

With regards to student education, “becoming the best” may mean training more students, better educated students, or more broadly educated students. If we aim to educate “students who are ideally prepared for their careers”, we need to ask ourselves what kind of careers our students are pursuing after graduation. In the past, our students have launched careers in a large variety of fields in government, industry and academia. It therefore appears that our education has to include chemistry expert knowledge, but also has to include fundamental academic skills, such as writing skills, communication skills, an understanding of social structures, and scientific ethics.

“Becoming the best” at research also requires institutional context. In a research plan, we need to recognize that, in any given subject, individual research groups in our department cannot outperform entire research institutes that may have much higher funding and many permanent research positions. In response to this problem, academic research collaborations are typically formed. Collaborations allow for temporary alliances to address a problem that is timely, pressing and (sometimes) well-funded. A departmental hiring strategy must allow us to take full advantage of the ever-changing research landscape for chemists in Canada. Our current and future faculty members must be broadly educated and have wide research interests, they must be adept at social interactions with cognate groups and be able to contribute knowledge to the global needs.³ As the network graphs shows, our departmental research groups have already been enormously successful in forging internal and international research partnerships.⁴ More collaboration on research and teaching strategies can only increase the impact of our activities.

It is our intent to become the most collaborative and diverse chemistry department in Canada.



³ Note that this is very different from “cluster hires”, i.e. hiring faculty members in a narrow field of research. The research emphasis in cluster hires is narrow and deep, akin to government labs and research institutes. Research in clusters has historically been at a risk of losing its mandate as research fields evolve.

⁴ The size of the circles indicates the number of publications generated per researcher in the last 20 years. The number of articles correlates well with the number of collaborators – the number of co-authored papers is indicated by the number and thickness of the lines. Only articles indexed by Web of Science (Core collection) are shown, and only those which have authors at Queen’s University. The image shows only about 30% of the total network graph and not all departmental members are visible.

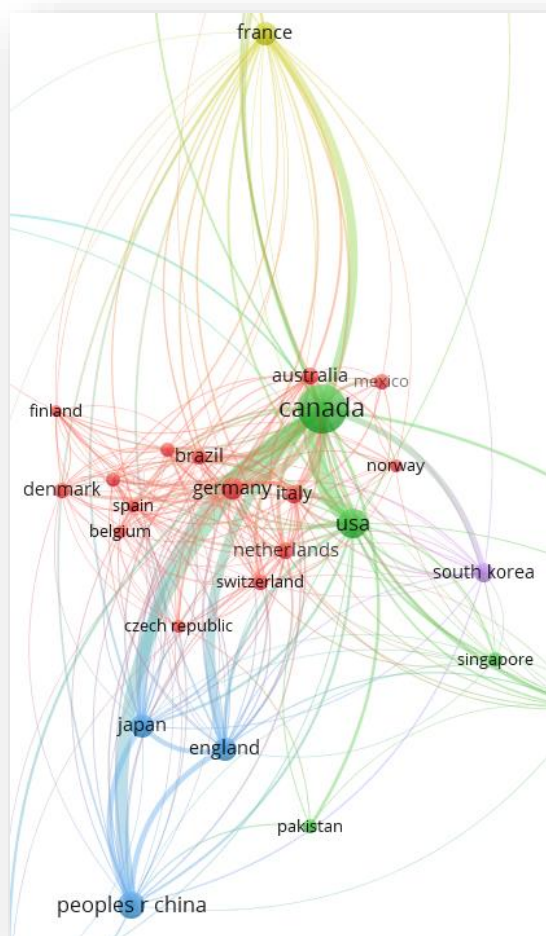
How can our vision to become more effective at teaching and research and to become the most collaborative and diverse chemistry department in Canada be best implemented? Even with the increased autonomy that is afforded by the activity-based budget model, the department is restricted in its ability to act on the trends mentioned in section 2.3. First, it is far from certain when and to what extent the activity-based budget model is going to be implemented. Second, the department alone has no authority to appoint more faculty. Third, the department has only indirect influence on the size of the first-year enrollment and has very little influence on the funds per student that are allocated to teaching service courses, online courses, or courses for chemistry majors.

The department administration is able, however, to sustainably improve the chemistry program, increase graduate and undergraduate enrollment, and enhance our ability to perform internationally competitive research. These initiatives may be expected to increase the quality of education and research and, importantly, can be performed cost-effectively within the activity-based budget model.

Given that the health of the departmental operation depends to a very large extent on the activity of its members, we identified three major drivers for departmental change: (1) number of active faculty, i.e. faculty who teach and/or perform internationally recognized research; (2) number and quality of undergraduate students in chemistry programs (3) number and quality of graduate students – both domestic and international. While sustainable growth is required for all three drivers, the overarching theme is that of even greater collaboration – collaboration among ourselves, but also with Canadian and international partners.

There are several other drivers of departmental change, and not all are explicitly discussed in this plan. These include number and quality of staffing support, i.e. support by chemistry administrative staff, by instrumentation managers, teaching lab support staff and instrumentation technicians. Also, the health and growth of the department are critically influenced by the financial and administrative support we receive from the FAS office, by our interactions with e.g. the School of Graduate Studies, the office of the Vice-Principal Research, Environmental Health & Safety, the Office for Partnerships and Innovation, the Advancement Office and, of course, by cross-faculty relations. The most important interdepartmental relation is certainly our collaboration with the Department of Chemical Engineering, due to our joint delivery of the Engineering Chemistry program. The Department Head is ultimately responsible for fostering these relations and for advocating for departmental interests.

The initiatives outlined below are our attempt to address the trends listed in *Section 3* by improving and growing our undergraduate and graduate programs and by increasing our research prowess.



4.2 Undergraduate Program

Background: The Queen's Chemistry undergraduate program graduates approximately 25 - 30 students per year with a degree of *B.Sc. (Hons) Major or Subject of Specialization* and a much smaller number with *Minor or General* degrees. The department has a capacity for up to 60 students per graduating class – limited by the availability of third-year and fourth-year lab spaces. A 2016 survey showed that nearly 50% of our undergraduate students continue with graduate studies in chemistry, whereas the other 50% find jobs in the chemical industry, health industry, in business and finance, or continue their education in professional schools or towards a teaching degree.

It has been over 10 years since the undergraduate course offerings were comprehensively reviewed and a new curriculum was devised. In its 2016-17 internal cyclical review (Queen's University Quality Assurance Process; QUQAP) and simultaneous Canadian Society for Chemistry (CSC) accreditation processes, the learning outcomes for each course were summarized and assessed. While the program was deemed adequate by the two review panels, several opportunities for improvements were identified. Of those, the following four initiatives were considered of high priority and are included in the strategic plan.

4.2.1 Increase of the number of students in Chemistry Degree programs ("concentrators").

We aim for a 25-40% increase in the number of students who graduate with a degree in Chemistry. This goal may be reached by combining several initiatives such as first-year information sessions, email and letter campaigns, in-lecture graduate research and career presenters, etc. The CHEM 112 course is an additional tool to increase interest in chemistry. The course is currently undergoing a review to improve the learning experience. We intend to increase the emphasis on active and inquiry-based learning - a concept internalized by chemists decades ago through our use of teaching labs and tutorials, but also central to the *Queen's 2011 Academic Plan*. We will further support this concept by providing more open-ended and problem-centred learning opportunities. The First-Year Review Committee will also consider splitting the course after the Fall term, i.e. to offer two "streams" of CHEM 112 in the winter term – one stream that is meant for students planning to enroll in the chemistry (and biochemistry) Major/Specialization Programs and another stream that is meant for everyone else. Program changes will be developed in 2018-19 with their first implementation starting in Fall 2019. The First Year Review Committee will lead these initiatives.

4.2.2 Review of workload and learning experiences of second year courses.

Students consider the workload in the fall term of their second year to be very high, prompting several students to switch to other degree programs. Without reducing the rigour of the program, it is possible to improve the learning experience by implementing several initiatives, such as replacing some labs with tutorials especially for the Fall courses – CHEM 211, CHEM 212 and CHEM 213, or by redistributing the fall term workload to the winter term. Again, these revisions align well with the recommendations of the *2011 Academic Plan*. Program changes can be developed



in 2018 with their first implementation in September 2019. The Undergraduate Chair together with the second-year instructors will lead these initiatives.

4.2.3 Expand experiential and inquiry-based learning.

Especially in third and fourth year courses, there exist a considerable opportunity to enhance experiential and inquiry-based learning. By adjusting the course content of *CHEM 397, 398, 399 Experimental Chemistry I and II* to include different means of assessment (lab reports, presentations, group reports, “journal articles”, reflective essays, etc.), students may be better prepared for a professional workplace. The *2011 Academic Plan* emphasizes that *Fundamental Academic Skills* and, in particular, writing skills deserve attention in the education of our students. Also in third year, opportunities exist to incorporate internships into the program. Should there be a lack of positions for our students, additional internship placements may be found by expanding the QCIC membership base to include local *ad-hoc* members, who may contribute such work placement opportunities. The Undergraduate Chair together with the chair of the QCIC and the *CHEM 397* instructor will lead these initiatives.

4.2.4 Introduction of a new course: *CHEM 111 Chemistry for Decision Makers*.

Concepts of chemistry pervade every aspect of modern life – be it nutrition, climate change, environmental protection and sustainability, health, manufacturing, forensics, and telecommunication, - even transportation, and beauty products (cosmetics, tattoos, skin care).

This new chemistry course will be specifically designed for students enrolled in non-science major programs and will build on middle school or high school chemistry knowledge. It is meant to provide science literacy to those who may encounter science concepts in their professional careers, be it law, business, health or engineering. It is understood that this may be the last chemistry course that such students will ever take. The content will be delivered by a group of instructors – academic and non-academic - who are exploring the impact of chemistry and chemicals on Canadian society. Depending on the demand and feasibility an on-line component may be developed in collaboration with the Centre for Distance Studies. An experiential lab component may be introduced in the medium- to long-term, should capacity exist in our existing laboratories and such labs could be made revenue-neutral.

The department will apply for initial support for this course through the funding allocated to the Principal’s Dream Courses. This new initiative aligns very well with the objectives of the *2011 Academic Plan*, which asks for a much greater extent of interdisciplinarity. The Department Head will lead this initiative together with a yet-to-be-identified possible instructor.



4.3 Graduate Education

Background: In the last 10 years, the Department of Chemistry educated on average 100-120 graduate students; roughly equally split between MSc and PhD students, between male and female students and between domestic and international students. Upon graduation, about one third of these students work in the private sector or in government positions, and the remainder continue either with further education or assume academic/teaching positions. On average, a chemistry research group therefore hosts four graduate students⁵ – one of the largest average group sizes of all departments at Queen's! Most faculty believe that their research funding would allow increasing this number by 20% to 50%. An increase in applications by strong graduate students is expected to increase the quality and quantity of the research that can be performed in our department.

At the time of writing of the Strategic Plan, there are substantial incentives to improve the graduate student experience, to increase the graduate program offerings, and to decrease the times to completion. The FAS office and the School of Graduate Studies (SGS) strongly support departmental actions to improve the graduate programs and incentivize initiatives that lead to increased program quality and program enrollment.

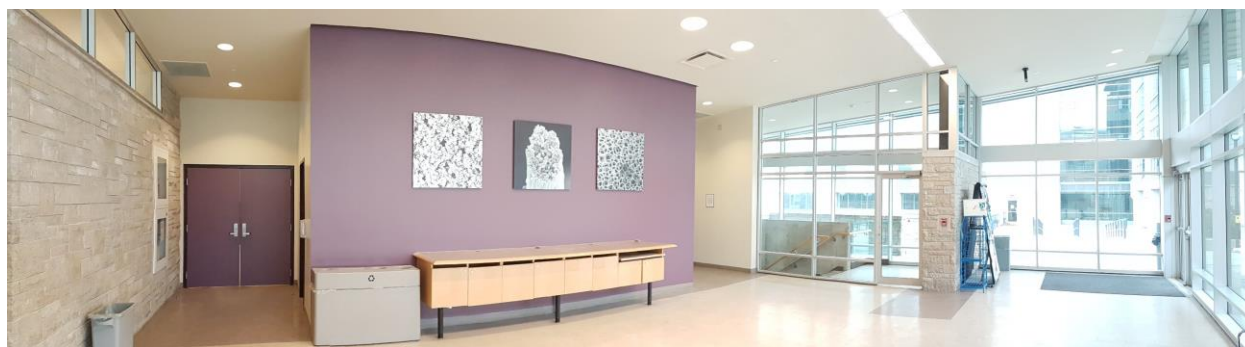
Our top three departmental priorities are poised to take advantage of these incentives.

4.3.1 Increase graduate student enrollment.

We will build on recent graduate recruitment success to further increase the number of domestic and international graduate applications and to increase our graduate enrollment to over 150 graduate students (5-6 per faculty member). Initiatives will include launching an annual recruitment event. Entrance awards and departmental graduate tuition awards (e.g. co-sponsored through advancement initiatives) will also help attract students to Queen's Chemistry. These recruitment initiatives will be led by the recruitment coordinator of the departmental Graduate Committee in consultation with the Graduate Chair and the Head.

Additionally, international graduate programs such as dual-degree programs and extended research stays abroad will differentiate our graduate program from that of other universities. International dual- and joint-degree programs aligns particularly well with the objective of the 2015-2019 *Queen's University Comprehensive International Plan*, which asks to develop 10 new international graduate and undergraduate academic programs. The Queen's Chemistry Innovation Council will help find industrial internships for interested graduate students. Funding from MITACS, NSERC, OGS, etc. may be leveraged with university funds.

Our initiatives are deemed successful if we are able to increase our enrollment to more than 150 graduate students – an achievable goal, especially if we can retain 25% of our 4th-year graduating



⁵ Several research groups house 10 or more graduate students.

class (i.e. 50% of those UG students who are continuing their education with graduate studies) to remain at Queen's for a graduate degree.

4.3.2 Improve the graduate student experience.

The frequency and quality of interactions between faculty and graduate students in formal and informal settings will be improved. Faculty will be reminded that attending social events and student seminars not only demonstrates interest in students' activities, but also helps with recruitment and retention of students. Faculty will also be reminded of their responsibilities with regards to a prompt review of e.g. scholarship applications, annual reports and thesis drafts to not inhibit the students' progress. The participation on supervisory committees and examining committees will be monitored and incentivized to ensure a fair distribution of the workload.

The graduate committee will examine possibilities to formalize career advice and mentoring within the department and in consultation with the QCIC. The graduate committee will also focus on reducing times to completion in consultation with the FAS office and the SGS. The latter initiatives are deemed successful, if the times to completion are less than 4 years for a Ph.D. degree on average and less than 2 years for a M.Sc. degree on average.

The department will allocate more financial support for conference travel and off-site activities such as visits to collaborator labs. By 2020, we aim to increase the support for graduate conference travel to \$500 annually per student. The Advancement Committee will lead the initiative to increase support for graduate conference travel.

4.3.3 Develop new graduate programs, certificates, and professional programs.

Our department currently offers over 50 graduate modules in support of the M.Sc. and Ph.D. degree programs in chemistry. Many of these modules are of sufficiently broad interest that they could be bundled to offer certificates or professional degree programs, i.e. graduate degrees that do not include a research component. Such non-research degree programs can help increase the reputation and international profile of our department by engaging mature students and researchers who have already launched a successful career. The programs could be set up so that they would balance an initial investment with a small income through student fees. The Graduate Committee chaired by the Graduate Coordinator will explore options of bundling advanced chemistry courses into new "professional certificate programs".



4.4 Research Activities

Background: It is widely acknowledged that the Department of Chemistry at Queen's has a long history of research excellence. However, there exists no single metric by which "research excellence" can be measured. The number of publications and associated citations are frequently used and several indices (Hirsch-index, G-index, i10-index) have been proposed to evaluate the scientific impact of a research group. The size of research grants, the number of invited presentations and reviews, and the number of awards are also commonly used to rank individual researchers. Many different metrics - from reputational surveys to the number of library holdings⁶ - are used by several organizations to obtain university rankings. Regardless of the specific metric used to quantify research excellence, one might reasonably assume that the *quantity* of our research activities is correlated to the number of active researchers in the department and the (perceived?) *quality* is related to the impact that our work has on a national and international stage.

Currently our department hosts 6 Canada Research Chairs (all Tier-I) including the endowed Bader Chair in Organic Chemistry. Since the 1990s we have also been able to attract seven 7 Queen's National Scholars, all of whom are top female researchers⁷. For reference, only 2-4 QNS positions are awarded every year, and less than 100 QNS are currently active in the 88 departments and professional schools at Queen's University. Members of our department publish about 120-150 peer-reviewed articles and file several patents per year. The fraction of female faculty is the highest of all chemistry departments in Canada; similarly, the fraction of Canada Research Chairs is among the highest nationally. These data speak to a research intensity and scientific reputation that places our department well into the top departments in Canada, despite our small size compared to departments at the most research intense universities (for example, McGill, University of Toronto, UBC).

Chemistry faculty obtain on average \$3M annually in research operating grants – mostly from NSERC but also from other government and private sector sources. Multimillion-dollar infrastructure grants, for example through the Canadian Foundation for Innovation (CFI), and our participation in large multi-institutional programs (currently: CPARC-CFREF; Ni-Electro-Can, CREATE) demonstrate that Queen's chemists are collaborating with one another and with colleagues across Canada and the world. Currently, funding agencies have committed over \$40M to research by Queen's Chemistry faculty.

Research in the department is as diverse as one might expect from the academic background of the principal investigators. There are several areas of research that our department is internationally known for – from green chemistry to materials science, from theoretical spectroscopy to fundamental synthetic chemistry, as well as several others. Research collaborations evolve when research groups with complementary expertise address a common scientific question. Indeed, as was shown in section 3.1 many scientific articles are co-authored by more than one PI from our department.

While our success in conducting world-renowned research is undisputed, the future of our research activities remains uncertain. For example, since retiring faculty were not automatically replaced between 2006 and 2016, the average age of the faculty has increased considerably and only 2 of the 22 research-active faculty are assistant professors. If we had a flat age distribution, one would expect 20% of the faculty (4-5 individuals) to be at the pre-tenure career stage. Hiring of new faculty is therefore of the utmost importance. In addition, the success of our research teams hinges on their ability to secure funding for themselves, and their ability to foster collaborations - especially interdisciplinary collaborations.⁸

⁶ Also considered are the quality of the recreational facilities, the quality of the cafeteria food, and the cost of housing. All these are beyond our control, though.

⁷ Of those six QNS are currently active (Beauchemin, Cann, Crudden, Petitjean, Ross, and Wang); Nathanson passed away in 2002. Capicciotti is expected to join the department in July 2018.

⁸ It also critically depends on the department's ability to support their research endeavours with access to shared state-of-the-art research infrastructure. Departmental infrastructure will be discussed in the next section.

The main drivers for departmental research excellence and our international reputation are therefore (1) the number and excellence of active researchers, including faculty, postdoctoral fellows, instrumentation managers and graduate students; and (2) the number and quality of collaborative interactions with other research groups within Canada and abroad – especially those in which Queen’s researchers play a leadership role. We identified two priorities with regards to enhancing our research prowess.

4.4.1 Aggressive hiring of faculty especially in areas that are strategic with regards to research and funding opportunities.

Rejuvenation of the department and investment into young researchers, must be one of our highest priorities. Hiring tenure-track faculty is one of the most effective ways to initiate change in the department, and to increase its diversity. Of course, we remain committed to employment equity and diversity in the workplace and in our new hires; we welcome particularly applications from women, visible minorities, Aboriginal peoples, persons with disabilities, and LGBTQ persons.

New hires are expected to build research groups that can compete with the best international scientists. Their research is expected to be original, innovative and independent. In consideration of sub-section 4.4.2, any new faculty member must also be able to demonstrate their willingness and capacity to collaborate with others in our department, at Queen’s University, in Canada and/or abroad.

In the past, hiring decisions were made mostly guided by our teaching requirements – hires were clustered around our course delivery requirements. Even though most of our undergraduate courses, and nearly all the graduate courses, are now bridging two or more traditional sub-disciplines (analytical, inorganic, organic, physical, theoretical and computational chemistry), faculty hiring still largely followed these conventional divisions. Meanwhile, research has become largely interdisciplinary with funding initiatives e.g. by NSERC, bridging chemistry with e.g. energy generation, health sciences, photonics, material sciences and even social sciences.

We identified the following areas of growth (in alphabetical order):

- i. analytical chemical instrumentation development for field and point-of-care use,
- ii. artificial intelligence and “big data” processing in theoretical chemistry,
- iii. chemistry at phase boundaries,
- iv. chemistry education research,
- v. chemistry in a changing global climate⁹
- vi. chemistry of low-dimensionality materials,
- vii. energy storage and conversion¹⁰
- viii. environmental engineering chemistry,
- ix. green chemistry,
- x. precision molecular medicine¹¹.

While we believe that the above selection of ten research areas addresses chemistry challenges of the future, we also acknowledge that federal and provincial initiatives may provide opportunities for growth in many other areas. Nevertheless, we tentatively identified these ten fields as the most promising for the next ten faculty hires to be completed by the end of this strategic planning period in 2023.¹² All ten research areas are well aligned with the Queen’s University 2012-2017 Strategic Research Plan, which highlights “Interdisciplinary Chemical Sciences (biological-medicinal, materials, computational-theoretical and environmental-analytical chemistry)” as well as “Innovative Materials” and “Materials Science”.

⁹ e.g., atmospheric, marine, and agricultural chemistry

¹⁰ e.g., photovoltaic, photonic and light harvesting research, battery and electrochemistry research

¹¹ e.g. pharmaceutical chemistry, carbohydrate chemistry, bioanalytical chemistry for health applications, etc.

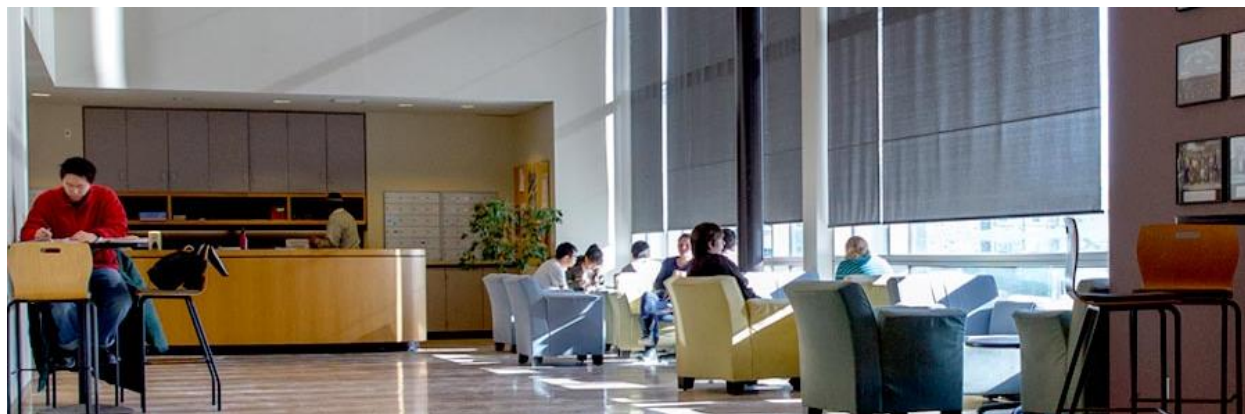
¹² Assuming a retirement rate of one professor per year (our 25 faculty stay on average 30 years in their position), this amounts to a net growth of five faculty in five years to a total of 30 faculty in 2023.

4.4.2 Foster collaborative research.

Our international research reputation is related to several metrics such as the number and value of research grants and awards, to the number of citations to our articles, our publication and patent rate, to the number of spin-off companies, and to bibliometric indicators such as the Hirsch-Index of our researchers. Similar metrics and many other factors also determine our position in university rankings. Importantly, many of these metrics relate to the interconnectedness (and relevance!) of our research to that of others. Research collaborations are by far the most effective means to bring our research to the world and to increase its impact. A well-connected researcher would almost certainly impact each of the above metrics. Of course, our department has a long history of intradepartmental and inter-departmental collaborations, especially with colleagues in the Department of Chemical Engineering. Close collaborations also exist with colleagues in the department of Physics and Astronomy, colleagues in the Faculty of Health Sciences, and many other departments across Queen's. Collaborations within Canada and with colleagues in other countries frequently arose *ad hoc*, following, for example, chance encounters at conferences. They are sustained by student exchanges, mutual visits of senior researchers, and teleconferences.

At the departmental level we will support collaborative research activities in several ways:

- I. *Support the effort by Canada Research Chairs and senior research faculty to write collaborative research grants.* To sustain our departmental infrastructure, it is necessary to write one major infrastructure grant at least every 5 years. The last CFI grant was awarded to our department in 2017, a joint Physics-led CFI initiative with some Chemistry involvement is currently under review. Also, several departmental members are partners on two CREATE grant initiatives on water research and on photonic materials research, respectively, as well as a Physics-led CFREF initiative. Within the period of the Strategic Plan our senior researchers will coordinate several infrastructure (e.g. CFI), training (CREATE) and networking (CFREF, NSERC, Strategic Networking, NSERC Strategic Project) grants. Departmental support for collaborative grants can take the form of partial relief from teaching and administrative duties and financial (matching) support. These support initiatives are coordinated at the discretion of the Department Head.
- II. *Provide more support for seminars and workshops by international visitors.* Our seminar program is supported to a large extent by endowments dedicated to present and former members of our department. These endowments give us room to fund extraordinary lecture series and workshops by prominent international visitors, as we have done previously. By coordinating our lecture series with that of other Ontario universities, we may be able to extend the global reach of our seminar program. The seminar coordinator in consultation with the Department Head and the Department Manager will initiate these activities.
- III. *Develop and implement a (social) media research strategy.* The visibility and accessibility of our research output is becoming an increasingly important component of our reputation and may be the determining factor in obtaining research grants, initiating and sustaining research



collaborations, recruiting graduate students and promoting faculty careers. It is commonly understood that publishing research in conventional scientific journals - even if they are of outstanding reputation – is no longer sufficient to guarantee its impact. Many journals can help promote our research through social media feeds. Universities can assist with press releases, and several websites (ResearchGate, Linked-In and Facebook) may help promote our work. While several of our colleagues and most students are quite successful in “branding” their work, the impact of our research may certainly be increased using a department-wide approach. In the next years, the department will develop a (social) media research strategy that may include a dedicated *QCHEM Research* page, an online repository of our articles, a coordinator for press-releases and a dedicated twitter feed. The Head in consultation with the Advancement and Planning Committee will develop this (social) media strategy.

Both initiatives – aggressive hiring of new faculty and fostering research collaborations - are very well aligned with the current Queen’s Strategic Framework (QSF). In the QSF, the plan pledges to “Increase research support through increasing research \$/faculty ratio”, to “Improve intra-and inter-faculty and cross-university collaboration to support university pillars nationally and internationally”, to “Integrate research to enable active learning and innovation”, and to “Focus on increasing and improving our impact through peer-reviewed publications, [...] and knowledge translation and innovation.”. All four components of the QSF will be enhanced by the prioritized initiatives listed above.

4.5 Infrastructure and Governance

Background: Chernoff Hall, the home of the Department of Chemistry, was constructed in 2002 and won several architectural awards for its excellent design and function. The building has aged well, but repairs have become necessary. Because of budget constraints, maintenance and repairs had been deferred for 10 years or more, so that an investment of several hundred thousand dollars is required to restore the building and, again, make it fully functional.

Similarly, the department needs to ensure maintenance and frequent renewal/replacement of our research and teaching infrastructure. Opportunities for reinvesting into research infrastructure arise in several ways, such as regular institutional grant applications to CFI and NSERC, and through funding obtained by conducting contract research (e.g. through the use of overhead funds and user fees).

Of particular concern are instruments that are used in undergraduate teaching labs. These instruments are expensive and there is no dedicated allocation in the operating budget that allows the department to maintain these heavily used instruments. Teaching infrastructure has been previously replaced using funds diverted *ad hoc* from the departmental operating budget, but advancement initiatives have recently provided additional sources of financial support.

We identified the following two departmental priorities:

4.5.1 Develop a plan for renewing research and teaching infrastructure.

The shared research instrumentation and departmental teaching infrastructure ranges in its suitability from “nearly new and excellent” to “decrepit and beyond repair”. Several of the departmental research instruments, such as the NMR facility and the mass spectrometry facility, are also used to support work by external researchers, e.g. academics who are not at Queen’s or researchers working in the private sector. While the research infrastructure is an important asset to our department, the responsibility of its maintenance and renewal/replacement of the instrumentation does not lie with a single person. The instrument managers who oversee the operation of the respective equipment, are by themselves typically not able to secure funds for maintenance and renewal. Similarly, individual faculty do not necessarily feel the responsibility for

replacing those instruments that have many users. The technical resources committee also does not have the mandate or capacity to write research grant proposals.

The Department Head together with the Technical Resources Committee will develop a plan to ensure prompt renewal of research and teaching infrastructure. This may require support and leadership by research-focused colleagues, such as Canada Research Chairs or Killam Fellows and other senior researchers (see section 4.4.2 above). To ensure a smooth operation of all our shared facilities, a succession and redundancy plan for instrument operation and management will be devised. Long-term funding will be secured to ensure prompt repair, renewal and replacement of undergraduate teaching infrastructure.

We have achieved our goal when we have secured on average \$1M per year in shared infrastructure funding, and have secured on average \$20,000 per year for undergraduate lab upgrades. The Department Head together with the Technical Resources Committee and departmental manager will devise and implement that plan.

4.5.2 Increase awareness of our capabilities among the private sector.

A very large fraction of federal and provincial funding is tied to academic-industrial collaborations. Collaborative research and development projects provide federal and provincial grants for innovative research. The private sector also plays an increasing role in training our students, for example through the availability of internships or of paid summer jobs. Finally, service contracts from companies provide a source of revenue for our department and help support shared research infrastructure such as NMR, mass spectrometry and electron microscopy facilities. Unfortunately, with the disappearance and relocation of conventional chemical and pharmaceutical companies from Ontario and Quebec, it has become increasingly difficult for us to find Canadian industrial partners.

The Department Head will engage with a large number of industry partners with the goal of fostering new academic industrial relationships. Here, the Queen's Chemistry Innovation Council can help foster these relations. The Queen's Office for Partnerships and Innovation (OPI) may also be able to help create new relationships. Instrumentation managers and faculty will help create a comprehensive service package to market our shared research infrastructure facilities. The outreach program will be considered successful, if the numbers of internships, external contracts, and collaborative research projects increase markedly.

