

**STRENGTHENING QUÉBEC**  
**as a centre for INNOVATION through NATURAL SCIENCES and**  
**ENGINEERING**

**MAKING HIGHLY QUALIFIED HUMAN CAPITAL OUR MAIN CONCERN**

**ADVISORY COUNCIL OF THE**  
**FONDS QUÉBÉCOIS DE LA RECHERCHE**  
**SUR LA NATURE ET LES TECHNOLOGIES**

**November 2003**

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## **MANDATE AND COMPOSITION OF THE ADVISORY COUNCIL**

The Advisory Council is tasked with counselling the Board of Directors of the Fonds québécois de la recherche sur la nature et les technologies on all important issues related to the fulfilment of the Fonds' mission, with a view to enhancing the relevance and impact of Fonds initiatives as regards the challenges facing Québec society.

The Advisory Council is also entrusted with promoting greater openness on international vistas, whether the various science and technology development policies of OECD (Organization for Economic Cooperation and Development) countries, or the issues they address.

More specifically, the Council's mandate is to provide the Board of Directors with opinions on strategic directions, new courses of action and constructive interaction with the socio-economic community, industry in particular.

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## 1. NATURAL SCIENCES AND ENGINEERING, SPEARHEADING INNOVATION AND DEVELOPMENT IN OUR SOCIETY

The field of the Natural Sciences and Engineering is vast, prolific and progress-inducing. It brings together a matrix of disciplines whose applications, which touch on numerous aspects of our daily lives, play a leading role in improving quality of life.

### Natural Sciences and Engineering (NSE)

| Scientific disciplines                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                  |                                                                                                                                                                                 |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Mathematics, computer science, physics, chemistry, biology, mechanical engineering, civil engineering, chemical engineering, metallurgy, electrical and electronic engineering, geology, forestry                                                                                                                                                                       |                                                                                                                                                                                  |                                                                                                                                                                                 |
| Quality of life                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                  |                                                                                                                                                                                 |
| Technology                                                                                                                                                                                                                                                                                                                                                              | Sustainable development                                                                                                                                                          | Health                                                                                                                                                                          |
| Radio, television, computers, telephone, Internet, household appliances, office technology, laser, transportation (cars, trains, planes, boats), security systems, civil infrastructure (roads, ports, dams, powerstations), plastics, manufacturing, machinery, production, textile fibres, heating and air conditioning, microtechnology and nanotechnology, robotics | Lighting, energy (electricity, gas, oil), sustainable water supplies, the environment, sustainable food supplies, raw materials (wood, petroleum, metal, cement), forests, mines | Medication, diagnostic and monitoring instruments, transducers, imaging, scanners, prosthetic devices, laser, implants, safe food and water, surgical instruments and equipment |

### 1.1 Natural Sciences and Engineering. Giving us the best that modern living has to offer

In less than half a century, major advances in science and technology have radically transformed our economy and have had far-reaching effects on our lives as individuals and as members of society.

In the 1950s and even the 1960s, Québec's economy was mainly resource-based. Now, in the early 21st century, a mere 40 years later, **the conversion towards the new economy, also called the knowledge economy, is well underway** thanks to propulsive sectors such as information technology, the aerospace industry, and pharmaceuticals, as well as biotechnology, sustainable development technology and emerging fields such as nanotechnology.

## A quiet revolution that engendered great strides

The Quiet Revolution of the 1960s, when innovators were already hard at work, foreshadowed the era of unprecedented scientific and technological advances witnessed 15 or 20 years later. In the late 1950s, Joseph-Armand Bombardier launched the Ski-doo, which quickly became his company's signature product. This innovation not only changed life in the tiny village of Valcourt, but life for many Quebecers. The Ski-doo would attract international acclaim to its inventor and lead to the creation of one of the biggest companies in Québec and even Canada, Bombardier, a diversified company known around the world.

But, clearly, it was **hydro-electric development projects**, beginning with Manic V, and, a few years later, the more ambitious James Bay project, that **characterized this decisive period for the future of engineering in Québec**. The challenges involved in carrying out these hydroelectric projects and in transmitting the energy generated (first 735,000-volt line in 1965) were instrumental in propelling Québec engineering into the major leagues and in causing world-class engineering firms such as SNC-Lavalin to emerge in Québec.

Among the **milestones that contributed to building our high-tech industrial capability**, notably in robotics, is **development of the Canadian Shuttle Remote Manipulator System**, or Canadarm. Constructed by Spar Aerospatial for the Canadian Space Agency and launched for the first time in 1981, the arm became a key component of American space shuttles. While this achievement is hailed as a symbol of Canadian technological know-how, Québec expertise contributed in large part, a case in point being Québec's electronics industry and the performance of companies such as CAE Electronics, which had a significant hand in the success of the project. This innovation also helped make Québec a point of convergence for excellence in the aerospace industry. Since then, the Canadarm has sired sizeable industrial spinoffs, including the sale of robotics components in Japan and Europe, the sale of simulators, and the development of robotic systems for the nuclear industry. The success of the Canadarm paved the way for an equally avant-garde invention, the Mobile Servicing System, to be used in the assembly and upkeep of the International Space Station.

The early 1980s also meant the **dawn of the computer age**. In Québec, it began with the introduction of the now-ubiquitous automatic teller machines that enable users to do their banking transactions without the assistance of cashiers. **Information technology** and the resulting ripple effects in the various spheres of activity are **symbols of the full-fledged arrival of the knowledge economy** that quickly upped the stakes and created new ways of working and doing business. Today's lifestyles are influenced in large part by the new dictates of this era of electronics and the Internet. The sweeping changes that have cut a wide swath across all of society have opened new doors on the future and on unexplored vistas.

## 1.2 Natural Sciences and Engineering, the basis for recent innovations

Natural Sciences and Engineering have been the basis of remarkable technological advances in an array of fields. Of the 25 strategic sectors identified in Québec's Policy on Science and Innovation, 15 are related to Natural Sciences and Engineering.

Here are a few examples of recent NSE innovations in Québec:

- ♦ In Vaudreuil, genetically modified goats synthesize spider webs in their milk. Nexia Biotechnologies, the grey matter behind this feat, extracts **a biodegradable fibre that is more resistant than Kevlar or steel**. It is now possible to produce this high-performance biomaterial in industrial quantities.
- ♦ **A microorganism-based process for decontaminating polluted soil** has been patented under the name Biopile by Biogénie, a Sainte-Foy company counted among of the best of its kind in the world.
- ♦ At Hôpital du Sacré-Cœur in Montréal, a robot makes it possible to perform delicate heart and brain surgery through openings that are smaller than laparotomy incisions. Within the next few years, **nanorobots** will be able to release medication at specific points in the human body. And thanks to robotics, Victhom, located in Saint-Augustin, a Québec City suburb, has developed a bionic leg, which is a major breakthrough in the field.
- ♦ Québec's **super lithium-metal-polymer battery**, produced and marketed by Hydro-Québec, is geared primarily to the telecommunications industry, but will also be a component in a first contingent of electric cars for urban use, with a view to vast improvements in public transit in big cities.

And the list could go on to include geomatics, optics and photonics, and advanced materials.

The worldwide boom in innovations in the field of the Natural Sciences and Engineering is shaping our future and that of the entire planet. The panoply of innovations that will change our lives tomorrow is being crafted today before our very eyes **in sectors as far-flung as nanotechnology, virtual reality, cutting-edge robotics and micro arrays**.

### 1.3 A critical contribution to economic development

Now more than ever, society's economic growth, job creation and quality of life depend heavily on the collective capacity for innovation and knowledge-sharing. **Competitiveness and innovative capability hinge to a large extent on the quality of manpower available and the amount of R&D conducted**. This is particularly true for Natural Sciences and Engineering, **an engine of technological and industrial development**. Today's R&D and innovation are the jobs of tomorrow.

#### A snapshot of Québec research and innovation

Québec's position is enviable in many respects, with advantageous showings in a number of high value-added technological sectors, whether optics and photonics, pharmaceuticals or aerospace. It also has distinguished itself both nationally and internationally for its R&D.

The latest *Research Infosource* ratings by **Research Money**, published at the end of June 2003, put **24 enterprises headquartered in Québec among the top 100 Canadian companies for R&D investment in the second quarter of 2002**.

But even though Québec has made remarkable strides in industrial R&D in the past ten years, **much remains to be done if it is to meet the challenges of a knowledge- and innovation-driven economy.**

#### **Assets and drawbacks. Two sides of the same coin**

Science and technology in Québec is a double-edged sword. **The first edge**, which reflects the progress and gains of the past 20 years, points to a **solid foundation and immense potential.**

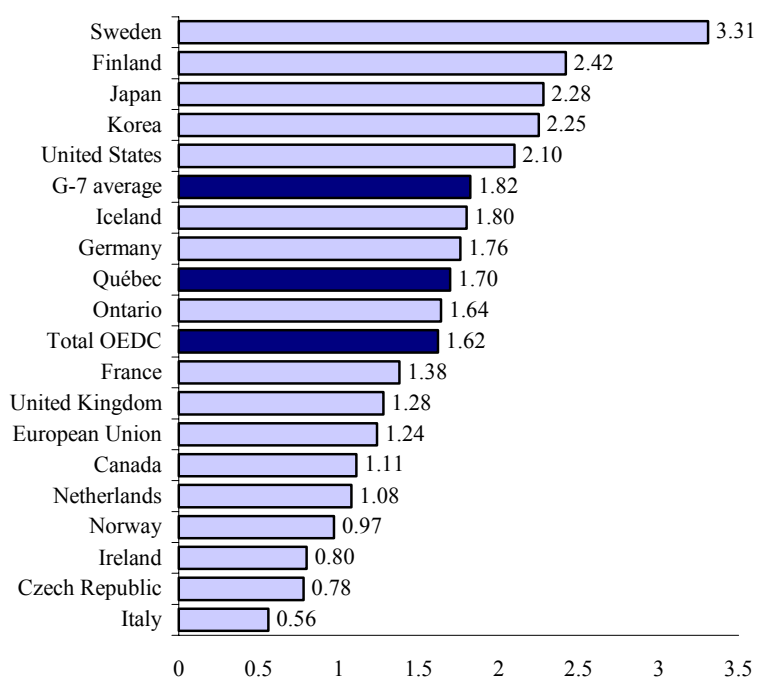
- ♦ **The number of Québec companies engaged in R&D has enjoyed uninterrupted growth since the late 1980s.** Half of these businesses are in the manufacturing sector (Ministère du Développement économique et régional, 2003).
- ♦ **A few industrial sectors are R&D leaders** (aerospace, pharmaceuticals, communication materials and engineering consultancy), fuelled largely by Natural Sciences and Engineering.
- ♦ In the past 20 years or so, **companies that are heavily knowledge-based have accounted for nearly 60% of net job creation** (Conseil de la science et de la technologie, 1998). In 2000, Québec businesses had 31,621 industrial R&D employees, that is, a little over one third of the Canadian total (Statistics Canada, 2002).
- ♦ **Québec's share of industrial R&D spending for Canada as a whole is 27.5%**, proportionally bigger than its population (24.1%) or economy (21.5%). With slightly over 4000 R&D companies, Québec accounted for 41% of the Canadian whole in 2000, outstripping even Ontario (Ministère du Développement économique et régional, 2003).
- ♦ **High-tech companies are a driving force behind GDP, export and job growth:**
  - In 1996, high-tech companies represented **13.6% of all enterprises** and their production, **20% of the GDP** (Bureau de la statistique du Québec, 1997);
  - From 1991 to 2000, high-tech exports rose by an average 13% a year, outpacing GDP growth (4.2%) (Institut de la statistique du Québec, 2002a);
  - In 2000, for the first time ever, **high-tech companies'** contribution to manufacturing-sector exports (32.2%) **outdid that of low-tech companies** (29.8%), most of which export raw materials (29.8%) (Institut de la statistique du Québec, 2002a);
  - In the past 10 years, **the increase in highly qualified manpower has occurred primarily in fields related to Natural Sciences and Pure Sciences** and the number of jobs of this kind has soared by 73%, the best performance of all job sectors (Centre d'étude sur l'emploi et la technologie, 2001).

On the other hand, there are certain **weaknesses hampering our development and slowing down our ability to adapt to the needs of today's knowledge society.**

- ♦ **Over 70% of Québec companies are sub-technical** (Bureau de la statistique du Québec, 1997). They invest very little in advanced technology or materials and equipment compared to companies in OECD countries.

- In the late 1990s, the **high-tech adoption rate in Québec** was 72%, third **after Ontario (81%) and Alberta (80%)**. As a proportion of gross domestic product (GDP), corporate investments in equipment and machinery put Québec among the stragglers in the race, that is, 20th out of 22 OECD states, with a rate of 9% in 2000, lower than that of Ontario (9.1%) and considerably below that of the United States (10.5%) and Japan (12.9%), the three main target markets of Québec industry (Ministère du Développement économique et régional, 2003).
- The catching up that Québec has done in the past 10 years has gone a long way towards closing the gap with the world's most highly industrialized countries. While **R&D corporate spending in relation to the GDP was slightly above the average posted by OECD countries in 2001, it is still below that of G-7 countries**. In addition, countries such as Sweden and Finland are still far ahead of Québec.

**Intramural R-D expenditure of companies as percentage of GDP,  
2001, Québec, G7 and main OECD countries**



Source: OECD, 2003; Ministère du Développement économique et régional, special compilation.

- The proportion of **SMBs engaged in R&D is very low**. In Québec, the lion's share of industrial R&D is concentrated in but a few companies. In fact, of the 4034 companies that conduct R&D, 50 account for two thirds of total R&D (Institut de la statistique du Québec, 2003a).
- **As for development**, in 1999, **Québec universities** were number one for royalties, mainly because of a group of researchers from Université de Sherbrooke. However, they are **under-represented** in proportion to their relative weight (29.2%) in terms of total research in Canada, with a mere 17% of patents, 21% of invention disclosures, 22% of active licences and 9% of spin-off companies (Statistics Canada, 2000).

## 2. HUMAN CAPITAL, THE LEADING ISSUE OF THE XXI<sup>st</sup> CENTURY

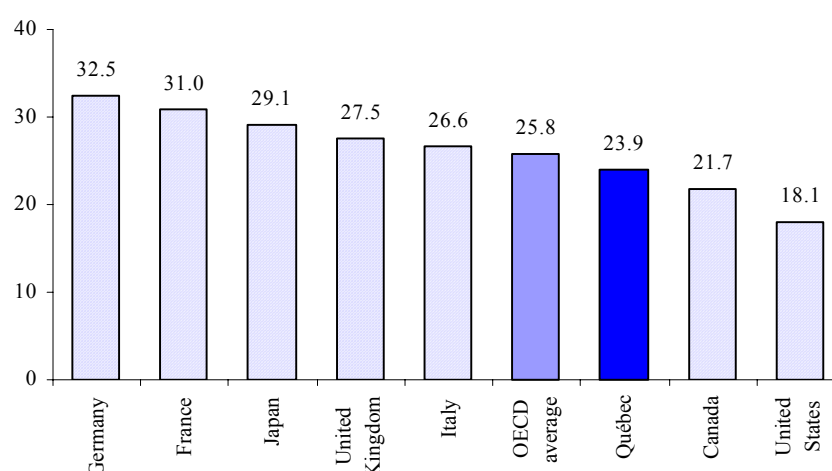
A society founded on knowledge cannot exist without leading scientific and technical practitioners. **Intellectual and human capital become the sinews of war in the race for innovation.** They are the **girders that support a knowledge economy**. It is widely acknowledged that Québec has a considerable amount of catching up to do if it wants to remain in the race and be considered a major international player.

### 2.1 Highly qualified personnel, crucial for innovation and foreign investment

Training of researchers and highly qualified personnel is the main contribution to innovation of university NSE research. The proportion of Pure and Applied Science graduates is a gauge of a State's ability to create a pool of highly qualified personnel, to innovate, and to ensure the sustainability of research through a new generation of professionals.

- In 2000, nearly **one quarter (24 %) of the degrees** awarded by Québec universities were in **Pure and Applied Science** (Ministère du Développement économique et régional, 2003);
- Overall, however, this performance is **below the average for OECD countries (25.8%), which, in turn, is below that of five G-7 countries.**
- **The availability of a sufficiently large pool of qualified personnel and high-calibre research centres is crucial** if a region is to develop scientific and technological convergence points, attract foreign companies, and enhance its position on a North American scale. A recent OECD document concludes that **multinationals increasingly tend to establish their R&D locations near scientific and technical centres of excellence**, concentrated regionally in groupings of high-tech companies or near big universities or public laboratories (OECD, 2003).

**University degrees in Pure and Applied Science, G7 countries, average of OECD countries and Québec, 2000**  
(percentage of total)



Source: Ministère du Développement économique et régional (2003).

### **MONTRÉAL, ONE OF NORTH AMERICA'S LEADING TECHNOCENTRES**

In recent years, Greater Montréal's economy has changed to accommodate more and more knowledge-based technology sectors. Today it is recognized as one of North America's leading technocentres. According to Montréal Technovision's report on performance indicators, Montréal fares very well among North America's 14 major technological cities:

- ♦ 14th for population;
- ♦ 10th for technology jobs;
- ♦ 9th for information technology;
- ♦ 8th for biopharmaceuticals;
- ♦ 5th for the aerospace industry.

Take, for example, MDS Pharma, recently established in Montréal. This company, with 1200 employees, 400 of them chemists, has a turnover rate of 10% a year. This means that it needs 40 new chemists a year, but, in any given year, barely 250 chemists graduate from Québec universities. The odds are therefore that any similar companies will settle elsewhere than Montréal, perhaps in France or Philadelphia.

According to E&B Data, which documents investment projects, in 2000-2002, nearly two thirds of the industrial investments posted for the region were made by foreign companies. A breakdown by sector shows that the information technology, telecommunications, biomedical and aerospace sectors were among those that attracted the most foreign investment in terms of project value and volume alike. Several international-calibre high-tech sectors have chosen Montréal:

- ♦ in the aerospace industry, Pratt & Withney, Honeywell Aerospatial and Bell Helicopter Textron;
- ♦ in information technology, Oracle, CAE Electronic and Cognicase;
- ♦ in telecommunications, Nortel Networks and Ericsson Research Canada.

Québec has six of Canada's seven multinational pharmaceutical research centres. The foreign companies with bases in Montréal account for a quarter of the jobs in the four high-tech sectors:

- ♦ 58.7% in biopharmaceuticals;
- ♦ 25.9% in the aerospace industry;
- ♦ 21% in information technology;
- ♦ 14.6% in telecommunications.

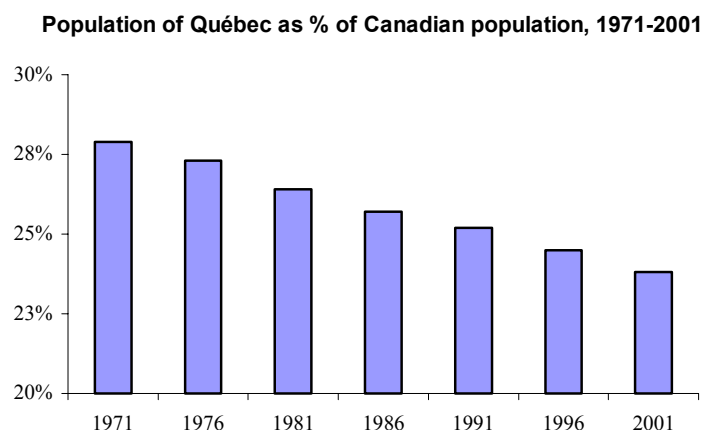
Greater Montréal is one of the privileged few places that can boast the presence of three strategic industrial clusters of world-class high technology sectors. According to The Economist Intelligence Unit, these clusters are attracting potential investors, especially to urban centres. This has become a new location criterion for decision-makers. Greater Montréal is also well placed in terms of emerging sectors that will be pivotal for the future, e.g. nanotechnology, new materials, sustainable development and climate change technology.

## 2.2 Québec is not in a position of strength

In the next few years we can expect an out-and-out worldwide battle for highly qualified personnel in general, and in Natural Sciences and Engineering in particular. Industry Canada posits that some 180,000 researchers, scientists and engineers will be needed in order for R&D to reach the targeted 3% of GDP by 2010. **And Québec is weakly positioned because its manpower pool is relatively low.**

Certain socio-demographic or circumstantial factors are conspiring to dry up this pool, making the **short-term situation critical**, and the medium-term situation, disturbing, for Québec's standing:

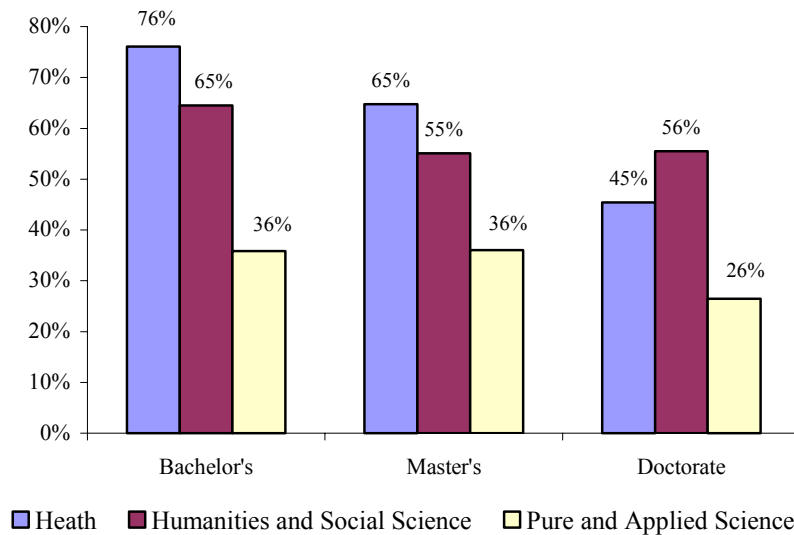
- ♦ **Population decline is sapping the future manpower pool** in most Western countries. Since population aging is happening more quickly in Québec than elsewhere in Canada, it is safe to assume that the situation will be no better here.



Source: Institut de la statistique du Québec, 2002b.

- ♦ Generally speaking, so far the population decline has not had an impact on university enrolment, as the figures of the past six years demonstrate (Meeting of Québec University Deans and Principals, 2003), **but recent trends in college enrolment** (Institut de la statistique du Québec, 2003b) **point to problems in the medium-term.**
- ♦ **Women account predominantly for the increase in university enrolment. However, they are less interested in Natural Sciences and Engineering**, despite the progress made thus far (Ministère de l'Éducation du Québec, 2003a). **In Pure and Applied Science, there are fewer female Master's (36%) and Ph.D. (26%) graduates than male graduates.** There are even fewer women in Engineering and Applied Sciences. Life Sciences is the sector that has the highest female enrolment.

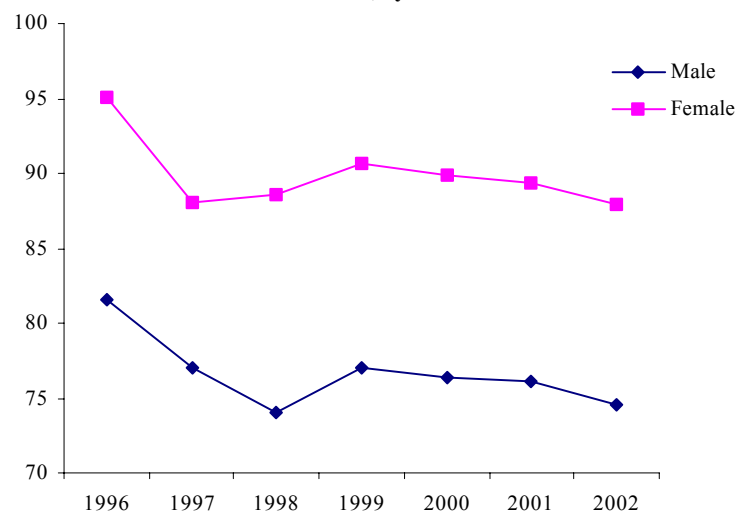
### Female graduates (Bachelor's Master's, Doctorate) by field of study, Québec, 2000



Source: MEQ, RECU; compilation Fonds Nature et Technologies.

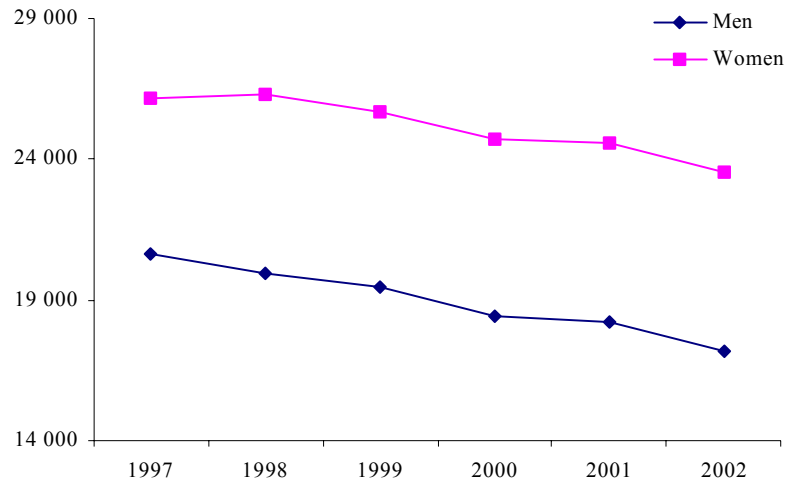
- **Traditionally, men are more interested in careers in Sciences and Engineering but do not do as well academically.** This situation augers ill for NSE because the low pass-rate of boys in secondary school and dwindling junior college enrolment exacerbate **the problem of population decline**. This male decrease is **particularly significant for the Applied Science** sector because it is the number one pre-university choice of these graduates (28.4%) and **the shortfall is not compensated by higher female enrolment in this sector**, which ranks 5<sup>th</sup> (8.2%) with women (Ministère de l'Éducation du Québec, 2003a).

### Graduate rate for a first secondary level diploma in regular and adult education, by sex 1995 to 2002



Source: MEQ, Indicateurs de l'éducation.

**New enrolments in pre-university and technical program in Québec's junior colleges, 1997-2002**



Source: Institut de la statistique du Québec, 2003c.

- ♦ **The proportion of foreign students is very high** in many engineering research laboratories and, in terms of university enrolment as a whole, increases with the level of study. At the Ph.D. level, nearly 20% of students are not Canadian citizens or permanent residents. In the Pure and Applied Sciences, the proportion is higher (24% and 32% respectively) (Ministère de l'Éducation du Québec, special compilation). A good number of these students will probably not remain in Québec.

Everything hinges on **the training and retention of highly qualified personnel**. According to several organizations (Conseil de la science et de la technologie, Meeting of Québec University Deans and Principals [CREPUQ]), there are no conclusive findings about shortages in general, but there is definitive information about recruitment problems in several sectors of activity. At a time when **human capital is a crucial strategic factor in Québec's future, Québec is faced with fierce competition**:

- ♦ **The research market is globalizing and expanding.** Countries that are already actively engaged in research, particularly OECD members, are stepping up their activities, while others jockey for position and try to establish competitive research systems that are more attractive to scientists.
- ♦ **The bid for qualified personnel is growing, especially in developed countries.** While some countries try to keep or bring back their top intellectuals, e.g. Canada and its **Research Chairs Program**, others have devised extremely ingenious ways of drawing highly qualified personnel, now aptly called strategic workers. In Canada, and notably in Québec, the brain-drain debate resurfaces regularly. Québec has yet to develop a vigorous two-pronged strategy aimed at the international mobility of these graduates and at keeping them here by offering them interesting career prospects. Ontario and the United States offer stimulating career prospects to new graduates from Québec.

- **Renewal of university teaching staff in every province of Canada and in numerous countries is putting unprecedented pressure on the demand for highly qualified human resources.** According to a 2001 study by the Canadian Association for Graduate Studies, universities will be looking to hire 30,000 professor-researchers in the next 10 years, that is, double the current Canadian demand for Ph.D.s.

According to Human Resources Development Canada and Emploi-Québec, the number of university professors will rise only slightly within the next few years and **there is a serious shortage of professors in fields such as engineering, computer science and medicine.** This has been attributed to competition with American universities and universities in the rest of Canada, and industrial competition in the race to recruit highly qualified personnel.

- **Market pressure is heavy** and is such that in some sectors, candidates are hired before they have obtained the qualifications needed to teach at the university level. The **labour market is particularly good for Applied Science undergraduates.** Two years after finishing their degree, 84% of them had a job and only 12% continued studying. This is markedly different from the situation for university graduates as a whole, 20% of whom opt to continue studying (Ministère de l'Éducation du Québec, 2001).
- Even though enrolment at all levels of study in Québec held relatively steady between 1995 and 2001, a 2.3% and a 5.7% decrease was recorded for Master's and Ph.D. enrolment respectively. The trend towards dwindling numbers at the Ph.D. level is even more acute in Pure (10.3%) and Applied (17.4%) Science.

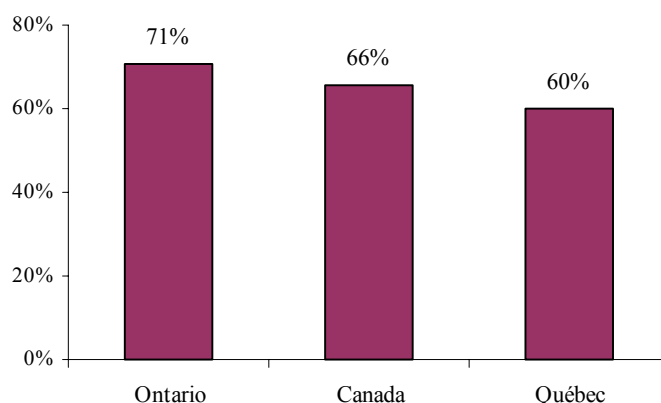
**Doctoral enrolment in Québec universities in Pure and Applied Science,  
1995-1996 to 2000-2001**

|                 | 1995-1996 | 2000-2001 | Variation |
|-----------------|-----------|-----------|-----------|
| Applied Science | 1 715     | 1 417     | -17.4%    |
| Pure Science    | 1 506     | 1 351     | -10.3%    |
| All fields      | 9 177     | 8 653     | -5.7%     |

Source: Ministère de l'Éducation, RECU; Fonds Nature et Technologies compilation.

- **Highly qualified corporate personnel is a weak link in the chain,** accounting for an insufficient proportion of R&D corporate personnel, a phenomenon **that impedes innovation.** This fact is even more worrisome given that companies will be called upon to play a key role in future when it comes to intensified R&D efforts and greater capacity to innovate. The following data speak for themselves.
  - Of all the **corporate R&D personnel in Québec**, professionals represent **60.2%** of personnel, while **in Ontario**, the percentage is **70.6%**. Québec is therefore below the average of **65.6% for Canada as a whole** (Statistics Canada, 2002).
  - **The relative weight of corporate researchers in Québec (40.8%)** in relation to the active population is **lower than that of Ontario (44.7%) and of G7 countries, which average 50.7%** (Ministère du Développement économique et régional, 2003).
  - In **Québec, 82.7% of corporate R&D professionals have a Bachelor's degree**, 11.3%, a Master's, and only 6%, a Ph.D. (Institut de la statistique du Québec, 2003d).

### R&D professionals in industry, as a proportion of all occupational categories, Québec, Ontario, Canada, 2000



Source: Statistique Canada, 2002.

This shortage of skills is such that the ability of companies to absorb innovations is relatively weak, which obliges Québec universities to produce more spin-offs than to transfer technology to existing companies that know the market.

## 2.3 A problem of skills and career management

Above and beyond concerns as to numbers, training young Quebecers in NSE is perhaps primarily a matter of skills, since **in order for graduates to be able to help build the economy of the XXIst century and make their way in a society that prizes innovation**, they must be **well trained and capable of meeting the requirements of the new careers**. What is more, to remain competitive and at the forefront of their sector of activity, **Québec companies will need manpower that is innovative, highly qualified and heavily connected to knowledge dissemination circuits**.

According to the Conseil consultatif des sciences et de la technologie (CCST), there will be **an endemic shortage of candidates with knowledge and skills**. While so far, generally speaking, training of Master's graduates is generally considered satisfactory by employers and students, the same cannot be said of training at the doctoral level.

- ♦ Students and employers alike say there is **lack of preparation for possible careers, lack of skills** (training too narrow, lack of openings), and lack of experience, and that guidance and supervision is of uneven quality (Fonds Nature et Technologies consultations).
- ♦ A few decades ago, Ph.D. graduates traditionally headed towards university careers, **but today the majority of openings are outside the academic community**.
- ♦ **Training has not kept pace and is still too academic**, making it difficult for Ph.D. graduates to adapt to the workplace.

- ♦ According to data from *Relance à l'université* (Ministère de l'Éducation du Québec, 2001), **63% of Ph.D. graduates in NSE work in a milieu other than a university**. After universities and junior colleges (37%), the professional, scientific and technical services sectors (34.5%) hire the most graduates, with public administration (9.1%), manufacturing (8.2%) and other industries (10.9%) lagging behind (Ministère de l'Éducation du Québec, 2001; special compilation; Fonds compilation).
- ♦ **Of the slightly more than one third of Ph.D. graduates in NSE that work within the academic community**, only 15% are university professors (Ministère de l'Éducation du Québec, 2001).

A number of organizations, including the Association de la recherche industrielle du Québec (ADRIQ), recommend creating conditions that are favourable to establishing graduate programs that focus on skills and that are **better tailored to industrial R&D requirements and practices**.

An increasing number of convincing experiments have been conducted, notably in England (TCS), France (CIFRE) and Alberta (Alberta Ingenuity Fund) on facilitating and supporting the entry of Ph.D. graduates into companies. Change is underway, slowly but surely.

## 2.4 Foreign competition, an emerging threat

In addition, **delocalization, spawned by globalization, in which companies in developed countries subcontract to foreign interests, is a serious threat to Québec's high-tech position and to its highly qualified personnel**. In fact, it is **veritable time bomb** that is not about to go away.

- ♦ This phenomenon is growing, primarily because of the gradual abolition of trade barriers and the search for low-cost expertise. Several multinationals, including IBM, Oracle and Microsoft, to name but the most famous ones, have started **using the services of the hordes of well-trained and affordable engineers available principally in India**. The differences in the cost of labour speak volumes: \$60,000 for a computer programmer in the United States compared with \$5000 in India. To borrow from a popular expression, just do the math! Incidentally, India produces 2 million university graduates a year.
- ♦ Even if **Québec has been spared thus far, it is only a question of time before our well-qualified and well-paid employees feel the crunch**. This trend is vast and worldwide. India is not the only provider of a huge pool of graduates who are fluent in English. So are the Philippines and South Africa, as well as China and Russia, which also have scores of graduates ready to work for a pittance. European countries are also turning to countries teeming with knowledge-sector workers, such as Ireland, Romania or Bulgaria. France uses the same approach with French-speaking countries in North Africa, notably Morocco and Tunisia.

If Québec is to be recognized as a centre for innovation, it would be well advised to make the emergence of a new generation of highly qualified workers a priority, and their entry into the industrial labour force, a prime objective.

### 3. AN IMPERATIVE: STRENGTHENING QUÉBEC'S POSITION AS A CENTRE OF INNOVATION WITHIN CANADA

#### 3.1 Canada's Innovation Strategy

With its *Innovation Strategy* launched over a year ago, **the Canadian government plans to catapult Canada to the 5th place in the world for R&D as a percentage of GDP**. This goal is a formidable challenge for the development of highly qualified personnel and industrial R&D.

- Since 1998, the Government of Canada has instituted a number of measures aimed at strengthening basic university research and supporting researcher training through the Canadian Foundation for Innovation (CFI), which manages a \$3.6 billion budget in major scientific facilities and equipment, and whose total contribution to date is \$2 billion, and the **Canada Research Chairs Program, aimed at establishing 2000 research Chairs in Canadian universities, a little over 500 of which would be in Québec**. These initiatives should help Canada regain some of its emeritus researchers and attract excellent candidates from outside Québec.
- Thanks to these two programs, the Canadian government also increased the budgets of subsidizing organizations and decided to grant universities an envelope to cover indirect research-related costs through the Canada Graduate Scholarships Program, aimed at increasing Master's and Ph.D. scholarships by 2000 each. The government also added two new groups to its networks of centres of excellence, bringing the total to 20, **five of which are headquartered in Québec, including the new research network in the Arctic, Réseau ArticNet**, helmed by a researcher from Université Laval.
- The Canadian government has also made certain **strategic choices** and developed specific **initiatives** in the following fields:
  - security;
  - sustainable development and renewal of energy resources (Kyoto Protocol);
  - climate change (Canadian Foundation for Climate and Atmospheric Sciences);
  - genomics (Genome Canada).
- The government is preparing to **set up technological and industrial clusters** in the various regions of Canada, with a focus on promising and underutilized sectors such as environmental technology and new health technology.
- Lastly, the federal government's **priority for the coming years is to enable SMBs to innovate and perform better in the new economy**. The plan is to provide them with the necessary support, ranging from research to marketing and protection of intellectual property to financing. To improve the economic potential of SMBs, the federal government intends to facilitate investment in the best technological practices and in professional development.

To strengthen its position as a centre of innovation within Canada, Québec must be an active participant in this innovation strategy. The preferred courses of action are presented in Québec's Policy on Science and Innovation that the new government has decided to update.

In terms of challenges pertaining to Natural Sciences and Engineering, three courses of action must be favoured, **in addition to the clear priority to be given to human capital: make public research the cornerstone of innovation, build innovation leadership in Québec, and develop new forms of partnership with the federal government.**

### 3.2 Make public research the cornerstone of innovation

Québec's Policy on Science and Innovation states that **"in itself, the natural sciences and engineering is of particular importance today, bearing in mind the accelerated development and dissemination of technological innovation. It is essential to strengthen the organization of research in this specific field and for the FCAR (now the Fonds québécois de recherche sur la nature et les technologies) to devote its full attention to it."**

The current trend internationally is to increasingly focus on investments in quality and genuinely original fundamental research. This is the **keystone to any high-performance research and innovation system**. It is well known that **establishing top-of-the-line public research centres** of international scope **is crucial in generating and maintaining sustainable quality research** and, in the long run, maximizing the benefits for society.

Over the past 20 years, Québec has unceasingly invested in excellence research infrastructures. Today it is well positioned in several areas of research thanks to its critical mass of researchers with superior expertise.

- Québec, through the Fonds Nature et Technologies, has, over the past three years, invested in **establishing groups of NSE researchers, thereby creating centres of excellence in research in priority sectors**, with Québec benefiting significantly.
- So far, **25 strategic groups** have been subsidized by the Fonds Nature et Technologies, in partnership with universities and a number of private associates, for a total of nearly **\$60 million over six years**. These strategic groups are called upon to play a very active, if not a defining role, in training highly qualified personnel and in transferring knowledge. Nearly 4000 undergraduate and graduate students are guided and supervised by the 779 university researchers in these centres of excellence and take an active part in research work.
- Investments by the Québec government and the CFI in research facilities, to the tune of over \$350 million for Québec's NSE researchers so far, have enabled **many research centres to revamp** their equipment.
- These **strategic groups of high-calibre researchers** concentrated in recognized centres of excellence **provide leverage and are a springboard for enhancing Québec's research status within Canada, for brokering a sizeable share of federal government subsidies, and for exercising genuine scientific leadership in the fields concerned**. However, this performance will be possible only through sustained long-term efforts by these centres of excellence.

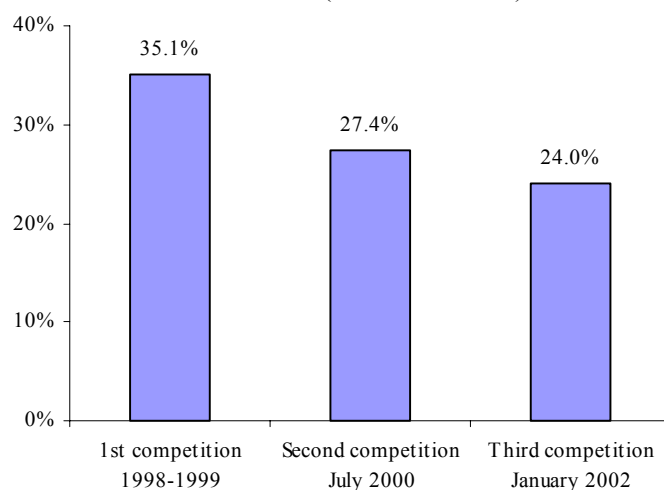
#### A worrisome backslide

Recent data on the ranking of Québec's NSE researchers within Canada show that they are losing ground with federal agencies:

- **At the first Innovation Fund program (Canadian Foundation for Innovation Fund) competition (1998-1999), Québec institutions did well**, obtaining 35% of the amounts earmarked for the program. By the third competition, **in January 2002, Québec's slice of the pie had dropped by 24%**;

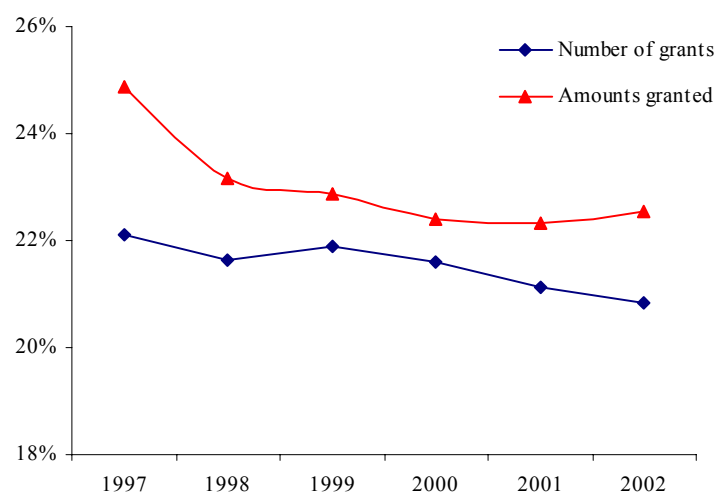
- As for Natural Sciences and Engineering Research Council of Canada (NSERC) programs, **the performance of Québec researchers and scholarship recipients has decreased slightly since the late 1990s**, from 24.9% to 22.6% of the Canadian whole from 1997 to 2002;

**Share of Québec universities and junior colleges in the CFI's Innovation Fund program**  
(CFI contribution)



Source: FCI

**Québec researches' and scholarship holders' share of NSERC scholarships and subsidies 1997-2002**



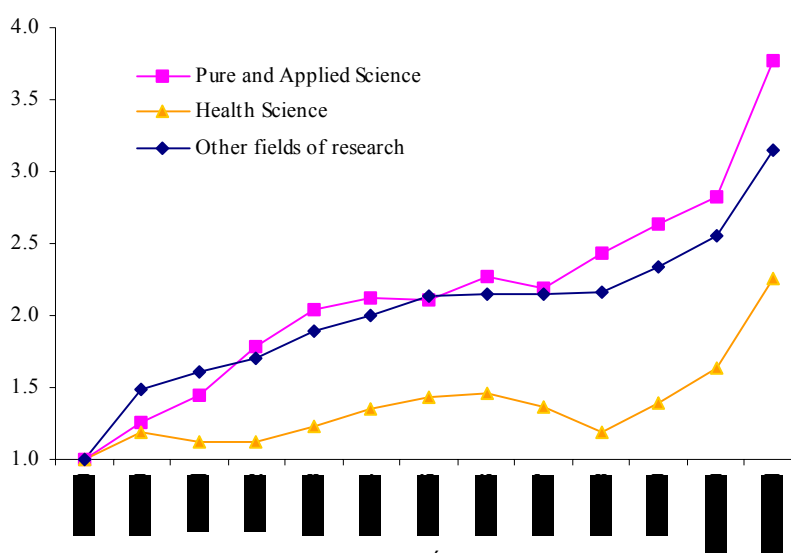
Source: NSERC

- The **other Canadian provinces have found ways of** increasing their share of federal subsidies **based on Québec's approach** to producing measures for enhancing research and innovation in Natural Sciences and Engineering. A case in point is the Alberta government's creation of the \$500 million *Alberta Ingenuity Fund* in 2000. The government of Ontario has two major tools, the *Ontario Challenge Fund* (\$750 million over 10 years) and its centres of excellence (annual public investment of \$35 million). New Brunswick recently created an innovation fund endowed with \$20 million a year.

Even if it is acknowledged that Natural Sciences and Engineering research is essential to the process of innovation, the facts show that **there has been a downtrend in provincial funding in this sector in the past ten years.**

- **The weight of research** in Pure and Applied Science relative to research as a whole **went from 46% to 42%** from 1989-90 to 1999-2000 (Ministère de l'Éducation, Système d'information sur la recherche universitaire [SIRU]).
- **Canadian private sector contracts and subsidies** (- 7 points) and **provincial government contracts and subsidies** (- 7 points) are mainly **responsible for this downturn**. Funding from the Canadian government held steady over this period (Ministère de l'Éducation, SIRU).
- Figures on university spending on contracts and sponsorships show that **subsidies from provincial sources have developed differently depending on the sector of research**. In NSE, growth in 2000-2001 was double that of 1988-1989. This growth ratio quadrupled in the health sector.

**Trends in provincial subsidies by field of research for Québec universities 1989-1990 and 200-2001**



Source: Ministère de l'Éducation, SIRU.

- In the past five years, the **Québec government has spurred university research in NSE through Valorisation-Recherche Québec (VRQ)**, with the NSE sector receiving 37% of the \$125 million invested by this organization in major research projects (VRQ, special compilation). This goes a long way towards explaining the provincial upsurge in this sector starting from 2000-2001. VRQ investments will end starting in 2004. Within the next few years, this shortfall will make the **weakness of provincial investment in innovative NSE research** (the Fonds Nature et Technologies has the smallest budget of the three Fonds de recherche du Québec) even more acute, at a time when universities will be scrambling to find recruits.

### **A promising development model, but with no lasting guarantee**

In recent years, commercial development of university research has made great strides with the introduction of development corporations by Valorisation-Recherche Québec and the creation of spin-off companies, **a model that even at this early stage is proving productive, but that must be consolidated.**

The development corporations (Sovar, Univalor, Valéo and MSBI) which led to the creation of the Development component of VRQ manage a portfolio for developing and commercializing research results for sponsoring universities. All **four corporations have already proven their mettle:**

- **increase in the number of patents obtained and growth of the economic benefits generated;**
- in all, 650 development dossiers have been examined since activities began, leading to 313 patents, **247 of which are currently being developed.**

In 2002-2003, Univalor created four spin-off companies. One of them, Cerestech inc., was formed to develop new biodegradable polymers based on work at the École polytechnique de Montréal.

Another venture capital company, MSBI s.e.c., bred three spin-off companies in 2002-2003, including DFT MicroSystems inc., specializing in advanced solutions in the realm of microprocessors using techniques developed at McGill University.

**Investment by these corporations has provided leverage**, so that every dollar invested in the projects is matched three-fold by other partners (Valorisation-Recherche Québec, 2003). Unfortunately, these development initiatives, which are few and far between and are still fragile, must be supported to ensure continuity and full benefit.

### **Continuity and balance in public investment: critical factors**

Building a strong research system and internationally recognized centres of excellence requires continuity in public support in order for Québec to keep its competitive position in these fields. Making public research the cornerstone of innovation also requires intervention that strikes the right balance between support for research on the one hand, and the transfer and development of knowledge on the other.

### 3.3 Building innovation leadership in Québec

In this era of globalization, many of the world's most developed countries are in a race against the clock to enhance their international competitiveness and take advantage of new market opportunities. **Winning this race increasingly hinges on the ability to quickly deploy resources to these emerging niches.**

This means **hefty funding** in order to develop specific fields. Developing a centre for innovation is a monumental task which forces small economies such as that of Québec to **focus investment in areas where they can exercise leadership and increase their international connections in other fields.**

This ability to come up with sizeable resources quickly is equally crucial for **reacting appropriately to complex economic, social and environmental issues** such as climate change, development of new energy sources, and sustainable forestry.

Hence the pressing need to **ensure Québec leadership and joint action in leading-edge spheres of endeavour that are strategic for its development, with a view to making them areas of excellence that are recognized across Canada and around the world.**

Take, for example, the following fields where Québec can play a leadership role:

- ♦ information technology;
- ♦ biotechnology;
- ♦ climate change;
- ♦ telecommunications;
- ♦ aerospace;
- ♦ new materials;
- ♦ robotics;
- ♦ hydro-electric engineering;
- ♦ marine science and technology;
- ♦ the northern environment.

**Building this leadership requires unprecedented joint action and synergy** on the part of all university, government and industrial community players.

Interesting joint initiatives are beginning to take shape, notably under the impetus of Valorisation-Recherche Québec and with the support of the Fonds Nature et Technologies.

The **Centre québécois de recherche et d'innovation en aérospatiale (CRIAQ)** conducts precompetitive research for optimizing innovation. Founded in 2002, CRIAQ is a non-profit consortium created to promote and carry out joint precompetitive aerospace research projects. By emphasizing research, innovation and training, CRIAQ helps increase the Québec aerospace industry's leadership and international competitiveness while offering stimulating careers for young researchers.

Similarly, in April 2001, **Réseau Nano-Québec** received \$10 million over three years from VRQ to structure, develop and promote Québec nanotechnology, a field in which Québec lagged behind industrialized States for research funding. Because of this subsidy, **Réseau Nano-Québec has achieved two important goals: doubling the number of researchers in the field (30 to 60 researchers), and undertaking structuring of research forces around five major themes:** nanomaterials, nanoelectronics and nanophotonics, nanobiotechnology and nanosystems, while creating conditions conducive to the full use of the scientific facilities obtained from Québec and the CFI. The Réseau is very involved in the development of a nanotechnology complex that will be

dedicated to the industrial development of nanotechnology in Québec, with a view to assuring effective links with the academic community in the areas deemed strategic by the industry.

Lastly, there is a **joint action strategy that has become a model in Canada**. Since 1996, **Québec's dairy industry has been at the forefront of a network of research alliances aimed at improving the competitiveness of this industry**. This is how three strategic research programs geared to the priority needs of this industry were launched by **Novalait inc.**, the Fonds de développement de l'industrie laitière, and the Fonds Nature et Technologies, in collaboration with the ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec (MAPAQ) and, more recently, Agriculture and Agri-Food Canada (AAC). These programs promote synergy among established and new researchers in matters related to training, and among milk producers and processors in matters related to technology transfer.

These collaborative experiences, while significant, are still sparse, especially in industrial sectors.

### 3.4 Develop a very active partnership with the federal government

In order to benefit fully from the federal innovation strategy, **Québec must, like the other provinces, get organized and make strategic investment choices in partnership with universities and companies**. The economic and social stakes for Québec are high.

The federal government is a crucial partner in enabling Québec to have these centres of excellence recognized and developed. Only the joint action and leadership described above will make it possible to influence the federal investment agenda.

Projects involving joint action with and positioning vis-à-vis the federal government, such as those described below, are proving to be very worthwhile, even at this early date.

- The partnership between Québec government departments and agencies and Environment Canada in the **OURANOS project**, dedicated to climatology and adaptation to climate change. This networking has led to an excellent positioning of OURANOS researchers vis-à-vis the Canadian Foundation for Climate and Atmospheric, which could prove to be a substantial source of funding.
- The partnership that has developed among several Québec agencies, the Fonds québécois de la recherche sur la nature et les technologies, the Fonds de la recherche en santé du Québec, Génome Québec, Valorisation-Recherche Québec and Québec universities (a partnership that includes the private firm CGI) for creating a **consortium to develop bioinformatic research in Québec**. The purpose of the partnership is to position Québec advantageously for the next Genome Canada competition.
- **Aluminum processing** in which all Saguenay – Lac Saint-Jean region stakeholders joined forces to promote and support this industrial innovation sector, **which led to the creation of a National Research Council (NRC) Canada aluminum technology centre in Chicoutimi, among other achievements**. In the wake of this development, the Fonds also granted funding to all aluminum researcher associations in Québec.

**While the federal government is poised to establish technological and industrial clusters in Canada**, Québec leaders must continue to encourage, support and even orchestrate any efforts to approach this level of government **in order to create genuine strategic momentum for innovation and recognition of Québec leadership in these niches**.

SMBs stand to gain from sector-based dynamics of this kind. Measures are intended for smoothing the way for proven SMBs to join these technological innovation clusters in order for the ripple effect to spread to big multinationals. Necessarily, government research centres and junior college technology research centres will be partners for certain initiatives.

## 4. CONCLUSION

### 4.1 Making human capital our main concern

The battle for highly qualified human capital must be waged on three closely related yet separate fronts: **promotion, training and careers.**

#### Promotion

- ♦ **Numerous interesting initiatives** for promoting scientific and technical careers in schools are already underway with the support of the ministère du Développement économique et régional (MDER) and an array of agencies (Société pour la promotion de la science et de la technologie [SPST], Conseil du loisir scientifique [CLS], etc.), as well as public (municipalities, school boards) and private (big companies) partners. These courses of action will require continued support.
- ♦ **What is lacking** in order to arouse students' interest in scientific and technological careers **is a greater number of direct links between young people and researchers.**

#### Our proposal:

**That the Fonds Nature et Technologies develop an initiative consisting of summer practicums for college students** (general and technical programs) **in** university, government and industrial **research venues**, and that it develop the necessary partnerships with junior colleges, universities, government research centres and companies to complement the NSERC program for undergraduates.

#### Training

- ♦ **The first matter is quantitative: how to attract the brightest and best young Quebecers to the various research-based occupations**, especially those requiring advanced training (Master's, doctorate, postdoctorate), **by assuring a better fit with priority needs in different sectors of activity.**
- ♦ The Fonds is **a leading supporter of training of highly qualified personnel**, with **nearly two thirds of its budget** directly or indirectly earmarked for that purpose. It manages a merit scholarship program for the Master's, Ph.D. and postdoctoral levels that complements the NSERC program. However, the need of Québec students for financial support remains considerable. **Scholarship applications have increased by at least 35% in the past two years, but only 17% of Master's or doctoral students are awarded federal or provincial merit scholarships**, which means that, to a large extent, demand far exceeds supply. This percentage could reach 24% with the new federal scholarship program for higher studies, which is still insufficient for attracting the best performers in this sector.

**Our proposal:**

Increase the Fonds Nature et Technologies scholarship budget, with a primary focus on stepping up the training of highly qualified personnel by the academic and industrial community, in sectors deemed to be strategic, and on fostering on-the-job training in partnership with industry.

- ♦ **The second issue is qualitative**, namely, to better prepare young people for the different research occupations and to ensure they have the required skills.

**Our proposal:**

**That the Fonds Nature et Technologies use the best international experiences as templates for a number of innovative training projects**, and that it develop the required partnerships, in particular with the ministère de l'Éducation du Québec, the universities and NSERC.

**Careers**

- ♦ In contrast with the trend worldwide, at the moment, Québec industry cannot offer graduates, doctorate holders in particular, worthwhile career prospects due to lack of the required skills.

**Our proposal:**

**Facilitate and support the entry of highly qualified personnel within companies** by drawing inspiration from the best Canadian and international experiences. Financing could come from qualifying tax credits, from joint Fonds Nature et Technologies/company job entry subsidies, or from leverage from the NSERC program.

## **4.2 Strengthen Québec as a centre of innovation through a solid collective effort**

### **University excellence research centres in NSE**

- ♦ Attracting and retaining the best researchers, capturing the interest of major corporations, and developing scientific and technological clusters is conditional on maintaining existing internationally recognized university research centres and creating new ones.
- ♦ In the past 20 years, Québec has constantly invested in these centres of excellence research, in particular through its contribution to modernizing scientific equipment and facilities and to establishing strategic groups of researchers in key sectors. Sustained and long-term effort is required for maintaining their performance, for making heavy investment in scientific facilities and equipment pay off, and for affirming Québec's leadership in a certain number of centres of excellenc

**Our proposal:**

That the Fonds Nature et Technologies consolidate its action to support the development of infrastructure for centres of excellence in NSE in Québec.

**Building innovation leadership in strategic sectors**

- ♦ Leadership and concerted action by all academic, government and industrial stakeholders make it possible to rapidly deploy resources to targeted areas of action so as to seize new market opportunities or contribute to finding solutions to environmental problems.
- ♦ **These joint targeted investments must figure among the strategic choices made by the Québec government.**
- ♦ Interesting initiatives were undertaken in Québec recently under the impetus of Valorisation-Recherche Québec and the Fonds Nature et Technologies. VRQ's funding operations will fold in 2004 and the Fonds cannot afford investments large enough to ensure the joint action required to develop the centres of innovation deemed priorities for Québec.

**Our proposal:**

Institute an innovation fund for targeted sector-based support for innovation and research initiatives, developed in tandem with universities, junior colleges, governments and industry, including proven SMBs.

Use the models implemented internationally and in other parts of Canada (Ontario, Alberta, Maritime Provinces) as templates.

Entrust the Fonds Nature et Technologies with management of this fund for the ministère du Développement économique et régional.

**Develop a very active partnership with the federal government**

The federal government is a crucial partner in enabling Québec to have these centres of excellence recognized and developed. Only the joint action and leadership described above will make it possible to influence the federal investment agenda.

**Our proposal:**

Position Québec's centres of excellence within the strategy to establish technological and industrial clusters and negotiate the conditions for partnership investment with the federal government.

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