Canada Foundation for Innovation
Fondation canadienne pour l'innovation

# 2010 analysis of investments in research infrastructure

December 2010

FINAL REPORT

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# GLOSSARY OF TERMS

| | |
|---|---|
| **AUCC** | Association of Universities and Colleges of Canada |
| **CFI** | Canada Foundation for Innovation |
| **CRC** | Canada Research Chairs |
| **HQP** | Highly qualified personnel |
| **IOF** | Infrastructure Operating Fund |
| **IR** | Institutional reports |
| **KT** | Knowledge transfer |
| **LOF** | Leaders Opportunity Fund |
| **NSERC** | Natural Sciences and Engineering Research Council |
| **OECD** | Organisation for Economic Co-operation and Development |
| **OPEA** | Overall performance and evaluation audit |
| **O & M** | Operations and maintenance |
| **OMS** | Outcome measurement study |
| **PDF** | Post-doctoral fellow |
| **PERAF** | Performance, evaluation, risk and audit framework |
| **PPR** | Project progress reports |
| **R & D** | Research and development |
| **SRP** | Strategic research plan |
| **S & T** | Science and technology |
| **TTT** | Traditional technology transfer |

# 1.0 INTRODUCTION

Created by the Government of Canada in 1997, the Canada Foundation for Innovation (CFI) strives to build our nation's capacity to undertake world-class research and technology development to benefit Canadians. Thanks to CFI investment in state-of-the-art facilities and equipment, universities, colleges, research hospitals and non-profit research institutions are attracting and retaining the world's top talent, training the next generation of researchers, supporting private-sector innovation and creating high-quality jobs that strengthen Canada's position in today's knowledge economy.

The CFI's national objectives are to enhance the capacity of institutions to:

- support economic growth and job creation, as well as health and environmental quality through innovation;
- carry out important world-class scientific research and technology development;
- expand research and job opportunities by providing support through research infrastructure for the development of highly qualified personnel;
- promote productive networks and collaboration among Canadian universities, colleges, research hospitals, non-profit research institutions and the private sector.

The Government of Canada's science and technology (S & T) strategy, *Mobilizing Science and Technology to Canada's Advantage*, identifies and strives to enable three key advantages — Entrepreneurial, Knowledge and People. In fulfilling its mandate, the CFI not only fosters these key advantages, but also aligns with the four core principles of the strategy: promoting world-class research excellence, focusing on priorities, fostering partnerships and enhancing accountability.

The research enabled by the CFI supports the necessary conditions for sustainable, long-term economic growth, including the creation of spin-off ventures and the commercialization of discoveries, which in turn supports improvements to society, health, the environment and public policy. To date, the CFI has committed more than $5.3 billion in support of more than 6,800 projects at 131 research institutions in 65 municipalities across Canada. These investments by the Government of Canada through the CFI have leveraged an additional $7 billion in partnership funding.

These expenditures of public funds have rightfully been accompanied by a growing insistence on greater accountability, and more accurate and meaningful measurement of results. The CFI has met these demands by developing several methods to collect data on its investments in R & D. For the first time, the CFI is presenting the findings from multiple lines of evidence in one report. The purpose of the 2010 analysis of investments in research infrastructure is to document the outputs and outcomes of CFI-funded infrastructure as they relate to the overall objectives of the CFI and its programs.[1] The information in this report is a synthesis of a range of evaluation activities detailed in Section 2.0. The findings illustrate the critical role that CFI infrastructure has played in achieving its national objectives and will inform future program evaluations and other special studies.

[1] The CFI logic model identifies the causal or logical relationships between activities, outputs, outcomes and the ultimate impacts of the organization and is presented as a component of the Performance, Evaluation, Risk and Audit Framework available at www.innovation.ca/en/evaluation/performance-evaluation-risk-and-audit-framework.

# 2.0 METHODOLOGY

Drawing upon its current performance, evaluation, risk and audit framework (PERAF), the CFI collects and analyzes information using: project progress reports (PPR); institutional reports (IR); outcome measurement studies (OMS); the overall performance evaluation and value-for-money audit (OPEA); and other special studies. Each of these tools and activities are described in the following sub-sections.

### *Project progress reports (PPR)*

Institutions are required to submit a PPR for each funded project by June 30 each year, for five years after the award agreement is put in place. Individual PPRs are prepared by project leaders and submitted by their host institutions. The PPR is a self-reported electronic survey with quantitative and qualitative sections, both of which are helpful in measuring the CFI's progress towards meeting its objectives. Open text boxes allow respondents to elaborate on their answers and provide valuable qualitative information. Project leaders are asked to report data "in the past year" only. Highlights of the project progress report analysis are presented in Appendix A.

Composition of the 2010 PPR sample

By the deadline of July 21, 2010, a total of 2,433 of the 2,748 required reports had been received, representing a submission rate of 89 percent (Table 1)

Table 1. Summary of PPR data sample, 2010 (n=2,433)

| Category | No. of funded institutions | No. of funded projects | No. of reports submitted | Response rate (%) |
|---|---|---|---|---|
| A. Large universities, hospitals and non-profit | 39 (46%) | 2,330 (85%) | 2,114 (87%) | 91% |
| B. Small universities[2] | 45 (53%) | 408 (15%) | 318 (13%) | 78% |
| C. Colleges | 1 (1%) | 10 (0.4%) | 1 (0.1%) | 10% |
| **Total** | **85 (100%)** | **2,748 (100%)** | **2,433 (100%)** | **89%** |

The CFI benefits from the strong submission rates of project progress reports. Project leaders, for the most part, submit all of the necessary reports by the deadline. Institutions are advised that future instalments for all CFI-funded projects will be withheld if outstanding reports are not submitted in a timely manner. Ultimately, all requisite reports must be submitted.

### *Institutional reports (IR)*

Institutions with one or more PPRs due are also required to submit an IR by July 31 each year. These reports are largely qualitative, and address the overall impact of CFI investments on the institution's ability to implement its strategic research plans in areas such as building capacity, partnership promotion and generating benefits for Canada. They also address challenges. The information collected through the IR is used to inform the CFI's annual report, outcome measurement and other evaluation-related special studies.

[2] Universities are categorized based on whether they receive greater than or less than one percent of total federal funding agency awards. For example, small universities receive less than one percent of total federal funding agency awards.

Composition of the 2010 IR sample

By the deadline of July 21, 2010, a total of 67 of the 85 required reports had been received, representing a submission rate of 79 percent (Table 2).

Table 2. Summary of IR data sample, 2010 (n=86)

| Category | No. of funded institutions | No. of reports submitted | Response rate (%) |
|---|---|---|---|
| A. Large universities, hospitals and non-profit | 43 (51%) | 29 (43%) | 67% |
| B. Small universities | 40 (47%) | 37 (55%) | 93% |
| C. Colleges | 2 (2%) | 1 (2%) | 50% |
| **Total** | **85 (100%)** | **67 (100%)** | **79%** |

The CFI benefits from the strong submission rates of institutional reports. Institutions, for the most part, submit all of the necessary reports by the deadline. Institutions are advised that future installments for all CFI-funded projects will be withheld if outstanding reports are not submitted in a timely manner. Ultimately, all requisite reports must be submitted.

***Outcome measurement study (OMS)***

Complementary data and information on research outputs and outcomes is obtained through the OMS, a detailed study of clusters of projects. The OMS assesses the degree to which CFI's investment in research infrastructure contributes to five outcomes: strategic research planning, research capacity, highly qualified personnel, research productivity and innovation.

Using both quantitative and qualitative data, the OMS methodology captures the richness of the impacts of the CFI and partner investments in a thematic area. Each OMS takes into account the research successes and innovation stories that cannot always be assessed through more traditional evaluation methods, such as surveys or progress reports. The OMS methodology includes an institutional self-study which involves the institution compiling a report that summarizes the research outputs and outcomes within a theme using an OMS template.[3] The resulting data report is assessed by a panel of independent experts during a 1.5 day site visit to the institution. The expert panels are comprised of Canadian and international experts from academia, industry and the public sector. Their assessment compares the theme's research outputs and outcomes to national and international contexts. Following each visit, the expert panel produces a report that is provided to the CFI Board of Directors and the institution.

Composition of the OMS sample

Since 2007, the CFI has conducted 19 OMS visits — including three pilot studies — and produced reports for each containing aggregate numerical data and expert panel ratings, as well as qualitative assessments and case studies. The OMS methodology has evolved over this time, leading to changes in some of the indicators. Therefore, a number of reports do not have complete data for all OMS indicators.

[3] For more details, visit www.innovation.ca/docs/accountability/OMS/2010/OMS_instructions_institution_2010.pdf

### *Overall performance evaluation and value-for-money audit (OPEA)*

As part of its Funding Agreement with the Government of Canada, the CFI is required to carry out an overall performance evaluation and value-for-money audit at least every five years. The evaluation measures the overall performance of the CFI in achieving its objectives. The audit examines the CFI's operations to ensure the economy, efficiency and effectiveness with which funds have been used.

In March 2010, the CFI completed its first OPEA. An independent third-party conducted the study and an international panel of seven experts in global research and research funding reviewed the findings and produced an independent report. Data obtained through the OPEA survey and interviews are presented throughout this report to highlight converging findings.

### *Special studies*

The CFI periodically conducts special studies to examine in more depth issues and topics related to its performance and impacts. This report cites one such study. A study conducted during the past year, which was partially sponsored by the CFI, was designed to learn more about the extent and nature of university and hospital research contracting activity in Canada.[4] The study is based on detailed survey data provided by 20 post-secondary institutions in Canada and a limited number of interviews with representatives of organizations involved in university research — mostly research funders from the private sector.

### *Data limitations and characteristics*

The data presented in this report comes from several sources. As with many analyses of R&D investments, there are several considerations to take into account when interpreting the data including:

1. Attribution: The research infrastructure investment made by the CFI is only one facet in a larger research endeavour. Because there are co-funders of the infrastructure, non-infrastructure support of research and training and many other contributing factors, it can be difficult to precisely attribute impacts.
2. Reference period: This report integrates CFI data from a variety of sources and reference periods. For example, OMS data included in this report comes from visits conducted between 2007 and 2010. The CFI's database for progress reports submitted for the 2009-10 fiscal year contains information on projects that commenced between April 1, 2005, and March 31, 2010. As a result, projects vary in their comparability and in some of their achieved results.
3. Time lag: There is great variety of CFI-funded infrastructure projects. This can affect the speed of implementation and generation of outputs and outcomes. Smaller infrastructure projects, especially those intended to attract and retain researchers, are reasonably easy to plan, finance and develop, whereas large complex awards may take several years to become fully operational.
4. Size and diversity of research projects: CFI-funded projects span all disciplines and a range of higher education institutions, including universities, colleges, research hospitals and non-profit research organizations. Some projects are also considered basic research while others are applied. Consequently, the data presented in the report incorporates a wide range of data.

[4] The complete report, *Knowledge Transfer through Research Co*ntracting, is available at www.impactg.com/index.php?descript=Publications.

# 3.0 RESULTS

This report combines multiple lines of evidence, in particular data obtained through the 2010 PPR and the 19 OMS reports (2007-10), to demonstrate research outputs and impacts achieved using CFI-funded infrastructure. Evidence is provided for the impacts that CFI-funded infrastructure has had on: innovation and benefits to Canada; strengthening Canada's capacity for innovation; highly qualified personnel and enhancing research productivity. These impacts relate to the CFI's national objectives (see Section 1.0).

## 3.1 INNOVATION AND BENEFITS TO CANADA

*The findings in this section demonstrate that through research and training enabled by the infrastructure, CFI funding provides a wide range of benefits in areas such as economic growth, health and social benefits, and environmental quality.*

Innovation includes the ability to develop new and improved products, processes and services. It drives productivity and growth, providing both direct and indirect benefits to Canada. The CFI collects and analyzes information about innovation using its OMS and PPRs. More specifically, the CFI collects information on traditional technology transfer, knowledge transfer of other types and knowledge transfer through people.

### 3.1.1 Traditional technology transfer

Canadians benefit from the creation, protection and revenue-generating use of intellectual property through, for example, patents, spin-offs or licensing agreements (Table 3). In 2009-10, the PPRs identified numerous instances of traditional technology transfer related to the CFI-funded infrastructure.

Table 3. Patents, licences and spin-off companies, 2010 (n=2,167)

| | No. of project leaders responding 'yes' | If yes, how many? |
|---|---|---|
| Patents filed | 165 (7%) | 435 |
| Invention disclosures | 138 (6%) | 291 |
| Spin-offs | 45 (2%) | 44* |
| Patents granted | 33 (1%) | 62 |
| Licensing agreements | 33 (1%) | 113 |

** Two project leaders identified a single spin-off.*

These activities have remained stable over the past three PPR reporting periods. A more general survey of intellectual property in the higher education sector conducted by Statistics Canada in 2010, however, shows a decline between 2007 and 2008 in the number of patents granted (479 patents and 346 patents, respectively) to Canadian universities and teaching hospitals. [5]

Traditional technology transfer (TTT) was deemed to be of "high" to "very high" importance in the majority of the research domains of the OMS themes (76 percent). Despite their importance, the level of TTT

[5] Statistics Canada, *Survey of Intellectual Property Commercialization in the Higher Education Sector (2008 – released Aug, 23, 2010)*, p. 21.

activities, and their value to the end users, was rated as “high” to “very high” in only half of the OMS themes (Table 4a). Thus, there is scope for greater TTT activities and outputs from several of the OMS research groups.

These findings are further substantiated by a recent survey[6] where one-quarter of project leaders indicated TTT activities were in place, while an additional 20 percent reported applications related to best practices in health, environmental benefits or public policies.

Table 4a. OMS innovation indicators as assessed by OMS expert panels: Traditional technology transfer (2007-10)

| OMS indicator | Very low | Low | Medium | High | Very high |
|---|---|---|---|---|---|
| Importance of TTT in the domain of the OMS theme (n=17) | 6% | 12% | 6% | 23% | 53% |
| Level of TTT in the thematic area at the institution (n=11) | 9% | 27% | 18% | 27% | 18% |
| Significance and value to users (n=8) | 0% | 25% | 25% | 37% | 13% |

### 3.1.2 Knowledge transfer of other types

OMS reports provide evidence of the importance of knowledge transfer beyond traditional technology transfer and commercialization. In particular, researchers are often involved in contract research, consulting and/or providing data or services to external parties as part of their relationship with industry (Table 4b). In all cases, the OMS expert panels rated broader knowledge transfer as being of high importance. In 72 percent of the cases, the panels rated the level of such knowledge transfer as “high” or “very high,” and in 70 percent of the cases, they rated its significance to users as “high” or “very high.” It is therefore evident that such knowledge transfer activities occur in most OMS themes.

Table 4b. OMS innovation indicators as assessed by OMS expert panels: Knowledge transfer (KT) of other types (2007-10)

| OMS indicator | Very low | Low | Medium | High | Very high |
|---|---|---|---|---|---|
| Importance of KT in the domain of the OMS theme (n=11) | 0% | 0% | 0% | 18% | 82% |
| Level of KT in the thematic area at the institution (n=11) | 0% | 9% | 18% | 27% | 45% |
| Significance and value to users (n=10) | 0% | 0% | 30% | 20% | 50% |

[6] KPMG, *Final Report: Overall Performance Evaluation and Value-for-Money Audi (OPEA) – Evaluation Component*, Oct. 30, 2009.

The PPRs identified a number of benefits supported through research with CFI-funded infrastructure (Table 5).

Table 5. Benefits to Canada, 2010 (n=2,167)

| | No. of project leaders responding 'yes' | If yes, how many? |
|---|---|---|
| New or improved products, processes or services | 402 (19%) | 979 |
| Improved health care protocols, processes or services including cost savings, etc. | 365 (17%) | 1,957 |
| Environmental benefits | 361 (17%) | 564 |
| New or improved public policies and programs | 248 (11%) | 399 |
| Best practices in manufacturing, organizational structure, healthcare, etc. | 136 (6%) | 689 |

Both the PPRs and OMS contain numerous examples of knowledge transfer, based on research and expertise developed using CFI-funded infrastructure. The following section highlights some of these benefits.

***Products and processes***

Research with CFI-funded infrastructure helps industry reduce costs and improve products and services in a number of ways, including more efficient processes and more effective materials. For example, gloves containing silver particles for burn protection initially cost $900 each to manufacture. Following collaboration with the CTT Group (*Centre des technologies textiles*) at Cégep de Saint-Hyacinthe, a new manufacturing technology was developed that reduced the unit cost to $92 and allowed for more rapid market penetration.

At École Polytechnique de Montréal, research into nanostructured materials led to the development of high-performance coatings that protect jet engines against solid particle erosion, with erosion rates being reduced by a factor of 20 to 50.

And at Ryerson University's Centre for the Study of Commercial Activities, researchers employed enhanced computer systems to data mine and visualize large spatial datasets to improve location-related decisions for industries such as real estate development, as well as for governments and non-profit groups.

***Health care protocols, processes and services***

Enabled by CFI-funded infrastructure, researchers in health-related fields have been taking a multi-pronged approach to tackling a range of diseases and conditions, and developing advanced and comprehensive services for their control and treatment. This approach includes: (1) *fundamental research* — focusing on research at the cellular and molecular levels and involving stem cells and the immune system; (2) *systems and models* — looking at the interactions of components of biological systems (e.g., balance between types of bacteria in intestinal disorders); (3) *translational research* — focusing on extracting clinical benefit from scientific advances, or the "bench to bedside" approach;[7] (4) *prevention and risk reduction*, e.g., research on the causes and risk factors for cardiovascular problems; (5)

[7] Examples include The Ottawa Hospital program, "Translation of Innovation into Medical Excellence," and the University of Alberta's Cardiovascular Translational Research Centre.

*pharmaceuticals and pharmacogenomics* — CFI-funded infrastructure is speeding up drug discovery and development, and enabling research into the use of genomics for personalized therapies; (6) *therapies and management* — e.g. protocols for timely and effective treatment of strokes; (7) *advanced imaging* — for applications ranging from diagnostics to image-guided surgery.

Bringing together a multidisciplinary group of researchers, the Centre for Hip Health and Mobility in Vancouver, for example, takes a comprehensive approach to hip-related problems, including research on ways to prevent hip fractures and reduce the burden of hip arthritis, especially in early stages of the disease. Research relating to diabetes is being done in a number of centres across Canada, with research ranging from development of low-glycaemic foods, to detailed comparative studies of methods for the management and control of diabetes, and to fundamental research underlying new treatments and eventually a cure.[8]

Progress on health research has economic as well as health implications. For example, the University of Alberta's Centre of Excellence for Gastrointestinal Inflammation and Immunity Research has estimated that gastrointestinal diseases generate an economic burden of $100 billion annually.[9] Research at this centre is both fundamental and clinical. It involves identification of the bacteria, viruses, genes and environmental factors involved in ulcers, inflammatory bowel diseases, and cancers of the liver and gastrointestinal system. On the clinical side, research includes identification of high-risk individuals and communities, and the study and evaluation of outcomes and treatments related to specific disorders.

### *Environmental benefits*

CFI-funded infrastructure provides advanced capabilities for environmental science on Canada's east and west coasts.[10] The CFI has funded networks of undersea sensors which are now improving the tracking of fish stocks as they move between rivers and oceans, and enabling better monitoring of the ocean environment.

Research with CFI-funded infrastructure is also helping to reduce the environmental impact of the oil sands while enabling enhanced recovery at lower costs. For example, the University of Calgary is developing methods for *in situ* upgrading of the oil sands, while the University of Alberta is researching improved technologies for processing bitumen, as well as the interactions between the different components of the oil sands and the fluid dynamics affecting the efficiency of oil recovery. For its part, the University of Regina has developed methods to reduce the costs of carbon dioxide ($CO_2$) capture from $55 to $20 per tonne, while using the sequestered $CO_2$ for increasing the recovery rates for heavy oil.[11]

### *Public policies and programs*

CFI-enabled research helps in building the evidence base for public policy. For example, the University of British Columbia is currently implementing the world's most extensive population health and learning observatory, which combines population-based databases across disciplines, geography and time, with a focus on ways of overcoming the adverse health effects of social, economic and environmental disadvantage. At the McGill Centre for Research on Children and Families, the Canadian Child Welfare Data Lab is collecting information on child welfare policies and programs — over time and across Canada — with a view to evaluating their impacts and identifying the characteristics of effective programs and policies for children and families.

[8] Examples include the Montreal Diabetes Research Centre, which brings together 43 investigators from 5 universities.
[9] PPR 2010
[10] Examples include the Ocean Tracking Network (Dalhousie University) and NEPTUNE and VENUS (University of Victoria).
[11] Regina OMS visit (April 28-29, 2009; updated July 24, 2009).

***Best practices in manufacturing, organization, and health***

Comparative research on methods and practices can be highly valuable in identifying and sharing best practices within and between organizations. For example, at Carleton University's Police Research Laboratory, research topics include: comparative effectiveness of investigation procedures; training methods and standards; decision-making in lethal force encounters; and the development of tools for linking crimes committed by serial offenders. To improve arthritis treatment and assess the effectiveness of new arthritis drugs, the University of Toronto/University Health Network is implementing a project to capture data, on a Canada-wide basis, on clinical treatments for arthritis, over a broad range of practice settings and making use of self-reports from patients.

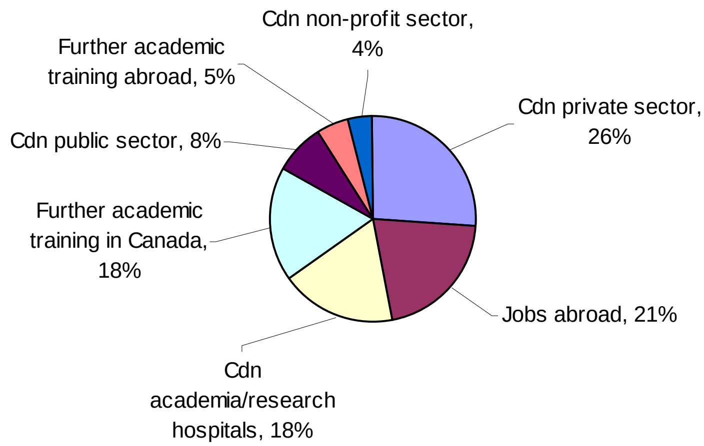
## 3.1.3 Knowledge transfer through people

CFI-funded infrastructure has substantial and lasting impacts through the highly qualified personnel (HQP) whose training has benefited from the use of the infrastructure. As detailed in section 3.3, the infrastructure was used as a key resource by more than 26,000 students and post-doctoral fellows, with a further 6,200 technicians being trained on the infrastructure.

OMS reports provide information on the sectors benefiting from an inflow of HQP with training on CFI-funded infrastructure. Of the more than 2,200 HQP for whom the post-training destination was known, approximately one quarter pursued further academic training in Canada or abroad. The career destinations of 77 percent of the trainees were varied and depended on the nature of the training they received (Figure 1).

*"In the 20-year history of Research In Motion, I have licensed exactly two technologies from university research teams. Over that same period I have hired more than 5,000 students as co-ops, interns, and full time employees. If you really want to understand commercialization, all you have to do is attend convocation at your local university. Armed with cutting edge technology from around the world, the latest tools, the latest techniques and processes learned from their work under the very best researchers, they graduate with much fanfare and go on to build the industry, institutions and society of our country. Now that is real commercialization."* (excerpt from *The Importance of Basic Research* by Mike Lazaridis. Keynote address at the Fourth Annual Research Money Conference, November 9, 2004).

Figure 1. Known destinations of highly qualified personnel based on 12 OMS themes (2007-10) (n=2,336)



The leading destinations for HQP were the Canadian private sector (26 percent) and academia/research hospitals (18 percent). A large proportion of graduates (21 percent) obtained jobs abroad (This likely reflects the high enrollment of international students in Canadian graduate programs, as well as Canadians undertaking post-doctoral positions abroad). The public and non-profit sectors attracted relatively fewer graduates (8 percent and 4 percent, respectively). At the majority of OMS visits, project leaders stated that the knowledge and technical skills gained through training were the primary mode of knowledge transfer to all sectors of industry at the local, regional, national and international levels.

While most institutions do not systematically track the academic or career destinations of their graduates, there are examples of strong links between graduates and local industry. For example, materials sciences graduates from Simon Fraser University (SFU) are often employed by small- and medium-sized fuel cell, alternative energy and other enterprises (e.g., nanotechnology and semiconductors) in British Columbia, and the geo-engineering program at Queen's University supplies about 20 percent of the private sector needs for HQP in the field of geo-engineering in Canada.

***Job creation***

CFI infrastructure facilitates the hiring of highly skilled personnel and students to support research and keep infrastructure operational. Students (undergraduate, graduate and post-doctoral fellows) are often hired by private companies due to their expertise and specialization.

The project leaders reported on job creation in the PPRs (Table 6).

Table 6. Benefits to Canada, 2010 (n=2,167)

| | **No. of project leaders responding 'yes'** | **If yes, how many?** |
|---|---|---|
| Jobs created in the academic /hospital sector | 809 (37%) | 3,140 |
| Jobs created in the private sector | 135 (6%) | 521 |
| Jobs created in the public/non-profit sector | 79 (4%) | 492 |

By way of example, University of Toronto researchers have created 11 spin-off companies in nanotechnology, including Axela (2005) and Rimon Therapeutics (2006), which are among Canada's top 10 life sciences companies. Although still in the start-up phase, these companies have already created a number of highly valued jobs (e.g., 45 jobs at Axela).

# 3.2 STRENGTHENING CANADA'S CAPACITY FOR INNOVATION

*The findings in this section demonstrate that, overall, CFI projects have state-of-the-art infrastructure and the CFI has had a significant impact on improving the technical and operational capabilities of the infrastructure. The world-class instrumentation and facilities have had a major impact on the attraction and retention of high-calibre researchers and on the multidisciplinarity of the research milieu. Collectively, these impacts are enhancing the competitiveness of Canadian research.*

In its 2008 *Momentum* report on university research and knowledge mobilization, the Association of Universities and Colleges of Canada noted that: "In today's competitive knowledge-based global economy, a highly developed national research capacity … is a major source of competitive advantage for Canada." The report observed that Canada is in the midst of a "global race for research talent," that the CFI and other funding initiatives "taken as a package seek to provide an internationally competitive environment," and that "many international researchers attracted to Canada in recent years have noted the importance of these initiatives in their choice of Canada as a research destination."[12]

Findings in this section present data on the comparative quality of CFI-funded infrastructure, the attraction and retention of researchers, multidisciplinarity and competitiveness.

## 3.2.1 Comparative quality of CFI-funded infrastructure

New or improved equipment, laboratories and buildings, and the latest databases provide current and upcoming researchers with greater capacity and opportunities for leading-edge research and training, enabling them to compete with the best in the world.

*"The CFI support has transformed the quality of Canadian research infrastructure. About two-thirds of [project leaders] and [project users] rate their infrastructure's technical capability as excellent or world-class"*

KPMG, Overall Performance Evaluation and Value-for-Money Audit (OPEA), Oct. 30, 2009, p. 2.

The PPRs mention a number of ways in which CFI-funded infrastructure bolstered the capacity of Canadian institutions for research, education and cooperation. CFI-funded infrastructure was cited as being instrumental in advancing the capabilities of researchers to investigate science and technology issues which could not previously be examined, or which could not be researched in as much depth and detail, or as quickly (e.g., in areas such as high-resolution imaging and detection of trace amounts of environmental contaminants). The infrastructure was often identified as being key to establishing or expanding the laboratory, enhancing training opportunities and linking fundamental and applied research.

Overall, the quality of CFI-funded infrastructure that was operational during the past year was rated as state-of-the-art by 64 percent of project leaders, while another 29 percent reported that their infrastructure was still highly useful for research (Table 7).

[12] The Association of Universities and Colleges of Canada, *Momentum: The 2008 report on university research and knowledge mobilization,* pp. 39-45.

| Table 7. Quality of operational infrastructure,* 2010 (n=2,151) | |
|---|---|
| **Infrastructure types** | **% of projects** |
| State-of-the-art | 1,372 (64%) |
| Still highly useful for research but no longer state-of-the-art | 623 (29%) |
| Useful for supporting research and training | 153 (7%) |
| Obsolete and no longer useful | 3 (0%) |
| **Total** | **2,151 (100%)** |

** Percentages exclude "not applicable" responses (n=17)*

Project leaders often made the point that CFI-funded infrastructure forms the core or centerpiece of their facility. Many of them claimed that their infrastructure stood up to the best in the world and was a key factor in sustaining a productive research environment. Project leaders also said that the capability for cutting-edge research offered by CFI-funded infrastructure served as a magnet to draw talent from Canada and abroad.

The OMS revealed that technical and operational capacity has undergone a fundamental transformation as a result of investments from the CFI and its funding partners. In most OMS themes, the infrastructure available prior to the first CFI award was rated by the expert panels as "useful for supporting research and teaching" to "obsolete." Now, however, the technical capabilities (e.g., accuracy, limits, throughput) of the infrastructure are rated as "state-of-the-art" or "still highly useful" in almost 95 percent of cases (Table 8), echoing the findings from the PPR (Table 7). Similarly, the operational capabilities (e.g., facility space, user capacity, or technical/professional support) of the infrastructure are now rated as "state-of-the art" or "highly useful" in all cases.

| Table 8. Technical and operational capability, pre- and post-CFI, of CFI-funded infrastructure, as assessed by OMS expert panels* (2007-10) | | | | |
|---|---|---|---|---|
| | **Status of infrastructure** | | | |
| **OMS indicator** | **Obsolete** | **Useful** | **Highly useful** | **State-of-the-art** |
| **Technical** | | | | |
| Pre-CFI capability (n=17) | 23% | 53% | 12% | 12% |
| Current capability (n=17) | 0% | 6% | 23% | 71% |
| **Operational** | | | | |
| Pre-CFI capability (n=17) | 23% | 71% | 6% | 0% |
| Current capability (n=16) | 0% | 0% | 31% | 69% |

** Percentage of all ratings*

In addition, OMS have shown that co-location of complementary equipment and creation of a centralized pool of technical expertise can further enhance the accessibility and value of an instrument, as well as the multidisciplinary nature of research.

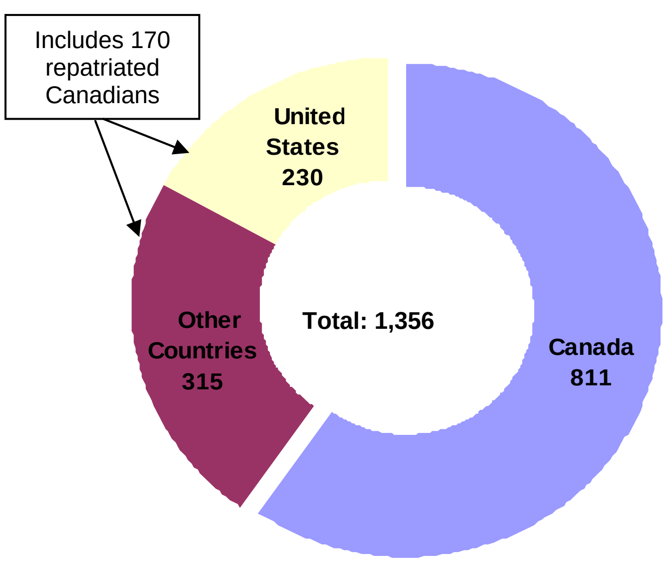
Although CFI funding has enabled researchers to work with state-of-the-art infrastructure, they face several challenges in attaining or maintaining this capacity. Recurring concerns among OMS participants were the cost pressures for operations and maintenance (Section 3.4.3) and uncertainty in securing matching funds for CFI awards. For example, across Canada, there was uneven provincial support for research and teaching — and matching support for CFI awards was not normally automatic. Project leaders and institutions noted other challenges, including the impact of space constraints and economic conditions. Space constraints may limit the expansion of research capacity at some institutions, and rising costs and budget restraints can cause disruptions or delays.

## 3.2.2 Attraction and retention of researchers

Infrastructure alone is not sufficient to strengthen the capacity for innovation. The development of human capital is also essential. The data and views gathered through a range of CFI evaluation activities have demonstrated that CFI-funded infrastructure has played a strategic role in enhancing the ability of institutions to recruit and retain the world's top research talent — a key CFI objective.

Project leaders reported in the PPR that infrastructure availability played an important role in the decisions of many of the 1,356 new researchers recruited to their institutions. Of these, more than 40 percent (or 545) of the researchers were recruited from international positions, with 42 percent from the United States, and Australia, France, Germany and China as other key sources. Of the researchers recruited from other countries, 31 percent were repatriated Canadians (Figure 2).

Figure 2. Number of researchers recruited by country of origin, 2010 (n=2,167)



In the OMS reports, the CFI infrastructure was found to have attracted new faculty members both directly (through LOF awards) and indirectly (other recruits). Recruitment from abroad was substantial; including many repatriated Canadians. In 88 percent of the cases, the OMS expert panels rated the CFI impact on attraction and retention as “high” (35 percent) or “very high” (53 percent), with more than 80 percent of the OMS panels also noting that critical mass was achieved in the thematic areas where this was assessed.

These findings are further corroborated by a recent survey (OPEA 2009) in which 77 percent (1,138/1,483) of the surveyed researchers acknowledge that CFI projects were of high or very high importance for staying in their present job position, or for joining the institution. This survey found that the top four factors for attraction/retention are the CFI infrastructure, availability of research funding, personal factors and the research environment in the department.

Both the OMS and the PPRs show that CFI-funded infrastructure has been powerful in attracting faculty from abroad, often bringing in external funding as well as expertise, reputation and international contacts. Correspondingly, the tangible, visible nature and technological attractiveness of the infrastructure was reported as being a helpful marketing tool by project leaders (PPR), and was often featured in tours and visits by prospective faculty and students.

*“Without CFI support for newly recruited faculty it is unlikely that Dalhousie could have attracted and retained as many researchers as they have, especially given the competitive nature of hiring in ICT related fields. The significant increase in faculty numbers in turn allowed the university to dramatically expand its graduate (and undergraduate) programs.”*

Dalhousie OMS Expert Panel Report, Nov 13-14, 2007, p. 2

Both the OMS and the PPRs have allowed project leaders and institutions to convey challenges related to the attraction and retention of researchers. The current competitive global environment and recent budget restraints make the recruitment and retention of top talent an ongoing challenge, especially at smaller institutions. Attempts to control spending have resulted in fewer new hires in a number of institutions, raising questions about balance and sustainability over the longer run.

### 3.2.3 Multidisciplinarity

The combined perspectives of researchers in multiple disciplines are often of great importance to broaden and deepen our understanding of complex or interwoven issues. As such, the fostering of multidisciplinarity can act as a powerful driver (key enabler) of capacity-building, innovation and national R & D competitiveness. Often themes, such as biomedical engineering or nanotechnology, are inherently multidisciplinary. For example, at the University of Calgary, the Biomedical Engineering group involves researchers from the Schulich School of Engineering and the faculties of kinesiology, medicine, veterinary medicine, science and nursing, who share facilities, collaborate on research projects, and co-publish articles. Detailed comments in the PPRs mentioned that the infrastructure often served as a focal point for multidisciplinary research. Infrastructure that is rated as world class or which is part of suites of facilities and equipment appears especially helpful in promoting multidisciplinary research, perhaps because it often requires substantial planning to integrate different disciplines.

In 76 percent of OMS, the expert panels credited the institutions with fostering multidisciplinarity to a “high” or “very high” degree (Table 9), with the same proportion also rating the significance of the added value as high to very high. In one example, the Centre for Food and Soft Materials at the University of Guelph was shown to integrate researchers in intersecting fields from 11 departments and five colleges, embodying an institutional culture of multidisciplinarity in research and teaching.

Table 9. Impact of CFI on multidisciplinarity as assessed by OMS expert panels* (2007-10)

| OMS indicator | Very low | Low | Medium | High | Very high |
|---|---|---|---|---|---|
| Degree to which the institution has deliberately fostered multidisciplinarity (n=16) | 0% | 12% | 12% | 38% | 38% |
| Value added to the conduct of the research by multidisciplinarity (n=17) | 0% | 0% | 24% | 35% | 41% |

** Percentage of all ratings*

### 3.2.4 Competitiveness

The significant investments made by the Government of Canada through the CFI are strengthening the competitiveness of Canadian R & D. Capacity building in research is achieved by providing the modern and high quality infrastructure needed to keep Canada's research facilities at the forefront. This enhanced capacity not only strengthens the ability of Canadian institutions to develop, attract and retain the world's best researchers and to harness the synergy benefits of multidisciplinarity, but also enhances the productivity of researchers (Section 4.4).

A survey conducted in the context of the OPEA found that project leaders, project users and department heads believe that Canadian research productivity has changed substantially, from "good" pre-CFI to "excellent" post-CFI, on average. Similarly, the OMS expert panels credited the CFI (and related partner investments) with having had a "high" (40 percent) or "very high" (60 percent) impact on the overall competitiveness of the research in all OMS themes (n=16). Furthermore, research activities were rated as competitive internationally in almost two-thirds of the thematic areas.

Among the notable examples of themes with an international reputation are the human genetics and genomics research groups at the Hospital for Sick Children in Toronto; NEPTUNE, the University of Victoria's undersea cable network; and the Helmholtz-Alberta Initiative in Oil Sands Research, a partnership between University of Alberta and the Helmholtz Institute in Germany.

# 3.3 HIGHLY QUALIFIED PERSONNEL

*The findings in this section demonstrate that CFI-funded infrastructure provides excellent training environments across Canada, providing access to world-class infrastructure and multidisciplinary research programs. Such resources have attracted thousands of new trainees to Canadian research institutions, have provided hands-on training to close to 30,000 HQP and technical personnel, and have expanded Canada's research opportunities and capabilities.*

In 2010, the OECD stated: "People are at the heart of the innovation process." In an economy which is increasingly knowledge-based, the discovery of new knowledge through research is essential for competitiveness — and people with training in research play a key role. Scientific infrastructure is fundamental for training and progress in research, especially in disciplines such as the health sciences, the natural sciences and engineering, which are heavily dependent on advanced infrastructure to remain at the leading edge of international research. Scientific infrastructure is also playing an important role in the social sciences and humanities through, for example, databases and digital media.

Findings in this section present data on the number of highly qualified personnel (HQP) trained, attracting the next generation of HQP, and the importance and quality of the training environment.

## 3.3.1 Number of HQP trained

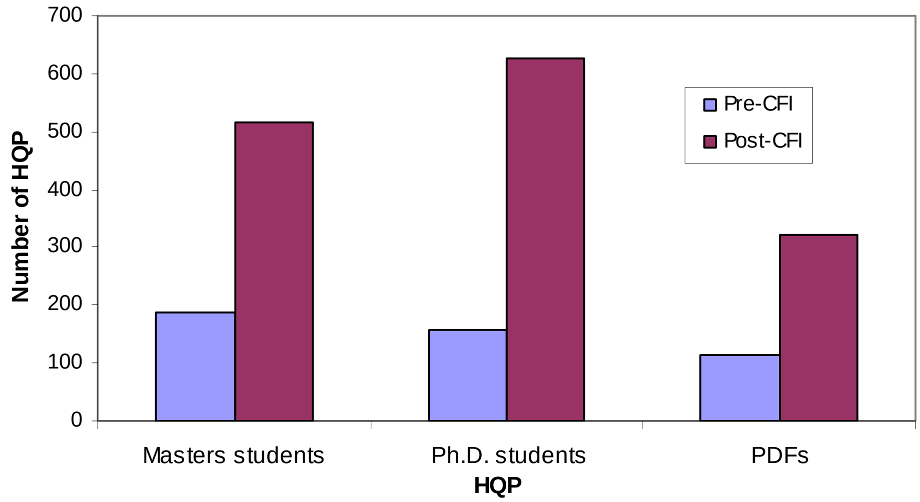
HQP includes Masters and Ph.D. candidates, post-doctoral fellows (PDF), undergraduates involved in research and research technicians. In 2009-10, project leaders reported that CFI-funded projects had provided training and research experience to more than 32,000 HQP (Table 10).

Table 10. Number of HQP using CFI-funded infrastructure, 2010 (n=2,433)

| | **If yes, how many?** |
|---|---|
| Post-doctoral fellows | 3,942 |
| Doctoral students | 7,416 |
| Masters students | 7,956 |
| Undergraduate students | 6,889 |
| Technicians | 6,209 |
| **Total** | **32,412** |

Of the CFI-funded projects that submitted PPRs, 86 percent reported that CFI-funded infrastructure had been used as a key resource for their students' research projects. The OMS reports have pointed to substantial increases in the numbers of HQP trained during a decade of CFI funding at these institutions. The number of student research trainees has increased by a factor of 2.5 for Masters students, 4 for PhD students and 2.8 for PDFs (Figure 3).

Figure 3. Research trainees per year* (2007-10) (n=13)




** From OMS*

## 3.3.2 Attracting the next generation of HQP

The PPRs found that CFI-funded infrastructure is an important, often essential, factor in student decisions on where to pursue their studies and research, particularly at the graduate level. In the past year, nearly 8,700 new post-graduate students (Masters, PhDs and PDFs) were attracted to laboratories and facilities with such infrastructure. The OMS further show that in close to 90 percent of the cases, the CFI has had a “high” to “very high” impact on the reputation of the training program, as well as on the quality of trainees and the training environment (Table 11).

Table 11. Impact of the CFI on HQP as assessed by OMS expert panels* (2007-10)

| OMS indicator | Very Low | Low | Medium | High | Very High |
|---|---|---|---|---|---|
| Level of impact on the quality of trainees (n=11) | 0% | 0% | 9% | 73% | 18% |
| Level of impact on the quality of training (n=16) | 0% | 6% | 6% | 57% | 31% |
| Level of impact on the reputation and competitiveness of the training programs (n=10) | 0% | 0% | 10% | 70% | 20% |

** Percentage of all ratings*

Infrastructure considerations are particularly important for those who have the widest range of choice (e.g., students with national scholarships). The OMS found that well qualified, top trainees are attracted to the training research environments afforded by CFI-funded facilities. Proxies for the quality of HQP include prestigious scholarships or fellowships or highly competitive placement for limited training opportunities. For example, in McGill University’s neurosciences group, 50 percent or more of the students hold competitive scholarships and at the University of Toronto’s nanotechnology program, the OMS report noted that there were 20 or more applications for each position at the graduate level.

### 3.3.3 Importance and quality of the training environment

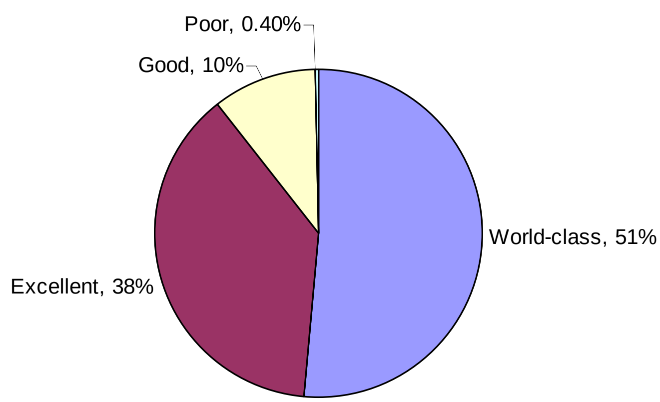
The quality of the research environment plays an important role in the training of the next generation of researchers, as well as in the professional development of research support staff. The access to modern infrastructure and equipment is a key contributor as it helps to shape the dynamism, competitiveness and productivity of the research environment, and provides cutting-edge opportunities for research and learning that enhance the skills and employability of HQP.

*"There has been a very strong impact of the CFI infrastructure on the institutional training environment, from fair to good prior to CFI to excellent now."*

KPMG, Overall Performance Evaluation and Value-for-Money Audit, Oct. 30, 2009, p. 3.

CFI-funded infrastructure provides HQP with access and training on state-of-the-art infrastructure. In 89 percent of the more than 2,400 annual project progress reports, the quality of infrastructure for training purposes was rated as either excellent or world-class (Figure 4).

Figure 4. Quality of infrastructure for training purposes, 2010 (n=2,226)




A number of training-related benefits were mentioned in the PPRs. Infrastructure is often a major drawing card for attracting students (as well as faculty) — a point mentioned by institutions of all sizes, including smaller universities such as PEI, Trent, Brandon and Lethbridge.

CFI-funded infrastructure enables students to undertake a wider range of research, often on new and emerging topics. Advanced infrastructure gives students an edge in their research, enabling them, for example, to tackle problems using larger, more realistic models. PPRs frequently mention the importance of analytical precision (e.g., isotopic microanalysis and geochronology at the University of Alberta) and speed (e.g., high throughput analysis at the University of British Columbia). For students, the combination of speed and precision is opening up many new research opportunities (e.g., systems biology and structural genomics at the University of Toronto / University Health Network).

The infrastructure also provides a venue and focal point for mentoring and teamwork among students. For example, the project report for robotics infrastructure at the Université de Sherbrooke notes that the research utilizing the infrastructure is "riche en termes d'échanges et d'entraide".

Some projects are designed specifically to facilitate and maximize collaboration and exchanges within and between institutions. Knowledge Translation Canada is a case in point. Anchored by infrastructure at The Ottawa Hospital, Hamilton Health Sciences, and St. Michael's Hospital (Toronto), Knowledge

Translation Canada is a national research network focused on ensuring that the results of research are applied "at the patient's bedside and in everyday health decisions."[13].

The project reports also noted that experience with CFI-funded infrastructure provides students with leading-edge marketable skills, often in new areas where employment opportunities are emerging, (e.g., interdisciplinary training at the University of Western Ontario's cardiovascular tissue engineering laboratory, which provides skills for the biotechnology and medical devices field).

For infrastructure developed in the context of health care, the skills and experience acquired by the trainees are often clinical as well as research-related. For example, at the University of British Columbia, the Blusson Spinal Cord Centre and the International Collaboration On Repair Discoveries together provide students with research and clinical experience in developing effective therapies for spinal cord injuries --, and at the Montreal Heart Institute Laboratories, medical residents and fellows now have the opportunity to learn through to learn about pharmacogenomics and genomic-related technologies through medical genetics rotations in these laboratories.

[13] Please see: http://www.ohri.ca/newsroom/newsstory.asp?ID=173 (April 30, 2009)

# 3.4 ENHANCING RESEARCH PRODUCTIVITY

*The findings in this section demonstrate that the CFI infrastructure is intensively used by the research community. This has an impact on the quantity and quality of research outputs as well as the level of research collaborations of project leaders. Both the utilization of infrastructure and the collaborative efforts of researchers involve a diversity of research community members that range from academic colleagues to partners from private organizations, and from the local to international levels.*

A growing body of research suggests that exchange of knowledge and information, and effective links between the three principal innovation funding/performing sectors — health, natural sciences and engineering, social sciences and humanities — are important contributors to a successful national innovation system, especially as a mechanism for transfer of S & T into the commercial sphere.[14] In the federal S & T strategy, partnerships are described as being "essential to lever Canadian efforts into world-class successes and to accelerate the pace of discovery and commercialization in Canada. Through partnerships, the unique capabilities, interests and resources of various and varied stakeholders can be brought together to deliver better outcomes." [15]

Findings in this section present data on research outputs, networking and collaboration, and utilization of infrastructure.

*"The quality and quantity of Canadian research are both up substantially in 2009 as compared to 1990 (as investigated in the 1990 NSERC study)."*

KPMG, Overall Performance Evaluation and Value-for-Money Audit, Oct. 30, 2009, p. 2.

## 3.4.1 Research outputs

The primary outputs of researchers have traditionally been defined as publications and presentations. Scientists also turn to other communication media (e.g., open-source journals, media interviews) for dissemination and outreach. In the past year, 89 percent of project leaders indicated that there were 31,371 research outputs related to the CFI-funded infrastructure. Of these:

- 14,841 (47%) were presentations at conferences;
- 13,805 (44%) were peer-reviewed publications;
- 420 (1%) were books; and
- 2,305 (7%) were other research outputs, including book chapters, television and radio interviews, academic lectures and workshops.

The OMS allows a broader view of research productivity by taking into account not only the quantity of outputs but also their quality through proxies such as the impact of the journals in which they appear, and evidence of the influence of these papers from citations. Prestigious awards and invitations that play leading roles in high-level international meetings are other valuable forms of evidence. Overall, the OMS expert panels rated the CFI-funded infrastructure as having had a "high" to "very high" impact on both the quantity and quality of research at the institutions studied (Table 12).

[14] Science, Technology, and Innovation Council, *State of The Nation 2008 - Canada's Science, Technology and Innovation System*, September, 2008.
[15] Government of Canada, *Mobilizing Science and Technology to Canada's Advantage, 2007.*

Table 12. Impact of CFI on research productivity as assessed by OMS expert panels* (2007-10)

| OMS indicator | Very low | Low | Medium | High | Very high |
|---|---|---|---|---|---|
| Level of impact on quantity of research (n=16) | 0% | 0% | 31% | 31% | 38% |
| Level of impact on quality of research (n=17) | 0% | 0% | 18% | 47% | 35% |

** Percentage of all ratings*

Many researchers also noted that a fundamental output of their activities is the enrichment of HQP training. The HQP-related contributions of researchers include the creation of new scholarly programs (undergraduate or graduate levels, multidisciplinary), development of seminar series on theme subjects and their support of student participation in national and international conferences.

### 3.4.2 Networking and collaboration

Researchers typically engage in collaboration and networking to advance or apply their research through the transfer and sharing of knowledge, expertise and skills. These linkages can provide a means of greater integration with the academic community and end-users that may lead to enhanced productivity and impact.

A total of 738 project leaders reported that they had signed or entered into 2,640 formal collaborative research agreements. The predominant types of agreements were collaborative research agreements (53 percent) and research contracts (39 percent). While formal agreements with international collaborators were widespread (23 percent), most collaborators were reported to be from Canada (77 percent). Similarly, a special study of research contracting found that more than 16 percent of contracts originated from foreign organizations while 84 percent were Canadian. The value of these foreign research contracts far exceeded their proportion within the study sample, accounting for about 31 percent of the overall value.

In addition, data from a recent Statistics Canada survey established the value of research contracts in Canada at nearly $2 billion for 2008,[16] pointing out that research contracting now provides more money to universities and hospitals than any single granting council, while the export of services through contracts supports hundreds of research related jobs in Canada. In a recent publication, *Research Money* also noted that the steady increase in research contracting between successive editions of the Statistics Canada Survey — from $289 million in 1998 to $1.97 billion in 2008 — parallels Canada's investment in research talent and infrastructure, which began in the late 1990s.[17]

Many project leaders noted that infrastructure enabled more extensive networking and collaboration across geographic regions (from local to international) and across various sectors. The availability of world-class infrastructure is often cited as a focal point and venue for networking and collaboration. For example, the project report for the Amundsen icebreaker notes that the researchers involved are forming a network that will likely lead future international efforts to study the Arctic Ocean). Another example of infrastructure as the focal point for international and interdisciplinary collaboration is the Laboratory for Brain, Music, and Sound (BRAMS) at the Université de Montréal, as it offers "the best infrastructure currently available worldwide for experimental approaches to the neuroscience of auditory cognition"[18]. In

[16] Statistics Canada*, Survey of Intellectual Property Commercialization in the Higher Education Sector*, , 2010)
[17] *Research Money*, Vol. 24, No. 14, September 23, 2010
[18] Project progress report, *Laboratory for BRAin, Music and Sound (BRAMS): The Biological Foundations of Music,* 2010.

addition, 77 percent of project leaders identified CFI-funded infrastructure as playing a key role in enhancing opportunities for informal research collaborations.

The OMS reports also provided a number of examples of both formal and informal networks and linkages, including major national and international collaborative initiatives in which Canadian project leaders were key investigators. In most of the themes, the expert panels rated highly the degree to which researchers established external networks and collaborations, and very highly the level of impact of the CFI on formal partnerships with end users (Table 13). Similarly, the added value derived from external networking and collaborations (both formally and informally) to the research and/or development of user applications was rated "high" (53 percent) or "very high" (29 percent) by the expert panels (Table 13).

Table 13. Networking and collaboration activities of infrastructure users as assessed by OMS expert panels* (2007-10)

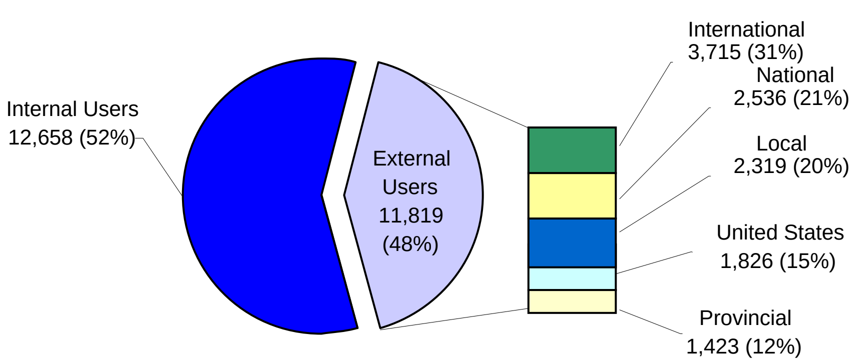
| OMS indicator | Very low | Low | Medium | High | Very high |
|---|---|---|---|---|---|
| Current degree of external networking and collaboration (n=17) | 0% | 5% | 24% | 59% | 12% |
| Level of impact on the number and importance of partnerships and their financial contributions (n=17) | 0% | 0% | 0% | 24% | 76% |
| Value added by external networking and collaboration, both formal and informal (n=17) | 0% | 6% | 12% | 53% | 29% |

** Percentage of all ratings*

### 3.4.3 Utilization of infrastructure

The provision and optimal use of modern facilities and equipment are key factors to improving the effectiveness, competitiveness and quality of research. During the past year, project leaders who said their CFI supported infrastructure was fully or partially operational reported that 24,477 researchers advanced their research using these facilities and equipment. As depicted in Figure 5, 52 percent of users come from within the institution that houses the infrastructure, while external users account for 48 percent.

Figure 5. Users of research infrastructure, 2010 (n=2,167)



Findings from OMS revealed that infrastructure is generally well shared internally. However, the degree of access by external users varied depending on the theme and institution. Among the features that enhance external use, one of the most important is the co-location of instruments in multidisciplinary and multi-user facilities, since it allows for more efficient use of financial and human resources.

A prime example of the benefits of CFI-funded infrastructure to external users from the private sector is 4D LABS at Simon Fraser University. This fabrication facility provides local businesses with cost-effective access to state-of-the-art fabrication and characterization infrastructure that is critical for their product development. Such access not only eliminates the need for Vancouver-based companies to invest in costly equipment, but it also provides them with expert advice from the university's world-renowned scientists and engineers.

The recent study on knowledge transfer through research contracting found that companies accounted for between 25 percent and 30 percent of all research contracts awarded to universities — both in number and value. The access to state-of-the-art research expertise and infrastructure, the opportunity to assess potential new hires (HQP) and the perceived independence and credibility of faculty researchers were described by the private sector research contractors interviewed for the study as important in their decision to collaborate with universities.

With openness toward sharing the CFI-funded infrastructure with a wide spectrum of users — and despite the operations and maintenance of the infrastructure being labeled difficult by nearly 30 percent of project leaders (Table 14) — most project leaders reported that the infrastructure was either "fully utilized" (73 percent) or "over-subscribed" (11 percent).

Table 14. Operations and maintenance of the infrastructure,* 2010 (n=2,167)

| | Ability to obtain funding (% of projects) | Ability to attract and retain skilled personnel (% of projects) |
|---|---|---|
| Easy | 354 (16%) | 551 (25%) |
| Reasonable | 1,209 (56%) | 1,126 (52%) |
| Difficult | 430 (20%) | 309 (14%) |
| Very difficult | 174 (8%) | 181 (8%) |
| **Total** | **2,167 (100%)** | **2,167 (100%)** |

** Only the project leaders that qualified their infrastructure as operational were asked to rate these issues.*

For now, the efforts of a number of project leaders in securing revenues from internal and external users through collaborative research, research contracts and user fees have provided much needed funds for operations and maintenance. Revenues from end-users alone were estimated by project leaders to have reached more than $60 million during the last year. As well, many institutions are praising the CFI Infrastructure Operating Fund (IOF) for helping them address the O & M challenge. However, a recent OMS report found that uncertainty around O & M issues is a growing concern in many institutions. As IOF allocations generated by older CFI-funded projects are being depleted, and as infrastructure is losing its state-of-the-art status thereby threatening associated revenues from external users, there are concerns about the long-term utilization and sustainability of CFI investments and the effect on research capacity building and productivity.

# 4.0 BEST PRACTICES FOR RESEARCH OUTCOMES

*CFI-funded infrastructure has facilitated and underpinned a great diversity and breadth of research outputs, outcomes and benefits to Canada. While there are many ways in which research successes are achieved, there are several key features common to the most successful projects and research facilities. Best practices include: strategic research plans which incorporate both internal institutional priorities and external priorities of the region or province; integrated and multidisciplinary research facilities which provide access to diverse users; and networking of researchers with partners from all sectors within a region which address common needs and interests.*

Findings in this section present data on strategic research plans, facility and organization effects, and regional and knowledge networking effects.

## 4.1 Strategic research plans (SRP)

A special characteristic of the CFI approach is that institutions must prepare a strategic research plan (SRP) which is used in reviewing applications for infrastructure awards. The CFI (followed later by the Canada Research Chairs program) was the first major federal funding program to have this requirement, which has encouraged institutions to think strategically about how to maximize the impact and efficient use of their research infrastructure.

*"There has been a tremendous impact on the quality of the Strategic Research Plans within the institutions."*

KPMG, Overall Performance Evaluation and Value-for-Money Audit, Oct. 30, 2009, p. 2.

The CFI has had a dramatic effect on strategic research planning at most of the institutions studied in OMS. The strength of the process at most institutions changed from "very low/low" to "high/very high" over approximately a decade of CFI funding (Table 15). The CFI's investments were deemed to have had a high impact on the realization of the SRP's objectives.

Table 15. The impact of CFI funds on institutional SRPs as assessed by OMS expert panels* (2007-10)

| OMS indicator | Very low | Low | Medium | High | Very high |
|---|---|---|---|---|---|
| Strength of the SRP process prior to the CFI (n=17) | 6% | 64% | 24% | 6% | 0% |
| Current strength of the SRP process (n=17) | 0% | 6% | 29% | 41% | 24% |
| CFI impact on any changes to SRP process (n=17) | 0% | 0% | 12% | 47% | 41% |
| Level of impact on the realization of the objectives of the institution's SRP (n=17) | 0% | 0% | 18% | 59% | 23% |

* *Percentage of all ratings*

SRPs are driven by the internal vision at the faculty and institutional levels, and most commonly, by the office of the vice-president of research and faculty deans. However, external factors also influence an institution's vision for its research and investment priorities, with such factors rated as having a "high/very high" impact in 76 percent of OMS (n=17). The main drivers are regional economic opportunities and provincial governments' priorities or policies. For example, Saskatchewan's interest in carbon dioxide

($CO_2$) capture technologies and Quebec's focus on health systems, have had a significant impact on the plans at University of Regina and Université de Montréal, respectively. The needs and interests of local or regional small to medium enterprises (e.g., relating to the University of Regina's development of $CO_2$ capture technologies for oil companies in southern Saskatchewan) have also had an impact.

There is strong evidence that institutions pursue the priorities identified in their SRPs by allocating significant investments in financial and human resources, including Canada Research Chairs positions, targeted new hires and internal research chairs (Table 16). While the proportions vary across institutions, there is general alignment between the CFI and institutional investments: the greater the proportion of CFI investment in a theme, the higher the allocation of human resources.

Table 16. Human resources and financial investments in SRP focal areas as assessed by OMS expert panels* (2007-10)

| OMS indicator | Very low | Low | Medium | High | Very high |
|---|---|---|---|---|---|
| Number of Canada Research Chairs in theme vs. institution-wide (n=16) | 0% | 0% | 19% | 31% | 50% |
| Number of new faculty member hires vs. institution-wide (n=17) | 0% | 18% | 12% | 35% | 35% |
| Other institutional research funding in theme (n=16) | 6% | 13% | 13% | 37% | 31% |

** Percentage of all ratings*

Well planned SRPs were found to be key to the success of many OMS themes. The 2008 OMS summary report[19] stated that "institutions that were particularly successful in terms of outcomes had deliberately and explicitly implemented plans including research, training, and knowledge and technology transfer activities around integrated facilities."

## 4.2 Facility and organization effects

*Facility effect:* There are some common features that strengthen the impacts of research endeavours. One is the "facility effect," which arises from the collective power of integrated suites of state-of-the-art equipment, usually housed in purpose-built facilities and deliberately sited to maximize accessibility and multidisciplinary, multi-sectoral effects. A prime example of the facility effect is the 4D LABS at Simon Fraser University, a multidisciplinary materials sciences facility that provides open access to researchers and local industries. The industrial partners are attracted by the presence of researchers possessing relevant expertise and access to state-of-the-art emerging technology (i.e., a critical mass of equipment and personnel). This effect maximizes the benefits to users (including HQP), increases multidisciplinarity and permits efficiencies in the operations and maintenance of the infrastructure.

*Organization effect:* The facility effect can be further enhanced by institutions that deliberately have organized their research priorities, training and innovation-related knowledge and technology transfer activities around such centralized multi-user facilities. In the "organization effect," the deliberate planning of diverse activities around major facilities plays a key role in the growth of a research domain and in achieving research outcomes. The Montreal Heart Institute, for example, has created a highly successful centre for coordinating clinical trials at multiple centres and internationally. The Université de Montréal has aligned multiple investments in this centre, including institutional funds (more than $40 million), provincial support and an interactive training environment that allows for the involvement of many trainees in clinical trials. This leads to extensive partnerships with both health practitioners and the pharmaceutical industry.

[19] For more details, visit http://www.innovation.ca/en/evaluation/outcome-measurement-study-oms

### 4.3 Regional and knowledge networking effects

*Regional effect:* Institutions can leverage funds even further through enhanced coordination at the regional level. This involves research and education partnerships with other academic institutions, federal and provincial organizations, and the private sector. Collaboration can also extend to the provision of advanced and comprehensive services both to the public (e.g., health care at research hospitals) and to specific social and economic groups (e.g., farmers), who in turn may provide input and perspectives that can assist in further development of both the research and services (e.g., self-reports from patients on the effectiveness of treatments for conditions such as arthritis).[20]

Both the research and services can feed into a local/regional "clustering" effect involving new and enhanced products and services provided by a wide range of mutually interdependent organizations. A good example is the pharmaceutical cluster in Montréal, which is being further strengthened by the combined effect of CFI investments and the Centre of Excellence in Personalized Medicine (CEPMED, one of the Centres of Excellence for Commercialization and Research). Utilizing CFI-funded infrastructure, such as the Beaulieu-Saucier Pharmacogenomics Centre at l'Université de Montréal, CEPMED is developing and commercializing ways of tailoring pharmaceuticals and medical care to the genetic profiles of patients.

*Knowledge networking effect:* Through the Internet, research infrastructure is being networked to an increasing degree, with collaboration and exchanges between researchers, sharing of databases and computing resources (e.g., High Performance Computing), and outreach to the general public (e.g., NEPTUNE, an undersea observation network, linked to the Internet). Wider networking is particularly noticeable for projects involving the humanities and social sciences.

The Museum of Anthropology at the University of British Columbia is an interesting example of both the regional and knowledge networking effects. Designed to support collaborative research with Aboriginal communities, the infrastructure includes a new research wing in the museum and research stations in partner communities which connect through a reciprocal research network linking 15 museums and institutions and more than 700 researchers, community members and museum professionals involved in over 780 research projects. Collections of materials and artifacts are being digitized for even wider access.

# 5.0 FUTURE DIRECTIONS

This report represents the first steps in integrating the findings of the CFI's diverse evaluation and outcome measurement activities. Building on this framework, annual updates will be provided on the results of ongoing activities (PPR and OMS), while incorporating findings from any special studies or past evaluations. Future reports could focus on emerging topics in S & T or include more in-depth analyses of issues of relevance to the CFI.

[20] For example – University of Toronto / University Health Network: *Post-Marketing Surveillance Infrastructure for Arthritis: Supporting the optimal use of therapies and best practices for rheumatologic care in Canada*.

# APPENDIX A

## 2010 Project progress report analysis: highlights

***Key findings from the past year include:***

### Research infrastructure leads to social and economic benefits

**Research infrastructure helped create more than 4,000 academic, private and public sector jobs.**

The availability of the infrastructure led to:

- creation of 4,153 academic, private and public sector jobs;
- development of 979 new or improved products, processes or services;
- development of 689 best practices in manufacturing, organizational structure, healthcare, etc.
- creation of 564 environmental benefits;
- creation of 399 new or improved public policies or programs;
- development of 901 invention disclosures, patents and licensing agreements;
- 435 patents filed and 62 granted; and
- creation of 44 CFI-linked spin-off companies.

### Fuelling brain gain

**More than 12,500 researchers advanced their research using CFI-supported infrastructure.**

- 98% of project leaders reported that the availability of CFI-funded infrastructure was at least somewhat important in their decision to join the institution;
- 12,658 researchers (including the project leader, other principal researchers and other faculty at the institution) advanced their research by using CFI-supported infrastructure;
- Overall, 1,356 new researchers were recruited. Of this number, approximately half (40%) were recruited internationally.

### Meeting Canada's need for knowledge workers

**More than 19,000 post-doctoral fellows and graduate students have used CFI-funded infrastructure as a key resource in their research project.**

- 8,692 post-doctoral fellows and graduate students were attracted to the institutions, partly due to the availability of the infrastructure.
- A total of 19,314 post-doctoral fellows and graduate students used the infrastructure as a key resource in their research project.
- A total of 6,209 technical personnel have been trained on the use and maintenance of the research infrastructure.

### Enhancing Canada's international reputation

**More than 11,500 visiting researchers made use of CFI-funded infrastructure.**

- 11,819 visiting researchers from around the world made use of state-of-the-art infrastructure at Canadian universities, colleges and research hospitals.

### Fostering collaboration

**More than 2,500 formal research collaborations have been reported.**

- Project leaders reported a total of 2,640 formal collaborative research agreements.
- 77% of project leaders said that the availability of CFI-funded infrastructure had enhanced opportunities for informal research collaborations.