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Key Acronyms	
BEL	Best Equipped Laboratories – these are the best-equipped international labs identified by OPEA respondents
CFI	Canada Foundation for Innovation
HQP	Highly Qualified Personnel
OPEA	Overall Performance Evaluation and Value-for-Money Audit
OMS	Outcome Measurement Studies (a newly developed, ongoing CFI evaluation technique, in operation since 2007)
PL	Project Leader of a CFI project
PU	Principal User of a CFI project
SOA	State-of-the-art
SRP	Strategic Research Plan

EXECUTIVE SUMMARY

Introduction

This document reports on the evaluation component of the overall performance evaluation and value-for-money audit (OPEA) of the Canada Foundation for Innovation (CFI), which was required under CFI's Funding Agreement with Industry Canada.

The Canada Foundation for Innovation

The CFI is an independent corporation created by the Government of Canada in 1997 to fund research infrastructure. Its mandate is to strengthen the capacity of Canadian universities, colleges, research hospitals, and non-profit research institutions to carry out world-class research and technology development that benefits Canadians. Since its creation in 1997, the CFI has committed almost $5.2 billion in support of 6,353 projects at 130 research institutions in 65 municipalities across Canada.[1] The CFI normally funds up to 40 percent of a project's infrastructure costs which are invested in partnership with eligible institutions and their funding partners from the public, private, and voluntary sectors who provide the remainder.

Some CFI features are unique; others, while not unique in and of themselves, are unique in their combination:

- The CFI requires each institution to have an institutional Strategic Research Plan (SRP) that sets priorities based on its strategic vision for the future.
- Awards are made to eligible institutions, not individual researchers or Project Leaders.
- The CFI funds most types of research infrastructure and implementation costs, not just "equipment". Projects of all sizes are eligible, and infrastructure from all research disciplines is supported.
- The Infrastructure Operating Fund supports a portion of operations and maintenance of the infrastructure anticipated for as long as the infrastructure is still being used for research purposes during. However, the amount of funding provided by the CFI is limited and the institutions are expected by the CFI to find this support from other sources once CFI funding has expired.

Methodologies

The key methodologies were: (1) review of documents related to the CFI's alignment to the federal science and technology (S&T) prorities, and review of earlier studies of the CFI's achievements and model; (2) A review of existing data from the CFI's Project Progress Reports (PPRs) and the CFI's Outcome Measurement Studies (OMS); (3) Web surveys of a census of CFI Project Leaders (PLs) and Principal Users (PUs) of CFI projects; (4) Web surveys of a stratified, representative random sample of Canadian Department Heads and Vice-Presidents Research, and of international experts who have participated in CFI application reviews; (5) Interviews with key informants in the federal granting councils and federal and provincial agencies; (6) Analysis of the need for new and renewal infrastructure; and (7) Limited comparison to similar questions asked during the 2008 – 2009 evaluation of Genome Canada, and to questions asked of NSERC's Equipment Grants program in a 1990 evaluation.

[1] CFI web site, September 2009: www.innovation.ca/en/about-the-cfi/cfi-overview

Findings on Results

Strategic research planning: There has been a tremendous impact on the quality of the Strategic Research Plans (SRPs) within the institutions. This is especially true at the V-P Research level, while there is still room for improvement at the departmental level. The SRPs have been used by many institutions to maximize the impacts of the CFI investments, and the impacts are strongest when the SRP itself is strong – sometimes to the institutions' surprise.

Strategic planning with other research institutions and other funding organizations has improved notably and is now rated as moderate to good. However, key respondents often mentioned that further coordination of effort would be welcomed, if possible.

Quality of Canadian research infrastructure: The CFI support has transformed the quality of Canadian research infrastructure. About two-thirds of PLs and PUs rate their infrastructure's technical capability as excellent or world-class, and about half rate its operational capability this highly.

Institutions have harnessed the collective power of integrated suites of state-of-the-art equipment, often across departments and often in purpose-built facilities that are deliberately situated to maximize accessibility, multidisciplinarity and multi-sectoral effects — an outcome the CFI calls the "facility effect". This collective power is greatly strengthened by an "organization effect", in which institutions deliberately and explicitly address this strength in their SRPs and facility designs, and organize their research, training, and innovation programs around it.

These impacts could not have occurred to nearly the same extent through programs focused on individual researchers with individual equipment requests, or without the SRP requirement.

Canadian research productivity: The quality and quantity of Canadian research are both up substantially in 2009 as compared to 1990 (as investigated in the 1990 NSERC study). In addition, the PLs, PUs, and Department Heads believe there is a substantial pre/post-CFI difference in Canadian research productivity, from good pre-CFI to excellent now, on average. Especially where large, integrated infrastructure investments are strongly tied to the institution's SRP, the CFI and partner investments have had strong – and sometimes remarkable – impacts on research productivity.

State-of-the-art infrastructure continues to be one of four key factors that are the most important in fostering outstanding research productivity. (The others are critical mass, sufficient research funding, and the departmental research environment – and state-of-the-art equipment, instruments, and facilities attract and support these other factors.) Both this study and the 1990 NSERC study found that roughly three-quarters of the difference in research quality and quantity between Canadian labs and the BELs would disappear if the Canadian labs were equipped like the BELs. These consistent findings almost two decades apart give great confidence in concluding that the impacts of research infrastructure on productivity are tremendous.

Overall, there is a clear convergence of the research capacity, the funding streams that support them, and the research productivity that results, and the gap between Canadian research productivity and the international BEL research productivity has narrowed significantly.

Attraction and retention: The CFI projects were rated as being of high or very high importance by 77% of PLs/PUs for staying in their present job position, or for moving (if they did). Regarding attraction, about 28% of PL/PU respondents overall had changed job positions (other than through promotion) within the past five years. There has been significant attraction from abroad – at least 56% of PLs and PUs have come from international positions. Regarding retention, about 44% of PLs/PUs had considered taking another job within the past five years. Of these, 24% had received a firm offer.

The top four factors for attraction/retention are the CFI infrastructure, availability of research funding, personal factors, and the research environment in the department. The CFI noted that context is important for discussing attraction and retention – mobility (even within Canada) is often the key to career advancement.

Training of highly qualified personnel (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. The PPRs show that more than 90% of the CFI projects have been used as a key resource in the research projects of HQP (including post-doctorate fellows and/or graduate students). On average, the infrastructure has been used by 16 HQP per project.

All institutions studied in the OMS have greatly expanded and improved their training programs in response to these strengths. Roughly two and a half times more HQP are being trained in the OMS themes per annum. There were many new graduate and undergraduate curricula, explicit multidisciplinary courses, training conducted collaboratively across faculties or with other institutions (including colleges) or countries, deliberate training of research project leaders and administrators, and collaboration with external users (including entrepreneurship training). The institutions also noted that the quality of students and postdoctoral fellows attracted to the themes had increased (e.g., more have won prestigious scholarships and fellowships).

Collaboration and networking: The CFI projects are key resources in fostering academic collaboration and networking. This effect is particularly strong for PLs/PUs, but also (to slightly lesser extent) at the departmental and institutional level. The average total number of researchers per project ranges from 10 to 17, and the PLs report that the availability of the infrastructure has enhanced opportunities for collaborative research, especially within the institution and with other research institutions. The OMS found numerous examples of major national and international collaborative initiatives in which the Canadian PLs were key investigators.

The CFI projects are also important for collaborations with end-users (i.e., potential users of the research results outside of the academic research community who intend to develop practical applications from the research findings). The PLs and PUs in the OPEA survey alone had undertaken about 6,800 collaborations with end-users over the past year, or about 6.4 collaborations per PL/PU and about 10.2 collaborations per Department Head. About 64% of PL/PUs' and 80% of Department Heads' end-user collaborations, respectively, are with Canadian organizations; there is a significant international component as well.

Socio-economic impacts: Two-thirds of both PLs/PUs and Department Heads have actively explored practical applications of their research. This exploration has been conducted through a very wide variety of mechanisms, which is consistent with best practices for technology transfer and knowledge translation of university research as seen through earlier KPMG reviews of many academic technology and knowledge transfer organizations world-wide. There are also many types of practical impacts being explored – not just industrial. The PPR data show that about 30% of the projects have generated new or improved products, processes, services, or cost savings, while 25% have generated new or improved public policies and programs, and 18% have created private or public sector jobs.

The OMS made it clear that substantial thought is devoted to creating linkages to external user organizations, and to how these innovations would be used. It was common to find active investigation of practical applications, for many types of users, in all sectors, including in public good areas such as health care systems or natural resource policies and practice. It was also clear that some practical applications will arise through knowledge translation (i.e., development of proprietary knowledge by the industrial partners, without patenting being involved).

The OMS Expert Panels did, however, identify occasional weaknesses in the strategic planning for innovation, linkages to users, and exploitation activities in some themes.

Findings on Program Design and Delivery

Program design: The overall architecture of the CFI is sound – there are no significant "gaps", and the individual Funds are well-designed and well-delivered. Strengths of the CFI model include: its support for all disciplines and all kinds of infrastructure (including buildings, construction, software, databases, etc.) in a "one-stop" model; the Strategic Research Plan process, which has proven to be unexpectedly important to both the researchers and the institutions; the sufficiently large budgets to allow state-of-the-art infrastructure to be obtained and upgraded over time; the CFI's due diligence both during proposal review and during project implementation and operation; and its very low operating and administration costs per dollar disbursed (as seen in comparison to other foundations reviewed by KPMG in 2007).

There are two possible issues to consider:

- Institutions and provincial representatives worried about being able to support operations and maintenance (O&M) over the long-term. Through the Infrastructure Operating Fund, the CFI allocates an additional 30% of the CFI's portion of each project's budget for O&M, which the institution may use as and when it sees fit so long as the project is still being used for research. The evidence suggests that this IOF allocation is insufficient to support O&M beyond the first few years, especially for large projects. However, the community does not mainly see this as a CFI problem, as opposed to an issue for the institutions and provinces.
- Additional coordination with other funding agencies at both national and provincial levels would be welcomed if possible (especially for major investments), as occasionally the infrastructure is available but not the research funding, or vice versa.

Program delivery: The CFI guidelines for preparing and rating proposals are very clear. The majority of respondents see the funding approval process as transparent and equitable, and the funding approval as free from bias and conflict of interest. Virtually no one finds any of these factors to be poor or very poor.

Findings on Relevance

There is a strong continuing need for, and continued relevance of the CFI. This is tied to the dramatic improvements in institutional strategic thinking; the strong "facility effects" and "organizational effects"; the convergence of resources being put into strategic research, training, and innovation efforts; the very strong impact that state-of-the-art research infrastructure has on research capacity, including training of HQP; the unique features of the CFI model overall; and the relevance that this research capacity has for Canada overall and for individual provincial priorities. On the last point, respondents pointed out that focusing too much on federal priorities could easily neglect provincial and/or institutional priorities, and would likely put co-funding and long-term O&M support at risk.

Second, there is a strong need for new and/or upgraded projects and facilities (with both high technical and operational capabilities) in order for Canadian research to stay competitive with global efforts. The total "ask" from the CFI alone (i.e., not including partner contributions) is estimated at roughly $5 billion over the next five years. Instead of simply updating existing infrastructure to keep it operating properly, there is increasing interest in more "full-service" and sophisticated facilities with strong user support, which the study team believes is related to the "facility effect".

Conclusions

The findings overall point to a strong impact of the CFI on Canadian research infrastructure, which in turn has had strong impacts on research capability and productivity, training, attraction and retention, and collaboration. Although many impacts on innovation remain in the future, there is good reason to believe that the institutions and researchers are putting significant effort into this area. The CFI has also led to considerably more and considerably stronger strategic research planning at the institutional level, as well as moderately more at department and provincial levels, and this planning has been unexpectedly successful at leveraging research strengths. These effects together have led to a clear convergence of research capacity, the funding streams that support them, and the research productivity that results.

The Canadian research community requires new and upgraded infrastructure in order to remain internationally competitive – the study found that research infrastructure continues to play a large part in research productivity. Also, the CFI's goals remain consistent with federal and provincial priorities.

The overall architecture of the CFI is sound, contains no major gaps, and has a number of advantages compared to many other research infrastructure support programs world-wide. The individual Funds are well-designed and well-delivered.

No significant problems with the CFI or its impacts were identified. However, there are three areas worthy of further consideration:

(1) The data suggest that the "facility effect" and the "organization effect" have not been fully recognized by the institutions (and until recently by the CFI itself). This has implications for outreach and, possibly, application review.

(2) There may be some room for improvement in strategic planning done collaboratively with other research institutions and other funding organizations. The study team notes that such external planning would require specific resources devoted to it.

(3) Long-term support for operations and maintenance of infrastructure remains worrisome for the institutions and provinces, although it is unclear that the CFI should increase its support here.

In sum, the evaluation of the CFI and its impacts was overwhelmingly positive. Although some minor operational refinements are suggested, the CFI's model and program delivery are both outstanding, and the CFI remains a critical foundation for Canadian research.

1 INTRODUCTION

1.1 OVERVIEW

This document reports on the evaluation component of the overall performance evaluation and value-for-money audit (OPEA) of the Canada Foundation for Innovation (CFI), which was required under CFI's Funding Agreement with Industry Canada.

The evaluation component included two special studies identified in the CFI's Performance, Evaluation, Risk, and Audit Framework (PERAF): (1) the international comparison (operational benchmarking) study; and (2) the study of the need for new and renewal research infrastructure.

2 THE CANADA FOUNDATION FOR INNOVATION

For a complete description please see: www.innovation.ca.

2.1 OVERVIEW

The Canada Foundation for Innovation (CFI) is an independent corporation created by the Government of Canada in 1997 to fund research infrastructure. The CFI's mandate is to strengthen the capacity of Canadian universities, colleges, research hospitals, and non-profit research institutions to carry out world-class research and technology development that benefits Canadians.

CFI funding enables institutions to set their own research priorities in response to areas of importance to Canada. This is intended to allow Canadian researchers to compete with the best from around the world, and help solidify Canada's position in the global knowledge-based economy. The CFI supports national science and technology objectives and strengthens Canada's capacity for innovation by:

- supporting economic growth and job creation, as well as health and environmental quality through innovation;
- increasing Canada's capability to carry our important world-class scientific research and technology development;
- expanding research and job opportunities for young Canadians; and
- promoting productive networks and collaboration among Canadian post-secondary educational institutions, research hospitals and the private sector.

High-quality infrastructure is intended to help Canadian research institutions attract, retain, and train highly skilled research personnel. It also is intended to lead to the creation of spin-off ventures and the commercialization of discoveries.

The CFI promotes the optimal use of research infrastructure within and among Canadian institutions and creates the necessary conditions for sustainable, long-term economic growth. The innovative research that results from great minds and solid infrastructure is intended to lead to improvements in public policy as well as in Canadian health, environment, and quality of life.

2.2 FUNDING

Since its creation in 1997, the CFI has committed almost $5.2 billion in support of 6,353 projects at 130 research institutions in 65 municipalities across Canada.[2] The CFI normally funds up to 40 percent of a project's infrastructure costs which are invested in partnership with eligible institutions and their funding partners from the public, private, and voluntary sectors who provide the remainder.

2.3 FUNDING ARCHITECTURE

The CFI funding architecture is based on a three-way program delivery system:

1. Open competitions for transformative infrastructure projects. The Leading Edge and New Initiatives Funds competitions are the main open competitions.
2. Pre-determined allocation-based program which gives universities the flexibility and rapid turnaround time needed to facilitate the recruitment and retention of leading researchers. The Leaders Opportunity Fund addresses this need.
3. A program to defray a portion of operating and maintenance expenses to ensure optimal use of CFI-funded infrastructure. The Infrastructure Operating Fund (IOF) addresses this need.

In addition to these three core programs, the CFI has also provided for strategic investments through the National Platforms Fund and Research Hospitals Fund. Finally, the CFI has created the Exceptional Opportunities Fund to address the rare instances where an exceptional research opportunity would be missed if a project was required to wait out a national competition.

2.4 ELIGIBLE COSTS

Infrastructure Projects: Eligible costs include all goods and services required to bring the new infrastructure into operation, as well as warranties and service contracts included in the infrastructure purchase price.

Infrastructure Operating Fund: Under the Infrastructure Operating Fund (IOF), the costs of operating and maintaining CFI-funded infrastructure are eligible. Unlike the majority of CFI's programs, no partner funding is required.

2.5 NATURE OF CFI-FUNDED PROJECTS

Data from the CFI's Project Progress Reports (PPRs) from 2001 to 2008 (but excluding 2002, since the CFI adjusted the deadline date for reporting in that year) indicate that:

- Over the last 8 years, 40% of total CFI projects are in Health, 24% are in Science, 21% are in Engineering, and 10% are in Environment. (Until recently, the social sciences and humanities were not reported separately.)
- The majority (84%) of projects are at large universities, hospitals and not-for-profit organizations. Small universities comprise 15%, and colleges 1%.
- CFI's contribution to these projects was $2.8 billion, of which $1.7 billion (or 62%) represents awards made by the Innovation Fund, the CFI's largest fund in terms of dollars (but with a relatively small number of projects compared to other CFI Funds).

[2] CFI web site, September 2009: www.innovation.ca/en/about-the-cfi/cfi-overview

- From the most recent PPRs (2008), about 70% of total projects were fully operational, and for those projects in year five about 90% were fully operational.

2.6 IMPORTANT FEATURES OF THE CFI FOR EVALUATION PURPOSES

There are several features of the CFI that are worth bearing in mind for evaluation purposes. Some of these features are unique; others, while not unique in and of themselves, are unique in their combination:

- The CFI requires each institution to have an institutional Strategic Research Plan (SRP) that sets priorities based on its strategic vision for the future. Institutions are especially encouraged to set priorities in areas that integrate ideas and knowledge from many disciplines and sectors, and that build on each institution's individual advantages. During major competitions, institutions may submit an updated SRP when submitting a proposal. The SRP represents a major change in requirements placed on public institutional research planning.
- Awards are made to eligible institutions, not individual researchers or Project Leaders. Thus although the initiative for a given application may come from the PL, the institution can choose not to support the application if is does not fit within their SRP. Thus institutions have considerable influence on the infrastructure requested, the research and training programs based on that infrastructure, access and joint usage of infrastructure across departments and faculties, etc., again ideally tied to their SRP.
- The CFI funds most types of research infrastructure and implementation costs, not just "equipment". This includes (but is not limited to) buildings to house the equipment, construction and implementation costs, training for operators, databases, software, information technology support systems, etc. Projects of all size are eligible, and infrastructure from all research disciplines is supported. This is in contrast to many other international infrastructure programs, which are usually far more fragmented and in which a given program supports only restricted types of infrastructure, only one or a few disciplines, only infrastructure within a narrow size range, etc.
- The IOF supports a portion of operations and maintenance of the infrastructure anticipated for as long as the infrastructure is still being used for research purposes during the period claimed. However, the institutions are also expected by the CFI to find this support from other sources, as the CFI presumes that this will be done if the infrastructure is indeed important to the institutions' SRPs, and this is agreed upon in the Award Agreements signed by the institutions.

3 METHODOLOGIES

3.1 OVERVIEW

The OPEA was based on the Treasury Board Secretariat's integrated Results-Based Management and Accountability Framework (RMAF) and Risk-Based Audit Framework (RBAF). For the CFI, these tools were customized to be appropriate to the CFI's unique model and circumstances. The result is referred to as the Performance, Evaluation, Risk, and Audit Framework (PERAF[3]), which is the CFI's current evaluation framework and risk management tool. The PERAF takes into account data from multiple lines of evidence that includes the current evaluation, annual project progress reports (PPRs) completed by CFI-funded Project Leaders (PLs) and submitted by the institutions, institutional reports, internal reviews and risk analyses,

[3] Development of the PERAF was an extensive exercise carried out in 2007 – 2008, in preparation for OPEA.

external evaluations, the CFI's recently developed Outcome Measurement Study (OMS; which is an evaluation tool so far unique to the CFI), and other data.

The major evaluation questions were related to the CFI's Results, Program Design and Delivery, and original and continued Relevance. The detailed evaluation questions and individual instruments are found in a separate appendix document.

3.2 METHODOLOGIES

3.2.1 Document Review

In the first part of this exercise, federal S&T goals were compared to the goals and actions of the CFI. Key documents reviewed were:

- Federal S&T Policy Statements
- CFI Funding Agreement
- CFI Corporate Plans
- CFI Communication documents
- Annual Reports, as these discuss the CFI's corporate Plans and how CFI's objectives have evolved to fit federal goals.

The second part of the exercise included review of previous evaluations that have been done of the CFI and its programs. These include evaluations of the:

- New Opportunities Fund (two studies: Hickling Arthurs Low, January 15, 2002; and SPR Associates, 2007);
- The Innovation Fund, College Research Development Fund, and University Research Development Fund (KPMG, 2003)
- The evaluation of the Canada Research Chairs Program (R.A. Malatest and Associates, Dec. 2, 2004.) – this included a review of CFI vis-à-vis equipment grant programs of the Natural Science and Engineering Research Council, since the CFI includes support for CRC award holders.
- Evaluation of Foundations, KPMG, February 2007 (this report has case studies of six foundations, one of which was the CFI).

Finally, an overview of the CFI's 2009 consultations ("*Future Directions"*) with the Canadian community was reviewed.

3.2.2 Review of Available Data

A complete report of the review of available data is found separately.[4]

Review of Project Progress Reports (PPRs): The CFI collects project-related information for the five years following finalization of an award. For this component of the OPEA, 5,003 PPRs were analyzed. This includes reports from 2001 to 2008, but excludes 2002 since the CFI adjusted the deadline date for reporting in that year. CFI's financial database was also analyzed during this component of the OPEA, but those (primarily descriptive) data are not reported here.

Review of Data from the Outcome Measurement Studies (OMS): The OMS was established as a tool in the CFI's suite of evaluation activities in 2006. OMS assesses outcomes and impacts

[4] *Canada Foundation for Innovation OPEA Project - Evaluation Component Report on the Analysis of Available Data. KPMG, September 10, 2008.*

across a group of related CFI projects within an integrated research theme (e.g., advanced materials, neurosciences) at a given institution. The OMS methodology involves an in-depth questionnaire submitted to institutions, followed by validation by a visiting OMS Expert Panel[5] whose report is the key output of the exercise. The main data source for the findings reported here was the OMS Integrated Report, which summarizes the information from the first nine OMS Thematic Studies done.[6] A limited review was also done of findings from seven additional OMS Thematic Studies conducted since that report was prepared. Note, however, that the statistical figures reported here are from the first nine OMS studies only; summary statistics for all 16 have not yet been compiled.

The study team notes that OMS has studied all sizes of institutions and many different disciplines, although the OMS themes were chosen as representing relatively large investments within the context of each individual university, and representing integrated sets of CFI projects linked to the SRPs. Thus, it is reasonable to expect that similar trends will be found within other similar large and integrated CFI investments – the strong impacts discussed below will almost certainly be found for other themes with similar characteristics.

3.2.3 Web Survey of Project Leaders and Principal Users

A web survey was conducted of a census of 4,727 Project Leaders (PLs) and 4,358 Principal Users (PUs).[7] Adjusting for incorrect e-addresses etc., there were 7,323 potential respondents in the sample. The response rates were:

- 1,483 respondents in total, for a 20% response rate overall;
- 1,115 PL responses, for a response rate of 29%; and
- 349 PU responses, for a response rate of 10%.

The study team notes that, while these response rates are somewhat lower than ideal, they are still entirely acceptable and will produce reliable and defensible results. There are several reasons for this:

- The research community is suffering from an ever-increasing reporting burden, and in having conducted over 100 studies of research programs over the past 20 years, the study team has found that response rates are steadily decreasing as a result. Obtaining survey response rates over 30% is now very difficult.[8]
- Response rates are typically lower for web surveys involving very large samples, presumably because respondents believe that their individual response will count for less.
- There is no reason to suspect any response bias. In fact, in a number of other studies of R&D programs conducted by the study team in which possible response bias by non-respondents was specifically investigated[9], none was found.

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[5] Panel members have expertise in both the theme science and its potential applications.

[6] *Canada Foundation for Innovation OMS 2008 Summary Report,* KPMG, October 30, 2008.

[7] The CFI applications identify all the intended Principal Users for each CFI project.

[8] In a recent similar study, KPMG succeeded in obtaining a response rate from Principal Investigators of about 50%, but only after numerous telephone follow-ups with the individual PIs, and only after actually talking to the PIs (i.e., not simply leaving voice messages). This is obviously impossible with a sample of several thousand PIs.

[9] For example, by conducting interviews with non-respondents to surveys (the interview process results in a high response rate) and comparing the statistics from these interview respondents to those from the survey respondents.

- Similar to the point immediately above, there is no reason to suspect that award holders have different opinions from non-award holders. Individual PLs are often involved in several CFI projects – they may be successful in one application but not in another, and many of the respondents also use CFI infrastructure for which they are not designated PLs or PUs.
- Finally, the study has employed multiple lines of evidence, and all sources point to the same conclusions.

3.2.4 Surveys of Vice-Presidents Research, Department Heads, and International Experts

Surveys were conducted of a stratified random sample of Canadian V-Ps Research, Canadian Department Heads, and international experts. V-Ps Research was sampled to be representative of institutions of different sizes (e.g., universities, colleges, and research hospitals) and regions. Department Heads were sampled in similar fashion, but also representative of different disciplines. The international experts were selected across disciplines, but were individuals known to be knowledgeable about the CFI from participation as a reviewer in one or (ideally) more CFI award competitions. We obtained responses from

- 22 V-Ps Research (the study target was 20);
- 54 Department Heads responded (the target was 45); and
- 33 Experts (the target was 30).

3.2.5 Interviews with Key Informants

Interviews were conducted with 16 key informants drawn from CFI senior management, Canadian central agencies (e.g., Industry Canada), Canadian university granting councils, provincial funding partners who provide a portion of the remaining 60% of project funding, and members of the Science, Technology, and Innovation Council.

The list of key informants is found separately in the Appendix.

3.2.6 Analysis of New and Renewal infrastructure Needs

The study investigated the likely "ask" that the CFI will experience over the next five years for entirely new CFI projects or renewal of existing projects. This supplemented a "renewal needs" study conducted for the CFI in 2006.[10] It also drew upon a "Best Equipped Laboratory" (BEL) methodology and analysis conducted in 1988 for the Natural Sciences and Engineering Research Council (NSERC).[11] The questions related to the need for new and renewal infrastructure was integrated into the surveys for PLs, PUs, and Department Heads.

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[10] *Future Investment Required in Canadian Research Infrastructure Final Report*. KPMG, September 26, 2006. This is often referred to as the "renewal needs study".

[11] *Final Report for the Evaluation of the Equipment Grants Program of the Natural Sciences and Engineering Research Council.* The DPA Group (now KPMG). October, 1990. Also reported publicly in: *A Survey of Canadian Academic Research Equipment: Its Adequacy and the Implications for Research Capability.* A. Dennis Rank and Douglas Williams. **Equipping Science for the 21st Century,** John Irvine ed., Edward Elgar Publishing, Cheltenham, UK, 1997.

3.2.7 Comparison to 2008-2009 Genome Canada Study

Some questions were deliberately designed to be similar or identical to questions used in the 2008 – 2009 evaluation of Genome Canada[12], so that both organizations could benefit from comparisons between the findings.

4 FINDINGS ON RESULTS

4.1 STRATEGIC RESEARCH PLANNING

4.1.1 Data from the OMS

The strategic research plans (SRPs) – a unique feature of the CFI program – have been used by most of the institutions to maximize the impacts of the CFI investments. The impacts are strongest when the SRP itself is strong – this has sometimes been to the institutions' surprise. The most effective SRPs combine strong institutional vision and leadership, management and coordination (both at the institution and department levels), outstanding research leadership, and leveraging of complementary resources (e.g. of provincial funds, Canada Research Chairs) to maximize impacts. The OMS found many instances of additional strategic planning done with other research institutions (of all types, including research hospitals and colleges).

Although the SRPs naturally focus mainly on improving institutional research capacity, some additionally put strong emphasis on improving access, innovation, and translation of the research findings for external users.

4.1.2 Data from OPEA

The SRP has been found to be useful by the institutions, especially at the V-P Research level. See exhibit 4.2.

Exhibit 4.2 – Value of current internal strategic research planning

Ratings by:	
Department Heads	Overall = 3.5 (somewhat valuable to valuable) (58% valuable or very valuable) (21% not very or not at all valuable)
Vice-Presidents Research	Overall = 4.3 (valuable to very valuable) (86% valuable or very valuable) (0% not very or not at all valuable)

Rating scale: 1 = Not at all valuable, 5 = Very valuable

Exhibit 4.3 shows that there has been a tremendous impact on the quality of the SRPs within the institutions. This is again especially true at the V-P Research level, while – although improved – there is still room for improvement at the departmental level. Note that the international experts rated the quality of Canadian institutions' strategic research planning higher than at their own institutions.

[12] *Evaluation of Genome Canada – Final Report*. KPMG, May 13, 2009

Exhibit 4.3 – Quality of the Strategic Research Plan in the institution *

Ratings by:	*Pre-CFI*	*Now*
Department Heads	Overall = 2.6 (fair to moderate) (21% excellent or good) (42% fair or poor)	Overall = 3.7 (moderate to good) (62% excellent or good) (10% fair or poor)
Vice-Presidents Research	Overall = 2.4 (fair to moderate) (14% excellent or good) (43% fair or poor)	Overall = 4.2 (good) (95% excellent or good) (0% fair or poor)
Experts (rating Canadian institutions)	Overall = 2.9 (moderate) (8% excellent or good) (12% fair or poor)	Overall = 4.3 (good) (59% excellent or good) (0% fair or poor)
Experts (rating their own institution)	Not applicable	Overall = 3.5 (moderate to good) (52% excellent or good) (11% fair or poor)

** Rating scale: 1 = Poor, 5 = Excellent*

The V-Ps Research also see large improvement in strategic research planning done collaboratively with other research institutions and research funding organizations, as seen in exhibit 4.4. Comparing exhibits 4.4 and 4.3, there has not been quite as much impact of the CFI on external planning as for internal planning, and there appears to be slightly more room for improvement. Although strategic planning with other research funding organizations is now rated as moderate to good, respondents in the OPEA and the OMS often mentioned that further coordination of effort would be welcomed, if possible. The study team notes that such coordination tends to be quite difficult.

Exhibit 4.4 – Quality of strategic research planning done collaboratively with other external organizations

	Ratings by Vice-Presidents Research	
Collaboration with:	*Pre-CFI*	*Now*
Other research institutions	Overall = 2.4 (fair to moderate) (9% excellent or good) (41% fair or poor)	Overall = 3.4 (moderate to good) (59% excellent or good) (14% fair or poor)
Other research funding organizations (including provinces)	Overall = 2.6 (fair to moderate) (14% excellent or good) (32% fair or poor)	Overall = 3.5 (moderate to good) (64% excellent or good) (23% fair or poor)

** Rating scale: 1 = Poor, 5 = Excellent*

4.2 QUALITY OF CANADIAN RESEARCH INFRASTRUCTURE

4.2.1 Findings from Project Progress Reports

The PPR data show that, across all Funds, 30% of infrastructure is comparable to the best in the world, and 64% of infrastructure is comparable to the best in Canada. Infrastructure comparable to the best in the world ranged from a high of 38% of projects in 2004 to a low of 29% in 2008. Infrastructure that was comparable to the best in Canada ranged from 35% of projects in 2001 to 65% in 2007 and 2008.[13] The study team notes some "projects" are individual pieces of equipment, while others are complex installations in which naturally a considerable amount of routine equipment is required. Thus it is entirely normal that less than 100% of the infrastructure is state-of-the-art.

On average about 80% of CFI-funded projects were fully utilized, and an additional 8% were fully utilized and over-subscribed. The remaining 12% were underutilized, mainly because they were not yet operational.

From the 3,262 projects providing data, facility space has the longest useful life *since purchase* (17 years) and computer infrastructure has the shortest (7 years). At the time the OPEA study was done, the infrastructure now has a useful *remaining* life that ranges from about 3 years (computing equipment) to 13 years (facility space). The study team notes that these "useful lifetime" figures are essentially identical to those found in the 2006 "renewal needs" study.

4.2.2 Findings from the OMS

The OMS data show that the CFI has transformed the quality of Canadian research infrastructure, at least at institutions which have made relatively large infrastructure investments in integrated themes. The CFI-funded infrastructure in the OMS themes studied is equivalent to at least the best in Canada. Some themes have state-of-the-art (SOA) infrastructure equivalent to the best in the world in technical capability (see section 4.2.3 for a definition), if not always scale. Other sites, while partially SOA, were not at world levels because of considerably smaller size or lack of any unique capabilities.

The impacts are intimately tied to a large "facility effect" – the collective power of integrated suites of SOA equipment. This collective power is greatly strengthened by an "organization effect" – in which institutions deliberately and explicitly address this strength in their SRPs and facility designs, and organize their research, training, and innovation programs around it. Considering the size of the CFI investments and the presence of the facility effect and the organization effect, almost certainly these impacts would not have arisen to nearly the same extent through funding programs focused on individual researchers, or those driven by individual equipment requests, or those without the SRP requirement.

[13] In earlier reporting years, respondents had the option of one or two additional responses, i.e., average compared to other labs and above average compared to other labs. Thus it is difficult to know if the change in rating over time is due to changes in the quality of infrastructure or to how respondents interpreted the ratings, or perhaps to a general increase to the quality of international research infrastructure.

4.2.3 Findings from OPEA

The OPEA data in Exhibit 4.5 show that the average Canadian laboratory is still somewhat behind the international community's Best Equipped Laboratories (BELs). One would probably expect the "average" Canadian lab to be less capable than the best in the world, so the fact that a substantial proportion of Canadian labs have roughly equal capability as the BELs is compelling. OPEA respondents were asked separately about "technical capability" and "operational capability":

- "Technical capability" refers to the technical and scientific specifications such as measurement capabilities, scientific outputs, accuracy, throughput, database functionality, etc. of specialized research equipment; while
- "Operational capability" refers to the infrastructure's building and operating space, user capacity, routine IT and computing capabilities, operating and maintenance levels, non-research equipment such as cranes or milling machines, etc.

These factors were asked about separately because the "renewal needs" study found that renewal applications were often requesting to not simply upgrade aging instruments to SOA capability, were also requesting supporting infrastructure to substantially enhance user access and support as well. The latter was tied to the greatly increased user demand that the facilities had experienced after the original CFI investments.

Exhibit 4.5 – Average ratings of infrastructure quality

Ratings by:	*Respondent's' area & institution*	*Int'l BEL rating by Cdn respondents*
PLs/PUs		
Technical capability	3.8 (63% excellent or world-class)	4.7 (96% excellent or world-class)
Operational capability	3.4 (45% excellent or world-class)	4.6 (93% excellent or world-class)
Department Heads		
Technical capability	3.5 (49% excellent or world-class)	4.8 (98% excellent or world-class)
Operational capability	3.1 (30% excellent or world-class)	4.7 (98% excellent or world-class)

** Rating scale: 1 = Poor, 5 = World-class*

Exhibit 4.5 also shows that the Canadian infrastructure's operational capability is somewhat lower than its technical capabilities. This is much less true in the international BELs, and similar findings are discussed later in this report. The study team suggests this may point to an unmet need overall, and possibly to a poorly-recognized "facility effect" on the part of the institutions and PLs – the applicants may be underestimating the user demand created by large-scale integrated facilities, and the amount of management and user support required to serve it (not all support services will be of high scientific interest).

4.3 CANADIAN RESEARCH PRODUCTIVITY

4.3.1 Data from the Project Progress Reports

There is only a small amount of data on this point from PPRs, but the PLs report that the CFI infrastructure has had a significant effect in their ability to obtain research grants from many sources.

4.3.2 Data from the OMS

The infrastructure provided by the CFI and its partners has had strong – and sometimes remarkable – impacts across all 16 theme areas investigated through the OMS. There are transformative step function impacts[14] in the research capacity at half of the 16 institutions studied to date compared to pre-CFI. Prior to the first major CFI investment at each institution, there were serious limiting factors, including one or more of: little or no research strength in these themes, a lack of integration, inadequate and outdated infrastructure, a lack of critical mass, the lack of ability to serve external users – or sometimes all of these. At the other institutions, there were strong, but more incremental, impacts – in some cases probably limited by lack of formal cohesion within the research theme or lack of clear focus in the institution's strategic research plan. For at least one institution, the CFI-funded projects dramatically expanded an existing strength.

Overall, there is a clear convergence of the research capacity, the funding streams that support them, and the research productivity that results. Many of the themes have been transformed in terms of the nature of research topics that can be investigated and the methodologies used to investigate them. The OMS Expert Panels rated several research lines as world-class, and at least one at Nobel level.

Other impacts related to research capacity and productivity include[15]:

- Total publications per PU have increased about 50% per year, and at least 3,000 articles from the first nine OMS themes studied have used the CFI-funded infrastructure as a key resource.
- Total funding for the CFI-funded facilities and related initiatives (i.e., not necessarily directly related to the CFI projects, but in related research themes) is four to five times the CFI investment alone.
- The themes attracted nearly seven times as much total sponsored research funding per annum vs. pre-CFI. The annual research funding per Principal User (PU) has, on average, tripled.
  - For context, the study team notes that total federal S&T university funding has increased about 2.3 times from 1999/2000 – 2006/2007 (i.e., including the CFI, the granting councils, Canada Research Chairs program, etc.)[16]
- The themes have in total about 80% more faculty compared to pre-CFI.

[14] If displayed as a graph, step functions look like steps on a stairway – an abrupt change from one level to another, rather than gradual ramps. They imply quick and dramatic changes.

[15] These statistics are from the first nine OMS studies only.

[16] Source: Statistics Canada CANSIM, table 384-0036 (HERD expenditures by the federal government).

4.3.3 Data from OPEA

Quality and Quantity of Canadian Research: The quality and quantity of Canadian research are both up substantially in 2009 as compared to 1990 (as investigated in the 1990 NSERC study[17]), as shown in exhibit 4.6.[18] This is, of course, exactly what is hoped for as a result of CFI and other federal S&T investments. Not shown is that both quality and quantity are, unsurprisingly, higher at larger institutions.

Exhibit 4.6 – Average ratings of research quality and quantity in PL/PUs' area and institution*

Ratings by PLs/PUs:	*1990 NSERC study*	*2009 OPEA study*
Quality of research	3.0 (good)	3.8 (excellent)
Quantity of research	2.9 (good)	3.5 (good to excellent)

** Rating scale: 1 = Poor, 5 = World-class*

Further, although the research productivity of the international BELs has also increased since 1990, the gap between Canadian research productivity and the international BEL research productivity has narrowed significantly, as seen in exhibit 4.7

Exhibit 4.7 – Difference between Canadian labs and BELs average ratings*

Ratings by PLs/PUs:	*1990 NSERC study*	*2009 OPEA study*
Research quality	1.5	0.9
Research quantity	1.5	1.1

** Differences where the rating scale was: 1 = Poor, 5 = World-class*

Impact of Infrastructure on Productivity: Of interest is how much impact research infrastructure alone has on the quality and quantity of research done. Exhibit 4.8 shows that PLs, PUs, and Department Heads believe there is a substantial pre/post-CFI difference in Canadian research productivity, from good pre-CFI to excellent now, on average. The study team suggests that the slightly lower ratings for research quantity may be linked to the slightly lower infrastructure operational capability at Canadian facilities discussed in section 4.2.

[17] *Op Cit*, DPA, 1990.

[18] In 1990 we unfortunately did not ask about technical vs. operational capabilities of the infrastructure.

Exhibit 4.8 – Research productivity pre- and post-CFI *

Ratings by:	*Pre-CFI*	*Now*
PLs/PUs (personal productivity)		
Quality of research	Overall = 3.3 (good) 38% excellent or world-class 18% fair or poor	Overall = 4.2 (excellent) 83% excellent or world-class 2% fair or poor
Quantity of research	Overall = 3.1 (good) 30% excellent or world-class 22% fair or poor	Overall = 3.9 (excellent) 72% excellent or world-class 3% fair or poor
Department Heads (their departments)		
Quality of research	Overall = 3.2 (good) 27% excellent or world-class 20% fair or poor	Overall = 4.1 (excellent) 82% excellent or world-class 2% fair or poor
Quantity of research	Overall = 2.9 (good) 18% excellent or world-class 20% fair or poor	Overall = 3.8 (excellent) 64% excellent or world-class 2% fair or poor

** Rating scale: 1 = Poor, 5 = World-class*

Not shown is that there is an inverse relationship of the CFI impact to the size of institution – i.e., the smaller the institution, the more marked the pre/post-CFI change in research productivity (which also seems reasonable).

Impact of BEL-level Infrastructure on Productivity: Exhibit 4.9 shows the comparison to international Best Equipped Laboratories (BELs), in which Canadian respondents were asked to identify a BEL in the same or very similar research area to their own, and then rate:

- Their own research productivity now (i.e., with CFI equipment);
- The research productivity of the international BEL; and
- Their opinion of what their own research productivity would be if they had the research infrastructure at the international BELs; and

The Canadian researchers believe that roughly three-quarters of the quality difference (78%, as measured by the difference in average ratings) and the quantity difference (76%) between their Canadian labs and the BELs would disappear if the Canadian labs were equipped like the BELs. Of considerable interest is that these figures are virtually identical to the figures obtained in the 1990 NSERC study[19] – these consistent findings almost two decades apart give great confidence in concluding that the impacts of research infrastructure on research productivity are tremendous. In addition, exhibit 4.9 shows that there is still room for improvements in Canadian research quality and quantity based on having better research infrastructure. This finding was also confirmed in the OMS.

[19] In the 1990 NSERC study, researchers rated the impact of equipment at about 73% for overall research quality and 74% for research quantity. In the 1990 study, BEL respondents were also asked to make similar ratings – how much their research productivity would suffer if they had the Canadian research infrastructure. Their opinions were almost identical: BEL respondents believed their productivity would drop by about three-quarters of the difference.

Exhibit 4.9 – Research productivity with/without BEL infrastructure*

Ratings by:	*Respondent's' area & institution*	*International Best Equipped Lab (BEL)*	*Respondent, if had Int'l BEL equipment*
PLs/PUs			
Quality of research	3.8 (excellent)	4.7 (excellent to world-class)	4.5 (excellent to world-class)
Quantity of research	3.5 (good to excellent)	4.6 (excellent to world-class)	4.4 (excellent to world-class)
Department Heads			
Quality of research	3.7 (good to excellent)	4.8 (world-class)	4.4 (excellent. to world-class)
Quantity of research	3.7 (good to excellent)	4.8 (world-class)	4.4 (exc. to world-class)

* *Rating scale: 1 = Poor, 5 = World-class*

Other Factors Influencing Productivity: Of course, research productivity in general (and the differences in research productivity between Canadian labs and the BELs) is influenced by factors other than research infrastructure. Exhibit 4.10 shows that there is a cluster of four key factors (highlighted) that most affect the ability to foster outstanding research productivity. ,, There is little difference among the four, and state-of-the-art infrastructure is included in them – and one could reasonably argue that SOA equipment, instruments, and facilities attract and support the other three factors (this was certainly argued by OMS respondents).

Exhibit 4.10 – Factors fostering outstanding research productivity (Percent of respondents rating the factor as high or very high in importance)

	V-Ps Research	*International Experts*
Factor		
CFI-funded infrastructure (State-of-the-art infrastructure, for Experts)	100	92
Critical mass of top researchers	100	96
Availability of research funding	95	100
Research environment in department	90	100
Research environment in institution	90	84
Remuneration level	35	84

Of interest is that the research environment within individual departments is perhaps somewhat more important in fostering excellence than that in the institution generally. This is indirectly supported by the OMS findings – even small and less well-known institutions were able to develop research strengths in highly focused areas through their SRPs and their CFI and partner investments.

4.4 ATTRACTION AND RETENTION

4.4.1 Data from the Project Progress Reports

The infrastructure was an important factor in retention for 47% of projects, and on average these projects attracted about three researchers each year. Of researchers that were attracted because of CFI-funded projects, from 16% to 23% were recruited from the US, and another 17% to 27% were recruited from other countries. About 74% of projects indicated the infrastructure played an important role in retention; these institutions retained an average of 4.2 researchers.

The study team notes that it is difficult to estimate true attraction or retention figures from progress reports, as it is possible to have overestimation because of double-counting by different PLs, or underestimation of the facility and organization effects, or both.

4.4.2 Data from the OMS

There were numerous examples of key scientists and research program managers who would clearly not be at the institution under study if the CFI infrastructure were not in place. These individuals are constantly recruited and have many excellent options for moving should they choose. Some thematic studies also pointed out vulnerabilities should the institutions choose not to continue to build upon and support their research strengths – key PLs or PUs may leave.

4.4.3 Data from OPEA

Attraction: Regarding attraction, about 28% of PL/PU respondents overall had changed job positions (other than through promotion) within the past five years. This represented about 30% of PLs *vs*.16% of PUs, which probably reflects their relative seniority and reputation. The overall percentage is very similar to the 25% of Genome Canada PLs who reported they had changed jobs within the past five years, so this is likely a typical figure for senior Canadian scientists. Exhibit 4.11 shows that there has been significant attraction from abroad – at least 56% of PLs and PUs (there was little difference between them) have come from international positions.

Exhibit 4.11 – Where PLs and PUs were attracted from – Percentage of PLs/Pus*

A training position (e.g., PhD, PDF) in the same institution	4%
A training position (e.g., PhD, PDF) in a different Canadian institution	12%
A Canadian academic position	20%
A Canadian industry or government position	4%
A Canadian not for profit position	1%
- Sub-total all Canadian	***40%***
A training position in a US academic institution or research hospital	24%
An academic position in a US institution	11%
An industry or government position in the US	3%
- Sub-total all US	***37%***
A training position in another country	9%
An academic position in another country	8%
An industry or government research position in another country	3%
- Sub-total all international	***19%***
- Sub-total 'other'	***4%***

*NOTE: Exhibit totals do not equal 100% due to rounding errors

Retention: About 44% of PLs/PUs had considered taking another job within the past five years – 44% of PLs and 47% of PUs. (Again, the 2009 Genome Canada study had a very similar figure for PLs, so again this is probably a typical figure.) Of these, 24% had received a firm offer – 24% of PLs and 25% of PUs. There was little difference by size of institution.

Impact of the CFI on Mobility: The CFI projects were rated as being of high or very high importance by 77% of PLs/PUs for staying in their present job position, or for moving (if they did):

- 82% of PLs and 62% of PUs;
- 78% at large institutions, 72% at small institutions, and 60% at colleges

For comparison, the 2009 Genome Canada study found that Genome Canada support was important or very important for 45% of PIs for moving, and 55% of PIs for staying where they were. So CFI (at 77%) appears to be even more important than the Genome Canada support for attraction and retention.

Exhibit 4.12 shows that the PLs/PUs rated the CFI infrastructure as the highest of nine factors attracting or retaining them that were asked about. The top four factors (highlighted) for PLs/PUs are the CFI infrastructure, research funding, personal factors, and the research environment in their department. The Department Heads and V-Ps Research also rated CFI as very important for attraction and retention, and the top four factors were nearly identical to those for PLs/PUs, although there is an interesting difference regarding critical mass and level/prestige of position.

The CFI noted that context is important for discussing attraction and retention: mobility (even within Canada) is often the key to career advancement.

Exhibit 4.12 – Factors affecting attraction and retention (Percent of respondents saying the factor was "high" or "Very high" importance for attraction or retention)

		Ratings by			
	PLs/PUs overall	*Department Heads*		*V-Ps Research*	
		Attraction	*Retention*	*Attraction*	*Retention*
Factor					
CFI-funded infrastructure	77	90	86	80	90
Availability of research funding	71	86	85	70	90
Personal (e.g., location, lifestyle)	71	84	78	70	75
Research environment in the department	69	96	96	80	81
Critical mass of top researchers	66	80	80	75	85
Research environment in the institution	61	66	78	75	81
Level & prestige of position	52	78	85	65	62
Teaching load	46	52	63	35	38
Remuneration level	42	66	65	50	60

4.5 TRAINING OF HIGHLY QUALIFIED PERSONNEL (HQP)

4.5.1 Data from the Project Progress Reports

Each year, the institutions have attracted about 1.5 post doctoral fellows (PDFs) and 4.6 graduate students per project, in large part due to the availability of the infrastructure. More than 90% of the CFI projects have been used as a key resource in the research projects of HQP (including post-doctorate fellows and/or graduate students). On average, the infrastructure has been used by 16 HQP per project.

4.5.2 Data from the OMS

All 16 institutions studied in OMS have greatly expanded and improved their training programs in response to these strengths. There were many new graduate and undergraduate curricula, explicit multidisciplinary courses, training conducted collaboratively across faculties or with other institutions (including colleges) or countries, deliberate training of research project leaders and administrators (a kind of joint "organization effect" and "facility effect"), and collaboration with external users (including entrepreneurship training). The institutions also noted that the quality of students and postdoctoral fellows attracted to the themes had increased (e.g., more have won prestigious scholarships and fellowships).

Roughly two and a half times more HQP are being trained in the OMS themes per annum, and at least 2,200 HQP have been trained to date on the CFI-funded infrastructure in the first nine OMS themes studied. In the first nine OMS studies, about half of the graduates are currently in further training, 11% are in Canadian industry, 7% in Canadian government, and 6% in Canadian not-for-profits.

4.5.3 Data from OPEA

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, as seen in exhibit 4.13. Note that the change in training environment pre/post-CFI is even slightly stronger than the pre-post/CFI change for the quality of the PLs/PUs' personal research seen in exhibit 4.8.

Exhibit 4.13 – Quality of the training environment*

Ratings by:	*Pre-CFI*	*Now*
PLs/PUs	2.6 (fair to good) 15% world-class or excellent 42% fair or poor	3.9 (excellent) 72% world-class or excellent 6% fair or poor
Department Heads	2.9 (good) 20% world-class or excellent 27% fair or poor	3.9 (excellent) 74% world-class or excellent 2% fair or poor

** Rating scale: 1 = Poor, 5 = World-class*

4.6 COLLABORATION AND NETWORKING

4.6.1 Data from the Project Progress Reports

The average total number of researchers per project ranges from 10 to 17, and the PLs report that the availability of the infrastructure has enhanced opportunities for collaborative research, especially within the institution and with other research institutions. There have been nearly as many external users as internal users.

4.6.2 Data from the OMS

The OMS found numerous examples of major national and international collaborative initiatives in which the Canadian PLs were key investigators. These were facilitated by the facility and organization effects, which helped bring PLs and PUs together on common problems or using common tools (especially if tied to a strong SRP).

4.6.3 Data from OPEA

Academic Collaboration and Networking: The CFI projects are key resources in fostering academic collaboration and networking, as seen in exhibit 4.14. This effect is particularly strong for PLs/PUs, but also (to slightly lesser extent) at higher levels.

Exhibit 4.14 – Importance of CFI projects for fostering academic collaboration and networking*

Ratings by:	*Average rating*
PLs/PUs	4.2 (important) (79% important or very important) (3% not very important or not at all important)
Department Heads (Asked about MOUs or contracts dep't to dep't, institute to institute, etc.)	3.8 (important) (60% important or very important) (8% not very important or not at all important)
Vice-Presidents Research (Asked about MOUs or contracts dep't to dep't, institute to institute, institution to institution)	3.8 (important) (50% important or very important) (0% not very important or not at all important)

** Rating scale: 1 = Not at all important, 5 = Very important*

Collaboration with End-Users: Within the past year, exhibit 4.15 shows that there has been at least 6,800 collaborations by the PL and PU respondents to OPEA with end-users (i.e., potential users of the research results outside of the academic research community who intend to develop practical applications from the research findings). The PLs and PUs in the OPEA survey alone have undertaken about 6,800 collaborations with end-users over the past year. The exhibit also shows that the CFI projects have been important to foster these collaborations for PLs/PUs. This is also true (though to a lesser extent) for Department Heads and Vice-Presidents Research.

Exhibit 4.15 – Collaborations with end-users (Figures from OPEA survey respondents only)

Ratings by:	*No. of collaborations in the past year*	*No. (%) using CFI projects as key resources*	*% rating CFI as important or very important*
PLs/PUs	6,800 ~4.6 per PL/PU	5,200 (76%)	78%
Department Heads	218 ~4.0 per Head	155 (71%)	47%
Vice-Presidents Research	Not asked	Not asked	50%

Exhibit 4.16 shows that, on average, there have been about 6.4 collaborations with end-users per PL/PU in the past year, three-quarters of which used the CFI projects as key resources, and about 10.2 collaborations per Department Head, about 70% of which using CFI projects in a significant way. For PLs/PUs, there are only small differences in use of CFI projects as a key resource by type of end-user, but Department Heads show more variation in the use of CFI project by type of user; it is unknown if this is significant.

Note that 64% of PL/PUs' and 80% of Department Heads' end-user collaborations, respectively, are with Canadian organizations; there is a significant international component (with OMS data suggesting that the CFI projects are a significant attractor for international organizations to collaborate).

Exhibit 4.16 – Collaborations per respondent with end-users

	Avg. No. in the past year		**Percent of collaborations in which CFI projects were a key resource**	
	PLs/PUs	Department Heads	PLs/PUs	Department Heads
Canadian industry	2.0	5.6	76%	75%
Canadian government	1.0	1.6	76%	69%
Canadian not-for-profits	1.1	1.0	77%	72%
International not-for-profits	0.4	0.4	72%	80%
US industry	0.2	0.1	76%	100%
International industry	0.3	0.1	77%	50%
US not-for-profits	0.5	1.0	74%	90%
International government	0.3	0.2	70%	50%
US government	0.5	0.3	79%	50%
TOTAL	6.4	10.2	76%	71%

4.7 CREATION OF SOCIO-ECONOMIC IMPACTS

4.7.1 Data from the Project Progress Reports

About 30% of the projects have generated new or improved products, processes, services, or cost savings, while 25% of projects have generated new or improved public policies and programs, and 18% of projects have created private or public sector jobs.

4.7.2 Data from the OMS

End-user organizations in government, industry, and non-profit organizations contributed at least $47 million to date to the first nine OMS themes studied, or roughly 37% of the value of the CFI awards.

Many thematic activities were specifically directed towards innovation and practical socio-economic impacts. Though some were at a relatively early stage, it was clear that substantial thought is devoted to creating linkages to external user organizations, and to how these innovations would be used. It was common to find active investigation of practical applications, for many types of users, in all sectors. It was also clear that not all practical applications will arise through traditional technology transfer (i.e., patenting and licensing). Several OMS themes will also produce impacts in public good areas such as health care systems or natural resource policies and practices, and some important commercial impacts will happen through knowledge translation (i.e., development of proprietary knowledge by the industrial partners, without patenting being involved).

The OMS Expert Panels did, however, identify occasional weaknesses in the strategic planning for innovation, linkages to users, and exploitation activities in some themes.

4.7.3 Data from OPEA

Two-thirds of both PLs/PUs and Department Heads have actively explored practical applications of their research. Such exploration has been conducted through a very wide variety of mechanisms. This is consistent with best practices for technology transfer and knowledge translation of university research[20] – many useful mechanisms go far beyond traditional tech transfer (i.e., patenting and licensing) in order to fully maximize exploitation of research findings and academic expertise.

The types of mechanisms were quite similar to that in the 2009 Genome Canada study. However, the CFI PLs and PUs were often less active than the Genome Canada scientists, which is as expected given the more substantial (and short-term) Genome Canada focus on practical socio-economic outcomes.

Exhibit 4.17 shows that there are also many types of practical impacts being explored – not just industrial, and not just through traditional means. The 2009 Genome Canada study showed substantially higher figures for exploration of industrial and (especially) health care products and processes – again, this is not unexpected given Genome Canada's recent targeted emphasis. However, the figures are very similar between the CFI and Genome Canada for environmental benefits, general societal benefits, and best practices.

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[20] A summary report of practices used in 20 Canadian and international S&T organizations is found in *Analysis of Precarn's Commercialization Model.* KPMG, August 20, 2007.

Exhibit 4.17 – Applications already in place, or in active development (Percent of respondents)

Type of application	*PLs/PUs*	*Department Heads*
"Traditional" industrial tech transfer	25%	35%
Indirect industrial knowledge transfer	21%	23%
Best practices in health, manufacturing, organization etc.	21%	10%
Various societal benefits (teaching, planning, the economy, etc.)	19%	23%
Environmental benefits	15%	17%
Public policies & programs (including codes, standards, etc.)	13%	10%
Health care protocols, diagnostics, therapeutics, etc.	13%	19%

5 FINDINGS ON DESIGN AND DELIVERY

5.1 PROGRAM DESIGN

5.1.1 Overall Architecture of the CFI

A review of research infrastructure funding models used in the international community conducted during the 2003 CFI evaluation, plus comments made by the international reviewers in this OPEA study, showed that the overall architecture of CFI is complete and well-founded, with no significant "gaps".

The international experts pointed out many advantages (as well as some disadvantages) of the CFI model, but noted that *all* models have pros, as well as some cons. The 2003 CFI evaluation arrived at the same conclusions, and together with OPEA many strengths of the CFI model were noted, including:

- The CFI supports all disciplines, all kinds of infrastructure (including buildings, construction, software, databases, etc.) in a "one-stop" model;
- The Strategic Research Plan process has proven to be important, and had led to increased institutional buy-in;
- The CFI has sufficiently large budgets to have allowed state-of-the-art infrastructure to be obtained and upgraded over time, including infrastructure for some "Big Science" projects; and
- There is a great deal of due diligence – perhaps too much, in the opinion of many in the academic community – but in the view of the study team, not undue given the large amount of funding that is often involved.

Further, the March 2007 KPMG *Evaluation of Foundations*[21] found that CFI had the lowest operating and administration costs per dollar disbursed of all the foundations reviewed.

Thus there are good reasons to think the CFI model is very sound. There are two possible minor exceptions on the design and delivery side:

[21] *Op Cit.* KPMG, 2007

- The question of who should support long-term infrastructure operations and maintenance; see section 5.3; and
- The question of additional coordination with other funding agencies at both national and provincial levels.

5.1.2 Design and Delivery of Individual CFI Funds

Exhibit 5.1 shows that the individual Funds are rated as well-designed and well-delivered. The Department Heads tend to be least satisfied, while V-Ps Research most satisfied, and the PLs/PUs are in between. There is not much variation by size of institution.

Exhibit 5.1 – Design and delivery*

	Ratings by:					
	PLs/PUs		*Department Heads*		*V-Ps Research*	
Fund	*Design*	*Delivery*	*Design*	*Delivery*	*Design*	*Delivery*
New Initiatives	4.1	4.0	3.9	3.8	4.3	4.2
Leading Edge	4.0	3.9	3.7	3.7	4.2	4.3
Leaders Opportunity	4.1	4.0	3.9	3.6	4.5	4.3
Research Hospital Fund	3.5	3.4	3.2	3.4	3.6	3.5
National Platforms	3.4	3.4	3.5	3.7	3.4	3.4
Exceptional Opportunities	3.6	3.6	3.5	3.8	3.8	4.0

** Rating scale: 1 = Poor, 5 = Excellent*

5.2 PROGRAM DELIVERY

The CFI guidelines for preparing and rating proposals are very clear, as seen in exhibit 5.2. There is little variation by size of institution.

Exhibit 5.2 – Clarity of CFI guidelines for preparing and rating proposals (Percent of respondents)

	Clear or very clear	Not very clear or not at all clear
Clarity of CFI guidelines for preparing proposals & understanding how they are rated		
PLs/PUs	62%	10%
Department Heads	64%	0%
Vice-Presidents Research	95%	0%
Clarity of CFI guidelines for rating proposals		
Experts	88%	0%

Exhibit 5.3 shows that the majority of respondents see the funding approval process as transparent and equitable. The opinions of the international experts and V-Ps Research are probably especially notable here.

Exhibit 5.3 – Funding approval process: transparency and equity (Percent of respondents)

	Good or very good	Moderate	Poor or very poor	Don't know
Transparent				
PLs/PUs	62%	17%	9%	13%
Department Heads	54%	24%	4%	17%
V-Ps Research	85%	10%	0%	5%
International Experts	80%	8%	0%	12%
Equitable				
PLs/PUs	59%	12%	8%	21%
Department Heads	59%	13%	2%	26%
V-Ps Research	75%	15%	0%	10%
International Experts	72%	12%	0%	16%

The majority of respondents also sees the funding approval as free from bias and conflict of interest; see exhibit 5.4. The opinion of international experts is notable here also because they are intimately involved in the review process for the CFI, and most have extensive application review experience in their own countries as well.

Exhibit 5.4 – Funding approval process: bias and conflict of interest (Percent of respondents)

	Good or very good	Moderate	Poor or very poor	Don't know
Free from bias				
PLs/PUs	54%	12%	7%	27%
Department Heads	51%	16%	2%	31%
V-Ps Research	60%	15%	5%	20%
International Experts	80%	8%	0%	12%
Free from conflict of interest				
PLs/PUs	57%	8%	5%	31%
Department Heads	58%	11%	0%	31%
V-Ps Research	85%	5%	5%	5%
International Experts	75%	8%	0%	17%

5.3 SUPPORT FOR OPERATIONS AND MAINTENANCE

5.3.1 Data from the Project Progress Reports

Of operational projects, between 77% and 82% have indicated it was “easy” or “reasonable” to obtain sufficient funds for operations and maintenance (O&M).

5.3.2 Data from OPEA

A significant proportion of academic respondents (especially Department Heads) indicate a lack of sufficient resources for O&M. Provincial representatives also worried about O&M long-term, especially in the face of declining provincial budgets. See exhibit 5.5. This topic was also frequently raised during the OMS site visits.

The perceived adequacy of financial resources data show an inverse relation to the size of institution, likely explained by the inverse relation of institution size to the cost of infrastructure and related O&M costs.

Exhibit 5.5 – Operations and maintenance resources (Percent of respondents)

	Good or very good	Moderate	Poor or very poor	Don’t know
Financial resources				
PLs/PUs	31%	33%	32%	4%
Department Heads	17%	40%	36%	6%
Human resources				
PLs/PUs	32%	29%	34%	5%
Department Heads	15%	40%	36%	9%

The study team notes that the CFI’s Infrastructure Operating Fund allocates an additional 30% of the CFI’s portion of each project’s budget for O&M, which the institution may use according to the CFI’s Policy and Program Guide when it sees fit so long as the project is still being used for research[22]. (Until 2005, the IOF could only be drawn upon by the institution for the project’s first five years, and there appears to be some belief within the community that this still applies.) While there is clearly a problem around long-term O&M, consultations undertaken independently by the CFI indicates that the community does not see this as mainly a CFI problem, as opposed to an issue for the institutions and provinces. The study team notes that there is good reason to have partners guarantee O&M as it helps ensure true long-term commitment to the SRP.

It is not entirely clear why the OPEA data conflict with CFI project progress report data, in which the majority of PLs say it’s “easy” or “reasonable” to obtain sufficient O&M. The study team suggests this is likely the difference between near-term vs. long-term resources.

[22] See section 4.6 of the CFI Policy and Program Guide:

http://www.innovation.ca/en/programs/cfi-policy-and-program-guide

6 FINDINGS ON RELEVANCE

6.1 OVERVIEW

There are several findings discussed earlier which point to the strong need for, and continued relevance of, the CFI:

- The dramatic improvement in – and sometimes the sheer existence of – institutional strategic thinking that would not exist without the CFI (discussed in section 4.1);
- The strong "facility effects" and "organizational effects", which would be nearly impossible to generate with smaller, discrete programs. This in turn has led to a convergence of resources being put into strategic research, training, and innovation efforts.
- The very strong impact that state-of-the-art research infrastructure has on research capacity, including the nature and quality of training of HQP (discussed in section 4.3);
- The unique features of the CFI model overall, and the strong design and delivery of individual Funds (discussed in section 5.1).

To this are added additional findings discussed below:

- This research capacity is relevant to federal priorities, but also addresses many individual provincial priorities (discussed below in sections 6.2 and 6.3)
- The strong need for new and/or upgraded projects and facilities (with both high technical and operational capabilities) in order for Canadian research to stay competitive – the total "ask" from the CFI alone is estimated at roughly $5 billion over the next five years (discussed below in sections 6.4 and 6.5).

6.2 DATA FROM KEY INFORMANTS

All key informants interviewed agree on the continued strong need for the CFI, and agreed with the points raised in section 6.1. A number of other important points were raised with respect to the CFI's relevance, including:

- CFI is seen as consistent with federal S&T priorities, and much spending is directed towards the federal priority areas.
  - If further federal targeting were mandatory, a separate targeted fund was worthy of investigation, since respondents pointed out that focusing overly much on federal priorities could easily put the CFI at odds with provincial and/or institutional priorities, and was to be avoided.
  - Losing focus on provincial priorities would likely put co-funding and O&M support at risk. These resources are already difficult for provinces to find, since provinces are suffering a loss of tax revenues due to the global financial crisis (and had considerable difficulty with co-funding even beforehand).
- The current "market driven" application process for new and renewal projects is sensible.
- All but one respondent said there is a continued need for CFI – i.e., for infrastructure funding to be delivered by a separate organization because:
  - As federal funding becomes limited, the granting councils would cut back on infrastructure funding (as they did in the 90s).
  - A foundation model works well to deal with funding across fiscal years. Funding delivered by fiscal year doesn't work with infrastructure (especially large infrastructure);
  - The CFI funds infrastructure across all disciplines, including infrastructure for multi-disciplinary research. This is more difficult to coordinate across separate granting councils.

  - The councils are not used to dealing with the institutions as players.
  - The Granting Councils are not used to dealing with large capital investments.
- The strategic impacts were noted to be large, and somewhat unexpected.
  - Related to this, the CFI brought in the institutions as players in their own right.
  - However, the management and accountability requirements for these projects (especially the large ones) may have been underestimated.
  - Both the CFI and the provinces may have underestimated the strategic importance and planning function of the provinces themselves.
- Strengthening collaborative planning across funding organizations, provinces, and institutions (possibly including colleges, although not all respondents would agree) would be welcomed.
  - Related to this topic, integrating and supporting the social sciences and humanities remains difficult. This was also a common complaint from OPEA survey respondents from SSH fields, who noted that finding co-funding for SSH projects is difficult or impossible, and the CFI application review criteria seem biased towards creation of industrial benefits.

6.3 FINDINGS FROM THE DOCUMENT REVIEW

The key documents reviewed indicate a high degree of consistency of CFI's activities and intended outcomes with federal government S&T policy goals and objectives. Numerous studies included in the document review concluded that the CFI's role is unique and important within Canada's innovation system. In particular, the Malatest/Circum[23] study for NSERC concluded that NSERC's equipment grants programs do not duplicate CFI.

6.4 NEED FOR NEW INFRASTRUCTURE

About 25% of PLs/PUs will lead an application for a new CFI infrastructure project within the next five years. (A "new" application was defined as infrastructure that is unrelated to previous CFI investments.) Roughly 80% of the lead applicants will be current PLs.

The total "new ask" from the CFI alone (i.e., without co-funding) over the next five years is:

- About $711 million from the PL/PU survey respondents to OPEA alone;
- Using a weighted average of the response rates from PL vs. PU leads, and assuming there is no response bias[24], the total "new ask" from the CFI alone for new infrastructure is extrapolated to be very roughly $2.6 billion over the next five years;
- About 66% of this ask will be in 2009 and 2010.

[23] *Joint Evaluation of Research Tools and Instruments Grants (RTI) and Major Facilities Access Grants (MFA) Final evaluation report,* Circum Network Inc. and R.A. MALATEST & ASSOCIATES LTD. August 7, 2007

[24] The 2006 "renewal study" specifically investigated possible response bias for renewal requests, and found none.

6.5 NEED FOR RENEWAL OF EXISTING INFRASTRUCTURE

6.5.1 Size of "Renewal Ask"

About 23% of PLs/PUs will lead a renewal application in next 5 years. (A "renewal" application was defined as being for infrastructure related to previous CFI investments.) Roughly 83% of the lead applicants will be current PLs.

The total "renewal ask" from the CFI alone (i.e., without co-funding) over the next five years will be large fraction of original infrastructure cost. The OPEA data show the renewal ask will be:

- About $764 million from the PL/PU survey respondents alone;
- Using a weighted average of the response rates from PL vs. PU leads, and assuming there is no response bias, the total "renewal ask" from the CFI alone is extrapolated to be approximately $2.8 billion over the next five years;
- About 51% of the renewal ask will be in 2009 and 2010

This figure of $2.8 billion is about equal to the total CFI funds of $2.7 billion disbursed to date. However, the 2006 CFI "renewal" study estimated that renewal requests would be about 53% of original project costs. The reason for the difference is uncertain (although the "renewal needs study[25]" was for the New Opportunities Fund and the Innovation Fund, and had a small sample).
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6.5.2 Type of Renewal Request

There is a general disinterest in simply updating existing infrastructure to keep it operating properly:

- Only 17% of the renewal ask will be for maintenance of the infrastructure's existing capabilities;
- 39% of the ask will be to upgrade technical and scientific capabilities to state-of-the-art; and
- 43% will be for state-of-the-art upgrading, plus upgrade of operational capabilities (facilities, IT, technical support, etc.)

The study team believes this is related to the "facility effect" seen in OMS, with increasing interest in more "full-service" and sophisticated facilities, not simple requests for instrumentation and equipment. A possible policy implication for the CFI is that the application review may require more emphasis on operational and management effectiveness (i.e., not just technical and scientific capabilities).

7 CONCLUSIONS

The OPEA evaluation concluded that the CFI has had a tremendous impact on Canadian research infrastructure, which in turn has had strong impacts on research capability and productivity, training, attraction and retention, and collaboration. Although many impacts on innovation will only be fully realized in the future, there is good reason to believe that the institutions and researchers are having significant impacts in this area. For example, many different avenues for achieving practical impacts are being pursued across many sectors and for many types of application, by about two-thirds of CFI Project Leaders and Principal Users.

The impacts are intimately tied to a large "facility effect" – the collective power of integrated suites of state-of-the-art equipment, often in purpose-built facilities, and deliberately sited to maximize accessibility, multidisciplinarity, and multi-sectoral effects, often across multiple departments.

[25] *Op Cit.* KPMG, September 26, 2006.

This collective power is greatly strengthened by an "organization effect" – in which institutions deliberately and explicitly address this strength in their Strategic Research Plans (SRPs), their facility designs, and the organization of their research, training, and innovation programs. The CFI has fostered considerably stronger strategic research planning at the institutional level, as well as moderately more at departmental and provincial levels, and this planning has been unexpectedly successful at leveraging research strengths. These effects together have led to a clear convergence of research capacity, the funding streams that support them, and the research productivity that results.

The CFI continues to be highly relevant, both because the research community requires new and upgraded infrastructure in order to remain internationally competitive, and because its goals remain consistent with federal and provincial priorities.

The overall architecture of the CFI is sound, contains no major gaps, and has a number of advantages compared to many other research infrastructure support programs world-wide. The individual Funds are well-designed and well-delivered.

No significant problems with the CFI or its impacts were identified. However, there are three areas worthy of further consideration:

(1) The data suggest that the importance of the "facility effect" and the "organization effect" have not been fully recognized by the institutions (and until recently by the CFI itself).

- The facility effect leads to increased user demand for the services of large-scale integrated facilities, but the data suggest this demand has not yet been fully met. This is evident in Canadian infrastructure's operational capability being somewhat lower than its technical capability (an effect not seen in the best-equipped international facilities). The study team notes that high usage facilities require a substantial amount of management and user support, which should ideally be tied to strategic planning. This may imply some refinement to the CFI's application review process, perhaps putting more emphasis on a proposed facility's operational and management effectiveness (i.e., in addition to its technical and scientific capabilities).
- Both the facility effect and organizational effect may have implications for the CFI's outreach and communication to institutions (e.g., by encouraging institutions to link these effects to their Strategic Research Plans, and by providing examples of the successful use of, and best practices for, SRPs).

(2) There appears to be some room for improvement in strategic research planning done collaboratively with other research institutions and other funding organizations. The study team notes that such external planning would require specific resources devoted to it.

(3) The evidence suggests that long-term support for operations and maintenance is inadequate, and this remains worrisome for institutions and provinces. However, it is unclear that the CFI (as opposed to its partners) should increase its support here.