Canada Foundation for Innovation
Fondation canadienne pour l'innovation

Outcome Measurement Study:

Expert Panel Report

University of Regina
April 28-29, 2009

Updated – July 24, 2009

Table of Contents

Tables and Figures

Tables

Figures

Funding Synopsis

Project Leader	Number	Project Title	Program	CFI Amount
Asghari, Koorosh [initially Amit Chakma]	1685	Sustainable Heavy Oil Research Facility	RDF	$1,008,931
Idem, Raphael	2509	Scanning Electron Microscope for Materials Characterization in Energy and Environmental Research	NOF	$50,449
Tontowachwuthikul, Paitoon	5609	International Test Centre for Carbon Dioxide Capture (ITC)	IF	$1,800,000
Yang, Tony [initially,Mingzhe Dong]	6927	Enhanced Oil Recovery Research Infrastructure	NOF	$77,609
Raina, Renata	6676	Inductively Coupled Plasma Spectrometer (ICP-MA) for Analysis in Energy and Environment Research	NOF	$58,931
Coulson, Ian	7009	Establishment of a new high-resolution cathodoluminescence imaging and spectroscopy research facility	NOF	$82,061
East, Allan	7118	Simulation of Complex Chemical Reactions	NOF	$57,200
Chi, Guoxiang	9198	Geofluids characterization and modeling facilities	NOF	$44,803
Aroonwilas, Adisom	9389	High-pressure/High-temperature Continuous Flow Stirred and Tubular Reactor System for Green house Gas Mitigation Research	NOF	$58,487
Huang, Guo	201740	Energy and Environmental Research Laboratory	CRC	$150,402
Chan, Christine	202942	Visualization Infrastructure for Energy Informatics Laboratory	CRC	$104,314
Aroonwilas, Adisom	14074	Integrated Energy-Flux Monitoring System	LOF	$52,327
Chi, Guoxiang	16619	Cryo-SEM-EDS system for compositional analysis of geologic fluids	LOF	$96,501
Henni, Amr	18311	Measurements of the Heat of Reactions of CO2 in New Promising Chemical Solvents	LOF	$83,792
14 projects			**Total**	**$3,725,807**

Lexicon

Legend of CFI funds:

LOF	Leaders Opportunity Fund
NOF	New Opportunities Fund
IF	Innovation Fund
RDF	Research Development Fund
CRC	Canada Research Chair

Other Acronyms:

CASC	International CO_2 Storage Assessment Centre
CCS	Carbon Capture and Storage
CFI	Canada Foundation for Innovation
CO2	Carbon dioxide
CRC	Canada Research Chair
EOR	Enhanced Oil Recovery
GGTC	Greenhouse Gas Technology Centre
IOF	Infrastructure Operating Fund
IPAC – CO2	International Performance Assessment Centre for Geological Sequestration of Carbon Dioxide
ITC	International Test Centre for CO2 Capture
NAISE	North American Institute of Sustainable Energy
O&M	Operations and maintenance
OMS	Outcome Measurement Study
PL	Project Leader
PTRC	Petroleum Technology Research Centre
PU	Principal User
SRP	Strategic Research Plan
UofR	University of Regina

Summary of Theme Area

An independent Expert Panel visited the University of Regina (UofR) on April 28-29, 2009, to assess the outcome of CFI's investment in infrastructure enabling research related to ENERGY. To date, CFI has invested in 14 projects with 12 Project Leaders (PLs) and 6 Principal Users (Pus) for a total CFI investment of $3,725,807 which represents 43% of the total CFI investment at this institution. The total infrastructure investment in this Theme comes to $9.3 million when the institutional and partner funding are included. The scope of this review included 11 projects implemented between 1999 and 2006. Three recently awarded projects (#14074, #18311 and #16619) are not included because the infrastructure has only recently been implemented or is still being acquired. The Energy theme at the University of Regina includes research related to Enhanced Oil Recovery (EOR), Carbon Capture and Storage (CCS), and the production of energy from sources that have a limited impact on the environment such as hydrogen and biofuels. In this study the principal emphasis was on CCS and, indirectly, its application to EOR. Furthermore, in this report we often refer to carbon dioxide capture and its use in enhanced oil recovery or for other purposes as CO2 technology. Energy research at UofR has evolved around unique opportunities related to petroleum production in Saskatchewan.

Much of Saskatchewan's conventional petroleum resource is in the form of heavy oil, the production of which has been a significant focus of research activity at UofR. Early identification of the potential opportunities -- in this area such as CO2 recovery from provincial coal-fired power plants and the use of CO2 in enhanced oil recovery in the Weyburn oil field south of Regina -- helped position UofR at the forefront of research internationally, particularly in the area of carbon capture and sequestration.

The Energy theme has been identified as an important focus for the University of Regina since the 1980's when the first capacity in research in Energy and petroleum production were developed. This emphasis was a main part of its first strategic research statement in 1999. The most recent version of the Institutional Strategic Research Plan from 2006 continues to identify Energy and Environment as one of five major research thrusts for the University. Strong partnerships with industry and all levels of government have enabled the university to position itself as a world leader in research on CCS, and clean energy production and use.

There have been mutually beneficial influences on the University and CFI investment for key external bodies. Of particular importance were the initiations in the late 1990's of the Petroleum Technology Research Centre, the International Test Centre for Carbon Dioxide Capture, and the large-scale commercial CO_2-driven enhanced oil recovery operation of EnCana Corporation at Weyburn which, in turn, led to the IEA GHG Weyburn-Midale CO_2 Monitoring and Storage Project. In addition there has been major investment by governments in the Greenhouse Gas Technology Centre.

CFI's OMS Process

The Outcome Measurement Study (OMS) is a new tool in the CFI's suite of evaluation activities designed to assess the degree to which the CFI's investment in research infrastructure is a critical contributing factor in the realisation of five outcomes: strategic research planning, research capacity, highly-qualified personnel, research productivity, and innovation (including benefits and partnerships). The OMS helps demonstrate how the CFI is achieving its mandate and it provides a valuable resource for planning purposes. The OMS is a learning exercise done in partnership with the participating institutions. It is different in objective and approach to typical merit-review processes. Funding is not compromised by the findings of these visits, nor are they used to rank disciplines and/or institutions.

The OMS methodology involves a two-step process. Institutions first prepare a detailed Institutional Data Document using an in-depth questionnaire that sets a standard framework to report accomplishments and outcomes. This is followed by an on-site validation visit by a panel of international experts whose findings on the impacts of the CFI investment are complied in a report that is the key output of the OMS exercise. The OMS scope is unique, looking at a specific research theme area across an institution rather than examining an individual project, program or department. The theme is normally selected in discussion with institutions based on several factors including the degree of synergy between the institution's Strategic Research Plan and areas of major CFI investment. This approach lends itself to characterizing the synergies and interactions among different organizations and labs, research platforms, diverse disciplines and various types of research investments. It intends to capture with numbers and narrative the outcomes of CFI and partner investment across the spectrum from basic research discovery through to societal benefits.

The OMS explicitly recognizes the CFI as one player in a large and complex system of research support. Careful discussion of the relative contributions of funding programs, organizations, and other factors exogenous to the CFI is coupled with longitudinal analysis in order to document attribution realistically and in context. Other stakeholder funding agencies (e.g. provincial, federal) not only contributed to the design of the OMS tool, but regularly send representatives to the visits as observers, maximizing the value of the extended effort required of institutions and the CFI on data collection.

OMS Expert Panel

The members of the Expert Panel responsible for the OMS visit at the University of Regina on April 28-29th 2009 are identified below. The CFI worked with the institution to identify potential expert reviewers who were independent from the institution and have recognized expertise in this theme. The panel members volunteered a considerable amount of their time to participate in the OMS process. The CFI is grateful for their support and assistance.

Chair

Dr. Kevin Keough FCAHS
Principal, Kevin Keough Consulting Incorporated
Interim Executive Director, Alberta Prion Research Institute

Members

Dr. Martin Feely
Senior Lecturer
Department of Earth and Ocean Sciences
National University of Ireland, Galway, IR

Prof. John Oakey
Head, Energy Technology Centre
Cranfield University, UK

Dr. Charles E. Taylor
Director, Chemistry and Surface Science Division
National Energy Technology Laboratory
U.S. Department of Energy, USA

Key Findings

- The thematic area of Energy reflects institutional response to priorities of all levels of government and national and international industry regarding recovery of petroleum and reduction of carbon footprint from coal-dependent energy production plants.
- The investments of the Canada Foundation for Innovation in infrastructure used for energy research have enabled the University of Regina to achieve a leading international position in research and development in carbon capture and storage.
- The Canada Foundation for Innovation and the Canada Research Chairs program had major positive influences on the strategic research planning at the University of Regina.
- CFI-funded infrastructure has had a dramatic effect on recruitment and retention of faculty members. It has enabled a remarkable increase in sponsored research funding, from a very little before 1999 to more than a million dollars per year since 2004.
- Enabled by CFI-funded infrastructure, the number of graduate students in the energy area has increased about 18-fold over the past decade. The quality of the students has increased enormously. Nearly 50% of graduates are employed in Canadian industry. The institution needs to recruit more post-doctoral fellows and highly-skilled technical assistants in the energy area.
- The availability of CFI infrastructure has contributed to a more than five-fold increase in the numbers of refereed papers published by researchers in the energy area. Shared use of the CFI equipment has led to internal and external collaborations and participation of faculty members in many external partnerships and networks, both academic and industrial.
- There are strong linkages to the private sector in Canada and abroad. CFI infrastructure has been prominent in furthering the University's involvement with the Petroleum Technology Research Centre, in the creation of the International Test Centre for CO_2 Capture and the Greenhouse Gas Technology Centre. Each of these entities involves both public and private partners. The infrastructure has helped to strengthen interactions with HTC Purenergy, a public company that holds licenses on carbon capture technologies from the University of Regina.
- The carbon capture technologies along with the development of the International Test Centre and the emerging North American Institute for Sustainable Energy are attracting the interest of major international companies such as Doosan Babcock and Mitsubishi Heavy Industries in Regina. SaskPower, the operator of the provincial coal-fired power generating plants, is intent on becoming a stronger partner. The Government of Saskatchewan continues to enlarge its support for energy research as an area of strategic importance to the province. As it develops the next update of its strategic research plan the Institution will need to account for these new opportunities. The University will face a challenge in balancing the traditional ethos of free inquiry with the opportunities presented to work with government and industry by its leading position in carbon capture research.

Overall, the CFI investment has produced a very substantial impact on research output and quality at the University of Regina. It has had a major influence on the ability of researchers at UofR to work with many international industrial partners for application of research in industry.

Overview

"CFI has enabled a medium-sized Canadian University to become globally competitive in a key area of research – carbon capture & storage and climate change mitigation."

The University of Regina (UofR) became an independent degree-granting institution in 1974. It has nine faculties and offers 25 academic programs. Some 1,540 faculty and 750 staff work at UofR. The enrolment is of 11,500 students which include 1,400 graduate students (18% of whom are international). UofR offers since 1997 a leading Canadian undergraduate petroleum engineering program and a burgeoning graduate program in the energy field. Its operating budget in 2009-2010 is over $142 million and its total annual sponsored research funding is about $22 million. It is one of two universities in Saskatchewan, the older and larger University of Saskatchewan being in Saskatoon.

Saskatchewan has extensive energy reserves in the form of heavy oil, oil sands, natural gas and coal. It is the second largest provincial source of petroleum in Canada with production of oil accounting for 15% of the national total. Exploitation of its petroleum reserves is a high priority for the Province of Saskatchewan and the Government of Canada. In addition to petroleum, the Province is a major producer and user of coal for power generation. Its interests in reducing carbon dioxide (CO_2) emissions have fostered major investments in research at UofR on Carbon Capture and Storage (CCS) and the use of CO_2 to drive enhanced oil recovery (EOR).

The emergence of Energy as a major focus for research at the University of Regina began in the 1980's. Development of the theme was initiated with investment for petroleum research at the University under the Canada - Saskatchewan Heavy Oil – Fossil Fuels Agreement which was targeted to the development of capacity to exploit the province's fossil fuel resources.

The Energy research at UofR has both benefitted from and contributed to the involvement of a substantial number of national and international energy companies. The initial major University-Industry partnership in the energy field began in the late 1990's with EnCana Corporation and its partners in a project that uses CO_2 injection for Enhanced Oil Recovery from the Weyburn oilfield south of Regina. In 1998, a partnership among the provincial federal government agencies, the University of Regina and the Saskatchewan Research Council jointly created the Petroleum Technology Research Centre (PTRC). The PTRC is responsible for the management of an $80 million 8-year project in carbon capture and storage that is situated at the Weyburn oil field. This project is called the "International Energy Agency Greenhouse Gas R&D Project in CO_2 Monitoring and Storage at the Weyburn-Midale field" (IEA GHG Weyburn-Midale CO_2 Monitoring and Storage Project). The UofR was involved with the Weyburn project from 2000 to 2004, and through its ongoing work in the PTRC's EOR program, continues to contribute to CO2-EOR research applicable to the project. The participation of its researchers in PTRC-sponsored projects has been fundamental in UofR attaining a world-leading position in carbon capture and storage.

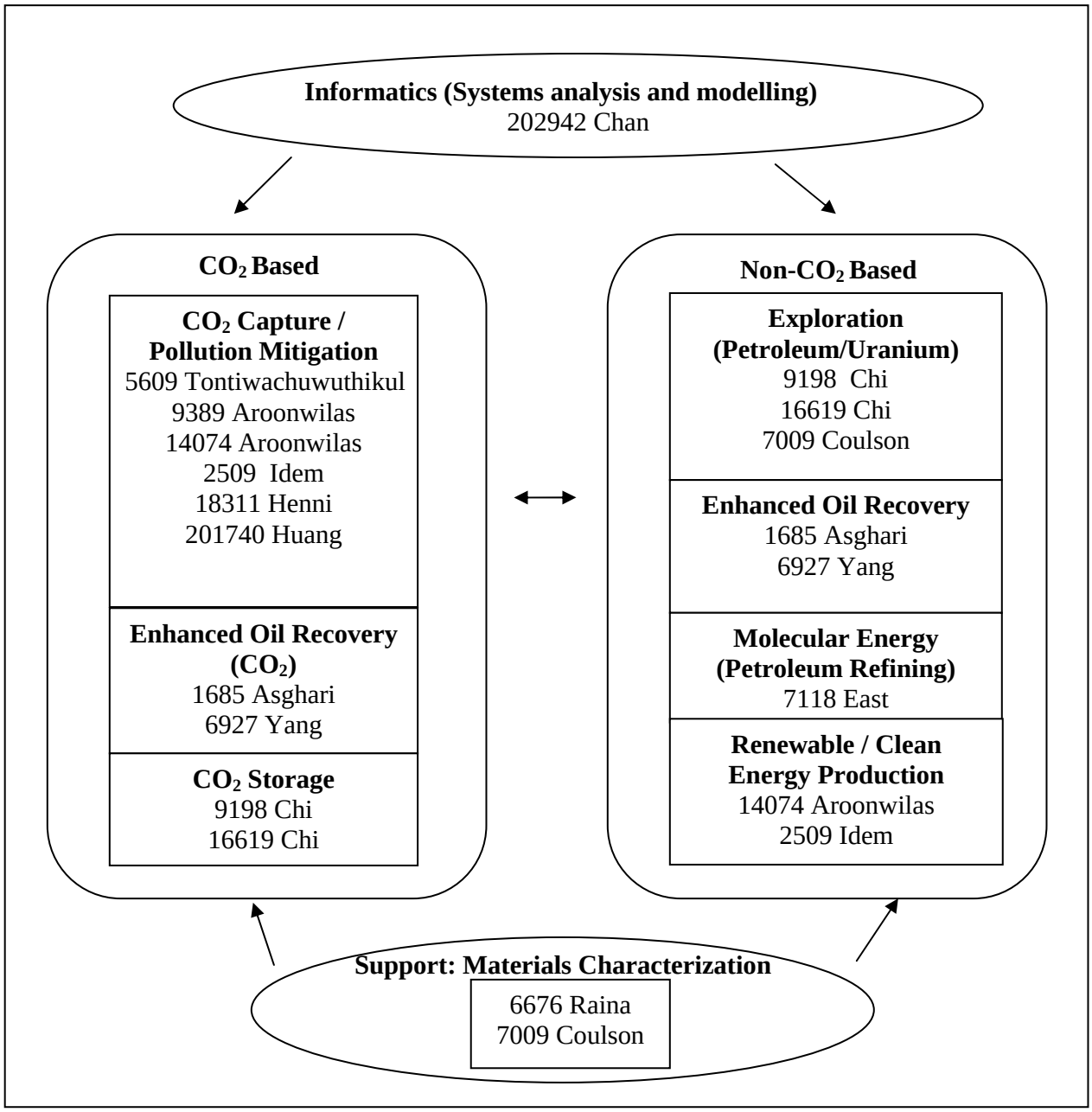
The PTRC has been a vital contributor to the development of energy research at the University and in Saskatchewan. It has fostered and enabled collaborations between university researchers and industrial partners in energy research including EOR and carbon capture and storage. The PTRC is located in Innovation Place – Regina, a research and innovation park operated by a crown corporation on land leased from the University. Innovation Place is located on land contiguous with the University campus, and this facilitates a great deal of university-industry interaction. The UofR leases space from the PTRC for its petroleum and CCS research programs. The strategic location of the university research space in Innovation Place has been a major motivator in establishing productive interaction with industrial partners.

Investments by the institution, industry and governments, in conjunction with CFI, for additional R&D infrastructure and space for energy research have enabled the University of Regina to become a major international research centre for carbon capture and storage and to be a substantial contributor to economic growth and government policy.

The timing of the CFI awards was critically important in the evolution of research at the University of Regina and in propelling the institution into being a leading international site for research in CO2 and climate change mitigation.

The linkages between the fourteen CFI-funded projects are illustrated thematically in Figure 1. In combination, these projects address a comprehensive array of energy related issues, spanning both CO2 based and non- CO2 based energy related problems. Among these are energy exploration, recovery and refining; CO2 storage, capture and greenhouse gas mitigation; and the development of alternative renewable forms of energy production. Addressing these research problems is facilitated through a systems analysis and modeling approach provided by Dr. Chan (project 202942) and through materials characterization support provided by Dr. Raina (project 6676) and Dr. Coulson (project 7009). The infrastructure of twelve of the fourteen projects is utilized by more than one research group.

Figure 1 – CFI Energy Projects at the University of Regina



1. Institutional Strategic Research Planning

"The past decade has seen unprecedented growth at UofR. The campus has doubled in size and 44% of the faculty have been hired since 2000. CFI has been critical in building research capacity in all areas."

1.1 Strategic Research Planning (SRP) Process

Strength of SRP process prior to the CFI	Low
Strength of SRP process now	High
CFI impact on any changes to SRP process	High
CFI impact on the realization of the objectives of SRP	High

Energy research at the University of Regina began in the 1980's with investment from the Canada-Saskatchewan Heavy Oil – Fossil Fuels Agreement, which fostered the early development of research capacity in enhanced oil recovery and CO_2 capture. In the mid-1990's, the institution began systematic academic planning and, in 1998, the President of the University had identified energy and environment as two of five important academic themes. In 1998, both the federal and provincial governments, the Saskatchewan Research Council and UofR committed to the construction of the first major centre for energy research and development, the Petroleum Technology Research Centre (PTRC), which subsequently became a catalyst and focal point for applied energy research in Saskatchewan. The first CFI-directed SRP in 1999 identified petroleum and environment as two of the three primary areas of research focus for UofR

In 2000, in response to the creation of the Canada Research Chairs (CRC) program and its linkage to CFI for infrastructure support, a new more detailed version of the SRP was developed which identified energy and environment as one of five major research themes for the University.

A renewed SRP, adopted in 2006, continued to identify the broad theme of energy and environment as one of five strategic research areas for the university. This plan showed the influence of the CFI and CRC programs in the allocation of CRCs to the various themes of the SRP. In the 2006 SRP, subthemes of the energy area were identified as 1) present and future global energy needs, 2) the cleaner production of oil/coal energy and CO2 capture & storage, 3) enhancing heavy oil recovery by injection of CO2 into reservoirs, 4) the manufacture of clean energy fuels (biodiesel) and 5) climate change, and global policies relating to energy and environment.

The strategic emphasis on Energy research has enabled UofR to have extensive interactions with a range of public and private sector partners in developing this field. The Institution, in turn, has influenced both government and industry in applying institutional technologies and knowledge and building the University

capacity into their strategic development planning. This has led to the development of shared facilities which are used to great effect.

The existing SRP is substantially influenced by opportunities that CFI and CRC programs present. The University is currently developing a new SRP. A continuation of the important role of CFI and the CRC program is anticipated in the planning process but, the timing and developments over the past decade provide the University with a special opportunity to more fully involve government and industry in future research planning.

1.2 External Influences on SRP

Impact of external factors and programs on SRP	Very High

The institutional SRP reflects a strong influence of the history, social structure, and economic opportunities of southern Saskatchewan. The energy theme of the SRP responds to major strategic foci of the provincial and federal governments. Both levels of government, and in particular, the provincial government have invested substantially in physical facilities and equipment for research in energy at UofR. In concert, CFI funding has equipped the Institution with state-of-the-art analytical equipment and pilot plant facilities.

The ability to interact with industry in the energy theme has had a strong influence on the directions of research planning at UofR. The industrial development of captured CO_2 for Enhanced Oil Recovery by EnCana Corporation in their Weyburn field and the opportunities arising from that development have been pivotal in the emergence of the institution as a major force in the areas of carbon capture & storage and enhanced oil recovery. Most of the electrical power in Saskatchewan is produced in coal-fired plants which have large CO2 emissions. The provincial government wants to find ways to reduce those emissions and this is driving the building of research capacity at UofR. SaskPower, which is the crown corporation responsible for power generation in Saskatchewan, is a key partner in this area. The Institution has been responding to government policies by adapting and targeting its research priorities to increase its research capabilities through (1) the allocation of two of its five Tier 1 CRC appointments in the Energy theme (40% of its senior CRC and 20% of its total CRC contingent), (2) the hiring of a substantial number of faculty in new positions in the energy area, and (3) investing in rental and construction of space for energy research.

1.3 External Effects of SRP

Impact of SRP on planning and action at other institutions	Don't know
Impact of SRP on planning and action at municipal, provincial or national levels	Don't know

Although information was provided to show the positive impacts of the UofR energy research, the Expert Panel could not attribute with certainty the level of influence that the SRP process per se at UofR has had on other institutions and organizations.

There is a very significant array of partnerships and collaborations with the public and private sector that indicate that the R&D capacity at UofR has been considered in their planning. The continuation of the interactions with the University by the outside parties demonstrates that there is positive impact coming from the collaborations.

The research capacity that now exists at the University of Regina enables the provincial government to support further development in the energy field. As indicated during the OMS visit by the provincial representative, this is being pursued vigorously.

The plans and actions taken by the University of Regina have enabled both major research and development and demonstration projects to be planned and initiated with a large number of industry partners. To date, most of these have been at the regional level. A prominent measure of the impact is that investments under the SRP have enabled UofR to influence the provincial government and Royal Dutch Shell to invest $10 million in the International Performance Assessment Centre for Geological Sequestration of Carbon Dioxide.

There are significant collaborations and research funding support being provided by agencies such as Natural Resources Canada, the Alberta Research Council and the Alberta Energy Research Institute.

The President of HTC Purenergy advised that access to the people and infrastructure capacity of the University's energy programs was a significant factor in the company remaining in Regina. In addition, the UofR capacity is attracting the attention of major international companies like Babcock Doosan which is currently considering investments in the city of Regina.

1.4 Complementary Investments by Institution

CRCs in theme vs. institution wide	High
New faculty member hires vs. institution wide	Very High
Other institutional research funding	High
Operations and maintenance resources	Medium
Infrastructure Operating Fund allocated	High
Other investments	Very High

Faculty members

New appointments in the Faculty of Engineering and the Faculty of Science since the start of acquisition of CFI-supported infrastructure as shown in Table 1 below reflect a strong Institutional commitment to building capacity in the energy field.

Table 1 - New Faculty Hires in the Theme Area since 1999

Faculty	Dept./Program	Current 2008/09 Faculty*	New Hires Since CFI	New Hires in Energy since CFI	% of New Hires in Energy
ENGINEERING	Electronic Systems	5	1		0%
	Environmental Systems	7	4	2	50%
	Industrial Systems	10	7	2	29%
	Petroleum	9	9	9	100%
	Software Systems	5	3		0%
ENGINEERING Total		**36**	**24**	**13**	**54%**
SCIENCE	Chemistry / Biochemistry	9	7	2	29%
	Geology	7	4	4	100%
SCIENCE Total		**16**	**11**	**6**	**55%**
TOTAL		**52**	**35**	**19**	**54%**

**Includes professors only; lecturers and lab instructors are excluded.*

In the Faculty of Engineering there have been eight new hires in petroleum engineering and five additional new appointments in the energy theme for a total of 13 out of 24 new faculty members appointed into the energy field. Six of 11 newly-appointed faculty members in two departments of the Faculty of Science have been in the energy theme since the start of CFI. The systematic building of capacity in the area of energy shows that it is a major Institutional focus. The CFI investment has had an important enabling effect on the capacity building.

The Expert Panel was impressed by the large impacts of the CFI investment at UofR in the Energy theme – it provided the opportunity to build world-class infrastructure, to develop a new undergraduate petroleum engineering program (one of the largest in the country) and to recruit and retain numerous faculty.

Canada Research Chairs

The University of Regina has directed two of its ten Canada Research Chairs (CRC) to the field of Energy. Both appointments are senior Tier 1 CRC, of which there are five at the University.

Given the opportunity for even greater stature in world-leadership in carbon capture and storage and green energy technologies, the Expert Panel suggests that the Institution should consider enhancing its position through the appointment of an additional CRC in this area.

Other University support

The additional institutional funds that have been committed to the support of energy research total $763,884. Considering the size of the Institution, this is a substantial amount. The institution established two dedicated

technical positions supported by the Dean of Engineering's budget to maintain and operate the CFI-funded infrastructure. In addition, the Institution contributed just over $540,000 of institutional matching funds for the CFI awards.

The institution has made other significant strategic investments in support of energy research. It rents space in the PTRC facility for the housing of some of the research infrastructure and researchers. It has worked with partners in government and industry to build the International Test Centre for CO2 Capture and the Greenhouse Gas Technology Centre which together currently represents a $25 million investment.

Overall, the investment in research facilities, their maintenance and the large increase in faculty positions represent a major investment by the Institution and its partners in the area of energy.

The institution seems to rely heavily on graduate students for operation of the infrastructure. The Expert Panel urges the institution to find additional means to increase technical support for infrastructure in order to ensure that equipment is ready to be optimally utilized at all times.

CFI and institutional investments have enabled the University to attract investments in infrastructure from other funding partners. In 2001 the International Test Centre (ITC) for CO_2 Capture (a $12 million undertaking) which houses a state-of-the-art pilot plant facility for CO_2 capture with a full range of sophisticated analytical equipment was established. This facility is part of the $13 million Greenhouse Gas Technology Centre (GGTC) begun in 2008. Further development of the GGTC will house additional facilities for biofuels research and hydrogen production research and development. The University has entered into a partnership with Royal Dutch Shell and the Government of Saskatchewan to form the International Performance Assessment Centre for Geological Sequestration of Carbon Dioxide (IPAC-CO2). The founding investments of $5 million each by Shell and the Government are expected to attract at least another $15 million from industry for the Centre. Institutional investments have also included substantial time and effort on the part of senior administration and staff in developing the energy research portfolio.

CFI Infrastructure Operating Fund

The University of Regina allocates all of the contributions it receives from CFI through the Infrastructure Operating Funds (IOF) to the projects that generate the funds (IOF). For the energy-related infrastructure, a total of $700,250 in IOF allocations will be applied to the direct operational costs of that infrastructure.

2. Research Capacity

"We are lucky to have jumped early onto the carbon capture band wagon; we are 10-15 years ahead of other research centres."

2.1 Infrastructure Investment Value

Total Infrastructure Investment	Very High
Change in infrastructure investment	Very High

The intensity of the institutional focus on the Energy theme is reflected in its approach to CFI funding and the willingness of the institution and its partners to match CFI funding in this strategic area. As shown in Table 2, the overall infrastructure investment in Energy research at UofR is $3,725,807 which is 43% of the total amount awarded by CFI at this institution (total $8,710,937). The CFI funding of $3.7 million in the energy theme led to a total investment of $8.2 million with the partner funding being contributed approximately equally from the private and public sectors. The sources and timing of the total investments are shown in Figure 2 on the next page.

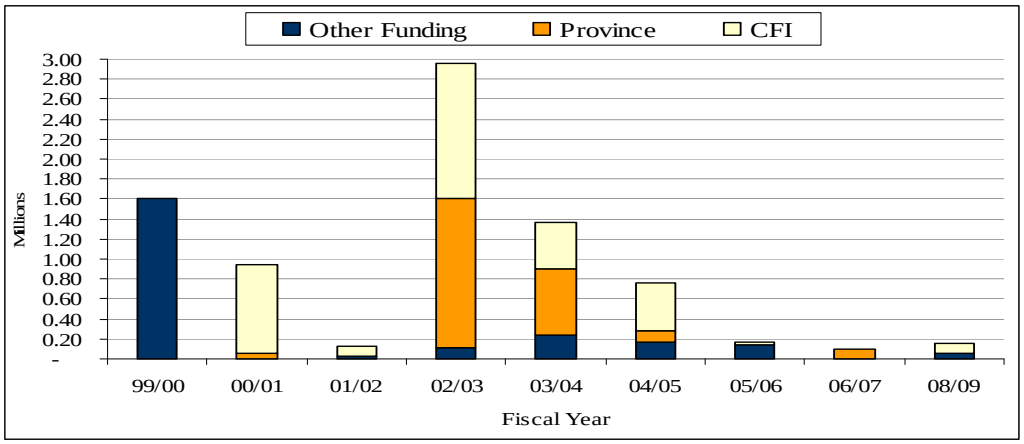
Table 2 - Value of CFI Investments at the University of Regina

	All UofR Projects		Energy Projects		% Energy	
CFI Award Recipients	**Value ($)**	**#**	**Value ($)**	**#**	**Value ($)**	**#**
All – UofR	**$ 8,710,937**	**44**	**$ 3,725,807**	**14**	**43%**	**32%**
Among New Faculty*	n/a		$ 1,587,299		n/a	
% New	n/a		43%			
In Engineering	**$ 4,486,603**	**12**	**$ 3,443,511**	**9**	**77%**	**75%**
Among New Faculty*	$ 2,298,375	7	$ 1,305,003	5	57%	71%
% New	51%		38%			
In Science (Chem. & Geol. only)	**$ 417,039**	**9**	**$ 282,296**	**5**	**68%**	**56%**
Among New Faculty*	$ 417,039	9	$ 282,296	5	68%	56%
% New	100%		100%			

* New faculty hired between 1999 and 2008

The core investments by CFI of $1 million in 1999 for the Sustainable Heavy Oil Research facility and $1.8 million in 2003 for the International Test Centre for Carbon Dioxide Capture have been crucial in the development of the current international-class capacity at the University of Regina.

Figure 2 - Cumulative Leveraged CFI Energy Infrastructure Investments



Source: Financial Services and Research Services (UofR); *other funding* primarily from industry.

In addition to the CFI infrastructure, UofR and its private and public sector partners made additional investments in Energy-related research:

- a $10 million Petroleum Technology Research Centre (1999)
- a $13 million Greenhouse Gas Technology Centre (2001)
- a $8.5 million International Test Centre for Carbon Dioxide Capture (2003)
- a $12 million International Performance Assessment Centre for Geologic Storage of CO2 (announced November 2008)
- a new 150,000 square foot addition to the Laboratory Building, costing more than $60 million, named the Research and Innovation Centre (to be completed in 2009), part of which will house energy-related research.

2.2 Capabilities

Pre-CFI technical capability	Useful
Technical capability now	State-of-the-Art
Pre-CFI operational capability	Useful
Operational capability now	State-of-the-Art

The facilities and equipment for energy research at UofR in the energy area prior to the onset of CFI were considered to be technically and operationally average at best. The CFI funding enabled UofR to develop technical capabilities of the very highest quality, and they represent good value for the investment of CFI and

its partners. The CFI investment was pivotal in building capacity that has enabled UofR to attract other major investments and in the development of significant partnerships with government and major national and international industries.

The Expert Panel was concerned about the breadth of activity for which these excellent facilities are used. The resources could be deployed to support other pre-competitive industrial scale research in areas related to those being followed at present. Furthermore, while having students use the equipment has pedagogical value, the practice of relying on students to operate the infrastructure can place expensive equipment at high risk of damage and less than optimal use in the absence of a full complement of permanent technical staff. And it also requires senior staff to spend valuable research time on continuously training new people, rather than driving the expansion of the research program. The Panel believes that the institution should use research associates to lighten the supervision load on the professors. This would provide medium term continuity in operations and research expertise and help ensure that UofR's industrial research is on schedule.

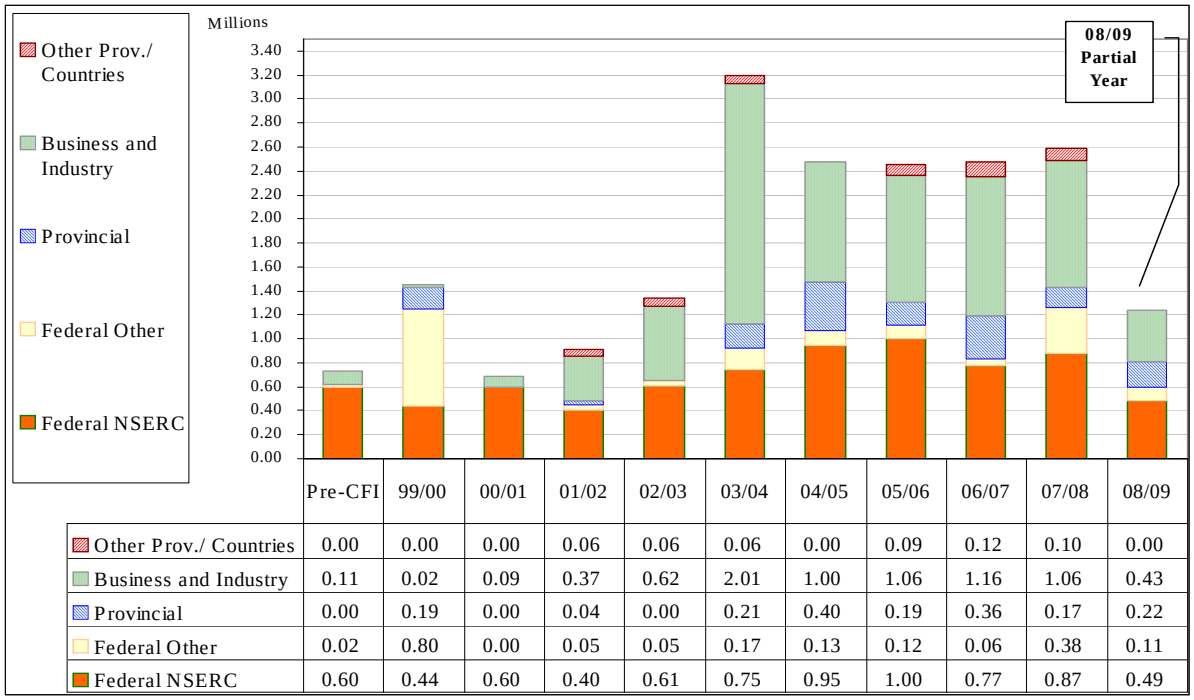
2.3 Sponsored Research Funding and Number of PLs and PUs

CFI impact on sponsored research funding	Very High
CFI impact on sponsored research funding per PL/PU	Very High

The presence of CFI-funded infrastructure has had an enormous impact on the sponsored research funding at the University of Regina. It contributed to the University's success in national competitions of funding agencies such as the Natural Sciences and Engineering Research Council (NSERC) and via industrially-sponsored research contracts. Figure 3 demonstrates the dramatic increase in funding from NSERC.

Since 1999, the growing group of 13 PUs has attracted over $17.5 million in direct research support. Table 3 shows the large increase in funding per investigator indicating the dramatic rise in their individual competitiveness.
These data leave little doubt about the dramatic rise in sponsored research, and the Expert Panel is certain that this positive outcome is directly impacted by the CFI-sponsored infrastructure.

Figure 3 - Sponsored Energy Research Funding by Year and Source



	Pre-CFI	99/00	00/01	01/02	02/03	03/04	04/05	05/06	06/07	07/08	08/09
Other Prov./ Countries	0.00	0.00	0.00	0.06	0.06	0.06	0.00	0.09	0.12	0.10	0.00
Business and Industry	0.11	0.02	0.09	0.37	0.62	2.01	1.00	1.06	1.16	1.06	0.43
Provincial	0.00	0.19	0.00	0.04	0.00	0.21	0.40	0.19	0.36	0.17	0.22
Federal Other	0.02	0.80	0.00	0.05	0.05	0.17	0.13	0.12	0.06	0.38	0.11
Federal NSERC	0.60	0.44	0.60	0.40	0.61	0.75	0.95	1.00	0.77	0.87	0.49

"Pre-CFI" includes fiscal years 1996/97 to 1998/99.

Table 3 - Sponsored Energy Research Funding and Number of Principal Users

	Research Funding	Number of Principal Users	Average Funding per Researcher
Pre-CFI			
96/97	$83,360.00	4	$20,840.00
97/98	$376,360.00	4	$94,090.00
98/99	$272,786.00	4	$68,196.50
Since CFI			
99/00	$1,449,747.00	8	$181,218.38
00/01	$685,253.87	9	$76,139.32
01/02	$915,923.39	10	$91,592.34
02/03	$1,334,952.96	12	$111,246.08
03/04	$3,194,875.76	12	$266,239.65
04/ 05	$2,474,783.02	13	$190,367.92
05/06	$2,453,756.91	12	$204,479.74
06/07	$2,480,731.22	13	$190,825.48
07/08	$2,585,024.33	13	$198,848.03

2.4 Critical Mass

CFI impact on number of Project Leaders (PLs) and Principal Users (PUs)	Very High – CCS Medium – EOR
Critical mass	Yes – CCS Don't Know - EOR

The infrastructure obtained with CFI support has had a very important impact on the ability of the institution to recruit and retain new faculty members in the Energy field. The infrastructure supports primarily three significant subthemes – carbon capture and storage, enhanced oil recovery and renewable energy sources. The impact of the CFI-funded infrastructure on carbon capture & storage has been very substantial. While there is a significant record of publication and related activities in the other two subfields, the overall impact of the CFI infrastructure in those other two subthemes is less than in carbon capture & storage.

Critical mass is challenging to assess in a systematic way. The University has sufficient researchers and research students spread over the thematic area to tackle many research and development questions. The greatest strength is in carbon capture and storage technology. The UofR has the largest numbers of researchers in that field of any Canadian institutions at this time. CFI infrastructure has been a significant determinant in the assembling of that body of expertise. The other subthemes are more difficult to assess because the institutional data document focused mostly on the capacity in carbon capture and storage. Although there is substantial overlap in the activities related to CCS and EOR research, it seemed that the subthemes of EOR and renewable sources have less overall strength than the CCS area. As noted, while there are substantial numbers of publications, these subthemes were not as developed in the information provided to the Panel.

While the University of Regina has sufficient faculty members and students for major CCS research activity, the limitation in technical support staff is likely preventing them from fully utilizing the facilities. The attraction of additional post-doctoral fellows will strengthen the critical mass.

2.5 Recruitment and Retention

CFI impact on number of faculty members attracted from abroad	High
CFI Impact on overall recruitment and retention	Medium

Recruitment and retention in the Energy theme has been excellent at UofR. There is little doubt that the CFI-funded infrastructure has had an effect on this process, with 80% or more of faculty recruited since 1999 continuing to work at the institution. Other factors such as accessibility to industry, government support and access to graduate students also played a part in this outcome.

The rating for CFI impact on faculty members recruited from abroad is inferred by the Expert Panel since Saskatchewan privacy laws prevented obtaining detailed information on this matter (i.e., names/origins). It was reported that 18 out of the 21 recent hires were recruited abroad. Most came from China and the United States. A few also came from Thailand, Iran, Nigeria and the UK.

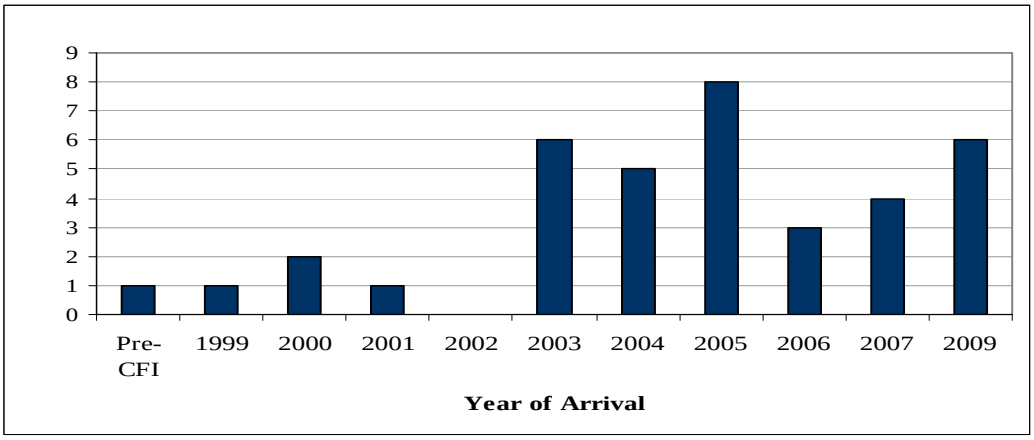
The Panel noted that, in this theme, the institution has hired a significant number of its own graduates. While acknowledging that UofR alumni have been trained in an excellent environment, and that UofR holds open competitions for recruitment, the Panel felt that a developing program like the one at the UofR could benefit from diversity of faculty backgrounds. This will enhance the University's ability to stay at the forefront of carbon capture & storage and other energy-related research. The institution would benefit from becoming more proactive in its recruiting strategies and in finding support for research faculty. There are very substantial R&D connections to industry, and private sector companies could be approached for salary support for research faculty or post-doctoral fellow appointments.

2.6 Visiting Researchers

CFI impact on number of visiting researchers	High

The favourable impact of CFI on the number of visiting researchers is clearly seen in Figure 4. Most of the visiting researchers have been from China. This seems to reflect both a strong interest on the part of the Chinese in this area, the reputation of the program and its faculty, and development of visits through personal contacts. Many faculty members have standing invitations for return visits. Many of the visits have led to longer term collaborations between the visitors and UofR researchers.

Figure 4 - Visiting Researchers by Year of Arrival



2.7 Multidisciplinarity

Number of disciplines involved	High
Degree institution fostered multidisciplinarity	High
Value-added by multidisciplinarity	High

The CFI-funded infrastructure supports research in a number of different disciplines across the Energy theme in both Engineering (Electronic Systems, Environmental Systems, Industrial Systems, Petroleum, Software Systems) and Science (Chemistry/Biochemistry and Geology). Besides the productive interactions between these disciplines within the university, external collaborations in Canada and internationally have helped to develop research projects with inter-disciplinary approaches.

As in most fields with complex questions and operational challenges, multidisciplinarity is essential in energy research. The research group shows evidence of applying multiple approaches to the serious challenges of the industry. The way in which researchers are encouraged to work with facilitating agencies like the PTRC provides a fertile environment for these interactions.

An awareness of developments and world market/political trends is critical for the research to be timely and cost effective. The researchers at UofR seem to be quite responsive to those emerging international trends in the energy field, especially those relevant to CO2 and its positive uses. Structured collaborations with socioeconomic researchers are not yet fully developed. But the Expert Panel expects them to emerge more fully as bodies such as the Greenhouse Gas Technology Centre reach their full potential.

3. Highly-Qualified Personnel (HQP)

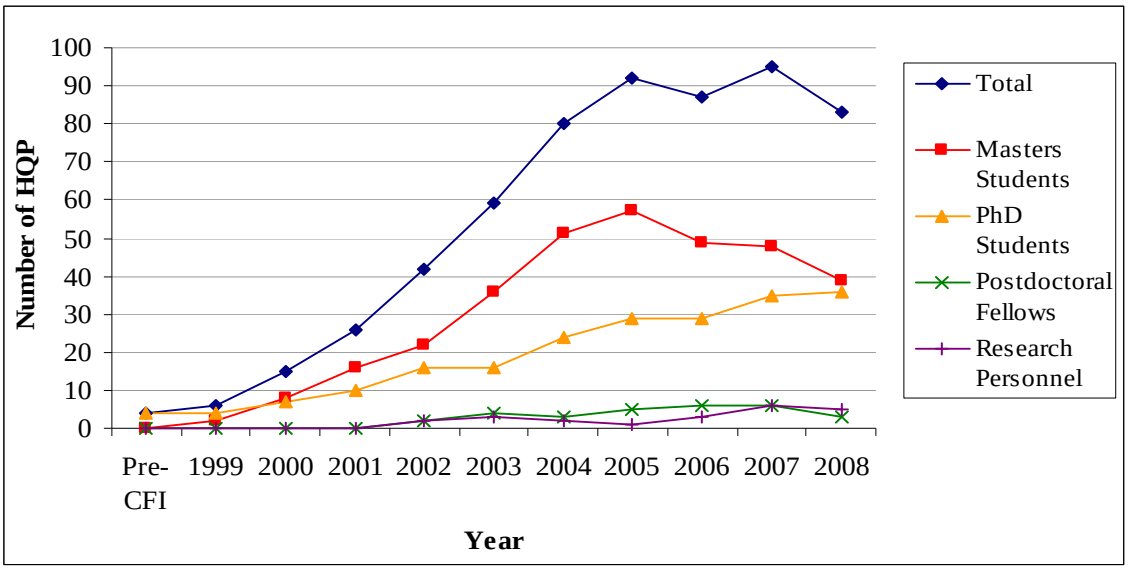
"The researchers coming out of UofR are highly trained and well published. They have the right knowledge to help us harness the technology. This is partly the reason that the HTC Purenergy company has chosen to stay in Regina."

3.1 Number of Research Trainees

CFI impact on number of masters students	Very High
CFI impact on number of PhD students	Very High
CFI impact on number of PDFs	Low

As shown in Figure 5 on the next page, there has been a very significant impact on the number of students being trained since CFI funding became available. The graduate enrolment in the energy-related program went from 6 students in 1999 to a peak of 95 in 2007. Since then the numbers of MSc students have declined from a peak of ~ 58 in 2005 to 40 in 2008. This reduction in MSc students over the 2005 to 2008 period likely reflects a number of factors but one of the most telling is that employment opportunities in industry for engineers increased dramatically over that period. In contrast, PhD numbers have maintained a steady increase from ~3 in 1999 to a cohort of ~ 38 students in 2008. Postdoctoral fellows and research personnel numbers really only begin to register in the system post 2001; from 2006 to 2008 numbers in each category were around 5 per year. The relatively low number of post-doctoral fellows might be expected in the early stages of an evolving research program. It should increase as the numbers of senior researchers increase and with extra effort in PDF recruitment. In particular, the area of carbon capture and storage seems to offer promising opportunities for the recruitment of post-doctoral fellows, research associates and research engineers.

Figure 5 - Number of HQP in training annually with Principal Users in the Energy Theme



3.2 Quality of Training and Trainees

CFI impact on quality of trainees	High
CFI impact on quality of training	High
CFI impact on the training programs' reputation or competitiveness	High

Since CFI funding began for the energy program the quality of applicants and training programs has significantly improved. There have been dramatic increases in applicant numbers over the years, and the academic quality of students accepted into the graduate research programs is reflected in their higher GPAs.

The quality of training has also been enhanced. For example, UofR initiated a new and very successful postgraduate Petroleum Systems Engineering Program in 2002. In 2006, an MSc in Process Systems Engineering was initiated and a new graduate course in fluid inclusion studies was also developed.

Another significant development is the worldwide delivery of workshops and training courses in CO_2 storage and enhanced oil recovery. These workshops have been of special interest to international industry.

The CFI investment has played a major role in the increased quality of the training programs and the graduates in this area. In turn, this has added to the international reputation of the University's Energy research sector since 1999.

3.3 Knowledge Transfer (KT) through HQP

Jobs in Canadian academia or research hospitals	Medium
Jobs in Canadian private sector	Very High
Jobs in Canadian public sector	Medium
Jobs in Canadian not-for-profit sector	Low
Jobs abroad	High
Further academic training in Canada	Medium
Further academic training abroad	Don't Know
Overall number of graduates	Very High

Since 2001, 86 students have completed graduate studies related to energy research at UofR. Table 4 shows the initial career destinations of graduates and PDFs. The largest proportion of graduates (48%) is employed by Canadian companies involved in oil exploration and production. In the remainder, 14% went on to further academic training (5 individuals went on to PhD research at UofR), while others are employed in Canadian academia (9%), Canadian government (7%) and 12% jobs abroad (e.g. China, Australia, Saudi Arabia and Nigeria).

Table 4 - Initial Career Destinations of Graduates and PDFs

Career / Training Destinations	Number	% of Total
Jobs in Canadian Academia	8	9%
Jobs in Canadian Industry	41	48%
Jobs in Canadian Government	6	7%
Jobs abroad	10	12%
Further Academic Training	12	14%
Unknown Destination	9	10%
Total	**86**	**100%**

This record is excellent in terms of the success in finding employment of the students after graduation and especially their attraction to industry. Comments from Project Leaders reflect a very vibrant and evolving graduate research community. This is seen in the increased numbers and quality of the student applicants, the increasing attractiveness of the graduates to industry, and the growing numbers of international students applying to the program.

4. Research Productivity

"By any measure the research productivity has increased enormously in the energy field at UofR over the past decade. This is due in no small part to the CFI-funded infrastructure."

4.1 Competitiveness

Overall competitiveness	Very High
CFI Impact on institution's overall competitiveness	Very high

The Expert Panel considers the University of Regina to hold a world-leading position in carbon capture and storage. While also considered to be competitive, research in energy production is more modest compared to some major institutions (e.g., University of Texas). That notwithstanding, the UofR has made important contributions in the use of carbon dioxide in enhanced oil recovery processes.

The CFI- supported infrastructure has been critical in advancing the research productivity in all the energy fields at the institution. In turn, this has enabled UofR to establish internationally competitive research programs in the energy theme.

There are links to the Alberta Research Council and the Alberta Energy Research Institute that are fostered through the PTRC, as well as some collaborations with the University of Alberta and the University of Calgary, which are major Canadian institutions in energy research. The Uof R collaborated with both institutions initially in the first phase of the Weyburn-Midale Project (2000-2004) and with U of C through the EOR program. As the first signatory of the Sustainable Technologies for Energy Production Systems (STEPS) Network, the UofR will continue to foster collaborations with these and other institutions. Stronger linkages to these institutions, with respect to the application of CCS technology to energy production could increase productivity across all institutions.

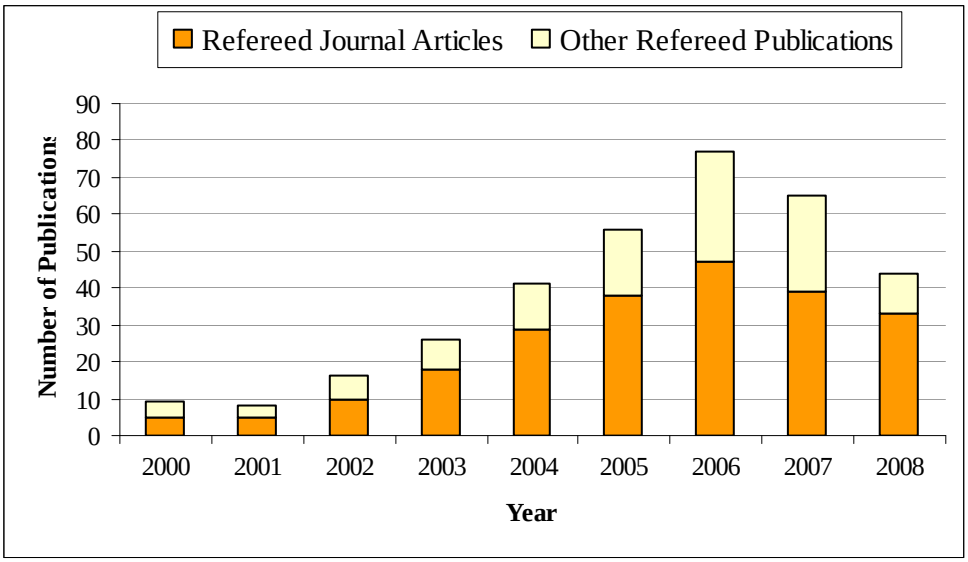
In the area of carbon capture and storage, the unique combination of pilot plant facilities together with very sophisticated analytical technologies has enabled the UofR to produce an exceptional level of output, and to attain a world-leading position.

4.2 Research Productivity

CFI impact on quantity of research	High
CFI Impact on quality of research	Very High

Figure 6 shows the evolution of published research since 2000 in the energy theme. In addition to 342 refereed publications, over 300 non-peer reviewed publications and presentations have been made over that period. This research output is excellent given the size of the institution and the fact that significant growth in numbers of researchers has occurred just since 2000. CFI investments have had a very substantial impact on both the quantity and quality of publications over that period.

Figure 6 - Refereed Publications in the Energy Theme



4.3 External Research Linkages

Degree of external networking and collaboration	High
Number of formal research networks	Medium
Value added by external networking and collaborations	Very High

The energy research group at the UofR has established a substantial number of collaborations within the institution, with various provincial bodies, and with a number of international institutions. About ten active collaborations are ongoing at any one time. The exceptional infrastructure at UofR, especially for carbon capture & storage studies, could sustain even more collaborative activities.

Currently the energy group has formal arrangements with a number of research networks:

- Sustainable Technologies for Energy Production Systems (STEPS): A Business-Led Network of Centres of Excellence (BL-NCE). UofR is an inaugural signatory Centre of Excellence on this new network
- Innovation Norway
- Petroleum Technology Research Centre

- ITC Sponsor's Consortium
- ITC Suncor Consortium
- Communities of Tomorrow
- Centre for Sustainable Communities
- AUTO21, Network of Centres of Excellence
- NSERC – H2CAN, NSERC Strategic Hydrogen Canada Network

Of particular note is UofR's position in the STEPS, which is led by PTRC. It indicates the important connection between UofR research and industrial development interests, as well as with other Canadian Universities that will be members of the Network. Through the STEPS network the CFI-funded infrastructure will be used to develop processes and products with significant likelihood of commercial application because of the early involvement of private sector partners.

The Expert Panel believes that the world-leading infrastructure at UofR could serve as the basis for a greater Canadian presence in carbon capture & storage and enhanced oil recovery. Developing new collaborations with other Canadian institutions involved in energy research would present great opportunities to do so.

While the researchers have very good links to industry in relation to CCS technology (amine scrubbing), they are not active, nor do they appear to be trying to be active, in other CO2 capture technologies. In the subtheme of clean energy production, they are planning for a large hydrogen rig that is linked to local industrial interests. It appears that UofR's 'unwritten' research strategy in the near to medium term is to stay close to the interests of local industry. This was of some concern to the Panel because it might hamper the broadening of research areas and delving into more risky longer-term research. The concentration on industrial targets, on the other hand, is perhaps why the energy researchers can maintain such good links with the provincial government, as their research contributes to industrial growth, and hence the local economy.

The Expert Panel noted that UofR has a substantial interdependency on HTC Purenergy, a small publically-traded company, for the commercial applications of UofR's patented amine-based CO_2-scrubbing technology. The partnership with HTC Purenergy has been very effective in enabling UofR to develop relationships with the major international developers of CCS and other petroleum infrastructure such as Doosan Babcock Energy Corporation. This extends the "reach" of UofR technology and expertise into the world market, and is helping to solidify its position as a major international competitor, especially in CCS technology development. Again, these developments have been strongly influenced by the presence of the CFI-funded infrastructure.

4.4 Sharing of Infrastructure

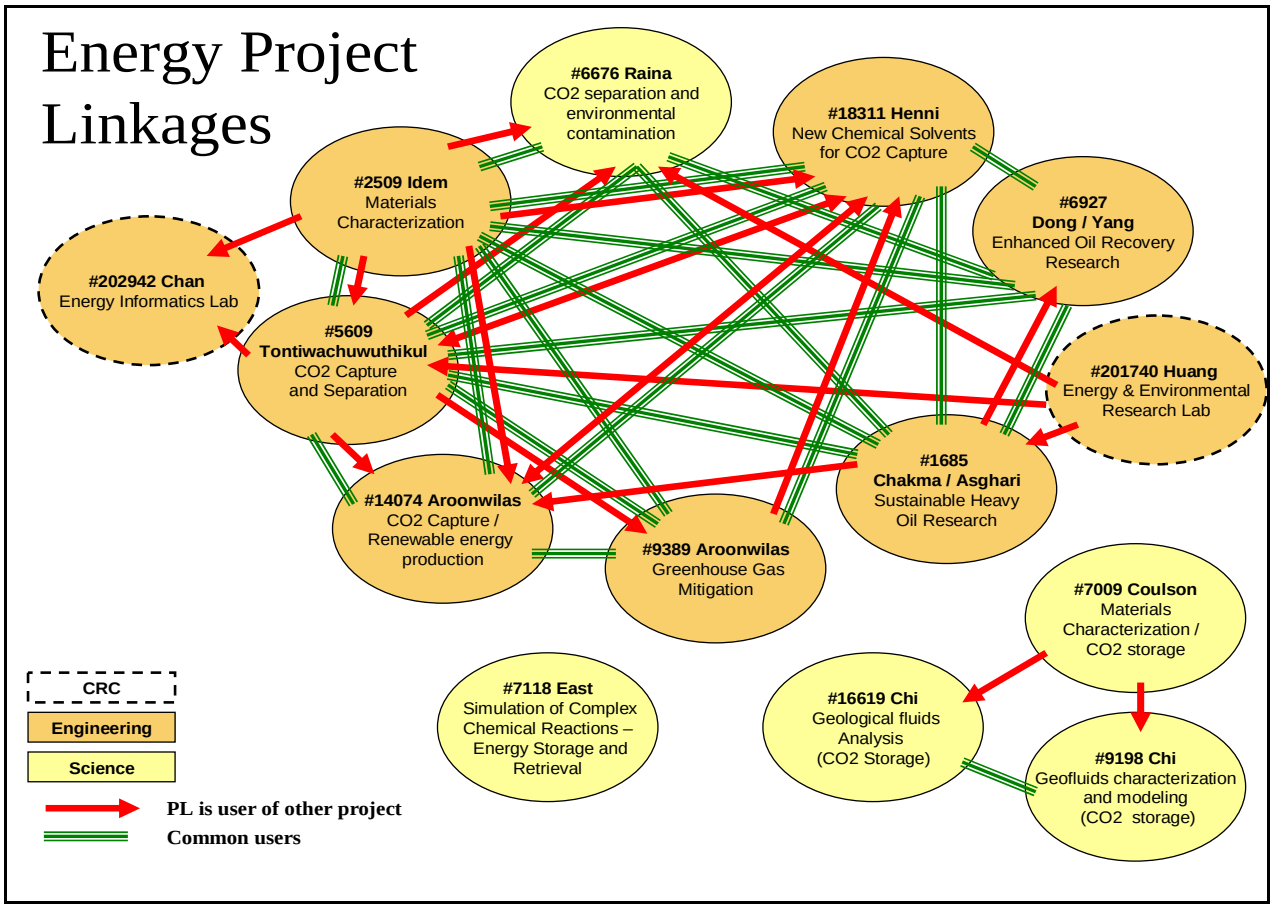
Sharing of infrastructure by researchers within the institution	Very High
Sharing of infrastructure with researchers from outside the institution	Medium

As is shown in Figure 7 below, there is a great deal of sharing of the infrastructure within the Institution. In that sense, the infrastructure developed with the help of CFI investments are true multi-user facilities. But it is not very clear how well the infrastructure is used by outside organizations working on early stage research. Usage data was provided for only three of the 14 projects:

- #5609-CO2 capture centre: 60% internal / 40% external
- #2509-scanning electron microscope facility: 70% internal / 30% external
- #9198-geofluids research facilities: 85% internal / 15% external

It should be noted, however, there are significant numbers of research contracts with major international energy companies which broaden the utilization of the equipment well beyond early stage research and development.

Figure 7 - Energy Project Linkages



5. Extrinsic Benefits

"The University of Regina has reduced CO2 capture cost from $55/ton to about $20/ton."

5.1 Partnerships

Number of partnerships with end user organizations	High
Importance of these partnerships	Very High
Amount of financial contribution made by end user organizations	Very High
CFI impact on these partnerships and contributions	Very High
Signs of an evolving industrial cluster	Yes

The University of Regina has created formal relationships with over 30 end-user organizations whose direct financial or significant in-kind contributions have been instrumental in the development of the Institution's strong position in the energy theme. Since the onset of CFI funding, the value of the partner contributions received or expected is approximately $32 million. The partners include Saskatchewan government departments, SaskPower, Canadian government departments and agencies, agencies of the Alberta government, several large petroleum corporations such as EnCana and Royal Dutch Shell, as well as smaller companies that specialize in petroleum production, or services and equipment for petroleum production.

Without the CFI investment it is hard to see how any of these partnerships would have developed. The infrastructure provided by CFI supports the intellectual capacity and enables the pursuit of the key strategic research questions. That capacity and the approach to applied problems attract the external partners.

There is evidence that an industrial cluster may be starting in this theme. The University's most prominent industrial partner until recently has been HTC Purenergy. HTC, in developing its licensed UofR technology for carbon capture, has relied on a number of local services and supplier companies in developing the HTC products. The development of the International Performance Assessment Centre for Geologic Storage of CO2 with Royal Dutch Shell, and the outreach to Doosan Babcock through HTC and the International Test Centre for CO2 Capture will attract other multinational companies to the region.

5.2 Technology Transfer

Importance of technology transfer in this field generally	High
Amount of technology transfer	High
Significance and value to users of technology transfer	High

The development of the University's technology transfer office was given a large impetus because of the availability of potential technologies in the energy area. Also the creation of Springboard West Ventures, which is involved in spin-off company development, has been stimulated in part by the potential arising from UofR's energy research.

Table 5 gives an account of the formal technology transfer activities in the energy area at the University of Regina. The numbers of disclosures and patent applications are considerable for a medium sized-university. However, the potential seems not yet fully realized, and more could be accomplished with the recruitment of industry-supported chairs, and the hiring of more technical support and research positions such as post-doctoral fellows.

Table 5 - Summary of Direct Technology Transfer

Indicator	Total Number
Invention Disclosures	38
Patents Filed	36
Licenses Granted	2 (+ 2 pending)
Royalties and Licensing Revenue	$644,512
Material Transfer Agreements	N/A
Start-ups or Spin-offs	0

It has been mentioned already that licensing of UofR technology is essential to the operations of HTC Purenergy. The value of their other technologies under development is more difficult to assess as they may not yet have reached sufficient maturity for licensing or other forms of transfer. But, private sector relationships continue to expand at UofR, and this provides an indirect but promising measure of potential in this area.

5.3 Knowledge Transfer of Other Types

Importance of knowledge transfer of other types in this field generally	High
Level of knowledge transfer of other types	High
Significance and value to users of knowledge transfer of other types	High

Contributions of the energy researchers to knowledge transfer are considerable. Table 6 provides an indication of the nature and the intensity of knowledge dissemination activities. The senior representatives from the Government of Saskatchewan, SaskPower, and HTC Purenergy who came to the OMS visit all spoke about the importance of the relationships between their organizations and the UofR energy researchers.

Table 6 - Summary of Indirect Knowledge Transfer

Indicator	Total Number	Examples
Direct participation in major external user R&D projects	20	Diagenesis and stratigraphy of the Viking Formation in Saskatchewan with Profico Energy; strategies to predict petroleum production with Prairie Hunter Energy Corporations; enhanced oil recovery and greenhouse gas storage in depleted reservoirs with the Saskatchewan, Alberta, and National Research Councils
Provision of data or services to users	24	Technical reports, cost studies, and feasibility studies for organizations such as PTRC, Saskatchewan Research Council, HTC Purenergy, Apache Canada, Saskatchewan and Canadian governments
Consultation Services	17	Gas Technology Institute and Rand in USA, Hatch Associates Limited, Husky Energy, Penn West Energy Trust, SaskEnergy-TransGas, HTC Purenergy, Saudi Aramco, Daqing and Shengli Oilfields in China
Invited presentations at user organizations	36	HTC Purenergy, PTRC, China National Petroleum Corporation, International Conference on Advance Petrochemical and Polymer Technologies, 10th Williston Basin Horizontal Well and Petroleum Conference, World Renewable & Environmental Conference, International Conference on Environmental Informatics, International Seminar on Carbon Sequestration and Climate Change
Participation in working groups and committees	19	Committee members for PTRC, Saskatchewan Research Council; advisory roles for Saskatchewan Government, SaskPower, Doosan Energy Inc.; participation in International CO_2 Capture Network
New research consortia	4	ITC Sponsors' Consortium, ITC Suncor Consortium
Improvements in best practices	15	Decision making tools, e.g. to generate higher accuracy prediction results, to aid government with policy decisions, for risk assessment of long-term CO_2 storage. Improved efficiency, e.g., in report generation work, to improve oil recovery and reduce operating costs
Public information, interaction, and service	36	Interviews by Innovation Canada Magazine and Radio Canada; Promoting science and engineering in high schools through judging science fairs and arranging tours of the CO_2 innovation lab

Source: NSERC 100 forms, CFI Annual Reports, Canada Research Chair Reports, ITC Website, University Industry Liaison Office, Confirmation of PL's and PU's

5.4 Socio-Economic Benefits

Importance of socio-economic benefits	High

The Enhanced Oil Recovery Program has contributed to substantial additional recovery from the Weyburn-Midale field to the benefit of the industry and government revenues. The Saskatchewan government receives about $1 billion in oil and gas royalties and the Weyburn field is the largest contributor to those funds. The UofR research enabled by the CFI-funded infrastructure has helped create employment in centres such as the PTRC and the ITC. PTRC directly employs 10 full-time staff, all of whom contribute in various capacities to projects connected to or originating from the U of R CCS research, including the Weyburn Project, the Vapex Project, and the Aquastore Project. PTRC also contributes significantly to the retention of the Petroleum Systems faculty, which includes 6 full-time faculty members and one full-time lab instructor. The Weyburn Project also employs additional staff at EnCana Corporation. ITC employs 10 at the ITC building, including a number of research assistants, and 3 additional staff at the Boundary Dam capture plant facility. HTC employs several Ph.D. graduates from the ITC research programs. Several ITC graduates have gone on to faculty positions at other universities around the world, such as in China and Thailand, and some have gone on to jobs in industry, also throughout the world. Several Petroleum Systems Ph.D. graduates and candidates have been employed as researchers for the Saskatchewan Research Council and at least 3 have taken faculty positions with the University of Regina. Others have gone on to faculty and industry positions throughout the world, particularly in China and the Middle East.

The indirect knowledge transfer activities listed in Table 6 have influenced competitiveness and operations at a number of companies, and have provided government with information and tools that have facilitated decision-making in the energy area.

The major reduction in the cost of CO2 removal achieved though UofR technology has enabled companies like HTC Purenergy, through their licensing arrangements with the institution, to provide direct employment themselves and through a number of companies on which they rely for goods and services. It has also enabled the company to prequalify to respond to an international tender issued by StatOilHydro for CO_2 capture on its gas burning plants. HTC Purenergy has struck an agreement with a major international company Doosan Babcock around UofR technology which will lead to about 15 new employees at HTC, and about 18 employees in a company that Doosan plans to establish in Regina.

From the environmental perspective, the CO2 reduction plant at the SaskPower Boundary Dam power plant, which is based on UofR technology, is removing 4 tonnes per day of CO2 from the emissions.

The benefits to date are real but they pale in comparison to the potential to contribute to Saskatchewan and beyond. UofR's research and development in enhanced oil recovery and alternative energy sources will make important contributions, but the major contributions are more likely to come through the carbon capture

technologies. These will provide a substantial competitive position to this institution and the province of Saskatchewan in a “greening” world economy. That said, contributions of this nature are very hard to quantify and will be best judged by history.

Challenges

"The field of carbon capture is one in which the institution is engaged in a "race to the finish at warp speed."

The University of Regina identified some important challenges to its ability to ensure that the energy research program maintains its current high level of competitiveness, and ideally moves to an even more preeminent position internationally. The following challenges were identified:

- Space – further development in research productivity will be limited by availability of space;
- Highly qualified technical experts – to fully utilize the infrastructure there is a need to have a larger number of technical staff to maintain and run the research equipment; and,
- Maintenance and upgrading of equipment – the O&M costs are high and ready sources of funding have not been identified yet.

The UofR noted that the CFI could show more flexibility in terms of how its funds can be used for building infrastructure itself, and CFI could assist with the movement of research outputs through to large commercial demonstration, and in the protection of intellectual property.

The institution also identified the need to establish a common business development vision with its partners, along with a need for a full scale demonstration plant for carbon sequestration. These points are well beyond CFI, but key government and private sector organizations have indicated their interest. The development of a commercial scale carbon capture plant which utilizes UofR technology will be a very important step in demonstrating to national and international users that this is a viable technology. A proposed commercial-scale capture plant to be operated in conjunction with one of SaskPower's coal-fired power generators as a partnership between the University and the Province may fulfill this need.
.

The Expert Panel agrees with the institution on the need for technical expertise and it raises two additional issues:

- Building the cadre of professional researchers and faculty – possibly aided by outside investments such as industry-sponsored chairs;
- Reducing risk of losing opportunity in commercial application of UofR technologies by achieving less dependency on HTC Purenergy as its sole partner. Currently, UofR technologies have been licensed only by HTC Purenergy. To achieve strong long-term return on its technologies, UofR needs to develop licensing arrangements with additional companies.

An important issue for the University of Regina will be its position on "energy research" as an independent academic pursuit of its own. Achieving an appropriate balance that is suitable for the University of Regina between industry-responsive and free-inquiry driven research will be very important in future development of the energy theme at the institution.

Conclusions

"CFI is one of the best investments on the UofR campus for return on investment."

Since 1999, CFI has invested $3.7 million in infrastructure for energy research at the University of Regina. This investment has generated over $32 million indirect co-funding for infrastructure and related R&D expenditures as well as the establishment of bodies such as the International Test Centre for CO_2 Capture at UofR. Both the private and public sectors have been major supporters of these initiatives.

The CFI investment has enabled the development of a new Petroleum Engineering Program at the University, and led to a very substantial increase in research output and training of graduate students. Significant numbers of intellectual property disclosures have occurred and these have led to the filing of a large number of patent applications. The record of research productivity, training of HQP, and knowledge transfer is very impressive for a moderately-sized institution like the UofR. Many strong linkages with public and private sector organizations have evolved in the Energy theme at UofR. The CFI-funded infrastructure and the creative researchers whom it helped to attract have been key to the building of those partnerships.

The Expert Panel considers that the University of Regina has achieved a world-leading position in carbon capture and storage and the application of CO2 technologies to enhanced oil recovery. Overall, the impact of the CFI investment is most impressive. Emerging developments are expected to increase the overall impact from the CFI and partner investments, especially in application of carbon capture and storage technologies.